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Chapter I

Introduction
Introduction

H. Peter Witzke and Thomas Heckelei

This volume is the outflow of the 65th EAAE seminar of the European Association of Agricultural Economists (EAAE), "Agricultural Sector Modelling and Policy Information Systems", held in Bonn, Germany, from March 29-31, 2000. The seminar was organised by the editors of this volume who felt that 12 years after a similar EAAE-Symposium in Bonn, it was about time to review the progress made and to discuss promising developments in this research area. Furthermore, it was intended to provide a forum for discussion between researchers and policy makers.

The editors of this volume were lucky to receive a rich supply of about 60 proposals from 16 countries reflecting the breadth of work directed to agricultural sector modelling and policy information systems. Because the sample of proposals is indicative of current emphasis in research, it is worth mentioning that, from a methodological point of view almost 25% of the supply might be called "econometric partial" analyses, another 25% “programming models” (half of which relying on PMP) whereas the remaining half of the proposals covered a multitude of quantitative methods such as Computable General Equilibrium models, “integrated or synthetic” approaches and many other categories typically seen in agricultural economics. Compared to major agricultural economics journals, however, the focus of the seminar on direct policy relevance implied some selectivity against strictly microeconomic approaches, for example Principal Agent analyses of specific decision problems. From the policy point of view, the editors’ invitation to the seminar clearly elicited a strong supply of papers (about 50%) on Agenda 2000, EU enlargement and WTO modelling with the other half focussing on environmental issues, other policy topics or methodology.

From this pool of proposals 24 contributed papers were accepted based on perceived quality and intended focus of the seminar after a two step review. The contributed papers were arranged in 11 “hot topic” parallel sessions to allow for sufficient discussion time. They were introduced by five plenary papers advancing or surveying state of the art methodology and key modelling issues. A set of 17 very interesting poster contributions could not be included in our paper sessions, yet frequently triggered most lively discussions in the poster sessions. To permit at least a very condensed account of the latter research efforts and results we like to present this work at least in one page “Briefs on Further Research” in the corresponding chapter of these proceedings. The discussions on the seminar and some effort on the part of the editors resulted in a revised set of papers. Due to fairly precise formal requirements for the papers turned in, and thanks to the majority of authors complying with them to a large degree, we had an already fairly homogenous set of revised papers at our disposal which was further standardised, including the exceptional cases. Of course, we were optimistic enough to assume that our endeavour would also reduce the frequency of typos, but we have to be realistic as well and accept the full responsibility for the remaining ones.

With the EAAE Seminar lying behind, we took the chance to have a new look at all contributions to find that they are quite naturally ordered in certain broad chapters, which are apparent in the table of contents. Nonetheless we like to comment of the final structure here for better orientation of readers.

The next Chapter II, “Reviewing Agricultural Sector Modelling” collects a number of surveys, which are really comprehensive, sometimes almost exhaustive, usually combining the oversight of a team of researchers and emanating from former plenary papers. These surveys provide an ideal starting point through the account of current research on agricultural sector modelling and policy information systems with high policy relevance. In the first
contribution for Chapter II, Luca Salvatici, Giovanni Anania, Filippo Arfini, Piero Conforti, Pasquale De Muro, Pierluigi Londero, and Paolo Schokai evaluate the comparative advantages of three major modelling approaches, namely “econometric”, “programming” and “equilibrium” (partial and general), to address major CAP developments towards different types of direct payments, production constraints and complex trade intervention measures. A major challenge identified for all approaches is "explicit" as opposed to "indirect" representation of policy in modelling efforts. Another large team of authors focuses on the third of the just mentioned approaches, "equilibrium models", as they are currently in use for the analysis of international trade and related resource issues. Frank van Tongeren, Hans van Meijl, Paul Veenendaal, Soren Frandsen, Chantal Pohl Nielsen, Michael Staehr, Martina Brockmeier, Dirk Manegold, Joseph Francois, Machiel Rambout, Yves Surry, Risto Vaittinen, Leena Kerkela, Thomas Ratinger, Kenneth Thomson, Bruno Henry de Frahan, Akka Ait El Mekki, and finally Luca Salvatici compare 18 current equilibrium models according to a well designed list of criteria. To them the major task for modelling will be the incorporation of consumer and public concern for food safety and the environment. On the other hand they consider the increasing exchange of computer code and databases among modelling groups to be the most promising development in the 90s. Niels Kærgård reviews the early origins and last three decades of agricultural sector modelling in Denmark. A major conclusion from this review is, perfectly consistent with those from the "cross country review" by Luca Salvatici and his colleagues, that there is no best model for all purposes and that different models may favourably complement each other. Alfons Oude Lansink and Jack Peerlings concentrate on the theoretical foundations and empirical application of recent microeconometric methodology to analyse farms and farm households. In their conclusion they stress the necessity to account for farm heterogeneity which seems to be highly rewarding both from the methodological point of view as well as in terms of policy relevance.

Chapter III is devoted to “Methodological advances on specific issues”, intended to improve the basis for but not pretending to be immediate policy relevant analysis. It starts off with Michiel Keyzer discussing the implications of current tendencies towards labelling of food products for agricultural policy information systems. He argues that the associated market power must not be neglected and proposes an computational/theoretical approach to address this issue through endogenously modelling producer markups. The recommendation to incorporate market power into policy information systems is certainly a challenge for future work, considering what most other contributors to this volume deemed feasible and relevant but it is perfectly in line with the major task identified by the survey team collected by Frank van Tongeren. Quirino Paris and Richard Howitt generalise one of the dominant approaches in current agricultural sector modelling, the PMP methodology, to a so-called Symmetric Positive Equilibrium Problem. It allows for a less restrictive technology representation in the PMP context and demonstrates the applicability of their approach with an example using typical farm data. Øyvind Hoveid investigates the theoretical linkages of price endogenous programming (PEP) models in the tradition of Takayama and Judge to general equilibrium in the Negishi format. These linkages suggest that the PEP approach is applicable to the cases of multiple consumers and economies with transaction costs, cases which have evaded quantitative modelling to a large extent so far. Quirino Paris, Elisa Montresor, Filippo Arfini, and Mario Mazzocchi propose a three step approach for rural policy impact analysis. It starts with a clustering of regions based on current development characteristics, continues with a PMP based policy impact analysis for these clusters, and finally checks whether and how policy impacts have changed the development status of regions in terms of cluster membership. The next contribution relates to econometric methodology. Mario Mazzocchi presents an approach to capture parameter instability in demand analysis, which is based on
the Kalman filter. In his application to meat demand in Italy, however, the Kalman filter did not obviate the use of dummy variables to fully reflect the effects of the BSE crisis.

Chapter IV, “Analysis: Agricultural Supply and Environment” brings together seven papers and a number of briefs which are joined by the assumption of exogenous prices and confinement to an analysis of agricultural supply and, possibly related, environmental effects. The chapter is opened by two analyses using econometric methodology. Jørgen Dejgaard Jensen presents the current status of "ESMERALDA", a model for Danish agriculture, which is able to predict regional results assuming an exogenous farm structure and hence exogenous aggregation factors for individual farms. Policy impacts on the latter result from behavioural functions estimated on a panel of farm-level accounting data. Gerry Boyle and Kieran McQuinn apply a dual supply response model within a mean variance framework to a panel data set on Irish wheat and barley producers and find them to be risk neutral. The evident policy conclusion is qualified, however, by a number of limitations acknowledged in their analysis. A wider range of papers in this chapter on supply analysis employ programming tools. Thia Hennessy, also working on Ireland, presents an Agenda 2000 simulation of multi-period linear programming models for representative dairy and cattle farms. Farm types were chosen based on cluster analysis. The changing importance of clusters is projected in a Markov chain analysis with constant transition probabilities, capturing trends in structural change. Bernhard Osterburg, Frank Offermann and Werner Kleinhanß present a new PMP type farm group model (FARMIS) for German agriculture, not regionally differentiated, but designed to consistently check and complement analysis with the regionally differentiated sister model “RAUMIS". Christian Flury, Nikolaus Gotsch, Peter Rieder report on a spatial linear programming exercise with disaggregated modelling of farm types and detailed consideration of regional differences in topography and yields. They stress the usefulness of the model to enhance the efficiency of policies addressing ecological problems of fallow land on steep slopes. Céline Graindorge and Bruno Henry de Frahan demonstrate the crucial importance of technology specification for simulating impacts of Agenda 2000. The conventional PMP specification is shown to generate exaggerated effects on income and even more on activity levels when compared with specifications based on endogenous yields or more flexible cost functions. Torben Wiborg and Svend Rasmussen explain the current status of KRAM, a dynamic, regionalised programming model for representative farm types in Denmark. Due to its detailed description of manure application and feeding technology it is already useful for analysing selected environmental policies even though certain modules, e.g. for investment, are still under construction according to the authors' outlook. Finally, there are five briefs on further research related to the topic of this chapter.

Chapter V addresses the policy analysis using national models. An important fraction of these analyses rest on a calibrated set of parameters. This is the usual case for CGE applications such as the one by Ferdinand Pavel. His model is designed to capture the distortions due to the market power of food processing and retailing companies in Bulgaria. The analysis shows that in this early stage of the transition process, the introduction of competition into the food chain is far more welfare improving than conventional tax and tariff reform packages. Olaf Wahl and Uwe Eiteljörge recommend for Russian trade policy an unequivocal liberalisation instead of reviving CIS oriented and protectionist trade arrangements. The analysis rests on RATSIM, a partial equilibrium model based on systems of microeconomic behavioural functions and on the Armington approach to incorporate bilateral trade flows with Russian trading partners. The next contribution by Gerald Weber uses CEEC-ASIM, a similar calibrated partial equilibrium model giving welfare effects and net trade results for 10 CEEC countries in considerable product differentiation. Adoption of the CAP results in clear welfare gains, usually because producer gains outweigh small losses in consumer welfare and CEEC contributions to the EU budget. Julian Binfield, Trevor
Donnellan, Kieran McQuinn present the principles of an econometric model for Irish agriculture developed under the auspices of the FAPRI-Ireland Partnership. A set of individual commodity models is usually solved over a ten-year horizon, linked to the FAPRI EU and world models, to perform medium run policy analysis, most recently on Agenda 2000 impacts. Finally we have John F.M. Helming, Paul J.J. Veenendaal, and Ludo Peeters in this chapter, explaining “SELES”, a user-friendly modelling tool used in the Flemish government to assess the agricultural and economy-wide effects of (manure) policies. Its core components are a PMP type, 8 region model specifically designed to address environmental issues which is linked to an input-output model for Flanders that permits to capture effects beyond agriculture.

Chapter VI collects policy analyses at European or international level. The first papers of this chapter emphasise CAP modelling. Patrick Westhoff and Robert Young II report on recent moves to incorporate country models for important EU countries into the Food and Agricultural Policy Research Institute's (FAPRI) efforts to prepare market projections and conduct policy analysis. They would complement the existing arsenal of multi-market, structural, dynamic, non-spatial, partial equilibrium models of international agricultural markets. Max Merbis explains the recent use of the “CAPMAT” accounting tool which is relying on the well known GE model “ECAM” to provide endogenous changes to CAP scenarios such as Agenda 2000. Options for future improvements refer to exogenous projections of world market prices, to the search for an updated “response model” and to the incorporation of FADN data. H. Peter Witzke and Andrea Zintl report on a new modelling tool for EU policy makers, the "MFSS99" (which is not a tanning lotion as Richard Howitt suggested; the impartial author of this introduction). This is a highly differentiated partial equilibrium model for the EU member states employing calibrated elasticities. The authors put considerable emphasis on transparency, reliability and policy relevance of the tool based on modelling structure and user interfaces. Thomas Heckelei and Wolfgang Britz present the CAPRI (Common Agricultural Policy Regional Impact) modelling system. CAPRI integrates regional PMP-type supply models with a multi-commodity market model. This concept allows for an unprecedented combination of regional disaggregation and full EU-coverage. Results of an Agenda 2000 scenario illustrate the type of information, which can be generated by this modelling system. Moving to the level of global modelling, Martin von Lampe presents a sensitivity analysis on the impacts of macroeconomic variables in South-East Asia on food demand. Simulations made use of the non-spatial partial equilibrium trade model WATSIM, which is highly differentiated in terms of regional and commodity representation. They confirm the importance of recent income drops in east Asia for the current slump in international markets. Previous contributions accepted some compromise in terms of “explicit policy representation” (see Chapter II) in exchange for wide commodity coverage. Giovanni Anania puts forward - as an example of focus on the former - a spatial mathematical programming model for wheat called CAMINÍA. It explicitly covers tariffs, minimum intervention price and variable levy policies, tariff rate quotas (TRQs), and preferential trading, albeit in the single product and partial equilibrium framework with perfect competition.

The closing session of the 65th EAAE Seminar was put under the heading of "the institutional setting of policy modelling", and opened with short speeches from representatives of three policy related agencies which acted as initiators, clients, participants and translators of agricultural sector modelling efforts and policy information systems. All speakers used the opportunity to put forward their views on the respective agency's proper role in the area of policy modelling. Dirk Ahner of DG Agri focuses first on past experiences with and use of policy information systems, then looks at ongoing activities and closes with ambitions for the future. He points out that in the past DG Agri frequently and quite successfully relied on the
SPEL modelling system. Recent years were characterised by a quite diversified use of modelling tools from all over Europe. This is considered a beneficial development perfectly in line with the arguments in favour of complementary use of models repeatedly expressed on this seminar. Another important statement for our profession concerns the strategy towards outsourcing policy research. Even though there have been ambitions to develop internal modelling capacities (to which the MFSS99 project, see Witzke, Zintl, certainly owes its existence), Ahner also pointed to severe resource constraints within DG Agri, rendering the outsourcing strategy almost imperative. A similar message is received by the editors of this volume from David Heath, director of Eurostat's section F responsible for Agricultural, Environmental and Energy Statistics. After briefly reviewing and evaluating past modelling activities with the SPEL system, for consistency checks, "nowcasting" and further analysis on behalf of policy makers, he introduces a new project, the Agricultural Information System AgrIS, which Eurostat is currently developing. This system is aiming at consistency checks and completion of missing data through an intensified communication with EU member states. Heath acknowledges that AgrIS data will require some "further general operations" for modelling purposes which are "usefully undertaken by one body" but - in line with his general thrust in favour of outsourcing - refrains from accepting this second stage of data processing as a task of Eurostat. On top of this, certain model specific steps will usually be required, motivating his picture of a three state rocket of data processing for modelling purposes, with the responsibility for the second stage to be clarified in the future. For the OECD, monitoring and analysing agricultural policies is part of the organisation's core competencies and tasks. Loek Boonekamp explains that it is mainly the international repercussions of national agricultural policies, which motivates OECD's involvement. The main quantitative contributions provided by the OECD are the well known PSE/CSE calculations - which is currently supplemented by the Policy Evaluation Matrix (PEM) approach - then the coordination of the Agricultural Market Access Database (AMAD) effort, and finally the OECD's own agricultural sector model AGLINK. Application and procedures within the latter are presented in more detail, concluding that the member state expertise generates significant synergies in the AGLINK framework.

These opening speeches stimulated a lively discussion chaired by Wilhelm Henrichsmeyer. After a while, however, a number of colleagues, who knew that the year 2000 is also the year of Wilhelm Henrichsmeyer's retirement, seized the opportunity to give improvised addresses acknowledging his professional life. Michiel Keyzer, Paul Veenendaal and Dirk Ahner thus shared some personal anecdotes with the audience. Siegfried Bauer, Klaus Frohberg and Richard Howitt gave their appreciative evaluations of Wilhelm Henrichsmeyer's work and influence in the area of quantitative policy consulting. Being ostensibly taken by surprise, the chair closed the seminar, announcing that he had no intention to completely retreat from the agricultural sector modelling community. Not only the authors of this introduction appreciated this intention.

After having looked at the seminar itself, we finally like to take the opportunity to express our gratitude to a number of people. Tracing back the origins of this volume, we have to admit that we put a large weight of responsibility on the secretary of the Chair of Agricultural Policy at Bonn University, Brigitte Sonnleitner-Schödel. Fortunately (and as expected), she did not only manage to deal with the associated multitude of tasks, but preserved her cheerful attitude almost through the whole period of preparation. It was in danger only when she had to remind the authors about the next necessary steps one time too often. In the immediate wake of the seminar and of course during the three seminar days we had to rely on more and more, in the end on almost all human resources we could get hold of. We thank Wolfgang Britz, Udo Bremer, Hans-Josef Greuel, Andrea Zintl, Elisabeth Paffenholz, Anni Wiertz, Martin von Lampe, Bettina Rudloff, Claus and Tanja Möllmann,
Reinhard Sander, Kai Bauer, Andreas Quiring, Hendrik Wolff, Marcel Adenäuer, Lorenz Wild and surely some others who should have been mentioned here for the services provided at the seminar. During the preparation of the Proceedings we were again shifting some workload on other shoulders, especially to Christine Wieck, who was responsible in part to check the "standardised format" we imposed on our authors.

To the authors we owe at least three big thanks: for their patience in waiting for the proceedings, a lot of good will regarding our continued and sometimes prolonged requests for changes here and there in their manuscript, and, most importantly, for their original contributions filling our structure with content.

Bonn and Pullman, October 2000
Chapter II

Reviewing Agricultural Sector Modelling
Recent developments in modelling the CAP: hype or hope?

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Abstract

In this paper, we analyse different approaches to modelling the major agricultural policy instruments of the Common Agricultural Policy (CAP). The literature surveyed includes econometric models, mathematical programming models, partial equilibrium models, and multisectoral models including both single-region and multi-region applied general equilibrium models. In order to keep the task manageable, we have elected to limit the greater part of the discussion to the last decade. The core of the paper is structured around a discussion of modelling approaches to four classes of policy instruments: direct price support schemes, partially decoupled payments, trade policies and multilateral commitments, and supply management tools. We conclude with an overall appraisal of the state of the art in CAP modelling and try to identify the needs for future research on agricultural policy modelling.

Keywords: CAP, Agricultural Policy Instruments, Econometric Models, Mathematical Programming Models, Partial Equilibrium Models, Multisectoral Models

1 Introduction

In this paper, we analyse different approaches to modelling the major agricultural policy instruments of the Common Agricultural Policy (CAP). Our goal is to assess the degree of realism of the approaches followed in order to represent the CAP by the different types of models. This means that we will not evaluate the strengths and weaknesses of the various models from a theoretical point of view or according to the interest raised by their results. Rather, the focus is on the models’ performance in terms of their capacity to model policies as closely as possible to how they work in practice.

The benchmark for our assessment is provided by explicit policy modelling, that is, the possibility to fix model variables exogenously, in the same way as they are actually fixed by the policy-makers. This is almost never the case. When the model structure does not allow to implement this “first-best” solution, an indirect policy modelling approach is used. In these cases, modellers must introduce a model-equivalent representation which should be as close as possible to the policy changes they are to affect.

* The paper presents some preliminary results of a research project financed by the Italian National Institute of Agricultural Economics (INEA) on “Empirical models for the evaluation of the impact of agricultural policies”, co-ordinated by Giovanni Anania. The overall objective of the research program is to provide a comprehensive analysis of modelling issues and applications related to the CAP.
In order to keep the task manageable, we have elected to limit the greater part of the discussion to the last decade. In the same spirit, we assume that our readers are familiar with the policy issues and policy instruments that are of prime importance within the context of the current CAP.

The main modelling approaches will be briefly presented in the following section. The core of the paper is structured around a discussion of modelling approaches to four classes of policy instruments: direct price support schemes (section 3), partially decoupled payments (section 4), trade policies and WTO commitments (section 5) and supply management tools (section 6). We conclude with an overall appraisal of the state of the art in CAP modelling and try to identify the needs for future research on agricultural policy modelling.

2 Main modelling approaches

The literature surveyed in this paper includes econometric models, mathematical programming models, partial equilibrium models, and multisectoral models including both single-region and multi-region AGE models.

Econometric models are largely used in order to measure the impact of specific agricultural policy instruments on farmers’ production decisions. Most of these models are focused on some specific tools or commodities, while we are still missing explicit attempts of accounting for a comprehensive set of policies, affecting different commodities, in the same econometric model. Another ‘standard’ limitation is that in most of these models output and input prices are not the result of the simulation, so that the impact of policy changes on equilibrium prices has to be postulated exogenously. On the other hand, it must be recalled that parameter/elasticity estimates emerging from econometrics models are often used as input for other simulation models, whose size and structure does not allow direct estimation of relevant parameters (as in the case of many partial and general equilibrium models).

Mathematical programming (MP) models used for agricultural policy analyses can be grouped into two categories: those deriving from the ‘classical’ MP and those that have adopted the more recent approach of Positive Mathematical Programming – PMP (Howitt, 1995; Paris and Howitt, 1998). In recent years, MP has evolved considerably, losing the features of a pure farm management instrument. Presently, it is an important instrument of policy analysis at the regional, national as well as EU level, with the objective of analysing the impact of agricultural policies on supply and on the socio-economic and environmental systems linked to the farming sector.

Partial equilibrium models have been widely employed in the analysis of the CAP. Most of the models considered are multi-product and aim to model the international trade in

1 Most of these models are built as modifications of the standard short run profit maximisation model (Chambers, 1988). The standard theoretical framework has been modified to account for price uncertainty and minimum prices (Chavas and Holt, 1990; Coyle, 1992; Oude Lansink, 1999), production quotas (Moschini, 1988; Fulginiti and Perrin, 1993; Helming et al, 1993; Gardebroek et al, 1999), tradable output quotas (Guyomard et al, 1995 and 1996a; Boots et al, 1997), land allocation and direct payments (Guyomard et al, 1996b; Oude Lansink and Peerlings, 1996; Ball et al, 1997; Moro and Scokai, 1998).

2 Examples of the first typology are represented by the Land Use Allocation Model – LUAM (Jones et al., 1995) and the AROPAJ model (Jayet, 1993). The PMP has been recently used in several European research projects (Barkaoui and Boutault, 1999; Gohin et al., 1999d; Heckelei and Britz, 1997 and 1999; Hofstetter et al., 1999; Martinez Vincent et al., 1999; Paris and Arfini, 1999).
primary commodities. They have been widely used in assessing the effects of the Uruguay Round Agreement on Agriculture (URAA). Not surprisingly, given their importance in the international negotiations on agricultural and trade policies, the focus is on developed countries and the products considered are mostly those of the temperate zones, such as cereals, oilseeds, dairy, beef and pork meat, and, more rarely, sugar and cotton.

The multisectoral analysis of agricultural and rural policies is another body of literature that is rapidly expanding (Hertel, 1999; Gohin et al., 1999a). A first distinction can be made between linear models and applied general equilibrium (AGE) models. Within AGE models, we can distinguish single-country from multi-country models. The latter are usually global in scope, though the level of sectoral and regional aggregation varies from case to case. As may be expected, the assessment of the consequences of the URAA and of the EU enlargement has been the major focus of these models.

3 Direct Price support

This section deals with modelling EU domestic policies that directly affect prices received and paid by producers. Although in the 1990s the CAP has started to shift away from price support, minimum guaranteed prices are still being implemented – as in the case of arable crops – and this raises the issue of the linkages between institutional and market prices.

In MP models output and input prices are always taken as exogenous. This implies that there is no room for an explicit modelling of the policy instrument, since these models do not differentiate between market and institutional prices. In principle, one should know ex ante (perhaps using a different type of model) what are going to be the actual market prices, rather than the institutional prices, introducing them into the model. Paris and Arfini (1999) provide an example in which, in order to assess the effects of price changes, different scenarios concerning the level of market prices are considered.

Econometric models usually focus on the supply side, so that prices are mostly exogenous, and applications exist which adopt the ‘extreme’ assumption that changes in

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4 Linear models are either based on input-output tables (Leat and Chalmers, 1991; Roberts, 1994; Serrão, 1998) or on social accounting matrices (Roberts and Russell, 1996). Originally, the term “applied”, rather than “computable”, GE models was given to “pure” neo-classical models, nowadays, the two terms tend to be interchangeable.

5 There are only a couple of examples of national AGE models modelling CAP instruments: the Modèle d’équilibre général de l’agriculture et de l’agro-alimentaire français - MEGAAF (Gohin et al., 1998, 1999b, 1999c) and one model referring to Hungary (Banse and Tangueramm, 1998).

6 ECAM (Folmer et al., 1995) is the only multi-country model without a global coverage. Most of the global models are based on large databases as in the case of the Global Trade Analysis Project – GTAP (Hertel, 1997) and other models that use the same database: MEGABARE (ABARE, 1996); Future Agricultural Resources Model - FARM (Darwin et al., 1995); World Trade Organization - WTO (Francois et al., 1996); Harrison et al. (1997); of the OECD-Rural Urban North South model – RUNS (Burniaux and van der Mensbrugghe, 1990) and Weyerbrock (1998) that uses the same database; and of the MICHIGAN model (Brown et al., 1996). There are also cases of global models of a smaller scale, both in terms of regions and products considered, as in the case of Fehr and Wiegard (1996), Nguyen et al. (1993), Harrison et al. (1995).
Recent developments in modelling the CAP: hype or hope?  

Institutional prices are entirely transmitted to market prices (Oude Lansink and Peerlings, 1996). However, more sophisticated modelling has offered the possibility to incorporate policies as elements influencing expectations on market prices. Accordingly, estimated elasticities account for the attitude toward risk, the price guarantee and the expectation formation.\(^7\)

In contrast to MP and econometric models, partial and general equilibrium models are primarily aimed at the evaluation of the market impact of ‘coupled’ domestic policies. Output and input subsidies can be represented through percentage price differentials between producer and consumer/user prices.\(^8\) However, this does not ensure an explicit modelling, since the model-equivalent representations always require some aggregation either across products or across policy instruments. In the case of aggregation across products, it is necessary to use an average subsidy; in the case of aggregation across policy instruments, it is necessary to use an equivalent subsidy, such as the PSE calculated yearly by OECD for a variety of countries and commodities. In both cases, the computation of the policy input for the model would require a much more careful and resource consuming evaluation than is usually the case.\(^9\)

Minimum guaranteed prices are usually included in partial and general equilibrium models by setting the domestic price exogenous within “price transmission” or “price linkage” equations that relates international and domestic prices (see section 5). This procedure does not account for domestic market price formation as a consequence of the existence of the guaranteed price schemes, and this could be a problem if there are constraints on the use of border policies. When the URAA export subsidy commitments become binding, as a matter of fact, the domestic price decreases; if the existence of a minimum price is not represented in the model, the simulated domestic price level could end up being unrealistically low (that is, below the intervention price).

Since CAP institutional prices (namely, intervention and threshold prices) influence the domestic market price, a crucial issue is the modelling of the transmission from institutional to market prices. In principle, an explicit modelling of the price support requires fixing exogenously institutional prices and letting the model determine endogenously the actual market price. Accordingly, the evaluation of the “elasticity of transmission” between intervention and market prices would provide a relevant input both for policy-makers (assessing the extent of the over/under-compensation of farmers implied by a given payment compensating a reduction in minimum guaranteed prices) and for other models (as in the case of MP models).

A more detailed treatment of price support policies appears to be possible in AGLINK. In this case, thanks to the market clearing mechanism that takes into account both exports and stocks, domestic prices can be different both from intervention and world prices. For example, for cereals and beef, the model assumes that, when domestic prices are above world prices and close to intervention prices, excess production will first be exported (through subsidies) up to the URAA limit, and then stocked; conversely, both subsidised exports and stocks are assumed to decline as long as the domestic price increases to well above the intervention

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\(^7\) This is the case of Oude Lansink (1999), where farmers are assumed to maximise a “mean–variance” expected utility function and the variance–covariance matrix can be specified according to a distribution truncated at the minimum price level.

\(^8\) If this price differential is endogenous (that is, it is adjusted in order to maintain a fixed producer price), this amounts to explicitly modelling a deficiency payment scheme.

\(^9\) The PSE, for example, provides a (first order approximation to the) subsidy equivalent in terms of producer welfare. Accordingly, the PSE is an appropriate policy index if one wants to assess the redistributive impact of policy changes; it is less so if one is interested in other types of impact as, for example, the supply response.
price. In this model, then, a change in the intervention price is not necessarily equal to the resulting change in the market price.

Other partial models in which, at least in principle, the linkage between institutional and market prices can be taken into account are FAPRI and SPEL/EU. In the former – considering the available documentation for the US model - domestic market prices seems to be differentiated from institutional prices, market prices being determined according to the degree of participation of farmers to support schemes. In the medium term simulator of SPEL/EU, prices are treated in an adaptive price expectation model that, if properly specified and weighted with expert judgements, should in fact incorporate the existence of intervention prices.

One further drawback to the representation of minimum guaranteed prices relates to the modelling of public stockholding associated with this measure, and implying both relevant administrative costs and relevant effects on exports and domestic utilisation. Proper modelling of stock changes requires a dynamic specification. However, even among the partial equilibrium models allowing for a dynamic specification – such as AGLINK, FAO–WFM, FAPRI and SPEL/EU – it is hard to find an endogenous determination of public stocks. The rationale behind this choice is that any decision on public stockholding is heavily subject to political considerations, and it is, thus, difficult to model. An exception is provided by AGLINK and FAPRI, in which public stocks are endogenous. In AGLINK, public stocks are related to the ratio of domestic to intervention prices; their functional form allows them to become extremely elastic as domestic price falls below the intervention price, falling to nil as domestic price increases well above the support level.

Also in general equilibrium applications there are conceptual difficulties in explicitly modelling public stockholding. The most common solution is to treat public stocks as exogenous factors, reducing the excess supply that needs to be exported through subsidies (Fehr and Wiegard, 1996; Harrison et al., 1995; Weyerbrock, 1998). The main drawback to this formulation is that it takes into account neither the public cost of stockholding – certainly relevant in the case of the CAP – nor the release of stocks, either on the domestic or foreign markets. A more realistic representation is provided by ECAM, where public stocks management (and the costs associated with it) is explicitly assumed among exogenous variables evolving over time.

In conclusion, the absence of modelling of public stockholding decisions implies an overestimation of EU (subsidised) exports, with a consequent overestimation of the effect of CAP on world prices. However, it could be argued that governments cannot handle permanent increases in public stocks: sooner or later these will either be destroyed or exported, and then the modelling of public stocks could boil down to the specification of an appropriate length for the stocks adjustment period. On the other hand, when public demand is explicitly considered, it is an exogenous component and, especially in the case of static models, it could be argued that the budget cost of the policy is somewhat overestimated.

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10 A stock component is included in FAO/WFM, without differentiation between private and public holding while only private stocks are included in SPEL/EU

11 Moreover, aside from specification problems, a model generating optimal stocks level in each period requires an inter–temporal optimisation mechanism, which is not incorporated in the models, whose dynamic is recursive.

12 The two models differ in the treatment of private stocks, which are exogenous in AGLINK but endogenous in FAPRI.

13 The assumption is that stored commodities “are ‘eaten’ by EC government agents” (Hertel, 1999: 19). In the short run (presumably before the stored commodities spoil), though, there could be fluctuations in world prices that allow the EU to reduce the level of stocks.
4 Partially decoupled payments

Modelling partially decoupled payments seems to be one of the most difficult challenges for applied agricultural economists. Since the 1992 reform of the CAP, the use of compensatory payments linked to fixed inputs like land (field crops) or livestock headings has become one of the major features of the CAP. Thus, researchers incorporated these new policy tools in their policy simulation exercises. In doing so, they had to deal with the partially decoupled nature of the compensatory payments, which implies distortions in factors’ allocation and changes in yields.

The modelling approaches vary typically according to the type of models and their level of aggregation. In fact, the modelling task turns out to be easier for those models that are built on explicit hypotheses concerning the optimising behaviour of individual farmers, and where single commodities are modelled explicitly (typically MP and econometric models); while it is more difficult for those models where behavioural relationships are represented by reduced form equations and where the level of aggregation is very high (typically, general equilibrium and large partial equilibrium models).

Considering, as an example, the case of compensatory payments for cereals, oilseeds and protein crops (COP) - the most widely studied partially decoupled policy tools - modelling explicitly individual profit maximisation leads to a straightforward extension of the expression for farmers’ profits, with the addition of the product of the (endogenous) land allocations multiplied by the (exogenous) COP payments. This clearly does not create any problem for MP models, where this extension can be easily managed in the standard optimisation set-up (Barkaoui and Boutault, 1998; Heckelei and Britz, 1997; Jones et al., 1995; Paris and Arfini, 1999). On the other hand, the nature of these models does not allow for an endogenous treatment of the effects on yields.

Econometric models incorporating COP payments are based on extensions of the standard dual profit function, that accounts for land allocation decisions. When researchers are forced to estimate their models on pre-reform data, the impact of direct payments can be evaluated simply modifying certain key equations (related to the equilibrium shadow prices of land allocated to different crops) and assuming that pre-reform parameters continue to represent the relevant technology (Oude Lansink and Peerlings, 1996). Using comparative static results, ‘implicit’ output supply/input demand elasticities with respect to compensatory payments can also be computed (Guyomard et al, 1996b), but it is acknowledged that the use of parameters estimated on the basis of pre-reform data in order to simulate a totally different policy environment is highly questionable. In fact, if post-reform farm data are available, the relevant parameters/elasticities can be estimated directly (Moro and Sckokai, 1998).

The main advantage of the previous model types is that both of them (MP and econometric models) take into account one of the key aspects of the new COP regime, the land allocation distortions (within the agricultural sector) generated by crop-specific payments. A limitation is that, being based on individual optimising behaviour, they cannot take into account some important ‘aggregate’ features of the COP regime, like the existence of a financial stabilizer based on the ‘base area’.

The situation is quite the opposite for large simulation models (either partial or general equilibrium models); in fact, in many of these models the level of aggregation does not allow to model correctly the land allocation distortions due to COP payments. Modelling problems are especially severe for those AGE models (such as MICHIGAN) where agriculture is modelled at a high level of aggregation. In these instances, as well as for certain large partial equilibrium models (such as FAO-WFM or SWOPSIM), compensatory payments are considered to be fully coupled, including the full amount of the per ton budget expenditure in the equivalent subsidy used as a price wedge.
Conversely, there are authors that model compensatory payments as if they were “fully” decoupled, like in Weyerbrock (1998), where COP payments are a component of the land rent, or in MEGAAF (Gohin et al., 1998), where payments are a fixed component of agricultural profits, tied to the historical base area. As a result, none of these AGE solutions addresses the key issue of land allocation distortions due to the partially decoupled nature of the compensatory payments.

When the level of aggregation on the supply side is less constraining, many models are able to model at least some features of the COP payments. For example, among AGE models several GTAP applications (Bach and Frandsen, 1998; Frandsen et al., 1998; Jensen et al., 1998; Nielsen, 1999) consider direct payments as an input subsidy to the land devoted to COP. Alternatively, when crop supply is represented as the product of land allocations multiplied by the corresponding yields, most partial equilibrium models (AGLINK, ESIM, SPEL/EU, WATSIM) and some AGE models (ECAM) consider COP payments as explanatory variables for land allocations only, but not for yields.

Finally, it is worth noting that some of the large models are able to account for aggregate features, such as the financial stabiliser ensuring that budget expenditure never exceeds a predetermined amount (ECAM and GTAP) or the “Blair House agreement” on oilseeds (AGLINK). In the former case, compensatory payments per hectare are reduced proportionally in case the land devoted to COP (including mandatory set-aside) exceeds the total ‘base area’.

5 Trade policies and WTO commitments

5.1 Trade Policies

Trade policies make domestic prices of exported and imported goods differ from (f.o.b. and c.i.f., respectively) border prices expressed in the domestic currency; in addition, many trade policies tend to reduce the strength of the ties linking fluctuations in domestic and international prices. This explains why trade policies - rather than being explicitly individually modelled - are in most cases represented through a “price transmission” equation or a “price linkage” equation. The former makes changes in the external prices only partially reflected by changes in the domestic prices: how partial the transmission depending on the value of an exogenously determined price transmission elasticity. The latter models the impact of trade policies as a “wedge” between the domestic and the external price: this “wedge” is assumed to represent the “net tariff equivalent” of all the trade policies in place.

The main problem with this routinely used modelling approach to trade policies is given by the fact that non tariff barriers (NTBs) to trade are very popular – they are likely to become even more popular as tariff protection declines as a result of currently implemented and future multilateral agreements - and cannot be properly represented through a tariff “equivalent”. It is so because such equivalence simply does not exist.

With specific reference to the CAP, as a result of a specific side agreement at the conclusion of the Uruguay Round negotiations, the EU is applying to its cereals and rice imports a “variable import tariff” which can barely be distinguished from a “variable levy”. Most models represent these “variable tariffs” through their “tariff equivalents”; however, the

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14 Quotation marks here mean that many factors (possibly) reducing the degree of decoupling are not taken into account: labour decisions of households, farmers’ investment decisions, risk perception of agricultural producers, existence of a positive marginal cost of taxation (Gohin et al., 1999e).

15 The “tariff equivalent” for an import quota that is not binding is zero. The “tariff equivalent” for a quota that is binding is a function of the equilibrium prices, hence the “tariff equivalent” of a given import quota varies with the market equilibrium and should be endogenously determined as part of the modelling effort.
“variable tariff” actually applied should be endogenously determined in the simulation exercise. This is seldom the case. In the same vein it should be recalled that “variable export subsidies” (export restitutions in the CAP jargon) cannot be represented through fixed or ad valorem “equivalent export subsidies”, but instead they should be endogenously determined.\(^{16}\)

Other relevant NTBs which cannot be adequately modelled through “tariff equivalents” include tariff rate quotas (TRQs) – like the tariff reduced import quotas in place in the EU for bananas, sugar, meats, grains, and fruits and vegetables - and tariff schedules which change seasonally - like those typically applied to EU imports of fruits and vegetables.

The price “wedges” used to model trade policies are often given by the PSEs. Using the total per unit PSE, or its per unit “market price component”\(^{17}\), as the “wedge” in the “price linkage” equation has several shortcomings:

i) Since the PSE is a measure of the support agriculture receives as a result of all agricultural policies, not only trade policies, when the “wedge” is given by the total per unit PSE it significantly overestimates the actual impact of trade policies.

ii) The per unit PSE may change (and, in fact, PSEs do widely change from one year to another) even if policies do not: the “price component” is affected by fluctuations in world prices as well as in exchange rates; while the “non-price component” depends on the quantity produced, and the latter may change from one year to another as a result of factors which have nothing to do with changes in the policies in place.

iii) While it could make sense to use PSEs as “wedges” when the goal is to model a full policy liberalisation (i.e. the elimination at once of all policies supporting agriculture), because PSEs do not allow for taking into consideration the different effects of the various trade policy instruments used, their use is much less satisfactory when a partial liberalisation is considered; it is even less so when the considered policy change foresees a redistribution among policy instruments of the support granted to farmers or the introduction of new policy instruments, as it is the case for the CAP reform (Laird, 1997).\(^{18}\)

Because of the variety of the trade policy tools used by the EU, and because of the characteristics of the on going CAP reform process, the most proper way to model EU agricultural trade policies is to do it “the hard way”, by explicitly modelling the most relevant ones. This appears to be relatively easier in partial equilibrium models cast in an MP framework (Anania, 2000); developments in AGE modelling in this respect are very promising.

Modelling specific trade policy instruments is often analytically and computationally difficult and requires detailed policy information, which sometimes is not easily available. Even modelling a tariff, which one might think of as a pretty straightforward task, can turn out to be a cumbersome exercise.

Firstly, models consider commodity definitions that are aggregated to a much greater degree than those used in the specification of the tariff lines. This means that relevant tariffs...

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\(^{16}\) Weyerbrock (1998) explicitly models both variable levies and export restitutions. The GTAP framework can accommodate explicit modelling of variable levies and export restitutions. In the FAO/WFM export subsidies are represented only indirectly, through an (exogenously determined) “price effect”.

\(^{17}\) This is the case, for example, of the GTAP modelling framework and of the work done at OECD (1999b) to develop the PEM modelling framework.

\(^{18}\) OECD (1999a) modified its way of measuring direct and indirect policy transfers to farmers, introducing the “Producer Support Estimate”: this more accurate and disaggregated classification of the support seems very promising for models which use PSEs to represent the effects of trade as well as domestic policies. Also with reference to OECD related activities, it is worth noting that even if AGLINK is currently using the PSEs as price wedges, work is under way to move towards explicitly modelling trade policy instruments (mainly including “equivalent” ad valorem tariffs, quotas, TRQs and variable levies).
need to be averaged. No matter what average is used, this induces a distortion in the model representation of existing tariff market protection. The higher the commodity aggregation in the model, the tariff dispersion, and the commodity disaggregation in the definition of individual tariff lines, the higher the distortion.

Secondly, fixed “per unit” tariffs are transformed in their “ad valorem” equivalent by using a reference border price. Whenever the border price in the model solution is different from the reference border price used to compute the “equivalent tariff”, the tariff protection assumed in the model will be distorted, as the money value of the “tariff equivalent” will be different from the fixed per unit tariff in place.

Thirdly, the tariffs indicated in the URAA country “schedules” are often used as the model tariff database (as in the case, for example, of the FAO/WFM). However, these maximum tariffs are not always binding, since they are very often significantly higher than applied tariffs: this means that their use as the model tariffs overestimates actual tariff protection. Furthermore, there are cases, including the EU for commodities such as sugar, bananas, and fruits and vegetables, where “Most Favoured Nation” (MFN) tariffs are seldom applied, as most imports occur under preferential tariff arrangements. When this is the case, using applied MFN tariffs in a model significantly overestimates existing market protection.

Finally, tariffs are modelled by imposing a wedge between the domestic and the c.i.f. border prices. If a tariff is prohibitive, this is meaningless and forcibly introduces an unrealistically large difference between domestic and “world” prices. However, it is not always known whether a tariff is prohibitive or not before a solution based on the specific policy scenario considered is found.

The EU has many preferential trade agreements in place that allow agricultural imports from preferred countries to occur at significantly reduced tariffs. EU export restitutions for most commodities are discriminatory as well, as they are differentiated by country of destination of exports. Modelling existing and foreseen EU discriminatory trade policies - which includes modelling EU enlargements - can be properly done only within a spatial trade modelling framework, i.e. within a framework which explicitly takes into account and reproduces bilateral trade flows. However, most modelling efforts are non spatial, and, surprisingly enough, this is the case even for some of the models used to specifically assess the implications of enlargements of the EU (ESIM; Frohberg et al., 1998). For those modelling efforts which can accommodate discriminatory trade policies thanks to the assumption that products produced in different countries are not perfect substitutes, the issue is whether this assumption does adequately represent reality, or whether it is used merely as a way to overcome the limitations of the model due to its non spatial nature. If there is enough evidence to believe that the assumptions made with respect to product differentiation do actually represent how consumers/users perceive products from different countries, then the model can properly assess most discriminatory trade policy. If this is not the case, then there is no short cut to using a (truly) spatial model.

19 Although less developed countries are most often the beneficiaries of preferential trade policies, the FAO/WFM, because of its structure, cannot take them into account. The GTAP framework is capable of accommodating preferential tariffs and subsidies, but in AGE models it is often the definition of the countries/regions to be a problem, as it may be inconsistent with that of the sets of the countries receiving the different degrees of preference.

20 Does it really make sense to assume that pork meats produced in Greece and Denmark are perfect substitutes (the EU being modelled as one country), and that this commodity (whatever it is…), is an imperfect substitute for pork meat produced in Poland, which, in turn, is not a perfect substitute for pork meat produced in Russia?
5.2 URAA commitments

The URAA established a new regime for agricultural trade under the headings of domestic support, market access and export competition. Domestic support reduction has not been an issue for the EU. Virtually no country, and certainly no major player, has been forced to modify its policies or is expected to have to do so in the near future as a result of its “domestic support” commitments. Nevertheless, several models – mostly AGEs - represent these commitments by imposing the agreed upon 20% reduction of the AMS to the model base domestic production support. In addition, when the implementation of this specific commitment is explicitly considered, models tend to ignore: (a) the existence of domestic support which is exempted from the reduction commitment (that included in the “green” and “blue” boxes and that which can claim the “de minimis” exemption); (b) that the AMS is a measure of total support, not only of the support due to domestic policies, and that it is affected by the fulfilment of the other URAA commitments (Anania, 1997); and (c) that a reduction by 20% of the coupled support would induce a decline in the AMS larger than 20%, because of the decline in production it will determine. The result is a significant overestimation of the liberalisation impact of the “domestic support” commitments.

Tariff reduction commitments are very often applied to maximum binding, rather than current (in the base scenario) tariff rates. Consequently, the impact of the URAA in terms of increased market access is significantly overstated. A distortion in the same direction is induced when the tariff reduction is applied to the “tariff equivalent” given by the “observed” difference between the domestic and the c.i.f. border prices in the base scenario; in fact, this difference incorporates the effects of trade policy interventions different from the tariffs; however, tariffs only are what has to be reduced as a result of the agreement (i.e. it is implicitly assumed that all policies having a market protection effect are to be reduced as a result of the agreement). The product definition used in the models is always more highly aggregated than that used for listing tariff reduction commitments in the country schedules. In most cases the average 36% reduction commitment is applied across the board to all tariffs considered in the models. Because countries committed themselves to reduce by a lower extent the most sensitive tariff lines, while cutting by more than 36% the lower, less sensitive ones, this implies overestimating the reduction in market protection as a result of the GATT agreement (Bureau et al., 1999).

“Minimum” and “current access” reduced TRQs are particularly relevant for the EU. Proper modelling of TRQs implies allowing for a switch (as a function of the volume imported) between two tariff levels - one for “in quota” imports, the other to be applied to “out of quota” imports, once the quota is filled. If imports above the TRQ take place, the TRQ is essentially irrelevant (but for the rents it generates and their effects). In addition, the model needs to allow for intra-industry trade, even if homogeneous goods are assumed; it is so, because the country that committed itself to the TRQs is often (as it is the case for the EU) a net exporter of the same commodities. Many TRQs carry the indication of the specific country (or countries) imports within the TRQ should come from; modelling this important aspect of the TRQs can be done, again, only in a spatial trade model (or in a model that differentiates imports by country of origin). In some cases (as the FAO/WFM, for example), imports by net exporters are assumed to be at least equal to the TRQs. However, this is consistent neither with the agreement (the commitment being allowing imports within the quota to occur at the lower tariff rate, if they are profitable), nor with what has been taking place (imports remained for many TRQs well below their volume).

Incorporating a minimum constraint on a trade flow (rather than imposing an equality) in an AGE model creates serious computational headaches. A procedure to model TRQs in an AGE has been proposed by Bach and Pearson (1996); for an attempt to model TRQs within the GTAP framework see Elbehri et al. (1999).
The export competition commitments - a 36% reduction of the export subsidy expenditure and a 21% reduction of the volume of subsidised exports - are represented in most models by imposing a 36% reduction of per unit export subsidies. *Per se* this does not guarantee that subsidised exports decline by at least 21%. In fact, in the first years of the implementation of the agreement it is the constraint on the volume of subsidised exports which has most often been binding, not the one on the expenditure. This means that modelling the two commitments as a 36% reduction of the per unit export subsidy underestimates the reduction in subsidised exports deriving from the implementation of the URAA. Some models attempt to model both commitments (Blake et al., 1998; Bach and Frandsen, 1998; Weyerbrock, 1998), but the maximum constraints on subsidised exports is often introduced as a constraint on exports as such, imposing the assumption that non subsidised exports cannot take place once subsidised exports reach the maximum volume allowed under the agreement. It is important to emphasise that allowing unsubsidised exports to occur once the commitments on export subsidisation become binding is specifically important in the case of the EU, where, for example, non subsidised exports in dairy products significantly increased as the commitments became binding. When the two “export competition” commitments are explicitly imposed, however, the possibility to have unsubsidised exports depends on how markets clear when one of the constraints becomes binding. In this respect, we already pointed out that most models do not have an endogenous determination of EU intervention stocks (see section 3): this means that an increase in the EU intervention as a consequence of URAA commitments (as it has been the case for butter, skimmed milk powder and coarse grains) is simply ruled out.

6 Supply management: quotas and set-aside

The product for which the effects of quotas – direct effects as well as the deriving rent – have been most frequently analysed is milk. Among the models where introducing production constraints is relatively simple, the MP and the econometric ones are to be mentioned. For the first type of models, modelling production quotas is only another constraint, usually regarded as a “law constraint” which is added to the structural and organisational constraints already included (Colson et al., 1999; Garoglio and Mosso, 1990). The MP framework allows for explicit modelling of quantity constraints and for the computation of the rents associated to production quotas. Introducing production constraints into econometric models is slightly more complicated. The most common approach (Moschini, 1988; Fulginiti and Perrin, 1993; Helming et al., 1993) is based on the definition of a restricted profit function including both constrained and unconstrained products. Also in this case it is possible to estimate the “shadow price” of the quota, but the most important outcome of econometric models is probably the estimated (implicit) supply elasticity of the product subject to the quota (Moschini, 1989; Fulginiti and Perrin, 1993). This parameter is essential in order to simulate the effects of scenarios in which quotas are removed or their volume modified.

Econometric models are also widely used in order to model the quota rights market, when they exist. Through the estimation of cost/profit functions for different types of farms, it is possible to derive the net demand for quotas and, therefore, the equilibrium price of the quota market; this set-up permits the analysis of many issues related to the management of quota transfers, such as geographical limitations, quantity constraints, taxes in kind, etc. (Guyomard et al., 1995 and 1996a; Boots et al, 1997). Both MP and econometric models,

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22 This is the case for SPEL/EU, while AGLINK allows unsubsidised exports only for some products.
then, permit an explicit modelling of production quotas, provide extremely valuable information in terms of quota rents and, in the case of econometric models, supply elasticities.

Also in the case of partial and general equilibrium models there are examples of explicit modelling of production constraints (SPEL/EU, ECAM). In AGLINK, the quota is always binding, since it is assumed that production capacity largely exceeds the quota. However, the most common modelling choice is to use an indirect approach based on (implicit) taxes. In the case of ESIM, quotas are represented through a producer “shadow price” (Munch and Banse, 1999). In some GTAP applications (Jensen et al., 1998; Nielsen, 1999) and in Weyerbrock (1998), a production tax is introduced and endogenously adjusted in order to ensure that the quota is not exceeded. An even more indirect approach is adopted in MISS, where the level of the rent is exogenously fixed: that is, it is assumed to what extent a price reduction does not affect the production level, but only the quota rent (Mahé and Tavera, 1989).

Alternatively, quotas are modelled in MEGAAF (Gohin et al., 1998) by means of an additional primary factor of production, which ensures that the zero profit condition holds when the production constraint is binding.

Finally, there are models that ignore altogether the existence of production quotas in the CAP. In the case of FAO/WFM, EU domestic policies are of no specific interest, while for some AGE models, the fact that the product under quota is inserted into much wider aggregates prevents any attempt to model product-specific policies (MICHIGAN; Fehr and Wiegard, 1996; Nguyen et al., 1993).

In terms of constraints on the use of inputs, the most relevant example is represented by the set-aside requirements introduced in 1992. Most of the models attempt to introduce this policy instrument by looking at the consequences both on the land allocation and through the slippage effect on yields. The impact on land allocation is modelled explicitly by MP models (Jayet, 1997), by SPEL/EU and FAPRI among partial models, and by MEGAAF and ECAM among AGE models. Adding yield effects is more difficult, since yields depend, on the one hand, on the quality of land set-aside or the possibility to follow a rotational scheme; and, on the other hand, on the increased availability of inputs relative to the cultivated land. Models where the yields adjust endogenously are able to reflect the changes in the use of factors of production. However, the absence of heterogeneous land does not allow for an explicit modelling of rotational set-aside. Consequently, it is always the case that at least some components of the slippage effect are indirectly modelled, since they are (or they should be) taken into account when determining the set-aside rate to be fed into the models, or the shifts of land supply (Blake et al., 1998; Weyerbrock, 1998), product supply (MISS) or land productivity (Frandsen et al., 1998; Salvatici, 1999).

Although it should be recalled that the set-aside requirement applies to farmers who decide to benefit from compensatory payments, the need of modelling voluntary participation is more evident in the case of the voluntary set-aside program. In order to obtain participation rates that vary endogenously, it is crucial to introduce producers’ heterogeneity.

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23 In order to be sure that a quota is modelled as a maximum (rather than a minimum) constraint, the production tax should not be allowed to assume negative values.

24 In all cases, the total amount of agricultural land is fixed, since even the multisectoral models do not allow for non-agricultural uses of land. This clearly rules out any possible intersectoral distortions through the land market.

25 These include not only the slippage effect on yield due to the quality of land, but also the slippage effect on the set-aside rate owing to the presence of the ‘simplified scheme’ (as a matter of fact, the effective set aside rate is always below the announced set-aside rate).

26 In fact, compensatory payments have been so high, that virtually all farmers found profitable joining the scheme.
into the models. Accordingly, one of the main problems in modelling participation is to specify and incorporate an explicit distribution of farms according to their structural characteristics.

Since among the partial and general equilibrium models we considered there is no producer heterogeneity, it is not surprising that farmers’ participation rate is either exogenous (MEGAAF, AGLINK)\(^{27}\) or resulting from the adjustment of the previous period level (FAPRI). Only MP models seem able to show an endogenous participation rate based on the differentiation of farms. As a matter of fact, MP models are the only ones that attempt to model not only voluntary set-aside, but also voluntary participation in agri-environmental policy schemes (Arfini, 1995).

7 Conclusions
The purpose of this paper has been to review some major conceptual issues associated with CAP modelling. The CAP has always used a wide variety of support measures in pursuing agricultural policy objectives, and there have been an increasing number of quantitative assessments of its implications. Over the last decade, though, the policy “mix” – in terms of instruments as well as objectives – has changed considerably.

Much of the traditional analytical work on the effects of the CAP has focused on price support policies, using partial and general equilibrium models in order to simulate the impact on prices. The results generated by these models can provide the prices to be used in MP models in order to have a more detailed analysis of the impact of the policy change in a certain area. Econometric models, on the other hand, seem able to provide a theoretically based modelling of firms’ behaviour. The major issue that still requires a better treatment both in the partial and in the general equilibrium representations of the CAP is the linkage between market and institutional (domestic and border) prices, with the related issue of modelling public stockholding behaviour. Apparently, modelling the joint outcome of market and policy mechanisms is an area that still deserves significant research efforts.

After the May 1992 reform there has been a shift in the mix of support in favour of direct payments as compared to market price support. Since there is agreement on the fact that the compensatory payments are only partially decoupled, an obvious use of empirical models would have been to quantify the degree of decoupling. In this respect, the approaches that seem better equipped to model the producers’ choices are the MP and econometric models. The results of MP and econometric models could provide a valuable input for partial and general equilibrium models, since we saw that in several instances compensatory payments are still considered either “fully coupled” or “fully decoupled”. General equilibrium models, in particular the single region ones, could have an increasing role to play, since they can be detailed enough both in terms of modelling supply and household heterogeneity, while taking into account the budget implications and the income effects deriving from decoupled transfers to rural households.

Modeling EU trade policy instruments is particularly demanding in terms of the capability of the model used to handle discriminatory policies and endogenously determined export restitutions and variable levies. MP and econometric models, for their structural characteristics, appear as the less appropriate to address trade policy issues. However, although in most recent years their popularity seems to have been declining, it is worth noting that spatial mathematical programming models can accommodate explicit modeling of several

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\(^{27}\) In AGLINK, for example, a comprehensive (that is, compulsory plus voluntary minus a slippage factor) set-aside rate is fixed exogenously and then applied to the expected harvested area for each product.
Recent developments in modelling the CAP: hype or hope?  

Modelling production constraints crucially impinges upon the models’ capability to handle inequality constraints. MP and econometric models provide useful insights into the assessment of the distortion introduced by a quota system, as well as of the consequences of a liberalisation of the sector (abolition of the quotas) or of the market for the rights to produce (exchangeable quotas). In this respect, also the modelling performance of partial and general equilibrium models can be considered quite satisfactory. On the contrary, in the case of set-aside most of the modelling efforts share the same limitations, namely the poor treatment of the slippage effect.

Finally, considering voluntary farm programs, the relative late introduction into the CAP could explain why studies that model this type of policies are still so scarce. However, “accompanying measures” are more and more important and the Agenda 2000 emphasises the importance of integrated rural development policies in declaring them to be the “second pillar of the CAP”. Accordingly, we should expect a greater effort on the part of CAP modellers to include such policies in their exercises, accounting for the fact that different farmers will take different decisions about participating to the programmes.

Despite all the problems that have been highlighted, we are convinced that the literature reviewed in this paper yields important insights and helps to frame positions on policy issues. In our view, one cannot say which model or approach is, in general, “best” or “preferred”, and the point to be emphasised is that models are not either right or wrong. However, the previous analysis has clearly showed that each type of models has “comparative (dis)advantages” with respect to the modelling of different classes of policy instruments: there is not such a thing as a single, all-purpose model. Since there is no methodological approach that can be the “jack of all trades”, it seems a good idea to exploit all possible synergies. Intermixing various approaches is not a goal in itself, but it is a good thing not to be confined to only one technique.

Before concluding, let us recall that an accurate assessment of policy changes crucially depends on a realistic modelling of the behaviour of the economic agents. In this respect, the most important enhancements include the introduction of imperfect competition, the modelling of the behaviour of differentiated types of household, and the use of dynamic settings. However, in many cases it would be interesting to model not only the economic agents, but the policy-maker behaviours as well. In the case of a “big player” such as the EU, in fact, it is certainly not realistic to assume that changes in the CAP will not lead to some adjustment by foreign policies and, likewise, that changes in foreign policies will not lead to CAP adjustments.

The quality of the data used is at least as important as the theoretical features of the models in order to determine their capability to properly reproduce agricultural policies. Data information needed to feed the models is scarce and its quality is often unsatisfactory.

On the one hand, a class of data where there could be tremendous improvements is represented by the policy data. When the actual value of a policy instrument (for example a tax or a subsidy rate) cannot be used in the model, as it is often the case, modellers must select the model-equivalent representation. There are many cases in which simple ad valorem equivalent representations are used, giving rise to inaccurate, or even misleading, conclusions. These “policy indexes” (e.g. PSE, average tariff, etc.), as a matter of fact, are easily available, but lack sound theoretical foundations.

On the other hand, there seems to be little doubt that the degree of confidence that policy makers have in models is weakened by the current state of knowledge of behavioural parameters. In the past, Shoven and Whalley went so far as to argue “for the establishment of an “elasticity bank” in which elasticity estimates would be archived, evaluated by groups of
“experts” (even with a quality rating produced) and an on-file compendium of these values maintained.” (Shoven and Whalley, 1984: 1047). Such a proposal could be more realistic now that we have examples of widely accessible global databases, as in the case of the GTAP or, as will hopefully be the case, with the Agricultural Market Access Database (Gibson et al., 1999). Indeed, it seems highly desirable to enhance the flexibility (and maximise the accessibility) of (good) databases in order to spread the development cost over as many users as possible.

Finally, the data issue is obviously related to the choice of the optimal size or level of detail of a model. Because of the complex nature of the programmes and the global interrelationships both among countries and among commodities, any model can easily clash with the limitations imposed by tractability. On the other hand, since CAP varies widely across farm commodities, with some receiving a great deal of support, while others are virtually free of intervention, by lumping several commodities together, little can be said that would carry any weight with agricultural policy makers. There would be a great appeal in maintaining a linked network of databases, various components of which could be combined at different levels of aggregation to be used in different models. This would be consistent with the overall idea that if policy modelling is to become more policy relevant, our profession should pursue the development of a whole set of models, interrelated where possible, tailored to address specific policy issues through the use of the most effective available methodologies.

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Review of agricultural trade models: an assessment of models with EU policy relevance

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Abstract

This paper provides an assessment of the present state of applied modelling in the area of international trade in agriculture and related resource and environmental modelling. This review has a deliberate bias on current European policy issues. The outcomes of negotiation rounds such as WTO trade negotiations and the Kyoto environmental summit, and the prospect of EU enlargement bear implications for European farmers, related supplying and processing industries and European consumers. The assessment of likely policy impact is bound to be complex and should be supported by quantitative modeling analyses that explicit the trade relations of European countries with third countries. We provide in this paper a comparative assessment of alternative modeling approaches. This includes theoretical modeling foundations, datasets employed and institutional aspects, such as model maintenance and dissemination of results. A typology of models is provided by structuring the assessment along a clear set of evaluation criteria.

Keywords: International Trade, Modelling, Trade Policy, Environment

1 Introduction

The prospect of a new round of trade negotiations under auspices of the World Trade Organisation, the perspective of enlargement of the European Union and international negotiations on transboundary environmental questions are some of the important policy issues that the European Union is currently facing. The assessment of likely impacts of policies in these areas is bound to be complex and is often supported by quantitative modeling analysis. This paper provides an assessment of the present state of applied modelling in the area of international trade in agriculture and related resource and environmental modelling. It attempts to support users of models and users of model results in finding the most suited modelling tool for the problem at hand.

1 Corresponding author. The paper has been written in the context of a larger concerted action project that is financially supported by the European Commission (FAIR6 CT 98-4148) and which assesses the usefulness of the Global Trade Analysis Project (GTAP) framework from a European perspective. The content of this report is the sole responsibility of the authors and does not in any way represent the views of the European Commission or its services. For inquiries concerning the concerted action: F.W. van Tongeren, Agricultural Economics Research Institute (LEI), P.O. Box 29703, 2502 LS The Hague, The Netherlands. E-mail: f.w.vantongeren@lei.wag-ur.nl
The general ‘filter’ for inclusion of models has been that the model should be relevant for current EU policy issues, be multi-commodity and multi-region in nature, has relevance for agriculture and natural resource based activities and be an applied equilibrium model (i.e. not a technical or time series projection model). The models should also be of a relatively recent vintage. This has resulted in the following list of 18 models:

**World models:**
*Partial models:* AGLINK (OECD), ESIM (USDA, Stanford University USA, University Göttingen), FAO World model (FAO), FAPRI (Iowa State University), GAPsi (FAL Germany), MISS (INRA Rennes), SWOPSIM (USDA/ERS), WATSIM (University Bonn, European Commission, Federal Ministry of Agriculture Germany)
*Economy wide models:* G-cubed (McKibbin and Wilcoxen, U.S. EPA), GTAP (Purdue University, GTAP consortium), GREEN (OECD), INFORUM (University of Maryland), MEGABARE/GTEM (ABARE Australia), Michigan BDS (University of Michigan), RUNS (OECD), WTO house model (WTO secretariat).

**EU agricultural sector models:**
SPEL/EU (EUROSTAT, University Bonn), CAPMAT/ECAM (SOW, CPB, LEI)

The requirement that the model should be relatively recent and likely to be used in the 1990s has led us to exclude important precursors such as the IIASA Basic Linked System (Parikh et al. 1984), The GOL model developed by USFA-ERS (Roningen and Liu, 1983), OECD's MTM model (Huff and Moreddu, 1990) and the Tyers-Anderson model (Tyers and Anderson, 1992). We have also excluded single-commodity trade models and linear (or non-linear) programming models that attempt to describe input-output relationships for a certain production process in great detail.

A large part of these models are still operational and are currently used for policy- and outlook analysis. Consequently, they are in a continuous state of flux and are evolving through successive updates and changes. This situation led us to conduct the model review at a point of time (early 1999) and provide a snapshot of all these models as they functioned at the beginning of 1999. Changes that could have occurred to the operational models since this date are not considered in this paper.

Information on the individual models has been gathered by the team of contributors using published papers and journal articles, unpublished working documents, electronic www documents and personal contacts.

**2 Model features**
A summary description of model features is provided in tables 1 to 3. This section highlights the various dimensions along which the models are described. A deeper discussion of the evaluation criteria and an elaborate description of each individual model is provided in Van Tongeren and Van Meijl (1999).

**2.1 Conceptual framework: Definition and scope**
*Representation of national economies: partial versus economy-wide models*
Partial models treat international markets for a selected set of traded goods, e.g. agricultural goods. They consider the agricultural system as a closed system without linkages with the rest of the economy. The main area of application of partial equilibrium models is detailed trade policy analysis to specific products.
On the other hand, economy-wide models provide a complete representation of national economies, next to a specification of trade relations between economies. There are three broad classes of economy-wide models: macro-econometric models, input-output models and Applied General Equilibrium models (AGE). A full economy-wide specification is obtained when the model is closed with respect to the generation of factor income and expenditures, which requires the explicit specification of factor markets for land, labour and capital.

**Regional scope**

Multi-region models differ with respect to their regional coverage. Global trade models attempt a closed accounting of the selected commodity trade flows for the entire world. If the model is economy-wide, the global model also includes a globally closed income accounting system. At the other end of the scale, a model might focus on trade between a selected set of trading partners, without attempting a globally closed accounting. Or it might even single out one group of countries, such as the EU-15, and describe its trade on world markets. A globally closed database does not imply that all regions or countries distinguished are treated with the same amount of detail.

**Linked individual country models or parametric differences between regions**

There are two broad approaches with respect to the modelling of individual economies within the global economic system. One approach starts by giving a detailed representation of individual economies, taking into account much of the institutional and economic details of the individual countries, and subsequently linking individual country models through trade flows, capital flows and possibly factor mobility between countries. The other route to global modelling starts by assuming the same modelling structure for all individual economies, and representing differences between economies in terms of data and parameters only. This 'one model fits all' approach yields a more transparent model structure, at the cost of losing country detail.

**2.2 Specification and modeling issues**

**Dynamic versus comparative static specifications**

Dynamic models allow the analysis of lagged transmissions and adjustment processes over time. Alternatively, the comparative static approach studies the differences between equilibria resulting from different assumptions on exogenous data or policy variables without analysing the time path between equilibria. Dynamic models can be used to trace the accumulation of stock variables, whereas static models are unable to do this.

Dynamic features can be incorporated in equilibrium models in several ways. The most frequently used approach is to specify a recursive sequence of temporary equilibria. Recursive dynamics do not guarantee time-consistent behaviour, which contrasts with intertemporal equilibrium models.

**Modelling of international trade**

In classical trade models assume that the goods of one producer perfectly substitute for those of another, i.e. goods are homogeneous. If the number of suppliers is sufficiently large, the market will approach the perfect competitive outcome and prices across suppliers will be

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2 In accordance with the international trade literature, ‘regional’ has a supra-national meaning in this paper, and not an intra-national (provinces etc.) one. A ‘country’ corresponds to the notion of a nation state. Whenever this report refers to regions, we mean an aggregate of individual countries. Regional aggregations of countries therefore do not necessarily represent a coherent geographical space, for example, a ‘Rest of the World’ region.
equalised. Homogeneity and competitiveness also imply that each actor in the market is either an exporter or an importer of the good, but never both, and models that include this assumption describe only inter-industry trade. Since prices are equalised and there is no other distinguishing characteristic of the goods, it makes no difference from which supplier a particular purchase is made. The homogeneity assumption is therefore associated with a ‘pooled’ market approach to trade modelling, where we see only what each actor brings to the market (supply) and what that actor takes from the market (demand). For obvious reasons, the pooled market approach is also known as ‘non-spatial’ modelling.

When product differentiation is possible, goods are called heterogeneous (and imperfect substitutes), and different buyers are willing to pay different prices to obtain the same quantity of the good. Hence, independent price movements among suppliers are possible. Another implication of heterogeneity is that each actor in the market may be both a buyer and a seller at the same time if goods are differentiated, and intra-industry trade can be captured.

The most popular way to introduce product differentiation follows Armington (1969) by assuming that imports and domestic goods are imperfect substitutes in demand. An alternative approach is to introduce product differentiation endogenously at the firm level on the supply side (Krugman 1979, 1980, Ethier 1979, 1982). In this approach fixed costs such as R&D or marketing costs are necessary to produce differentiated goods, and profits generated under imperfect competition are necessary to cover fixed costs. The heterogeneity assumption is associated with a bilateral (intra-industry) specification of trade, which keeps track of who trades with whom and allows for modelling of bilateral trade policy instruments.

**Representation of policies**

An adequate representation of policy instruments is essential in applied trade models. Tariffs and quantitative restrictions such as quotas are two important types of trade policy instruments. Tariffs can be introduced in a straightforward manner and are most of the time expressed as ad valorem tariff rates. Also specific (per unit) tariffs are then translated into ad valorem rates.

Quotas and other non-tariff measures are more difficult to implement, and there are basically two alternative ways to quantify these for use in applied models (Laird, 1997): the first is a tariff equivalent representation, while the second method specifies quantity restrictions directly as bounds on trade flows. In many situations this latter method is preferable. For example, if a quota is not binding in the benchmark, its tariff equivalent will be equal to zero, while the quota may become binding as the result of a policy simulation. This effect will not be captured when the quota is approximated by a tariff equivalent. Another case is the endogenous generation of quota rents and their distribution.

Next to border protection instruments, other relevant policies frequently need to be represented in models. For example, in relation to the EU’s GATT/WTO commitments ceilings on the volume of subsidised exports as well as bounds on the value of export subsidies may be relevant. In relation to the CAP, land set-aside and headage premiums are clearly examples of agricultural polices that do not directly affect border protection, but nevertheless have an impact on trade flows. In the area of (transboundary) environmental policy, tradable emission permits and tradable production quotas have emerged and should be captured appropriately.
Theoretical consistency

Judging the theoretical consistency of models has many facets, and the discussion here is far from exhaustive. At its most basic level, a model’s numerical results should be qualitatively in accordance with the theoretical foundations on which the model has been erected. At the level of numerical implementation of the model, theoretical consistency places requirements on the parameters used in functional forms, especially parameters used in demand systems and supply equations. These should satisfy essential regularity conditions.

Data and parameters

Data requirements are very demanding for multi-regional models of international trade. The amount of data is determined by the level of disaggregation (countries/regions, activities/commodities) and the theoretical structure (homogeneous/heterogeneous goods, bilateral/pooled markets).

The data need to be mutually consistent. Substantial adjustments to the published data are necessary, especially if trade is related to domestic inter-industry structures. While trade data with broad coverage are now widely available on a comparable basis, this is certainly not true for input-output data and for trade protection information. A coherent and consistent description of national economies in the form of a Social Accounting Matrix (SAM) usually underlies economy-wide models, although the SAM is sometimes only implicitly present in the database.

It is obvious that regular updating of datasets will improve the timeliness and relevance of results. The choice of base year for a modelling dataset has consequences, both for comparative static and dynamic models. The economic conditions that prevail at the point of reference determine the conclusions that can be drawn from alternative simulations.

The parameters used in behavioural equations determine the response to policy changes, and are therefore a very crucial element in each modelling exercise.

Two approaches to estimating model parameters can be distinguished: econometric estimation and calibration. Econometric estimation of parameters should ideally be done by simultaneous equation estimation methods that take into account the overall model structure. However given the size of applied trade models, identification problems, lack of data etc., this is not feasible, and one has to resort to single-equation estimation methods, using either time-series or cross-section data. Most applied trade modelers resort to calibration methods - also called the ‘synthetic approach’ - to generate a set of parameters that is consistent with both the benchmark data and the model’s theory. The calibration approach takes initial estimates of elasticities etc. from outside sources and adjusts certain other parameters in the given functional forms to the initial equilibrium dataset. Calibration therefore exploits theoretical restrictions, equilibrium assumptions and assumptions on functional forms to arrive at a point estimate.

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3 It is not a straightforward task to develop a sound set of criteria to judge the theoretical consistency of models. This theme is also closely related to the issue of model validation, which we have not taken up in this paper. There exists a sizable, and rather inconclusive, literature on model validation, see e.g. Van Tongeren (1995) for an overview. In addition the evaluation of theoretical and numerical validity would require much more information on the individual models than is available.

4 A recent joint initiative by USDA/ERS, Agriculture and Agrifood Canada, the European Commission, UNCTAD, FAO and OECD develops a new Agricultural Market Access Database (AMAD). Upon completion this will contain tariff-line level data on market access commitment- and implementation of about 50 WTO members. AMAD is expected to become publicly available in 2000. See Wainio et al. (1999).

5 Key parameters usually are: price- and income elasticities and budget shares in demand systems; substitution elasticities and input cost shares in supply systems; Armington (substitution) elasticities in import demand; if economies of scale are included, parameters that capture the degree of exhaustion of returns to scale (cost-disadvantage ratio).
3 Model overview

In this section we describe the features of the selected partial-, economy-wide- and EU-agricultural models. We first describe the design choices of prototypical standard multi-region partial models and standard economy-wide models. These standards serve as a point of reference for the individual models described in tables 1 to 3. In this section we give a very brief overview.

A standard partial equilibrium (PE) model has the following characteristics: global coverage, parametric differences between countries, comparative static, homogeneous goods, pooled markets, ad valorem price wedges (trade: tariff equivalents), theoretical consistency not implied by theoretical structure, and factor markets and non-agricultural sectors are exogenous. In general, all the selected models are pretty close to the standard model. They differ from the standard model because they are recursive dynamic (AGLINK, FAO World Model, FAPRI, GAPsi), endogenise land allocation (AGLINK, FAO World Model, WATSIM), model explicitly quantitative policies (AGLINK, ESIM, GAPsi, MISS and WATSIM) or include bilateral trade by using the Armington assumption (SWOPSIM, one application). Besides the design choices the models differ in their product and country coverage, which leads to a rather large differences in focus.

The standard approach economy-wide modeling is a multi-region applied general equilibrium (AGE) model with the following characteristics: global coverage, parametric differences between countries/regions, comparative static, Armington, bilateral trade relations, ad valorem price wedges (trade: tariff equivalents), theoretical consistency implied by model structure, endogenous volumes and prices on all markets, including factor markets. This standard multi-regional AGE model is a firmly established workhorse in international trade analysis. While retaining most of the standard assumptions, certain special features are introduced into some models to capture specific issues, such as developing country agriculture (RUNS) or aspects of the Common Agricultural Policy (some GTAP applications). Recursive dynamic variations of the standard model are now commonplace in global climate change research (GREEN, MEGABARE). Imperfect competition versions have gained ground in trade liberalisation of manufactures, and are likely to be used in the assessment trade liberalisation in services (WTO, BDS, GTAP). The most recent development is the intertemporal modelling of macroeconomic interactions between financial markets and real sectors (G-cubed). The size of the data collection effort for global models has in the past forced modellers to be rather economical as regards the regional and sectoral disaggregation. Two collaborative efforts to reduce this entry barrier exist to date: INFORUM and GTAP. The GTAP database is specifically tailored to the needs of general equilibrium modellers, and this has certainly contributed to its wider usage, also by non-GTAP modelling teams.

With regard to EU agricultural models we studied a partial equilibrium (SPEL) and a general equilibrium model (CAPMAT) which are both recursive dynamic.

4 Assessment of models

Nine out of the 18 surveyed models are partial models, according to Table 4. Partial models are in principle able to provide much product detail, and their main area of application is detailed trade policy analysis to specific products, which represent only a small portion of the economy. If agricultural trade policies do not lead to noticeable price shifts in other sectors, PE results will not differ significantly from AGE results. In industrial countries, with small agricultural GDP shares, the direct linkages of agriculture with other sectors is typically not very strong at the level of aggregation that AGE models tend to employ. An exception may be indirect linkages that run through markets for natural resources, especially land. In contrast, in Central and East European Countries (CEECs) with their relatively high share of agriculture
in GDP, significant second-round effects are to be expected from polices that pave the ground towards the EU enlargement process, and AGE models provide the only coherent way to analyse these.

In industrialised countries and the European Union, there do exist strong linkages, however, with sectors that are closely related to agriculture, either because they deliver key inputs such as fertilisers, herbicides, agricultural machinery, or because they process primary agricultural products, such as beef processing and dairy industries. Highlighting such interdependencies within the agricultural complex is one area where partial equilibrium models can potentially be very successfully used, and some of the recent partial models have taken up this challenge (WATSIM, ESIM). This aspect is also gaining importance in the presence of dramatically increasing trade shares of processed food products. Most of the partial equilibrium models surveyed here do not fully exploit this potential advantage because they have a focus on trade in primary agricultural commodities. As a result, there has been a tendency to use AGE models to highlight the forward and backward linkages within food supply chains, as well as to incorporate trade in differentiated food products.

The majority of the models has a global coverage, only three of them treat a regional subset of economies. One of those is a partial agricultural models (SPEL), one is economy-wide (INFORUM) and one is an EU-agricultural model with an economy-wide closure (CAPMAT/ECAM). Within the group of models that closes their accounting with respect to world trade, there are differences in regional emphasis. FAPRI focuses on the US, ESIM on Eastern Europe, MISS focuses on US-EU interactions, GAPsi emphasises the EU. A clear regional bias is less obvious in the economy-wide models with a global coverage. All of them include at least the major trading regions (US, EU, Asia Pacific).

The commodity coverage of partial models puts more emphasis and detail on agricultural commodities. Most AGE models include only 1-3 agricultural sectors, with the exception of RUNS and GTAP. The recent version of the GTAP database has an amount of agricultural detail that is comparable to partial agricultural models.

Only one of the models, INFORUM, features linked individual country models, while all others favour representation of differences between economies via differences in parameters. While in principle, individual country models can capture more regional economic and institutional detail, there are clear difficulties with this approach in terms of consistency and maintenance. Indeed, the linked country models approach seems to be less sustainable, and their contribution to global trade analysis has been rather limited. (The IIASA Basic Linked System, Parikh et. al 1988; The project LINK, Klein and Su, 1979).

Comparative static modelling has certainly not gone out of fashion, although ten models favour a recursive dynamic approach which permits them to generate time paths of variables and lagged adjustment patterns. Forward looking time consistent behaviour is only introduced into one model, G-cubed, which does not have a specific agricultural focus, but concentrates more on macroeconomic phenomena. Explicit introduction of time is certainly appealing to policy users of models, since this relates the model outcomes to concrete time periods. Comparative static models have reacted to this demand by generating projections without explicit modelling of the dynamics. While this procedure has some appeal, it is also not free of criticism, and some caution should be exercised. Partial models have to make assumptions on the development of a large number exogenous variables to produce a projected future dataset. In fact, the largest part of the projected future does not derive from the model, but from outside assumptions. Since the partial model itself does not provide a consistency check, it is questionable whether these assumptions are always consistent among each other. Projections with static general equilibrium models provide a consistency check, but these models rely on an extremely small number of assumptions for their projections. This implies that a large part of the step between two time periods is ‘explained’ by residual factors such as
TFP growth rates which accumulate much of deviations not included in the original model. Finally, the features of the ‘baseline’ in all dynamic models as well as in projections are critical for the interpretation of policy results which are obtained relative to the constructed baseline scenario.

Table 4: Basic modelling design choices

<table>
<thead>
<tr>
<th>Scope of representation</th>
<th>Partial Models</th>
<th>Economy wide models</th>
<th>EU-Agricultural models</th>
<th>Total</th>
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<tbody>
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<td></td>
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<td>- Partial</td>
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<td>- General</td>
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<td>Regional scope:</td>
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</tr>
<tr>
<td>- Global coverage</td>
<td>8</td>
<td>7</td>
<td>0</td>
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<td>- Non-global coverage</td>
<td>0</td>
<td>1</td>
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<td>3</td>
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<tr>
<td>Regional unit of analysis:</td>
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<td></td>
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<td></td>
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<tr>
<td>- Linked country models</td>
<td>0</td>
<td>1</td>
<td>0</td>
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</tr>
<tr>
<td>- Parametric differences</td>
<td>8</td>
<td>7</td>
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<tr>
<td>Dynamics:</td>
<td></td>
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</tr>
<tr>
<td>- Static</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>- Recursive dynamic</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>- Forward looking</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
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<tr>
<td>Modelling of trade:</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>- Homogeneous</td>
<td>8</td>
<td>0</td>
<td>2</td>
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</tr>
<tr>
<td>- Armington</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>- Monopolistic competit.</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>- Other</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Treatment of policies:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Tariff/price equivalents</td>
<td>3</td>
<td>5</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>- Explicit treatment of quantity restrictions</td>
<td>5</td>
<td>3</td>
<td>2</td>
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<tr>
<td>Data:</td>
<td></td>
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</tr>
<tr>
<td>Public data availability?</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Yes</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>- No</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Parameters:</td>
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<td></td>
</tr>
<tr>
<td>- Estimated</td>
<td>2</td>
<td>0</td>
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<tr>
<td>- Calibrated</td>
<td>6</td>
<td>8</td>
<td>0</td>
<td>14</td>
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</tbody>
</table>

Note: The table refers only to standard versions of models.

It is striking to note that all partial equilibrium models and the EU-agricultural models treat international trade in homogeneous products, while AGE models deal with trade in differentiated products by default. As already mentioned above, the volume of trade in processed food products is increasing relative to trade volumes in primary commodities. Since processed food can be considered to be of a more differentiated nature than primary products, it is highly relevant to come to grips with trade in differentiated products. By excluding intra-industry trade, and limiting the analysis to net trade, partial models capture the degree to
which countries are interwoven only imperfectly. These models also run the risk of predicting the empirically contestable phenomenon of extreme specialisation. Net trade in homogeneous goods also makes it impossible to incorporate bilateral trade policies. While the standard treatment of trade in differentiated products follows the Armington specification, two AGE models (BDS, WTO) incorporate firm-level product differentiation and economies of scale by default, and the standard GTAP model has been amended in that direction. These models focus on manufacturing and services, where these phenomena are perhaps more relevant than in agriculture. However, in food processing industries economies of scale and imperfect competition aspects are certainly relevant as well. A related issue is Foreign Direct Investment (FDI) by internationally operating processing and retailing firms. This is as yet untreated in the applied models surveyed, but requires the recognition of economies of scale at the plant level as well as at the firm level (Markusen, 1984, Markusen and Venables, 1998). It must be recognised, though, that hitherto the empirical basis for these industrial organisation issues is rather weak.

Ten models attempt to capture explicitly quantitative trade restrictions and CAP-type policies, while eight of the models resort to a tariff-equivalent representation. Policies are typically formulated at the commodity level or tariff-line level. It is at this level that policy makers need information, and partial models are in principle able to get down to the required level of detail, including specific institutional arrangements. Partial models, with their focus on selected sectors, are in principle able to give a more precise representation of policies, such as quantitative restrictions. However, our survey of partial model reveals that some partial models under-utilise that potential and resort to a tariff-equivalent representation of policies. Specialised models of the EU agricultural sector (CAPMAT/ECAM and SPEL-EU) are a notable exception as regards the representation of EU agricultural policies, and the treatment of budgetary implications. However their treatment of international trade is rather limited.

The inventory of models shows that some datasets are used by different models. Usually, modellers adjust the raw data to suit their specific needs, and consequently some duplication of efforts occurs. Nine modelling teams choose to make there dataset publicly available, either free of charge or at cost. This practice, which is increasingly observed within the modelling community, is considered a very useful step as it allows others to build on existing (and time consuming) work and it increases the transparency of modelling results. Sharing of databases has in the past been hampered by well known public good problems, which provide insufficient incentives for individual teams to contribute to database development. The INFORUM network provides an early example of an institutional set-up that facilitates sharing of data. INFORUM contributors submit (input-output) data in a form that matches their particular country model, and does therefore not require major adjustments to a common standard. In contrast, the GTAP framework enforces uniform standards on regional data and trade data. In addition, GTAP is supported by a strong group of institutional stakeholders which puts high requirements on the quality, timeliness and documentation of the data.

It turns out that 15 of the models surveyed here rely on calibration methods, and take there initial parameter estimates from the same published sources that sometimes date back a considerable time. Current models are dominated by ‘theory’ over ‘observations’. Econometric estimation of key behavioural parameters in applied models is certainly an underdeveloped area, although there are some initiatives to estimate partial models in consistence with micro-economic theory (ESIM, FAPRI, CAPMAT/ECAM). Recent developments in entropy estimation methods may help to alleviate some of the technical problems that one encounters in estimating large scale AGE models with limited data (see Golan et al., 1996).
Although not apparent from our earlier discussions, documentation of models is generally weak and scattered, with some notable exceptions (BDS, G-cubed, GTAP). Especially agency based models do not stand out by clarity of documentation. Modellers that are rooted in academia face stronger incentives to submit their work to peer reviews, which increases transparency. An important related aspect is the accessibility of models and data to outside users, who do not belong to the organisations or bodies which have (initially) financed or sponsored the development of these models. While nine models offer the possibility to obtain their datasets, the models themselves are often proprietary. However, some of the models which are presented in this report can be considered as ‘public goods’ (conditional on certain costs and guarantees) which can be used by or made available to interested organisations or persons. Thus, the SWOPSIM model developed by the Economic Research Service (ERS) of USDA has been made available to numerous academics who worked on the impact of agricultural trade liberalisation. The OECD AGLINK model is presently used by government services of OECD member countries. A part of the INFORUM models and modelling tools are in the public domain. At the present time, GTAP represents the most far reaching attempt to public availability, and has now several hundred users in the academic community as well as in research agencies all over the world.

Building an applied trade model is costly exercise, which tends to require several man-years of dedicated work on database construction, theory formulation, parameter estimation and computer implementation. In addition, the size of the investment implies that the basic design choices are to a large extent irreversible. Once a particular route has been chosen, the switching cost may become prohibitive. Some developments point towards a further reduction in entry costs to this type of work: (a) convergence towards standards in model building, where new models can build on established blueprints. (b) A major, and seldom fully appreciated, part of model building is devoted to database construction. GTAP has pioneered institutional innovations that lower the costs associated with database construction and database maintenance considerably. (c) The availability of powerful general purpose software packages renders it obsolete to develop own software to solve large scale models numerically. Additional advantages of using packages like GAMS, GEMPACK or GAUSS is the transferability, reproducibility (and therefore cross-checking) of models and ease of maintenance. Early partial equilibrium models have been implemented in spreadsheets, which was top technology at the time. Except for small scale models, and models for pedagogic purposes, spreadsheet models do not have much to commend them. They are inherently difficult to maintain and are very error-prone.

The degree to which models will contribute to new policy questions depends critically on their degree of adaptability. How capable are existing applied models to respond to newly arising policy questions? At a first glance, there are several issues on the current agricultural trade policy agenda that do not seem to fit well within existing trade modelling frameworks:
- ‘consumer concerns’ which are put forward as arguments to restrict imports of allegedly unsafe food products (e.g. hormone treated beef, genetically modified organisms).
- conservation of landscape as an argument to restrict imports from low-cost producers
- environmental concerns, which lead to production restrictions and ‘green trade’ issues.

Unfortunately, we do not have the benefit of hindsight. It is conceivable, however, that existing models will be adapted for use in the above policy areas. This encompasses at least two issues. First, how existing models can be adapted in terms of policy representations, and second, how the outcome variables that they provide can be translated into variables that arise on the policy agenda. With some creativity, the policy issues can be translated into preference and technology shifts, which interact with conventional import restrictions and production
restrictions. A main contribution from existing models is likely to be a structuring of the discussion and initial quantification, rather than detailed numerical assessment.

5 Concluding remarks

There is, obviously, no model that suits all purposes. Each model has its own merits, given the goals addressed by it and the issues treated with the model. This paper, and the longer Van Tongeren and Van Meijl (1999) report, try to guide potential users in making their choice for an appropriate tool. For this purpose we have identified relevant design choices and a set of dimensions to classify and assess applied trade models.

Ten years ago, the OECD and the World Bank convened a symposium that assessed the ‘state-of-the-art’ in agricultural trade modelling at that time, see Goldin and Knudsen (1990). The field has changed over the past decade, but to some extent the comments made at this symposium can be echoed today. Probably the most important innovations have not been theoretical, nor have they been technological. The most significant changes have been of an institutional nature, albeit supported by recent computer and communications technologies. Ten years ago, models, data and software were almost exclusively proprietary. Today, it has become more common to exchange computer code and to share databases. This tendency can be expected to be continued in the future. The ‘open source’ concept that spurred rapid innovations in some parts of the software industry may very well be the direction towards which the global trade modelling community is heading.

References


Table 1: Summary EU-agricultural models

<table>
<thead>
<tr>
<th>Description</th>
<th>modelling of trade</th>
<th>Goals</th>
<th>key applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPEL-EU University of Bonn</td>
<td>Recursive dynamic equilibrium model</td>
<td>Homogenous goods + pooled markets</td>
<td>Short and medium-term forecasts and policy simulations of the effects of agricultural policy decisions</td>
</tr>
<tr>
<td>Recursive dynamic equilibrium model production in EU-15</td>
<td>partial applied of agricultural</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAPMAT/ECAM SOW-VU, CPB, LEI</td>
<td>Recursive dynamic applied general</td>
<td>Homogenous goods + pooled markets</td>
<td>EU agriculture policy analyses</td>
</tr>
<tr>
<td>Recursive dynamic equilibrium model and a simulation and accounting tool</td>
<td>applied general equilibrium model</td>
<td></td>
<td></td>
</tr>
<tr>
<td>of agricultural production in EU-15</td>
<td>and a simulation and accounting tool</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Policy Representation</th>
<th>number of regions (r) or countries (c)</th>
<th>Global coverage? (y/n)</th>
<th>Number of sectors/ products</th>
<th>number of farm (f) or processed (p) products</th>
<th>Software</th>
<th>data availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPEL/EU</td>
<td>13 (c) + 1 (r) EU: 13 (c) + 1 (r)</td>
<td>n</td>
<td>5-6 DIGIT/NACE</td>
<td>114 (f)</td>
<td>Home made software</td>
<td>Y, cost</td>
</tr>
<tr>
<td>Price wedges and quota</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAPMAT/ECAM</td>
<td>13 (c) + 1 (r) EU: 13 (c) + 1 (r)</td>
<td>n</td>
<td>30</td>
<td>20 (f), 7 (p)</td>
<td>SAT in GAMS, ECAM home made software (FORTRAN)</td>
<td>n</td>
</tr>
<tr>
<td>Price wedges and quota, explicit bounds on volumes and values</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Table 2: Model summary of partial equilibrium models of trade in agricultural products

<table>
<thead>
<tr>
<th>Description</th>
<th>modelling of trade</th>
<th>Goals</th>
<th>key applications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard model</strong></td>
<td>Static partial equilibrium model, global coverage, no factor markets included</td>
<td>Homogeneous good + pooled markets</td>
<td></td>
</tr>
<tr>
<td>AGLINK OECD</td>
<td>Recursive dynamic model includes land allocation</td>
<td>Standard</td>
<td>To assist the OECD Secretariat in its annual medium term outlook. Conduct quantitative analysis agricultural policies on principal agricultural markets</td>
</tr>
<tr>
<td>ESIM USDA, Stanford, Goettingen</td>
<td>Standard model, land market included, special emphasis to Eastern Europe</td>
<td>Standard</td>
<td>Enlargement studies</td>
</tr>
<tr>
<td>FAO World Model FAO</td>
<td>Recursive dynamic model includes land allocation</td>
<td>Standard</td>
<td>Medium- and/or long- term projection model. Simulating impacts of policy changes.</td>
</tr>
<tr>
<td>FAPRI Iowa State University</td>
<td>Econometric recursive dynamic model, with a special emphasis on the US</td>
<td>Standard</td>
<td>Compound modelling system for: Policy analysis; Short-, medium and long term projections (1-10 years), annual baseline</td>
</tr>
<tr>
<td>GAPsi</td>
<td>Recursive dynamic model</td>
<td>Standard</td>
<td>EU agricultural policy analysis</td>
</tr>
<tr>
<td>MISS INRA</td>
<td>Standard model, four regions</td>
<td>Standard</td>
<td>Analysis of agricultural policy changes in EU and US</td>
</tr>
<tr>
<td>SWOPSIM USDA/ERS</td>
<td>Standard model</td>
<td>Standard: base model Armington: one application</td>
<td>Simulation of effects of changes in agricultural support policies on production, consumption and trade</td>
</tr>
<tr>
<td>WATSIM University of Bonn</td>
<td>Standard model</td>
<td>Standard</td>
<td>Three target periods with different aims: Short-term shock analysis (not yet available), Medium-term projections and policy analysis, Long-term projections and analysis of various shift factors.</td>
</tr>
<tr>
<td>Model</td>
<td>Policy Representation</td>
<td>Number of regions (r) or countries (c)</td>
<td>global coverage? (y/n)</td>
</tr>
<tr>
<td>------------------------</td>
<td>---------------------------------------</td>
<td>----------------------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Standard model</td>
<td>Price wedges</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AGLINK</td>
<td>Quantity restrictions modelled explicitly</td>
<td>11 (c) + 2 (r) EU: 1 (r)</td>
<td>Y</td>
</tr>
<tr>
<td>ESIM</td>
<td>Quantity restrictions modelled explicitly</td>
<td>7 (c) + 2 (r) EU: 1(r)</td>
<td>Y</td>
</tr>
<tr>
<td>FAO World Model</td>
<td>Standard</td>
<td>147(c) + 1 (r) EU: 15 (c)</td>
<td>Y</td>
</tr>
<tr>
<td>FAPRI</td>
<td>Standard</td>
<td>29 (c+r) EU: 1</td>
<td>Y</td>
</tr>
<tr>
<td>GAPsi</td>
<td>Quantity restrictions modelled explicitly</td>
<td>13 (c) + 4 (r) EU: 13 (c)+ 1 (r)</td>
<td>Y</td>
</tr>
<tr>
<td>MISS</td>
<td>Quantity restrictions modelled explicitly</td>
<td>1 (c) + 3 (r) EU: 1(r)</td>
<td>N</td>
</tr>
<tr>
<td>SWOPSIM</td>
<td>Standard</td>
<td>36 (r) EU: 2 (c) + 2 (t)</td>
<td>Y</td>
</tr>
<tr>
<td>WATSIM</td>
<td>Quantity restrictions modelled explicitly</td>
<td>4 (c) + 10 (r) EU: 1(r)</td>
<td>Y</td>
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</table>
## Table 3: Summary of economy-wide models

<table>
<thead>
<tr>
<th>Description</th>
<th>Modelling of trade</th>
<th>Goals</th>
<th>Key applications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard model</strong></td>
<td>Applied General Equilibrium model, multi-sector, comparative static, constant returns to scale in production, perfect competition on all markets, global coverage</td>
<td>Armington, bilateral flows</td>
<td></td>
</tr>
<tr>
<td>G-cubed McKibbin and Wilcoxen</td>
<td>Intertemporal applied general equilibrium and macroeconomic model.</td>
<td>Standard</td>
<td>Contribute to the policy debate on environmental policy and international trade, with a focus on global warming policies.</td>
</tr>
<tr>
<td>GTAP GTAP consortium/ Purdue University</td>
<td>Standard (default version) Recursive dynamic and imperfect competition versions available.</td>
<td>Standard Monopolistic competition versions available</td>
<td>Trade policy analysis, especially multilateral liberalisation. Agricultural policies.</td>
</tr>
<tr>
<td>GREEN OECD</td>
<td>recursive dynamic</td>
<td>Standard, except crude oil (homogeneous)</td>
<td>Asses the economic impact of imposing limits on carbon emissions</td>
</tr>
<tr>
<td>INFORUM INFORUM project/University of Maryland</td>
<td>Linked system of dynamic national macroeconomic models with inter-industry Input-Output linkages.</td>
<td>Price and income sensitive econometrically estimated import and export equations</td>
<td>Annual forecasts and policy analysis at national and internationally linked levels.</td>
</tr>
<tr>
<td>MEGABARE and GTEM, ABARE</td>
<td>recursive dynamic endogenous population growth, technology bundles in electricity and iron&amp;steel</td>
<td>Standard</td>
<td>Policy scenario analysis primarily in climate change but also in global agricultural trade reform and trade in strategic commodities (e.g. coal).</td>
</tr>
<tr>
<td>Michigan BDS Model University of Michigan</td>
<td>scale economies and monopolistic competition in manufacturing industries,</td>
<td>Monopolistic competition</td>
<td>To analyse microeconomic effects of trade liberalisation policies</td>
</tr>
<tr>
<td>RUNS OECD</td>
<td>recursive dynamic</td>
<td>Agriculture: homogeneous goods &amp; pooled markets Manufactures: standard</td>
<td>Analysis of Agricultural policies</td>
</tr>
<tr>
<td>The WTO housemodel</td>
<td>Standard and imperfect competition versions</td>
<td>Standard and firm level product differentiation</td>
<td>To analyse global trade analysis issues such as the upcoming WTO Round</td>
</tr>
</tbody>
</table>
Table 3 continued

<table>
<thead>
<tr>
<th>Policy representation</th>
<th>Number of regions (r) or countries (c)</th>
<th>Global coverage (y/n)</th>
<th>Number of sectors</th>
<th>Number of farm (f) or processed (p) products</th>
<th>Software</th>
<th>Public data availability</th>
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</thead>
<tbody>
<tr>
<td>Standard model</td>
<td>Ad valorem Price wedges</td>
<td>Global</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G-cubed</td>
<td>Standard and tradeable emission permits 4 (c) + 4 (r) EU: part of ‘other OECD’</td>
<td>y</td>
<td>12</td>
<td>1 (f) + 1 (p)</td>
<td>Gauss</td>
<td>N</td>
</tr>
<tr>
<td>GTAP</td>
<td>Standard in default version Volume and value restrictions (quota etc) available 27 (c) + 12(r) + RoW EU: 5 (c) + 1(r)</td>
<td>y</td>
<td>50</td>
<td>12 (f) + 8 (p)</td>
<td>GEMPACK and GAMS versions available</td>
<td>Y, at cost</td>
</tr>
<tr>
<td>GREEN</td>
<td>Standard quota, tradable emission permits 5 (c) + 7 (r) EU: 1 (r)</td>
<td>y</td>
<td>9</td>
<td>1 (f)</td>
<td>C</td>
<td>N</td>
</tr>
<tr>
<td>INFORUM</td>
<td>Standard macro-economic policy instruments, taxes and transfers 13 (c)</td>
<td>N</td>
<td>Varies by country: min. 33, max. 100</td>
<td>Varies by country</td>
<td>G</td>
<td>Y partly, free</td>
</tr>
<tr>
<td>MEGABARE/ GTEM</td>
<td>Tradable emission permits 27 (c) + 12(r) + RoW EU: 3 (c) + 1(r)</td>
<td>y</td>
<td>50</td>
<td>12 (f) + 8 (p)</td>
<td>GEMPACK</td>
<td>Partly, Y. See GTAP Energy parts: N</td>
</tr>
<tr>
<td>Michigan BDS model</td>
<td>Standard 34 (c) + RoW EU: 12 (c)</td>
<td>y</td>
<td>29</td>
<td>2 (f)</td>
<td>GEMPACK</td>
<td>Y</td>
</tr>
<tr>
<td>RUNS</td>
<td>Standard 13 (c) + 9 (r) EU: 1 (r)</td>
<td>y</td>
<td>20</td>
<td>11 (f) + 4 (p)</td>
<td>Fortran</td>
<td>N</td>
</tr>
<tr>
<td>WTO housemodel</td>
<td>Standard and import quota 5 (c) + 7 (r) + ROW EU: 1 (r)</td>
<td>y</td>
<td>19</td>
<td>3 (f) + 1 (p)</td>
<td>GAMS/MPSGE</td>
<td>Y</td>
</tr>
</tbody>
</table>
Models of the Danish Agricultural Sector and their Application in Policy Making: An Historical Survey

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E-mail: NIK@KVL.dk

Abstract
Since the late 1960s there have been a number of models of the Danish agricultural sector and of the interaction between this sector and the rest of the economy. The models are very different – partial programming models, econometric models, AGE models, input-output models, etc. This paper presents a survey of these models and gives examples of their applications. It is argued that each type of model is designed for the solution of specific problems, and that no single type of model is preferable for all types of analysis. Consequently, many different models are needed.

Keywords: Agricultural policy, Sector models, History of Econometrics.

1 Introduction
1. Food and agriculture policy has always been a central theme in the political debate in every nation. In the later half of the 20th century, however, there has been a new trend in many countries for the more professional debate to be largely based on calculations using empirical models. These models, and their applications in the Danish agricultural debate, are discussed in this paper.

In Denmark, the use of econometric and other advanced empirical models escalated in the 1970s. There had been earlier research in empirical modelling, but it was in the 1970s that the models began to be a part of the actual policy formulation process. Many of the models used today in both general economic policy and agricultural policy have their roots in the 1970s.

The prehistory of the models is described in Section 2 of the paper. There are a number of isolated early forerunners of the later model designers who deserve to be mentioned. These forerunners did not, however, create any sort of continuous tradition. Section 3 presents an overview of the agricultural sector models used in Denmark. In Section 4, different policy problems related to the agricultural sector are discussed, and the types of models that have been used in analysing these problems are presented. In the conclusion to the paper, it is argued that it is impossible to build a reasonable-sized model which could accommodate all the issues discussed. It could very well be sensible to have available a number of different models and parts of models from which a suitable combination could be used for analysing any particular problem.

2 The prehistory of the Danish models
2. Econometric estimations go back a long way in Denmark; in fact, the very first econometrician in the world (econometrics being defined as the mathematical statistical estimation of parameters in economic models) was the Dane E.Ph. Mackeprang (1877-1933). He estimated a number of demand functions in his dissertation Pristeorier (Price theories),
which dates from 1906 (for a description of Mackeprang’s work, see Kærgård, 1984 and Morgan, 1990). The dissertation was, however, treated very critically by the leading Danish economists, and even Mackeprang himself never afterwards used econometric methods.

Before the 1930s there were only two universities in Denmark where research in economics was carried out: the large and old University of Copenhagen (founded in 1479), and The Royal Veterinary and Agricultural University (founded in 1858). The economists at the University of Copenhagen were critical of econometrics, and agricultural economics formed a very minor part of their research area, while the Agricultural University had research only in very descriptive and applied economics. A major step forward was the foundation of an economic department at the new University of Aarhus in 1936. At this university, econometrics and other “modern” ideas (Keynesian theories, etc.) had a more prominent place. The leading economists there were Jørgen Pedersen (1890-1973) and a German, Erich Schneider (1900-1970); also on the staff in 1938-39 was the young Norwegian econometrician Trygve Haavemo (1911-1999), later to be a member of the Cowles Commission, a professor in Oslo and a Nobel prize winner. In the new university’s series of publications there appeared a number of interesting contributions during the early years. The first publication of all was Jørgen Pedersen’s *En Analyse af det engelske Smørmarked i Perioden 1923-36* (An Analysis of the English Butter market, 1923-36), dated 1937. He estimated by ordinary least squares methods a relationship whereby he explains the price of Danish butter in England by the quantity of Danish, New Zealand and other types of butter supplied.

In 1939 Trygve Haavelmo published two texts: *A Dynamic study of Pig Production in Denmark* and *Efterspørgselen efter Flæsk i København* (Demand for pork in Copenhagen). The model of pig production consists of seven relations estimated by a Frischian bunch map analysis. The aim was to model the effects of the crisis policy of the 1930s. Haavelmo’s second publication analyses the pork market in Copenhagen. Household budget data from 1931 are used to estimate income elasticity of pork and beef consumption and to investigate the substitution between pork and beef consumption. A time series from 1924-1938 is used to estimate a demand function for pork, where demand is determined by prices of pork and beef and by real income. The estimation technique is again regression and bunch-map analysis.

Another of the forerunners is Knud Rasmussen with his dissertation “Variance and Production Function Analyses of Farm Accounts” dated 1961. The data are account data from Danish farms, and a sample of 279 farms is used to estimate production functions of Cobb-Douglas types for each of the years 1945-1950. Knud Rasmussen did not of course have modern panel data methods available, but he was very careful in analysing the variances and the variation between the years. This led him to a model where the coefficients of labour and capital are constant, but the total level is variant over the years. In 1962 Knud Rasmussen, together with M.M. Sandilands, published a similar investigation of the production function estimated from British and Irish farm accounts data.

During the 1960s, Danish agricultural economics at both the agricultural university and the institute of agricultural economics changed from being pure applied and descriptive economics to being a study of more theoretical and model-oriented topics.  

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1 Knud Rasmussen (1918-1981) was educated at the University of Copenhagen, and was a part-time teacher at that university in the period 1948-1952. He was an Agricultural Economist at the University of Nottingham from 1952 to 1959. After 1959 he had a leading position in the Danish Farmers Marketing Board, and again taught part-time at the University of Copenhagen in agricultural economics and econometrics.

2 Research in agricultural economics in Denmark takes place mainly at two institutions: The Royal Veterinary and Agricultural University (KVL), founded in 1858 and since 1964 linked to the Ministry of Education and Research, and The Danish Institute of Agriculture and Fisheries Economics (SJFI), founded in 1918 and linked to the Ministry of Agriculture and Food Policy.
At the Agricultural University, A. Hjortshøj Nielsen obtained a PhD degree in 1964 with a thesis about linear programming and its application in agriculture, and Frede Andersen obtained a degree in 1966 with an estimation where pork supply was determined by prices of pork and barley in a distributed lag model.3

In 1967, at the Institute of Agricultural Economics, Arne Larsen4 published a statistical model for determination of the net result for Danish agriculture. This was the first research memorandum from the Institute, which previously had been purely a data-producing organisation. In the second memorandum, dated 1968, Larsen published an estimation of the productivity of Danish agriculture in the period 1927-1966.

The economists at the university of Aarhus were still active in the area. In 1969 they published a major analysis of *Projections of Supply and Demand for Agricultural Products in Denmark 1970-1980* (see Andersen et al.,1969). The study was financed by the Research Service of the United States Department of Agriculture, and includes cross section estimations of Engel curves and time series analysis of demand curves.

By around 1970, Danish economists were ready to build full-scale models of the agricultural sector, and the considerable number of partial analysis published after 1970 will not be treated.

### 3 Modelling the Danish agricultural sector.

3.1 The early 1970s was a boom period for Danish econometrics. The first macro models were built and used for economic forecasting and policy making. In 1973 the SMEC (Simulation Model of the Economic Council) was published and in 1974 a completely new version SMEC II was developed; in 1975 the first version was established of what is still the official macroeconomic model of the Danish administration, ADAM (Aggregated Danish Annual Model), see Andersen (1991) and Kærgård & Høj (1993) for the history of Danish macromodels.

3.2 The first sector model of Danish agriculture was also started during this period.5 The model was built at the Agricultural University by Frede Andersen and Poul Erik Stryg in 1973, based on ideas in Day (1963) (see Andersen & Stryg, 1976 and Andersen et al., 1974). The model was constructed as part of a major project aimed at forecasting the Danish agricultural structure and regional development for the period up to 1985. The model is often called the *KVL-model*.6

All the versions of the model have been mathematical programming models. The basis of the model was a number of typical farms defined according to their size measured by area and to their regional position. Originally there were eleven regions and four types of farm in each region. Each representative farm was formulated as an LP model, and the farms were connected with a regional constraint of land and some market clearing constraints.

The original model was a recursive programming model. The recursive element was formulated as a set of flexibility constraints setting the maximum deviation from year to year in, for example, number of farms. The flexibility constraints were estimated using historical observations.

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3 Both A. Hjortshøj Nielsen and Frede Andersen held posts at the University for many years.
4 Arne Larsen obtained a Ph.D. degree from Michigan State University in 1966 with research on econometric estimations of relations for land values in the United States, 1925-62. He was Head of the Institute from 1978 to 1999.
5 The description of the Danish agricultural models is based on Kærgård et al. (1996), where a more detailed description is found.
6 KVL relates to the Danish name for the agricultural university Kongelige (Royal) Veterinær (Veterinary) og Landbo (Agricultural) Højskole (University).
The main problem with the model was the flexibility constraints. In many cases these constraints determined the outcome of the model. The problems with the flexibility constraints were among the reasons that the model was reformulated in 1979. The flexibility constraints were then made variable in accordance with the ideas in Weinschenk et al. (1969). In this set-up the flexibility constraints changed from period to period, driven by the shadow prices. The model was now able to forecast the structural development in the number of farms in each group based on a relation between profit and change in number of farms in the group.

In the later versions, the number of geographical regions were reduced to three. The increasing specialization in Danish agriculture, the other hand, led to a requirement for a new grouping of the farms. They were divided into dairy farms (4 size groups), pork producing farms (5 groups) and arable farms (4 groups). The land area was divided into two soil types, clay and sandy soil. There are 15 different crops and 6 types of animal (dairy cows, beef cows, suckler calves, sheep, sows and porkers).

The data for the model were mostly taken from farm-based accounting statistics. The KVL-model was used for a number of different purposes: calculation of forecasts, calculating the consequences of different environmental taxes, CAP reforms and GATT agreements, analysing the effects of legislation, etc.

Recently the model has been replaced by the KRAM-model, which is a model in the same tradition and built at the same department (see Wiborg, 1998).

3.3 The first model produced by the Institute of Agriculture Economics was an input-output model (see Dubgaard and Pedersen, 1984). Today, however, an econometric model of the agricultural sector called ESMERALDA (Econometric Sector Model for Evaluating Resource Application and Land use in Danish Agriculture) and an applied general equilibrium model of the Danish economy named AAGE (Agricultural Applied General Equilibrium model) form the core of the arsenal of models at the Institute.

ESMERALDA is a static comparative econometric model. The purpose of the model is to provide a tool for analysing the different instruments in agricultural policy. The model has been developed since 1991, and the main approach is similar to that of Guyomard et al. (1996); for a more detailed description of the model, see Jensen (1996).

The core of the model is translog specifications of profit functions for the different sub-sectors. The data for estimating the models are account data for the period 1974-1993 for each of the sub-sectors. A linear trend variable is included in all sub-models to capture the impacts of improved species, productivity developments, etc. The model has been used for such purposes as the calculation of the effects of changes in the CAP.

3.4 The third main model for analysing the effects of agricultural policy in Denmark is AAGE. AAGE is a model of the total Danish economy, but with a fairly detailed specification of the agricultural sectors. The model was first specified in the Economic Council in 1993 as GESMEC (General Equilibrium Simulation Model of the Economic Council), where it was used for calculation of the effect of CO2 taxes and of a liberalization of the agricultural policy in EU (see Frandsen et al., 1994).

In 1995 Søren E. Frandsen moved from the Economic Council to the Institute of Agricultural and Fisheries Economics, but he continued to work with the model. The agricultural sector was further specified, and the model was changed from a general multi-purpose CGE-model to a model with special emphasis on the interaction between the agricultural sectors, the agro-industrial sectors and the rest of the economy. At the same time the model was renamed AAGE.

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7 Arne Larsen was at the same time both Chairman of the Economic Council and Director of the Institute of Agricultural Economics.
The model is mainly based on ideas from the Australian ORANI-models (see Dixon et al., 1982 and Horridge et al., 1993). The agents in the model are typical neo-classical constructions; producers maximize their profit given the technology, and the consumers maximize the utility given their total expenditure. There is perfect competition in all markets, and domestic and foreign goods are treated as imperfect substitutes. It is assumed that labour and capital are perfectly mobile between industrial sectors and between agricultural sectors, while labour movements between agricultural and industrial sectors are sluggish. Public consumption is exogenous.

The model includes 33 sectors, of which 5 are agricultural and 6 are agro-industrial. There is one homogeneous type of labour, one homogeneous type of capital and one homogeneous type of land (only used for agriculture). There are 13 different types of consumer goods, of which 5 are food products.

The core of the model is nested CES production and utility functions. For the calibration of the model is used an input-output table developed from the national input-output table published by the Danish Central Bureau of Statistics. The parameters are taken from different sources; the production parameters for the agricultural sector are based on ESMERALDA.

AAGE has been used for the calculation of the effects of changes in the agricultural structure, of integration of the Central European Countries into the EU, and of a ban on the use of pesticides.

3.5 Besides these three main models, there are a number of partial and ad hoc models which have been used for different purposes. And the agricultural models have been combined with other models, with regional models and with the international GTAP model (Global Trade Analysis Project, see Hertel et al., 1997). The Institute of Agricultural and Fisheries Economics has been very active in working with the GTAP model, and in combining AAGE and GTAP.

4 Agricultural policy and the models: Some cases.

4.1 Land policy has been a dominant element in the Danish agricultural debate for about a hundred years. In the first half of the 20th century the mainstream view was that land reforms should secure land for new smallholdings. Since the 1960s, however, the trend has been in the opposite direction (see table 1).

### Table 1. Number of farms in Denmark

<table>
<thead>
<tr>
<th>Year</th>
<th>1923</th>
<th>1946</th>
<th>1960</th>
<th>1980</th>
<th>1995</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of farms</td>
<td>200,700</td>
<td>208,100</td>
<td>196,100</td>
<td>114,200</td>
<td>66,200</td>
</tr>
<tr>
<td>Average Area, ha</td>
<td>15.5</td>
<td>15.3</td>
<td>15.8</td>
<td>25.3</td>
<td>40.6</td>
</tr>
</tbody>
</table>


Not only has the number of farms decreased rapidly, but the remaining farms have become highly specialized. In 1968 74.5% of the farms had both cows and pigs, in 1998 the figure was only 12.0%.

This trend has of course been heatedly debated. Some people are absolutely against the creation of big, industrialized farms, while others see this development as necessary for the rapid growth in productivity. This means that quantification of the economies of scale is central for the debate.

Experiments with direct estimation of the production function have been carried out by Kjeldsen-Kragh (1988) and Nørring (1990), but with rather different results. Kjeldsen-Kragh found that the positive economies of scale stop at around 50 cows and 60 sows. Nørring, on
the other hand, found that there were considerable unused economies of scale; in a comparison of the actual and the optimal structure, he calculated that there was “an excess production cost of approximately 10 billion Danish Kroner”, though this will decline by nearly 50 per cent before 2005 if the rapid structural change continues. 8

In an investigation for the Ministry of Agriculture, another technique was used (Ministeriet for Fødevarer, Landbrug og Fiskeri, 1998). Total productivity was calculated for farms of various sizes, and then the difference in productivity between an unchanged agricultural sector and a sector in which the structural changes would continue was calculated. The effects of this productivity gap were calculated by using the AAGE-model. The results indicated a total loss for the agricultural sectors in 2008 of 5.6 billion Danish Kroner, and an equal loss in agro-industry. It was calculated that real consumption in society would be 1.3 per cent lower in 2008 without structural development in agriculture.

These different types of economic calculation have not stopped the debate about the land legislation. They are not seen as authoritative, believable facts. One of the problems is that the economies of scale vary over time (Nørring found increasing economies of scale from 1973-1987). Another problem is that economies of scale may be brought about by many factors: economies of scale in farm production, market power, and correlation between the qualifications of the farm manager and the size of the farm. There is still reason for further professional debate about modelling and quantification of the economies of scale.

4.2 In connection with the GATT negotiations in 1993, the Danish Economic Council made calculations of the consequences of the total liberalisation of the agricultural sector. The model GESMEC (which, as mentioned in section 3, was an early version of AAGE) was used. Danish agriculture is a major export sector, which means that Denmark has a net benefit from transactions between Denmark and EU. But there are distortion costs and death weight losses for Danish society, just as there are for other EU societies.

The results for Danish society, according to the calculation, showed that consumption would increase by 1.7%, and there would be employment for 16,000 more people. But the positive Danish net export of agricultural products would mean that the terms of trade would be negatively affected. For land owners, liberalization would mean a land price fall of 46%; it is self-evident that the capitalized agricultural support would disappear (see table 2).

### Table 2. Effects for Denmark of a general liberalization of agriculture

<table>
<thead>
<tr>
<th></th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross National Product</td>
<td>0.7%</td>
</tr>
<tr>
<td>Real consumption</td>
<td>1.7%</td>
</tr>
<tr>
<td>Employed</td>
<td>16,000 persons</td>
</tr>
<tr>
<td>Terms of trade</td>
<td>- 1.5%</td>
</tr>
<tr>
<td>Price of land</td>
<td>- 46.2%</td>
</tr>
</tbody>
</table>

Sources: Det Økonomiske Råds formandskab (1993) and Frandsen et al. (1994).

The consequences for agricultural production would only be serious for the heavily supported cash crops and milk products. The less heavily supported pork and poultry sectors would be affected positively, because they would only experience a small fall in prices for their production, but bigger price falls for their inputs. All other sectors, including the agro-industrial sectors, would be positively affected.

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8 For evaluation of this and the following figures it could be relevant to know that the Danish gross domestic product in 1995 was 973 billion Kroner, of which about 50 billion was produced in the agricultural sector.
The results appear reasonable, and they are in good accordance with what actually happened in New Zealand when they phased out agricultural support in the mid-1980s.

4.3 A third case where models have been used is in the debate about pesticides. The Danish parliament decided in 1998 that they wanted to know what the consequences would be of a complete or partial ban of pesticides. In the discussion of this problem three types of information were used. Agronomists described on the basis of practical experiments the effects of not using pesticides on yields for different crops. From these figures microeconomists tried to describe the optimal changes in use of land and the rotation of crops (see Ørum, 1999). The extent to which robust crops would replace crops which needed protection against pests, funguses and weeds was estimated. A linear programming model was used, with profit being maximized given the agronomic restrictions. The calculations gave an estimate of the fall in profits for different types of farms. The profit reductions were calculated to be relatively small for cattle farms (24%) but considerable for potato (51%) and beet growing (39%).

Finally, the macroeconomic effects of this less productive technique without using pesticides were calculated. The productivity loss was taken from the microeconomic calculation, and the consequences for the whole economy were then calculated using AAGE (see Jacobsen & Frandsen 1999). The results indicated a shift from agriculture to urban sectors, and smaller agricultural exports. If equilibrium in the balance of payments was to be reestablished, it would require a fall in wages. The main results are given in table 3.

<table>
<thead>
<tr>
<th>Table 3. Macroeconomic effects of a pesticide ban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>Real consumption</td>
</tr>
<tr>
<td>Consumer prices</td>
</tr>
<tr>
<td>Nominal wages</td>
</tr>
<tr>
<td>Land prices</td>
</tr>
</tbody>
</table>

Source: Frandsen and Jacobsen (1999)

These calculations are of course based on a number of questionable assumptions, and there are many uncertainties. Nevertheless, the results indicating a considerable loss were so convincing that the Danish debate changed from the discussion of a possible pesticide ban to discussing optimal reduction in the use of pesticides.

5 Conclusion

Many models have been used in the discussion of Danish agricultural policy, but it seems appropriate that this should be so. It is often relevant to combine sector models with full scale macro-models. The sector models give details about the agricultural sector, but indicate nothing about the other sectors. The macro models give too few details for the sector of special interest (a macro model which could give the necessary details would be unmanageably large).

It might be relevant to have different types of sector models, too. The programming models and the econometric models have rather different qualities, and could supplement each other. The econometric models result in very continuous and gradual effects caused by neoclassical substitution and smooth functions, while the programming models with their limitationalities result in more drastic jumps for certain parameter values. Real life seems to be a mixture of smooth and unstable, jumping series, and it could be valuable to be able to model both types of effect.
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Micro econometric models for agricultural sector analysis

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Abstract
Micro econometric models are a useful tool for agricultural sector analysis. This paper provides a discussion of methodological aspects in the construction of micro econometric models. Attention is paid to the theoretical background, data requirements, empirical model selection and the estimation procedure. A discussion of several applications demonstrates the usefulness of micro econometric models for agricultural sector analysis.

Keywords: Panel data, Household Production models, Risk Models, Dynamic Models

1 Introduction
In the past decades, environmental and agricultural policies have become increasingly farm specific. Examples of farm-specific policy measures are the 1992 CAP reform, where the compensatory payments for farmers depend on farm-specific factors as region and size of the farm. Also, tradable quotas on milk (in EU countries) and emissions (phosphates in the Netherlands) are examples of farm-specific policy measures, in particular because the initial quota is based on historical production and use levels (‘grandfathering’). Analysis of farm-specific policy measures needs to be done using models that determine the effects of behaviour for groups of farms or individual farms. Models of individual farms are also required for the analysis of many other decision problems that depend on farm-specific factors such as investments in new farm assets (which depend on liability) and off-farm work decisions (which depend on the availability of household labour).

Micro econometric models are a useful tool in the analysis of farm-specific behaviour since they explicitly model the behaviour of individual farmers. Micro econometric models are defined as a set of behavioural relationships that are based on micro economic theory and estimated on farm data using econometric techniques. In the economics literature, micro econometric models have been developed for explaining input demand and output supply behaviour (profit functions) in combination with explaining household decisions (household models), income risk (risk models) and investments in fixed assets (investment models). The purpose of this paper is to discuss the methodological aspects of constructing micro econometric models and to provide an overview of several applications.

The remainder of this paper is organised as follows. Section 2 discusses the theoretical background of four groups of micro econometric models: profit function models, household production models, risk models and investment models. Data requirements are discussed in section 3. Next, attention is paid to criteria for selecting functional forms (section 4) and to issues in the estimation of the functions that reflect the behavioural relationships (section 5). The paper ends with a discussion of several applications that demonstrate the usefulness and limitations of micro econometric models.
2 Theoretical framework

In this section the theoretical framework of profit function models, household production models, risk models and investment models is discussed.

2.1 Profit function models

Neo-classical production theory forms the framework for profit function models. The theory is more widely discussed in Chambers (1988) and is only briefly be surveyed here. Profit function models are useful in analysing the effects of price changes (e.g. through taxation) and changes in fixed factors (e.g. changes in the amount of land and supply quotas). Farm-specific effects of e.g. policy changes can be aggregated to sector level.

The theory behind profit function models assumes that farmers maximise profit conditional on a convex production possibility set or technology T. This can be denoted as:

\[
\pi(p, w, z) = \max_{y, x} \{ p'y - w'x \mid (y, x, z) \in T \}
\]

where, \(y\) and \(x\) are vectors of quantities of outputs and variables inputs and \(p\) and \(w\) are the corresponding vectors of prices; \(z\) denotes the quantity of factors that are assumed to be fixed in the short term (e.g. supply quotas, labour, land, capital).

So the profit function gives the maximum profit a farm can reach given the input and output prices it is confronted with and the quantity of the fixed factors available on the farm. Given that supply quotas and other factors are taken fixed implies that a short term profit function is used. If factor use is (partly) endogenised a medium or long term profit function can be derived. Prices instead of quantities of the factors would then enter the profit function.

Differentiating the profit function with respect to price of output \(j\) and input \(i\) respectively (applying Hotelling’s Lemma) yields the supply function of output \(j\):

\[
\frac{\partial \pi(p, w, z)}{\partial p_j} = y_j(p, w, z) \quad j = 1, \ldots, M
\]

and the demand function for input \(i\):

\[
\frac{\partial \pi(p, w, z)}{\partial w_i} = -x_i(p, w, z) \quad i = 1, \ldots, N
\]

The supply and demand function show the relation between output supply and input demand and the output prices, input prices and the quantities of fixed factors. Technological change is in these models usually modelled as a fixed factor.

Differentiating the profit function with respect to fixed factor \(k\) yields the shadow price \(q\) of this fixed factor:

\[
\frac{\partial \pi(p, w, z)}{\partial z_k} = q_k(p, w, z) \quad k = 1, \ldots, K
\]

The shadow price of a fixed factor shows the money the farm is willing to pay for an extra unit of this fixed factor. It is also possible to assume a fixed output (e.g. production under a quota). The shadow price of a fixed output shows the extra (marginal) costs of producing one extra unit. In case of a supply quota the difference between the market price of the output and
the shadow price of production gives the maximum amount of money the farmer would be willing to pay for an extra quota right (the shadow price of the quota right).

2.2 Household production models

Household production models are a useful tool if issues related to agricultural households are of interest, i.e. off-farm and on-farm employment and savings. In household production models farms are divided into a production unit and a household (see Thijssen, 1988 and Elhorst, 1994). The relation between both is that the household supplies factors (labour and capital) to the production unit (and in household production models for developing countries the production unit supplies output to the farm household). It is assumed that the production unit maximises profit, and therefore, the profit function model as discussed in the previous section applies. In addition, there are demand functions for factors originating from the household. For the household utility maximisation is assumed. From utility maximisation the supply of factors and consumption follows. Factors can be used either in the production unit or supplied outside the farm (off-farm employment).

A general algebraic formulation of the household side of a household production model will be described below (see Varian, 1992:144-146). The indirect utility function gives the utility of the household as a function of prices of commodities and factors and income. The indirect utility function is given by:

\[ v(\mathbf{w}'\mathbf{q} + E, \mathbf{w}) = \max_{\mathbf{x}} \left\{ U(\mathbf{x}) : \mathbf{w}'\mathbf{x} = \mathbf{w}'\mathbf{q} + E \right\} \]  

where: \( v(\cdot) \) is the indirect utility function, \( U(\mathbf{x}) \) the direct utility function, \( \mathbf{w} \) the vector of commodity and factor prices, \( \mathbf{q} \) the vector of endowments of commodities and factors, \( E \) exogenous income and \( \mathbf{x} \) the vector of demanded commodities and factors.

Given the indirect utility function, by using Roy’s identity, it is possible to derive the Marshallian or uncompensated demand functions for commodities and factors. Roy’s identity is given by:

\[ \frac{\partial Y}{\partial Y} = -x_i(Y, \mathbf{w}) \]  

with:

\[ Y = \mathbf{w}'\mathbf{q} + E \]  

The net demand for factor \( i \) (\( x^N_i(Y, \mathbf{w}) \)) is given by:

\[ x^N_i(Y, \mathbf{w}) = x_i(Y, \mathbf{w}) - q_i \]  

where \( i \) denotes the \( i \)-th factor or commodity. The net demand for a factor or a commodity may be negative (e.g. for labour and capital) in which case the household is a net supplier of these factors.

2.3 Risk models

In the literature, uncertainty is included either directly through the specification of an Expected Utility or Mean-Variance function (Collender and Zilberman, 1985; Babcock et al.,1987), or indirectly through the incorporation of wealth variables (Chavas and Holt, 1990). Coyle (1992) and Oude Lansink (1999) have employed a Linear Mean-Variance approach in a
micro economic framework that accounts for the role of price risk in producer behaviour\(^1\).

Their approach allows for simultaneously determining the producers risk attitude and input demand and output supply behaviour.

In the linear mean-variance (LMV) framework, the preference ordering of an agents alternatives and expected utility are determined by the mean \((M)\) and variance \((V)\) of random payoff or income

\[
U = M - \frac{1}{2} \alpha V
\]

where \(\alpha\) is the coefficient of absolute risk aversion, i.e. \(\alpha > 0\), \(=0\) and \(< 0\) indicate risk aversion, risk neutrality and risk affinity respectively. Mean income is defined as :

\[
M = p'y - C(w, y, z)
\]

where \(p\) is the mean output price vector; \(w\) is an input price vector; \(y\) and \(z\) are vectors of output quantities and quantities of fixed inputs; \(C(w, y, z)\), defined as \(w'x\), is a cost function with regular properties (Chambers, 1988:52). Assuming output prices are the only source of uncertainty that the producer is facing, the variance of random income is given by :

\[
V = y'Vpy
\]

where \(Vp\) is the (symmetric, positive definite) covariance matrix of output. The indirect utility function corresponding to (11) is:

\[
v^*(p, w, Vp, z) = \max_y \left( p'y - C(w, y, z) - \frac{1}{2} \alpha y'Vpy \right)
\]

with first order condition :

\[
p - C_y(w, y, z) = \alpha Vp y
\]

The familiar "price is marginal cost" condition is obtained if either \(\alpha\) is zero or if price variance is zero (i.e. \(Vp\) is a null matrix). \(\alpha >0\) implies that the output price exceeds marginal costs, implying that output is lower than optimal output under risk neutrality. As under risk neutrality or price certainty, first order condition (13) characterises output supply, i.e. by solving for \(y\) to yield \(y^*\) as a function of \(w\), \(z\) and moments of the random output price:

\[
y^* = y(p, w, Vp, z)
\]

Furthermore, by using the envelope theorem and first order condition (13) it can be shown that variable input demand equations can be obtained by differentiating either \(v^*(p, w, Vp, z)\) or \(C(w, y, z)\) with respect to input prices \(w\).

\[
x(p, w, Vp, z) = - \frac{\partial v^*(p, w, Vp, z)}{\partial w} = \frac{\partial C(w, y^*, z)}{\partial w} = x(w, y^*, z)
\]

---

\(^1\) Coyle (1999) has extended this approach to account for both price and yield uncertainty.
2.4 Investment Models

In the Neo-classical literature on investments both primal and dual approaches for explaining investments within the adjustment cost framework have evolved. The primal approach requires an explicit specification of the adjustment cost function and uses a closed form solution for the Euler equation to derive a factor demand equation. Whereas a solution is tractable for a standard quadratic adjustment cost function, the problem becomes highly complex for more flexible specifications of adjustment costs, e.g. interactions between investments and the capital stock or third order effects (Pindyck and Rotemberg, 1983; Shapiro, 1986). More recently, GMM estimation procedures are employed in order to estimate Euler equations directly, thereby allowing for the estimation of more complicated functional approximations of the adjustment cost function (Pfann and Palm, 1993; Hamermesh and Pfann, 1996; Whited, 1998).

The dual approach on the other hand allows for deriving factor demand equations directly from an optimal value function (McLaren and Cooper, 1980; Epstein, 1981). Estimates of the dual function reveal some of the characteristics of the underlying adjustment cost function.

The standard dual model starts with the maximisation of the discounted flow of profit for the firm producing multiple outputs using variable and multiple quasi-fixed factors taking the form

\[
J(v, w, k, z, t) = \max_I \int_0^\infty e^{-rs} \left[ \pi(v, k(s), z(s), s) - w'k - C(I(s)) \right] ds
\]

where \( k \) is a vector of quasi-fixed inputs and \( I \) is the corresponding gross investments; \( \pi \) is defined as \( v'y \); \( v \) and \( w \) are (vectors of) market prices of netputs and quasi-fixed inputs, respectively; \( y \) is a vector of netput quantities (positive for outputs, negative for inputs) and \( z \) a vector of fixed inputs; \( s \) reflects technological progress as a time trend; and \( C(I) \) is the adjustment cost function which is assumed to be continuous and differentiable, convex and symmetric around \( I=0 \).

The Hamilton-Jacobi equation of the optimization problem in (16) has the form

\[
rJ(v, w, k, z, t) = \max_I \{ \pi(v, k, z, t) - w'k - C(I) + \langle I - k, J_k \rangle ^
\]

Assuming an interior solution, the first order condition of this optimisation is \( C_i = J_k \), implying that the shadow value of capital equals the marginal adjustment cost. Netput equations are derived by differentiating the optimised Hamilton-Jacobi equation in (17) with respect to \( v \) and applying the envelope theorem to yield

\[
y = rJ_v - J_k \dot{k} - J_w .
\]

Differentiating the optimal value function with respect to quasi-fixed factor prices and applying the envelope theorem gives investment demand equations:

\[
\dot{k} = J_{kw} (rJ_w + k - J_{\dot{w}}).
\]
3 Data

Constructing micro econometric models requires the estimation of behavioural relationships on farm level data. Panel data are data from a set of individuals (e.g. farms) over a number of years. These data are now becoming more frequently available for economic research (e.g. FADN data are available in most EU countries).

Panel data can be balanced or unbalanced, where a panel data set is balanced if all farms are in the sample during the whole time period the data set covers and unbalanced if farms rotate in and out the sample, with unbalanced panel data being more frequently available.

Usually, the 'raw' panel data need some transformation before they can be used in the estimation of behavioural relationships and the researcher needs to make a number of decisions. First, the researcher needs to construct a number of input and output categories from the large number of inputs and outputs that are available in the data set. Aggregating inputs and outputs implies that weak separability assumptions are made. A set of inputs \( H \) is weakly separable from another set of inputs \( J \) if the marginal rate of input substitution of \( H \) is independent of \( J \) (Chambers, 1988). The number of inputs and outputs should be large enough to reflect the technological conditions of the production process on the one hand. On the other hand, a too large number of inputs and outputs results in functions that are more difficult to estimate, and increases the probability of the occurrence of 'zero' observations. Also, the objective of the research may determine the number and composition of inputs and outputs, i.e. a model designed to determine the effects of a tax on N-fertiliser should include N-fertiliser as a separate input.

Second, in static models (profit function models, household models and risk models) the researcher needs to make a distinction between short term fixed and short term variable inputs and outputs. Generally, inputs and outputs are treated as fixed factors if their quantities cannot be adjusted in the short term without making significant adjustment costs. Usually, land, (family) labour and capital invested in buildings and machinery are examples of inputs that are considered fixed in the short term. Output or emission quota are often assumed to be fixed if quota trade is not allowed for or if quota trade is subject to severe restrictions (e.g. if quotas are tied to land. In investment models, demand and supply equations are derived for short term fixed inputs and outputs, where short term fixed inputs and outputs differ from short term variable inputs and outputs by their rate of adjustment.

A third consideration in the preparation of data is the choice of the units of the variables in the equations. Aggregating several small inputs or output in aggregate input or output indexes requires the use of monetary units. Also, capital is measured in units and it is important to keep in mind that the monetary units of the LHS and RHS variables are referring to the same base year. This can be achieved by calculating implicit quantity indexes as the ratio of value to the own price index, where all price indexes have the same base year.

The fourth consideration in the construction of the data involves the calculation of price indexes of the aggregate input and output quantities. A suitable price index is the Tornqvist price index which takes the following form for an input or output composed of \( k \) components on farm \( h \):

\[
\log P_{ih} = \sum_{i=1}^{k} 0.5(s_{i_{ih}} + s_{i_{ih}}) \cdot \left( \log p_{ih} - \log p_{ih} \right)
\]

where: \( P_{ih} \) Tornqvist price index for the input or output in year \( t \) on farm \( h \), \( s_{i_{ih}} \) share of component \( i \) on farm \( h \) in year \( t \), \( s_{i_{ih}} \) average share of component \( i \) in base year, \( p_{i_{ih}} \) price index of component \( i \) for farm \( h \) in year \( t \) and \( p_{ih} \) average price of component \( i \) in base year.

The price index given in (20) is not the price index that is used. The price index that is finally used is obtained by averaging (20) over all farms in the sample in one year. Therefore,
the Tornqvist price indexes vary over the years but not over the farms, implying that differences in the composition of an aggregate input or output or differences in the quality, are reflected in the quantity (Cox and Wohlgenant, 1986).

4 Choice of functional form

This section discusses criteria and considerations that underly the choice of the functional form that reflect the behavioural relationships of the farms in the micro econometric model. Selection of functional forms has been the subject of numerous studies in the economics literature. One branch of this literature has based the selection of functional forms on Monte Carlo studies which examine the ability of various forms to track a known technology (Guilkey et al., 1983). A second branch uses real data and estimates the Generalised Box-Cox (Box and Cox, 1963), which is considered to be the true function underlying the data generating process. The Generalised Box-Cox includes a variety of functions as nested hypotheses and parametric tests are carried out to test against the Generalised Box-Cox (Applebaum, 1978; Chalfant, 1984; Oude Lansink and Thijssen, 1998). A third approach to selecting functional forms uses ad hoc selection criteria such as theoretical consistency, domain of applicability, flexibility, computational ease, satisfying theoretical conditions and plausibility of the results (Lau, 1986; Baffes and Vassavada, 1989).

Selecting among functional forms for micro econometric models may involve all three methods described above. However, some restrictions need to be taken into account, that limit the choice possibilities. First, a micro econometric model that is based on neo-classical production theory should satisfy theoretical conditions as linear homogeneity, monotonicity and curvature conditions (convexity or concavity in prices). A literature review by Shumway (1995) shows that, if not imposed, the condition of convexity in prices is often violated in profit function models. The problem that curvature conditions are not satisfied is found for other approaches as well. Therefore, the functional form that is selected should allow in particular for imposing curvature conditions. Second, it should be noted that micro econometric models require the estimation of behavioural relationships on farm level data that often include negative profits (e.g. Helming et al., 1993; Moschini, 1988) and zero values for inputs and output.

The use of the popular flexible forms, Generalised Leontief and the Translog is ruled out a priori, since curvature conditions cannot be imposed on these functional forms without destroying their flexibility (Diewert and Wales, 1987). Moreover, the square root and logarithmic transformations cannot be applied to negative and zero values. Two functional forms that are capable of satisfying these conditions are the Normalised Quadratic (Lau, 1978) and the Symmetric Normalised Quadratic (Diewert and Wales, 1987; Kohli, 1993). The Normalised quadratic has the following general structure for a profit function:

\[ \pi^* = \alpha_0 + \alpha_v' \nu^* + \alpha_z' \z + 0.5 \nu^* \alpha_{vv} \nu^* + 0.5 z' \alpha_{zz} z + \nu^* \alpha_{vz} z \]  

Where \( \nu^* \) are normalised netput prices and \( \z \) are fixed inputs and outputs. The normalised quadratic is a relatively simple functional form, but has the important drawback that its estimation results depend on choice of the numeraire input or output, i.e. the input or output price that is used to impose linear homogeneity of the profit function in prices.

The Symmetric Normalised Quadratic has the general structure for a profit function:

\[ \pi = \alpha_v' \nu + 0.5(\theta' \nu)^{-1} \nu' \alpha_{vv} \nu + 0.5(\theta' \nu) z' \alpha_{zz} z + \nu' \alpha_{vz} z \]  

Where

\[ \theta = \begin{bmatrix} \alpha_{vv} & \alpha_{vz} \\ \alpha_{zv} & \alpha_{zz} \end{bmatrix} \]

It has a similar structure for a cost function or an optimal value function.
where, \( v \) represent nominal netput prices. Linear homogeneity of the profit function in prices is imposed by the fixed weight price index \( \theta v \). Note that all prices are used to impose linear homogeneity in prices and that the Symmetric Normalised Quadratic gives estimation results that are invariant to the choice of the numeraire.

5 Estimation issues

Estimation of a micro econometric model using panel data of farms should account for heterogeneity among farms in a sample. Accounting for heterogeneity is achieved by employing panel data estimation methods that typically allow for the estimation of farm-specific parameters. Two classes of panel data estimation methods are considered in this paper, i.e. a class of 'traditional' least squares or maximum likelihood methods and a relatively new class of Generalised Maximum Entropy methods.

Among the class of least squares or maximum likelihood methods, the Fixed Effects approach is the most prominent in the estimation of systems of input demand and output supply equations in the agricultural economics literature (see Baltagi, 1995, for an overview). The advantages of this method are its computational ease and the fact that it gives consistent estimates, when the explanatory variables correlate with the farm specific intercept. The Random Effects approach is another estimation method in the class of least squares or maximum likelihood methods. The Random Effects approach gives more efficient estimates than the Fixed Effects approach. However, the Random Effects estimates are only consistent if the explanatory variables are orthogonal to the firm specific effect. The orthogonality assumption in the Random Effects model can be tested using a Hausman test (Hausman, 1978) and is often rejected in the agricultural economics literature (Thijssen, 1992; Gardebroek and Oude Lansink, 1999). Hausman and Taylor (1981) proposed an alternative estimator to the Fixed and Random effects models. The Hausman-Taylor model discriminates between explanatory variables that correlate with the farm-specific effects and explanatory variables that are independent of the farm-specific effect. The Hausman-Taylor model gives consistent estimates, but is more efficient than the Fixed effects model. Gardebroek and Oude Lansink (1999) provide a Hausman-Taylor estimator for estimating systems of equations on unbalanced panel data.

A general characteristic of the least squares and maximum likelihood methods for estimating systems of equations in micro econometric models is that farms are assumed to have equal slope parameters and the farm-specific effect enters the equations as intercepts (Fixed Effects) or draws from a distribution (Random Effects, Hausman-Taylor model). This assumption is restrictive, since there is no reason to assume a priori that heterogeneity only enters the equations to be estimated as slope shifters. However, increasing the number of farm-specific parameters may be computationally cumbersome and results in a rapid decrease of the number of degrees of freedom and estimation precision.

An alternative for the class of traditional methods is a class of methods entitled Generalised Maximum Entropy estimation (see Golan et al., 1996). The advantage of this method is that it can estimate a system of equations that is fully farm-specific, i.e. through intercepts and slope parameters. The GME method has recently been applied to the estimation of farm-specific systems of input demand and output supply equations by Oude Lansink (1999) and to the estimation of farm-specific cost functions by Paris and Howitt (1998).
6 Overview of applications
This section provides a discussion of several applications that demonstrate the usefulness and limitations of micro econometric models. The overview of applications in this paper is limited to agricultural economic applications.

6.1 Profit function models
Following the first applications of duality theory in the agricultural economics literature in the early seventies (e.g. Lau and Yotopoulos, 1972), profit functions have by now been widely adopted by agricultural economists in the analysis of economic problems. A comprehensive overview of applications of profit and cost function models can be found in Shumway (1995). Profit function models have proven their usefulness in the analysis of a wide range of policy measures, such as set-aside policies (Oude Lansink and Peerlings, 1996), systems of mineral surplus taxes (Oude Lansink and Peerlings, 1997; Fontein et al., 1994) and systems of quota. Moschini (1988) and Helming et al. (1993) analysed the effects of the dairy quota systems in Canada and the Netherlands, respectively. Burton (1989) and Guyomard et al. (1996) analysed the effects of unrestricted dairy quota trade, whereas Oude Lansink and Peerlings (1995) analyse the effects of tradable and non-tradable N-fertiliser quota. Weninger (1998) assesses the effects of individual transferable fish quota. Babcock and Foster (1992) focus on the distribution of quota rents between owners and renters of marketable production quotas for tobacco in the US. Extensions to the basic model of quota trade are made Guyomard et al. (1995) with a siphon on dairy quota trade and by Boots et al. (1997) with the incorporation of upper and lower bounds on quota transactions. Bureau, et al., (1997) model quota mobility in the European sugar regime where they distinguish between A, B and C sugar, whereas Boots and Peerlings (1999) use a similar model to model the effects of a two-tier price system on dairy quota prices. Gardebroek et al. (1999) focus on the effects of technical factor utilisation on quota values.

6.2 Household production models
Applications of household production models are mainly in the area of household labour supply to the production unit of farms and in the area of off-farm employment (for an application for capital supply see Benjamin and Phimister, 1997). Traditionally economists assumed that production conditions affect consumption and labour supply to the production unit exclusively via income levels, and that production decisions are entirely independent of decisions about consumption and labour supply (see Singh, et al., 1986 for an overview of this empirical literature). Lopez (1984), Thijs (1998) and Elhorst (1994) developed micro econometric models that integrate the production and labour decisions of a farm household into a unified theoretical framework. The budget constraint is linearised in order to exploit the body of established results of traditional demand theory.

Another body of literature investigates off-farm employment. Although well documented for North America (see Hallberg, 1991), literature on off-farm work is scarce for Europe. An exception is Woldehanna, et al. (2000) who analyse the effects of the CAP reform on off-farm employment using a double hurdle model. In double hurdle models first the decision to work outside the farm is taken and in a second step the size of off-farm employment is determined. Examples of non-EU off-farm employment analyses are Kimhi (1996a) who investigates the role of farm work status on off-farm employment decisions; Kimhi (1996b) who looks at the effects of unobserved group effects on the allocation of time between farm work and off-farm work; Mishra and Goodwin (1997) who look at the role of income variability on off-farm employment and Tavernier et al. (1997) who examine the role of farm ownership on off-farm labour supply of farmers.
6.3 Risk models

In recent years, several authors applied the Mean-Variance framework thereby accounting for the role of price risk. Coyle (1992) applies the M-V framework to provincial data on livestock and crops production in Manitoba. However, his approach does not allow for estimating the producers risk attitude (see Coyle, 1994). Saha (1996) adopts a mean standard deviation framework that is capable of estimating the production technology along with the producers risk attitude. His approach allows for identifying different risk configurations, i.e. of increasing, constant and decreasing absolute and relative risk aversion. Saha applies the mean standard deviation approach to panel data of Kansas wheat producers and finds that producers are characterised by decreasing absolute and constant relative risk aversion. Oude Lansink (1999) adopts a Mean-Variance framework that simultaneously determines the producers risk attitude along with the producers optimal input demand, output supply and allocation of areas to different crops. His application to panel data of specialised Dutch cash crop farms shows that producers are risk averse.

Coyle (1999) provides an extension to the literature mentioned above by developing a Mean-Variance approach that accounts for both yield and price uncertainty. This framework determines the producers risk attitude along with optimal input-output decisions and is applied to provincial data of livestock and crops production in Manitoba.

Despite their relevance in the analysis of agricultural policy measures in general, risk models have not been as widely adopted to date as profit function or household production models.

6.4 Investment models

Applications of the primal dynamic model in the agricultural economics literature are rare to date. Lopez (1985) modelled investments in the Canadian food processing industry using aggregate data and Thijssen (1994 and 1996) focused on investments on Dutch dairy farms using panel data.


A general conclusion with respect to investment models is that they have not been widely adopted in the analysis of (farm)-specific policy measures.

7 Conclusion

This paper has provided a discussion of methodological aspects in the construction of different micro econometric models, i.e. profit function models, household production models, risk models and investment models. Attention was paid to the theoretical background, data requirements, empirical model selection and the estimation procedure. The usefulness
and limitations of different micro econometric models for policy analysis has been illustrated through a discussion of several applications. It is found that risk models and investment models have not been widely adopted in the analysis of (farm-specific) policy measures and that they need further development for these purposes. Future research should also increasingly attempt to account for farm heterogeneity, e.g. through the use of Generalised Maximum Entropy estimation methods. Finally, future research in micro econometric modelling should allow for a greater level of detail, both in terms of variables accounted for and in terms of (spatial) variation within farms in order to address environmental policy issues.

References


Chapter III

Methodological Advances on Specific Issues
Representing product differentiation and strategic behavior in agricultural policy models

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Abstract

Consumer concerns about food safety, environmental sustainability, and animal welfare call for a shift in focus of European agricultural policy models, as they cause products to become differentiated through labels, and their chains more strongly integrated vertically. The paper argues that this differentiation should be represented through separate products, rather than through supply of characteristics (Lancaster) or variable number of varieties (Dixit-Stiglitz). This type of product differentiation creates market power that is usually modeled through fixed producer markups. We argue that in the new setting it becomes necessary to endogenize these. In addition, governments have to take this strategic of firms conduct as given, and formulate their agricultural policy as optimal decisions under second-best, which also is a strategic decision, also to account for the interaction of newly formed regional trading blocks on world markets. The paper proposes a Lagrange multiplier method to determine the optimal direction of policy change for strategic agents so as to endogenize both the producer markups and the policy variables. The method applies to a general class of simulation models.

Keywords: Consumer Concerns, EU Agricultural Policies, Product Differentiation, Applied General Equilibrium, Imperfect Competition, Trading Blocks

1 Introduction

The situation on food markets in OECD countries has for several decades been characterized by satiated consumer demand with limited change in commodity composition and processing levels which were largely dictated by customs and tradition. The most revolutionary changes presumably originated from McDonalds and other fast food chains. Food policies largely focused on the farm, with income support as main aim, and were principally effectuated through exogenous specification of farm gate prices, production quotas, and later on through hectare and headage premiums. International trade policies generally consisted of restrictions on imports, through phytosanitary measures as well as tariffs and subsidized exports, partly in the form of food aid.

In such a context it is only natural that agricultural policy models for OECD countries emphasized the supply response of farm households at given prices, with farm incomes, net exports and the budgetary outlays of government as derived variables. However, structural changes on food markets and shifts in the focus of agricultural policy call for a reassessment and reformulation of existing models. Some of these changes are specific to the food sector, while others reflect general “new economy” developments. At the heart of these transformations lie the trends toward further product differentiation on the one hand, and towards concentration both at firm and government level on the other. Consumer concerns are the main drivers of product differentiation, and have a special bearing on food markets. Consumers increasingly want to be informed how each food item was made and to follow each step of transformation, from field to table. They often oppose new technologies, such as
those involving genetically modified organisms (GMOs). Consequently, food products become labeled and characterized by their mode of production (environmental sustainability, animal welfare, labor standards) as much as by their physical properties (food safety). This leads to product differentiation through labeling. The shift in policy focus is partly due to these developments. Since consumer concerns are also the concerns of taxpayers they create new demands on farmers to meet environmental standards and to respect animal welfare.

The concentration in the food sector is partly attributable to general new economy features as agriculture itself increasingly relies on R&D, while advertising plays a more dominant role in the other segments of the chain. Both create returns to scale as research findings can be used in a non-rival way. The stronger vertical integration in response to consumer concerns is another cause. Public authorities also play an active role in this process. To facilitate exports and to improve the international standardization of product norms and customs procedures, they also create new customs unions with neighboring states or accede to existing regional unions. These regional bodies make it possible for governments to operate at the same scale as firms. This regionalization process also promotes the international policy coordination, thus creating new forms of concentration in the public domain. After earlier opposition by several WTO members, a consensus seems to have emerged that regionalization is a reality to be reckoned with, even though it may cause trade diversion and in some cases creates large trading blocks that can exercise market power on the world market.

The implication for agricultural policy modeling is that the representation of these large firms and regional blocks and their mutual interaction as strategic agents deserves priority. The present paper discusses in general terms these trends towards product differentiation and concentration, without entering into empirical details, and focuses on the description of a flexible approach to model strategic behavior on food markets with special reference to Applied General Equilibrium (AGE) models.

The paper is structured as follows. Section 2 pursues the discussion of the reasons for emphasizing product differentiation and strategic behavior. Section 3 considers the modeling aspects. A brief discussion of the representation of product differentiation is followed by the formulation of a practical approach to model strategic behavior, the main subject of this paper. The key component is an agent-specific device to calculate the optimal direction of change for a vector of policy instruments, while anticipating the reactions of other agents. The model of optimal public choice under second best emerges as a special case. Section 4 concludes.

2 The need to represent product differentiation and strategic behavior

2.1 Consumer concerns, labeling, and vertical integration

This section reviews some of the causes of product differentiation and concentration that are specific to food markets, while choosing consumer concerns as point of entry. Partly as a result of trade liberalization, products are nowadays supplied in greater diversity, and consumers increasingly ask for better and faster information on how the goods they buy were produced. First, after various crises and scandals product safety has become a priority. The use of food additives is being challenged, vegetables should not contain pesticide residues, meat should be certified free of mad cow disease, and genetically modified organisms face strong opposition in some countries. Second, some consumers want to be assured that the

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1 See CBD (2000).
2 See Blandford and Fulponi (1999).
products they buy were produced in an environmentally friendly way. Third, animal welfare is an issue with implications not only for the meat sector but also for producers of furs, cosmetics and pharmaceuticals. Finally, labor standards also play a major role in current policy debates.

Labeling naturally leads to vertical integration since the supplier will find it necessary to control the quality of all critical ingredients. For some products, such as meat, the vertical integration will have to include processing and trade while for others, such as vintage wines or forestry products, it has so far been possible to “seal” the product and “freeze” its qualities before it leaves the farm or the region of origin. For products like fruits and vegetables, with ample scope for quality control, coordination strategies based on contract farming appear more likely. More generally the seller’s reputation becomes important for every buyer along the chain, and consequently suppliers will become less anonymous and produce under long-term contracts. However, as the diversified products necessarily carry labels as end-product, the foreign suppliers of the ingredients do not share in the rent from product differentiation, unless they participate in the brand, and this reinforces the dominance of the final, marketing and processing parts of the chain. Vertical integration may also have far-reaching consequences for the WTO process because whenever a vertically integrated chain spans several countries it becomes difficult to impose tariffs as the chain can avoid them relatively easily.

Vertical integration is also intimately linked to the new economy phenomenon of increasing returns. The higher knowledge intensity of production causes the share of fixed expenditures to rise relative to variable costs. This makes it more important for companies engaged in R&D to establish intellectual property rights (patents, licenses) and be assured that no one can copy their products without due payment. Recognition will also promote the diffusion of research findings. These returns-to-scale create concentration among the firms that are engaged in R&D. They also lead to vertical integration with the users of the R&D, because it is much easier to recover the associated costs within an integrated chain than through patents and licenses, and also because product differentiation makes it easier to dominate a specific niche market. Finally, it can be argued that consumer concerns foster R&D-intensity because the techniques that can be applied to meet the standards are often new and in need of improvement and because the inspection procedures to verify their satisfaction are increasingly sophisticated as well.

2.2 Policy response worldwide: regionalization

OECD governments currently seem to follow a dual course in their reaction to this concentration process. They can on the one hand be seen to promote the enlargement of markets through free trade agreements and customs unions so as to make it possible for producers to standardize their products and their marketing operations, and reduce their unit costs. The current consolidation of NAFTA and Mercosur into the Free Trade Area of the Americas and the accession of new member states to the European Union are illustrative in this respect. On the other hand, they conduct a competition policy to reduce monopoly power. However, establishing whether such power exists often proves to be very hard, especially because it no longer finds expression in prices exceeding average costs as network effects often lead suppliers (internet) to provide some products free of charge, while recovering the costs, say, through advertising. In addition, the trade liberalization process makes it harder to

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3 See Perry (1989); Royer and Rogers (1998).
4 See Hueth et al. (1999).
counter monopoly, since the tariff restrictions limit the possibilities of taxing away the monopoly rents.\(^5\)

Thus, the formation of regional country groupings is at the same time a vehicle of the concentration of firms and an attempt to control the process. Indeed, several developing countries are now opting for standardization of food norms at regional rather than at world level, to meet the demand of local markets because they appreciate that it is not in their interest to apply the norms of OECD countries in their mutual trade. Exports to OECD countries will then proceed under separate labels, much in the spirit of the label “export quality” that was been for many years common for many food products in the EU. At any rate, the regionalization process makes some of the regions more powerful on the world markets, while others actually become more disconnected than the individual countries because most of their trade is intra-regional. At any rate, trade models should be adapted to account for this development.

### 2.3 CAP response: multi-functional agriculture

As far as European agriculture is concerned, the attractiveness of expanding the geographic coverage is far from obvious. The EU already finds it hard to contain its production and the new members will only contribute to the creation of further surpluses. However, the upcoming accession of new members places further pressure on the Common Agricultural Policy (CAP) not only because of the financial burden but also because once it has been effectuated, the EU has more to gain from improved access to other countries.

Nonetheless, the EU has so far been unwilling to abolish its farm support altogether.\(^6\) Its current inclination is towards implementing the concept of multi-functional agriculture by which the agricultural sector should be capable of exporting without excessive subsidies, has safe production methods, maintains employment in rural communities, and contributes to the preservation of natural resources and natural heritages of the countryside.\(^7\) The basic idea is to replace gradually the publicly funded farm income support under the present CAP by rewards for services for which the consumer can pay indirectly, via the price of labeled products that meet consumer concerns, or directly, via entrance fees in parks, or as tax payers, via a contribution to landscape preservation. At the same time, farmers will have to pay for environmental damages caused. In such a setting, the countryside becomes much more than a producer of raw materials, and offers a variety of alternatives to agricultural employment.

Within this perspective, rewards for services that are linked to the mode of production of the farm become explicit. In this way, production characteristics such as animal welfare and preservation of rural life and natural amenities can receive their remuneration. Clearly, multi-functionality is not a panacea that relieves the EU and national governments from their responsibilities for maintaining viable conditions in rural areas. Nonetheless, by seeing to it that every region capable of earning sufficient revenue from the market no longer relies on government support, more funds are left for the less favored regions. The approach also allows to reward more directly the rural amenities that are being appreciated most highly, and since these proceeds do not fall with increased imports, it reduces the farmers’ vulnerability to foreign competition. From the perspective of the farmer multi-functionality offers a further channel of product differentiation, whereby landscape services are provided jointly with, say, the wool of the sheep that graze on it.

Most importantly, since multi-functionality payments can be viewed as a regular reward for services delivered, they should qualify relatively easily as WTO compatible measures.

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5 See Meiklejohn (1999).
7 See CEC (1998b).
And if they are effectuated, the system can yield income to the farmers in EU countries, reduce their dependence on price support and soften their opposition to further trade liberalization. Japan has adopted a similar position. While the approach seems promising, the EU and Japan are still to bring it into practice and they have so far only undertaken scattered efforts (e.g. nature management contracts to preserve bird life).

We conclude that product differentiation has to be accounted for in agricultural policy models because of the consumer concerns and Europe’s embracing of the multi-functionality approach. At the same time, labeling, vertical integration and higher R&D intensity promote concentration and thus create a scope for strategic behavior which national governments may seek to control or cope with, through strategic behavior of their own, which can possibly be strengthened through international cooperation and regional integration. The next section deals with the modeling of these phenomena.

### 3 Modeling product differentiation and strategic behavior

This section chooses the Applied General Equilibrium (AGE) framework as point of reference but the main discussion is less specific and avoids any detailed specification of an AGE model, both to facilitate exposition and to emphasize the generality of the approach proposed.

#### 3.1 The AGE framework

We consider a static AGE framework with r commodities covering the full economy. Actors in the economy are m consumers, n producers, and one government. Every producer maximizes profits subject to a technology constraint and redistributes these to the consumers who own the firm. Every consumer maximizes a utility function subject to a budget constraint that equates income to expenditure. Income consists of proceeds from the sale of fixed commodity endowments, a share in profits of the firms, minus taxes. Government only appears as an exogenous agent who levies (possibly negative) indirect taxes and redistributes the proceeds to consumers. The economy is closed (it may encompass the whole world), and commodity balances clear all markets. We initially abstract from strategic behavior and assume that all consumers and producers are price takers.

This type of specification defines a set of supply and demand functions, with prices and the rates of indirect tax as independent variables, entering three types of constraints: r commodity balances, one government budget balance and one price normalization constraint. By Walras Law, one balance is redundant and can be dropped. Hence, the model can be expressed as a system of (r+1) simultaneous equations, with r prices and one tax proceed variable as endogenous variables and tax rates as well as other model parameters as (r+1) exogenous variables.

Various well known extensions also fit within this framework. For instance, producer markups may be viewed as indirect taxes on output that are redistributed directly to the owner of the firm, and tariffs on international trade can be looked at as indirect taxes on firms that transform foreign goods into domestic ones or vice versa. Furthermore, a multi-country economy can be represented by defining a government budget to every country with the appropriate assignment of tax proceeds to the respective government. In short, an AGE-system of nonlinear equations with prices and tax proceeds as dependent variables and indirect tax rates as parameters offers a flexible basic framework that has found many applications in agricultural policy modeling for OECD countries, although their basic logic
was often simpler as policy was setting the farm price at more or less fixed levels, and a stronger price endogeneity would not reflect the actual policy regime. Consequently, the interactions with the non agricultural sector are generally treated in a highly simplified way, via the purchase of current inputs, and via the processing of farm outputs. The associated input output coefficients are kept fixed or derived from CES production functions with a weak empirical underpinning at best. If represented, market power of the processing industry only enters through fixed markup rates. A survey of such models falls beyond the scope of the present paper. Yet, several other limitations could be mentioned and – honoring a specific request by the organizers of this seminar – we list a few. First, agriculturally oriented AGE models to a great extent rely on calibration and are generally less firmly based on empirical data and formal econometrics than, say, household models, which are also more sophisticated in their specification of savings, investment, and accumulation of capital and skills is often more refined also. Second, agricultural AGE models could include far more of the knowledge from agronomy within their production structures, rather than in their periphery, for example, to deal with environmental issues and multi-functionality as public goods. Third, the succession of generations plays an important role in agricultural practice but did not so far find its way to agricultural AGE models, whereas it takes, through the overlapping generations literature, a prominent place in other parts of the AGE-literature. Fourth, random shocks play a central role in both the real business cycle (RBC) and the incomplete market branches of AGE modeling but are not considered in agricultural AGE-applications. At the more fundamental level, it seems worthwhile and is now possible to model the spatial continuum of land itself within an AGE context.9

All these modifications have important consequences for the specification of the AGE model but since they remain within the same general equilibrium framework, they all fit together in principle, and their selection for incorporation is essentially a matter of research focus.

Therefore, we now focus on the area of imperfect competition which, through the two items in the title of this paper, is most intimately linked to ongoing structural changes on agricultural markets themselves. On the one hand product differentiation impacts on the commodity classification, and on the other hand concentration has consequences for the exogenous variables in fact for their exogeneity itself, since it affects the optimal markup as well as the optimal government response. Hence, both ask for reconsideration of the standard AGE model with taxes and tariffs.

### 3.2 Product differentiation

Product characteristics can be depicted in either continuous or discrete terms. Lancaster (1979) is generally considered the pioneer of the continuous representation in which consumers demand quantities of characteristics (e.g. calories, proteins, fats), and purchase commodities so as to meet this demand.10 Alternatively, in the discrete formulation characteristics are attributes of the commodities and every combination of attributes defines a commodity, with a technology and market of its own.

The discrete formulation is the relevant one in connection with consumer concerns, labeling, and vertical integration. In addition, one can for every combination of attributes (market segment) determine a (real-valued) number of brands via the Dixit-Stiglitz

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8 Cf. Folmer et al. (1995) for an EU model; Narayana et al. 1991 for a model of India; Burniaux et al., 1994 for OECD’s world model; Hertel, ed. (1997), for the GTAP world model; Francois et al. (1994) for another world model. We refer to Gunning and Keyzer (1995), Ginsburgh and Keyzer (1997), and Srinivasan and Whalley (2000) for surveys and further discussions of these issues.


10 See Peitz (1997).
formulation. Utility from consumption of, say, a beverage is produced under constant returns to scale from the consumed quantity and the number of brands, where the entry cost for a brand acts as price, while the product defines the rent from product differentiation. But since the number of brands is real-valued, individual producers are infinitesimally small and have no incentive to act strategically.

If characteristics refer to the mode of production, they will be associated to a production technology and if this technology involves several segments of the production chain, vertical integration results because producers will need to apply non-price controls along the chain, through acquisition of input suppliers and contract farming, especially if transportation costs of the raw material are high (sugar beet), if its timely delivery is essential (fruits), or if the certification is problematic (meat), the producer.

The discussion suggests that the modeling of characteristics and chains is not difficult in principle as it only requires significant product disaggregation. However, four remarks are in order. First, the representation needs data that are not published by statistical agencies, and will often be kept under the seal of confidentiality by the companies concerned. Consequently, until these data gaps are filled, modelers and policy analysts will have to accept stylized representations. Second, the fine disaggregation and the product heterogeneity suggest a complexity that can presumably be handled more effectively by numerical simulation than by formal analysis. Finally, the Dixit-Stiglitz approach for determining the number of varieties only applies if the producers of the variety are themselves infinitesimally small and hence powerless. In fact, product differentiation segments the market into smaller, homogeneous niches, and makes the firm larger relative to the size of its market. Hence, strategic behavior has to be accounted for.

3.3 Strategic behavior

We now specify a general framework for a model in which both private firms and national governments act strategically and indicate how such a model could be solved. The analytical challenge is to avoid the strong simplifying assumptions that are, for example, common in new trade theory. The approach is inspired by concepts of multi-level planning that received much attention in the early seventies.11 Practical applications of multi-level planning were generally restricted to first-best situations where they could decentralize a central plan, i.e. to environments without strategic behavior by lower levels in the planning hierarchy and without distortions. In connection with food markets, the consumers and the individual farmers are typically the non-strategic actors located at the lower levels of the hierarchy. In this type of environment, a first-best reasoning that abstracts from all distortions remains useful to orient the general debate but practical policies will have to take the prevailing distortions as given, i.e. to operate under second best by determining directions for gradual changes in policy parameters that can improve the economy’s performance.

If abstraction is made of the practical aspects of empirical specification, the major difficulty is computational. The procedure proposed in this section operates at a given level of product differentiation and concentration since the number of commodities and the number of actors is fixed. It computes the gradients needed to update the various decision variables of the strategic agents. These gradients are informative in their own right and can also be used to update the decision variables until an optimum (or an equilibrium) is reached.12

The first step is the observation is that the common AGE-model with tariffs and markups offers a very flexible construct. In fact, every allocation on the boundary of a

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11 See Kornai et al. (1975), Kornai (1979), and Goreux and Manne (1973).
12 For a more elaborate presentation along similar lines, we refer to Ginsburgh and Keyzer (1997, chapter 11). An application to international trade can be found in Keyzer and Van Wesenbeeck (1999).
production set and on the isoquant of a utility function can be represented as a general equilibrium with indirect taxes, markups and income transfers among consumers. Here markups are indirect taxes on net outputs that accrue to the owner of the firm rather than to government. Most AGE-models actually operate in the opposite way and compute such an allocation at given tax, tariff and markup rates (or levels). Scenario studies with these models usually amount to calculating the effects of changes in these rates on equilibrium allocations and the consequences for the utilities of the various consumers and the profits of the firms.

The second step is the remark that strategic behavior amounts to determining the levels of these policy variables that optimize separately the objective of every strategic agent (utility of the consumer or the profit of the producer or the social welfare of the government under consideration), for given actions of the other strategic agents, while accounting for the effect of the own decision on the external environment.

An example: Cournot competition
To illustrate the basic principles, we specify a model for a single strategic firm. Cournot competition has been used most widely in this context. It considers a producer who takes the net supply of his competitors as given and anticipates the depressing effect on the price that would result from an expansion in his own production, which may lead him to restrict his net supply. In a general equilibrium setting, Chamberlin competition is a special case where the competitors (denoted by the subscript –j) do not supply perfect substitutes (therefore, each producer has a monopoly). Hence, both types of competition can coexist within a model where strategic producers anticipate the behavior of non-strategic producers. The profit maximization problem of strategic producer \( j \) supplying a quantity \( q_j \) of a commodity while purchasing inputs \( v_j \) at unit price:

\[
\max_{q_j, v_j} \left[ P_j(q_j, q_{-j}) q_j - v_j \right]
\]

subject to

\[
q_j \leq f_j(v_j),
\]

where \( P_j() \) denotes the price function for producer \( j \), which is assumed to be a differentiable function of producer \( j \)’s gross supply, and the gross supply of competing producers. The first-order condition w.r.t. input can for positive \( v_j \) be written:

\[
P_j(1 - \mu_j) \frac{\partial f_j(v_j)}{\partial v_j} = 1
\]

for

\[
\mu_j = -(q_j/R_j) \frac{\partial P_j}{\partial q_j},
\]

where \( \mu_j \) is the optimal mark-up rate, which can be interpreted as the negative of the inverse elasticity (the flexibility) of the net demand curve as perceived by the strategic producer. We can apply a separation between owner and firm by letting the manager of the firm pursue competitive profit maximizing behavior while taking the mark-up ridden prices \( P_j(1 - \mu) \) as given, for a markup set by the ‘master program’ of the strategic profit maximizer. This markup rate typically is the parameter that enters the standard AGE model described earlier.

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All the major difficulties are due to the calculation of this elasticity, which summarizes the actor’s knowledge of the environment’s response to the own action. The approach usually taken in the literature is either to introduce simplifying theoretical assumptions,\textsuperscript{14} or to derive in analytical form the elasticity function that determines the markup rate,\textsuperscript{15} but this requires far-reaching simplifications. Our gradient technique replaces the explicit and error prone calculation of derivatives and elasticities by the numerical evaluation of Lagrange multipliers, which is perfectly standard and automatic in most mathematical programming packages.

**Principal-agent problem and the optimal policy under second best**

We are now ready to move to a more general specification of the decision problem, starting with the principal-agent or leader follower model. The principal is strategically anticipating the reactions of the agent. His decision problem can be formulated as:

\[
\max_{0 \leq \theta, x} U(x, \theta)
\]

subject to

\[
G(x, \theta) \leq 0
\]

where \(x\) is an \(m\)-dimensional vector of endogenous variables, \(\theta\) an \(n\)-dimensional vector of exogenous variables (parameters) in the instrument space \(\Theta = \{a \leq \theta \leq b\}\), while \(G(x, \theta)\) is an \(m\)-dimensional differentiable vector function, and \(U(x, \theta)\) is a scalar objective. Clearly, problem (3.3) is very hard to solve, as we did not impose any convexity or monotonicity requirements on any of these functions. This was done not for simplicity of exposition but because such requirements are rarely fulfilled when the constraints contain price dependent supply and demand functions as is the case when they consist of an AGE model. Indeed, the flexibility of the proposed approach stems precisely from its applicability to such general specifications.

Next, we restrict the parameters to an exogenous value, and assume that (1) we can identify as a subset a system of equations \(F(x, \theta) = 0\) for which equality holds, and (2) this system is regular. In linear programming terms this means that we can find a feasible basis (recall that such a basis fully defines the AGE model sketched earlier). We can solve the system of nonlinear equalities \(F(x, \bar{\theta}) = 0\), which might amount to calculating a tax ridden equilibrium for given values of the parameters. At this equilibrium solution \(x^*\), and assuming it to be locally unique – which by Sard’s Theorem is generally\textsuperscript{16} the case – we can solve:

\[
\max_{x, \theta} U(x, \theta)
\]

subject to

\[
F(x, \theta) = 0
\]

\[
\theta = \bar{\theta}
\]

and where \(\mu\) is the Lagrange multiplier associated with the constraint on \(\theta\). The problem is numerically trivial because its optimal solution \(x^*\) is already known. All we use it for is to compute the associated multiplier value \(\mu^*\), which is equal to the analytical expression:


\textsuperscript{15} Cf. Mercenier and Schmitt (1996).

\textsuperscript{16} This means that if \(x^*\) is a solution there is generally no other solution in the neighborhood of \(x^*\), and that a small shift in \(\theta\) causes a small shift in \(x^*\). Clearly, it does not imply uniqueness of the solution itself.
\[ \mu^* = \frac{\partial U}{\partial \theta} - \frac{\partial U}{\partial x} \left( \frac{\partial F}{\partial x} \right)^{-1} \frac{\partial F}{\partial \theta} \]  

(3.5)

In applied policy analysis, anticipating the effect of a change in decision variables \( \theta \) on endogenous variables \( x \) and welfare criterion \( U \) is commonly the main question of interest. The direction of change in \( x \) and \( U \) usually is the main concern, and the right-hand side of the expression highlights a major difficulty in this respect. Whereas the signs of the derivatives themselves could in principle be derived from theoretical and empirical considerations, those of the inverse are only clear in very special cases, such as diagonal dominance, or gross substitution. As a rule, the answer can only be derived through calculation. Hence, we use program (3.4) to evaluate the expression \( \mu^* \), while assuming that the function \( F \) meets the requirements of the implicit function theorem.\(^17\) In fact, the criterion of this problem does not have to be the objective of any of the agents. For example, if we define it as \( U(x, \theta) = x_j \) the \( j \)-th element of \( x \), say, farm output, the multiplier will measure the derivative of this element with respect to \( \theta \), i.e. evaluate the total differential \( dx_j/d\theta \) itself.

Software implementation is straightforward. For example, in the GAMS language it suffices to define this program, initialize it at \( x^* \), and read off the Lagrange multiplier after very few iterations. Possible nonconvexity of the constraint set is of no consequence.\(^18\) Next, we can, in an iterative process with iteration index \( s \), use the value \( \mu^* \) of the Lagrange multiplier to raise the objective through a gradient step on \( \theta \):

\[ \theta^{s+1} = \theta^s + \rho_s \mu^s, \quad s = 1, 2, \ldots \]  

(3.6)

where \( \rho_s \) is a positive constant, to be set at a small enough value. Elements of \( \theta \) that reach a bound of \( \Theta \) are kept at this bound. The process continues until the sum of absolute values of the elements of the vector \( \mu^s \) that are not at bound has come sufficiently close to zero. This is a regular gradient process that will generally converge to a local optimum\(^19\) (but not necessarily to the global optimum!).

We can interpret (3.4) in policy terms for the basic AGE framework outlined earlier. The vector \( x \) of endogenous variables includes market prices and tax proceeds, while \( \theta \) is the vector of indirect taxes and possibly other policy instruments. These taxes are markups if the agent is a private firm but suppose that this is the program of a national government. Having solved the model for its endogenous variables, this government can now evaluate a social welfare criterion \( U(x, \theta) \), and, more importantly, use (3.4) to determine a direction of steepest ascent for improving this criterion. Even if without any iteration, this will provide useful information.

### 3.4 Multi-level programming

Next, we return to the principal agent problem and suppose that we assign a leader above this principal. Let the vector \( \tau \) denote this leader’s decision variables and let the constraints \( F(x, \theta, \tau) = 0 \) replace the earlier restriction \( F(x, \theta) = 0 \). Since writing program (3.4) in its

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\(^17\) See e.g. Ortega and Rheinboldt, 1970.

\(^18\) The requirement that the implicit function theorem should hold, basically means that the solution should exists and the Jacobian of \( F \) w.r.t. \( x \) should be non-singular. In practical terms, \( \theta \) should be free to move in all directions; the constraints should not include any equation expressed in terms of \( \theta \) only. For example, a strategic producer cannot vary all his netputs freely, since there is a production function that relates them.

\(^19\) One difficulty is that the gradient might not be a continuous function of the parameters, as the set of active constraints in \( G(x, \theta) \) could be shifting under a change in \( \theta \). This can be addressed by smoothing the series of derivatives (see Ermoliev and Norkin, 1997).
present form among the leader’s constraints would be quite uninformative, it is necessary to replace it by some closed form: \( f(x, \theta, \tau) = 0 \). For this we can use the first-order condition, but we assert that it can also be implemented without differentiation, via a scalar function, whose actual construction is somewhat technical and beyond the scope of the present paper. We can determine the effect of a marginal change on the leader’s objective as the multiplier \( \phi^* \) of the program:

\[
\max_{x, \theta, \tau} V(x, \theta, \tau) \\
s\text{subject to} \\
H(x, \theta, \tau) = 0 \\
f(x, \theta, \tau) = 0 \\
F(x, \theta, \tau) = 0 \\
\tau = \tau^* \\
\phi
\] (3.7)

where the vector function \( H(x, \theta, \tau) \) denotes additional restrictions faced by the leader. We suppose that the combined set of restrictions in (3.7) also meet the requirements of the implicit function theorem. Since this program has the same structure as (3.4), the earlier reasoning applies and the multiplier \( \phi^* \) can be used to update \( \tau \) in a gradient algorithm, while \( \theta \) is being updated in parallel via the multiplier \( \mu^* \). We note that as long as the function \( f(x, \theta, \tau) \) can be defined, the embedding can be repeated indefinitely. Hence, the approach makes it possible to compute in parallel all the gradients for any multi-level model, avoiding cumbersome nesting of computational procedures. In a three-level problem, the outer agent could be a regional grouping that chooses action \( \tau \), while anticipating the reactions of one strategic inner agent (a firm on the internal market) with action \( \theta \) who in turn anticipates the reactions (part of the vector \( x \)) of non-strategic agents (consumers and small firms), and takes the policy action (or reaction function) of the regional grouping as given.

**Nash equilibrium**

We now leave the setting of multi-level programming with a clear hierarchy and turn to the multi-agent games that can represent, say, several strategic firms and regional groupings interacting on the world market. If principal-agent models are looked at as Nash equilibria with a single strategic agent, all equilibrium models of imperfect competition can be considered to belong to this category. Under a Nash equilibrium specification every strategic agent is generally taken to assume no reaction from the other strategic agents. For clarity, we write the program of the individual strategic agent for a two level, principal-agent case, since the extension to the three-level problem (3.7) is straightforward:

\[
\max_{x, \theta_i} U_i(x, \theta_i, \theta_{-i}) \\
s\text{subject to} \\
F(x, \theta_i, \theta_{-i}) = 0 \\
\theta_i = \bar{\theta}_i \\
\mu_i
\] (3.8)

The program enables us to compute the gradient w.r.t. the decision variables \( \theta_i \). Alternatively, it is possible to define an assumed reaction function

\[
\hat{\theta}_{-i} = g_i^*(\theta_i)
\] (3.9)
and modify (3.8) accordingly.

Three textbook cases directly fit within this framework. First, the Cournot models of producer behavior treat profit maximization of the strategic firm as criterion, and its supply as strategic variable taking the supply of other strategic producers as given. Second Chamberlinian competition assumes that producers are monopolists on their own market but also takes the supply of other strategic producers as given. Finally, Stackelberg models use a reaction function as in (3.9). These cases generally refer to profit maximizing producers but they would also apply to (groups of) consumers who own a single firm. Clearly, it is also possible to specify games with markup rates as strategic variable rather than supply. Similarly, when governments set optimal tariffs to maximize a social welfare function as in the model of optimal tariffs, this function is the criterion and the tariff the strategic variable.

Scope for numerical implementation

For the principal agent problem (3.4) and the multi-level program (3.7), a sufficient and relatively mild condition for existence of a solution is that the assumptions of the implicit function theorem should hold for all the relevant parameter values. If this condition is met, it is not very difficult to guarantee convergence to a local optimum. Ermoliev et al. (forthcoming) also describe a stochastic algorithm to find the global optimum, although the practical efficiency of this technique is yet to be established.

However, conditions to ensure existence of the Nash equilibrium (3.8) are less clear. Existence can only be guaranteed as long as the decision programs of the strategic agents remain convex in the decision variables, as will for example be the case for a matrix game. We recall, however, that the constraints of an AGE model do not in general possess this property. Yet in empirical applications, it is possible to obtain an initial solution by calibration, and around this solution it will be easier to maintain existence and convergence. Finally, it may be useful to mention that the stochastic algorithm mentioned earlier could in principle find all equilibria of this problem.

Extensive numerical experience with the proposed approach was gained through computational exercises with an international AGE model containing 4 countries, with 3 consumer groups in each country, 2 period and 13 commodities in each period. In this model there are 7 strategic firms with increasing returns to scale and 3 strategic regional governments, operating under various assumptions regarding concentration. As the model was only partly calibrated, it could not be initialized at equilibrium. In this application, it appears that if the appropriate solution format is chosen convergence will not be a problem as long as strategic agents have perfect knowledge. It only becomes a serious difficulty when they are myopic and substitution is limited. Markup rates tend to explode in that case, suggesting non-existence of equilibrium.

4 Conclusion

We described the chain of causation from consumer concerns, via labeling, vertical integration and multi-functional agriculture to product differentiation and concentration at firm and at governmental level. We have argued that the modeling of this kind of product differentiation requires disaggregation of commodity classifications rather than inclusion of Lancaster type characteristics or Dixit Stiglitz type of love of variety. Next, we proposed a way to model strategic behavior in a multi-level context, at given levels of product diffusion.

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20 Cf. van Wesenbeeck, forthcoming.
differentiation and concentration. For this we defined a class of mathematical programs with equality constraints, whose feasible set consists of a single point. Hence, its optimum can be computed beforehand, by solving this set of equality constraints, prior to entering the optimization itself. The optimization itself only serves as a device for calculating the Lagrange multipliers. The very fact that the solution the program can be initialized at its optimum ensures that the device will work very rapidly, and for virtually every non-convex form, and thus allow to compute a direction of steepest ascent in an easy and reliable manner. This technique can also be used to compute the response elasticities of the model under consideration, and to derive optimal directions for policy change under second best.

Thus, while one may question whether consumer concerns and new economy trends will actually enable food processors and retailers to develop significant market power, producers of seeds and pharmaceuticals manifestly enjoy such power already. Moreover, until food trade has become liberalized in full, the ever larger country groupings will maintain some degree of power on world markets. Therefore, strategic behavior has to be modeled, if only because in such an environment with large private agents governments will not accept a role as a bystander.

References


Representing product differentiation and strategic behavior in agricultural policy models


General equilibrium on the back of an envelope: 
The case of transaction costs

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Abstract
The price endogenous programming models (PEP), in the tradition of Samuelson, and Takayama and Judge, can easily be extended from partial to general equilibrium models and will then have a firm foundation in economic theory. All sector specific details with respect to technology can nevertheless be retained and need not be translated to some special format as required by computable general equilibrium models. The main drawback of PEP models is their reliance on a representative aggregate consumer. However, the generalisation from a general equilibrium PEP model to a Negishi program with multiple budget constraints is straightforward. This opens for a relatively simple specification of general equilibrium in an economy with transaction costs, where production is conducted partly by households, and partly by corporate firms.

Keywords: Partial Equilibrium, General Equilibrium, Mathematical Programming, Transaction Costs

1 Introduction
The applied price endogenous programming models (PEP) is established by Samuelson (1957) and Takayama and Judge (1971), and surveyed by McCarl & Spreen (1980) and Labys, Takayama & Uri (1989). The class of models has two central features. First, the solution method is mathematical programming, and secondly prices can be endogenous and support economic equilibria. PEP models have been extremely popular within agricultural economics where mathematical programming have been much applied as a tool. To some extent, the PEP approach has been losing ground to the computable general equilibrium models (CGE), but the models are still living in numerous research departments for analysis of sector specific issues. The technique of mathematical programming has proved to be convenient in dealing with complex technological interdependencies.

The CGE approach specifies and solves complementary problems - a more general method than that of programming. However, because of this generality, complementary models have less structure than those of programming, and there are relatively few theoretical results on necessary and sufficient conditions for existence of a solution. For problems which do fit into the programming framework, there may consequently be benefits in staying with the less general methodology.

The potential power of the PEP approach comes from the close relationship found by Negishi (1960) between a solution to a optimisation programme and a general competitive equilibrium. The basic relationship is inherent in the Kuhn-Tucker theorem saying that a solution to the programme is a saddle point of the associated Lagrangean function (A. Takayama 1985). These results can connect applied partial equilibrium PEP models with general equilibrium theory in two ways. First, it can be checked whether the partial model is
consistent with some general one. Secondly, the missing relations to transform the partial model into one of general equilibrium can be added. It seems that this route has not been much explored. Hoveid (1999) finds actually along this way, that the conventional statement on applied partial equilibrium models --- income is fixed --- is wrong. The basic results are reviewed in section 2. In section 3 the PEP approach is specified as a Negishi programme with multiple consumers. This opens for further generalisation of the model to deal with multiple producer households. The paper ends with some concluding comments in section 4.

2 Price endogenous programming models

2.1 General equilibrium version

A general PEP model can be specified in a nutshell as:

\[
\text{Max}_{x,y} \left\{ W(x) + \tau'x \mid F(y) \leq 0 \quad q \geq 0, \quad x \leq y + e \quad p \geq 0 \right\}
\]

where \( x \in \mathbb{R}^J \) is a vector of consumption quantities and \( W: \mathbb{R}^J \to \mathbb{R} \) is a concave welfare function. \( \tau \in \mathbb{R}^I \) is a vector of exogenous nominal subsidies/taxes. \( y \in \mathbb{R}^J \) is a vector of netputs of production and \( F: \mathbb{R}^J \to \mathbb{R}^K \) is a convex linearly homogeneous transformation function. \( e \in \mathbb{R}^J \) is a vector of resources.

The constraints, \( F(y) \leq 0 \), represent all the technical constraints in the economy. There is at this stage no reason to introduce distinct notation for inputs and outputs. Neither is reference to time and space needed. Time and location is included in the commodity characteristics. These constraints comprise thus those of conventional production, transportation and storage. The first ones relate commodities of various type in a particular location and time. Transportation constraints relate commodities of a particular type and time in various locations. Storage constraints relate commodities of a particular type and location at various times.

The constraint \( x \leq y + e \) represent all commodity balances in the economy, at all locations and all times. Net demand cannot exceed net supply plus resources. \( q \in \mathbb{R}^K \) and \( p \in \mathbb{R}^J \) are Lagrange multipliers for the two constraints respectively.

For this simple model we have under rather general conditions\(^1\), the following result: If a solution, \((x^*, y^*, q^*, p^*)\), exists with balanced governmental budget, \( \tau'x^* = 0 \), then \((x^*, y^*, p^*)\) is a general competitive equilibrium of the economy. The result is well known in the theoretical literature, Negishi (1960), Ginsburgh & Waelbroeck (1981), A.Takayama (1985). The argument for the current context is given by Hoveid (1999) and will not be repeated in detail here.

The result follows from the Kuhn-Tucker theorem that an optimum in a convex program is a saddle-point of the associated Lagrangean function. Optimal \( x^*, y^* \), and Lagrange-multipliers \( p^* \geq 0, q^* \geq 0 \), of the Lagrangean of the program (1):

\[
W(x) + \tau'x + q'F(y) + p'(x - y - e)
\]

satisfies the following conditions: Profits of production \( y^* \) are maximised under prices \( p^* \):

\(^1\) An additional assumption is required to ensure that (1) is a well defined program with a bounded solution. The following one in terms of the set \( X(e) \) applies:

\[
X(e) = \{(x,y) \mid W(x) > -\infty, F(y) \leq 0, \quad y + e \geq x \}
\]

\( X(e) \) is compact and has a non-empty interior.
\[ y^* = \arg \max_y \{ p^* y | F(y) \leq 0 \} \] (2)

Maximum profits are zero:

\[ p^* y^* = 0 \] (3)

Provided the function \( W \) can be interpreted as the welfare of the representative consumer, costs of consumption are minimised under prices \( p + \tau \).

\[ (x^*) = \arg \min_x \{ (\tau + p^*)x - (W(x) - W(x^*)) \} \] (4)

In addition, all markets clear with multipliers \( p^* \) playing the role of competitive prices. The saddle point property thus implies almost all the central features of general equilibrium. The only missing conditions for a general competitive equilibrium are a balanced tax budget

\[ \tau'x^* = 0 \] (5)

and Walras' law:

\[ p^*e = (p^*+\tau)'x^* \] (6)

There is no simple way to arrive at balanced taxes in the optimal solution from within a single solve of the PEP model. One rate need to be made endogenous and several solves with subsequent adjustment of this rate is required. Having a balanced budget, Walras' law follows as a logical implication from the market clearing and zero profit conditions.

Were it not for the distorting taxes and subsidies \( \tau \), this result would be a case of the fundamental theorem of welfare economics, on the correspondence between social (Pareto) optima and competitive equilibria. Here, in the presence of non-zero taxes, we have a second-best optimum realised as a competitive equilibrium.

The model (1) is a general competitive equilibrium model for a closed economy, a Robinson Crusoe island, or in modern times, the whole world. It is somewhat dubious to have the welfare of all people represented with a single function and a single budget constraint, but when this representation is accepted, we have actually a model fitting the back of an envelope. An implemented model with \( F \) specified for the various sub-sectors, time periods and places, would require considerably more paper, but these complications should not prevent us from recognising the simple underlying structure of the model.

A note on non-convexities should be made. It is the saddle point property of the Lagrangean of the PEP program that is important for the relevance of the program in equilibrium modelling. The saddle point property may hold under weaker conditions than those stated here. In particular, the function \( W \) need not be concave, and the function \( F \) need not be convex. Such non-convexities will make it more difficult to calculate the optimum (equilibrium), though, because there may be several local optima for which the saddle point property does not hold. Such a local optimum is not an equilibrium. Standard methods of calculation, like the one in GAMS, look for local optimum and have no routines to judge whether a found local optimum is a global one.
2.2 From general to partial price endogenous programming models

For sector modelling purposes, it is highly inconvenient and largely irrelevant to implement a model with all production possibilities of all sectors in the whole world. This makes the case for partial equilibrium models. A partial equilibrium model should according to A. Takayama (1985) be one where certain equilibrium conditions are skipped and the associated variables are taken as fixed. Typically are market balances skipped and associated prices fixed for a large number of commodities. This introduces a distinction between the internal commodities with endogenous prices represented as, $x, y, p \in R^I$, and the external commodities with exogenous prices represented as, $x, y, p \in R^{J-I}$.

A partial PEP model along these lines is then:

\[
\text{Max} \quad x, y, x', y', \lambda \quad \{ \ W(x, x') + \tau'x + \tau'x + p'(y - x) \mid y + e \geq x, \quad F(y, y') \leq 0 \} \quad (7)
\]

The constraints, $F(y, y') \leq 0$, now represent all technical constraints in the economy with regard to netputs of internal commodities. Most likely, will some netputs of external commodities also be involved in these constraints, that is "imported" factors and products to be "exported". However, technical constraints with respect to merely external netputs need no representation. External netputs entering merely in such constraints will consequently vanish from the model.

A similar possibility for simplification is present for the objective function. If the "whole-world-objective" has the separable structure, $W(x, x') + W(x')$, only the first term need be included in the partial PEP. External consumption entering merely in the second term will vanish from the model.

With respect to equilibrium conditions, there is no essential difference to the general PEP model. There are zero profits, profit maximisation with respect to all commodities entering in $F$, and cost minimisation with respect to all commodities entering in $W$. Some care should be taken with the income dependency of consumption, though. The conventional wisdom is that partial models do not deal with income dependencies as "income is kept constant". However, that is not correct. An equilibrium model imposes necessarily a value balance:

\[
p^*(-y^* + e^* - x^*) = 0
\]

which by the zero profit condition is equivalent to

\[
p^*(e^* - x^*) = p'y^*
\]

Thus, some type of income balance is unavoidable even in partial models. One should consequently make sure that this balance makes sense.

There are two possible options available. First, one can keep the trade balance with external markets, $p'(y^* - x^*)$, constant by appropriate choice of tax rates. This is a typical choice for nation-wide models where the trade balance has political and economical relevance. Now we have, $p^*e^* - p^*x^* - p'x^*$, kept constant. That is, consumer expenditure at competitive prices are identical to resource rents minus trade balance. In a nation-wide model, the same should be the case with consumer expenditure at taxed prices. Hence, the tax balance should also be imposed. This, option is not natural in a sector model. Then it may be more appropriate to keep merely trade balance minus tax balance constant. This will lead to constancy of consumer expenditure at taxed prices minus rents on internal resources.
In equilibrium models that do not comprise the whole world, the first or second option will lead to sensible income dependency of the consumption of internal commodities. If this issue is not addressed through suitable adjustment of the tax rates, one ends up with some income dependency according to (8) - depending on tax rates but otherwise rather arbitrary. Nevertheless, this is standard for sector models with endogenous consumption. These models are thus not partial equilibrium in Takayama's sense. However, the analysis above shows how this defect can be mended.

3 Models with multiple consumers
3.1 Standard Negishi program
A single representative consumer for the whole world is definitely a crude idea that easily can be criticised, Kirman (1992). However, the refinement to several consumers is not difficult, at least not at the theoretical level. A Negishi program will therefore be specified in terms of the notation above and consumers, \{1, \ldots, H\}. Each consumer may have preferences, \(U_h(x_h)\), and endowments \(e_h\), of her own. The program needs also some exogenous positive weights \(\alpha_1, \ldots, \alpha_H\) with \(\sum_h \alpha_h = 1\):

\[
\text{Max} \quad x_1, \ldots, x_H, y \quad \{ \sum_h \alpha_h U_h(x_h) + \tau' \sum_h x_h + y + \sum_h e_h \geq \sum_h x_h, -F(y) \geq 0 \} \quad (9)
\]

Provided all the functions \(U_h\) satisfy the conditions of program (1) relative to \(F\), the program is well defined for all choices of \(\alpha\). Moreover, the structure of (9) is formally identical to that of (1), and a solution satisfies the conditions of profit maximisation, cost minimisation and Walras' law. However, a general equilibrium is not achieved until all consumers have their individual budgets,

\[
(p + \tau)'x_h - p'e_h = 0; \quad h = 1, \ldots, H \quad (10)
\]

satisfied. A simple iterative procedure for finding the appropriate weights will lead to this outcome. Let \(\alpha\) be a tentative vector of weights, and let \(\delta > 0\) be a scalar. Solving (9) leads possibly to certain budget violations, \(p'(x_h - e_h) \neq 0\). Let \(d \in \mathbb{R}^H\) be defined by:

\[
d_h = (p + \tau)'x_h - p'e_h \text{ when } (p + \tau)'x_h - p'e_h > 0, \quad d_h = 0 \text{ otherwise} \quad (11)
\]

A revised vector of weights \(\alpha^*\) is:

\[
\alpha^* = (\alpha + \delta d)/1'(\alpha + \delta d) \quad (12)
\]

If the process converges to \(d = 0\), the general equilibrium is obviously established, but most important is the following fact: Iterative solving of program (9) with adjustment of weights according to (11) and (12) converges to weights where all budget equations are satisfied. For a proof see Ginsburgh & Keyzer (1997).

3.2 Model with transaction costs and household production
The structure of the previous models presumed that all resources were freely transferable and that the distribution of endowments had no effect on aggregate production. The resource rents were distributed to their owners, though, and constituted the expenditure for which they
acquired consumption services. Hence, the distribution of endowments had at least some relevance to social welfare.

With transaction costs, the households may retain some of their endowments to conduct production on their own, either in family enterprises or more informal within the household. It will now be shown how general equilibrium in such an economy can be modelled with PEP.

Assume that all markets are perfect, but that transaction costs forces a distinction between commodities at the market place and commodities in consumption and production. Corresponding names will be applied - labour for example is found both as an endowment and at the market place - but some transformation is required to bring endowments of the household or firm to supply in the market place, or demand in the market place to consumption in the household. The technological possibilities of such transformation - together with all other technological possibilities - are represented with a convex and linearly homogeneous transformation function, $F: \mathbb{R}^2 \rightarrow \mathbb{R}^K$.

A firm has feasible plans with respect to net demand, $x_0$, and netputs, $y_0$, according to:

$$F(-x_0, y_0) \leq 0 \quad (13)$$

In the present static framework, firms cannot possess endowments of their own.

A household with endowments $e_h$ has feasible plans with respect to net demand, $x_h$, and consumption, $z_h$, according to:

$$F(-x_h, e_h - z_h) \leq 0 \quad (14)$$

It is of importance to note that this specification does not impose transaction costs, but merely allows them. The case depends on the structure of $F$. When $F(y_1, y_2) \equiv G(y_1 - y_2)$ for some function $G$, then

$$F(-x_h, e_h - z_h) \leq 0 \iff G(-x_h - e_h + z_h) \leq 0$$

and endowments can be delivered to the market, while consumption goods can be acquired, without transaction costs. With these specifications, the following Negishi program arises:

$$\max \left\{ \sum_h (\alpha_h U_h(z_h) + \tau^t x_h) \quad \mid \quad 0 \geq x_0 + \sum_h x_h, \quad F(-x_0, y_0) \leq 0, \quad F(-x_h, z_h - e_h) \leq 0 \right\} \quad (15)$$

There is a serious drawback to this specification. The variables $e_h$, $z_h$ are not immediately observable, and only seldom is the information available to construct $U$ and the function $F$. However, the exact forms of $U$ and $F$ are not at the centre of attention either. The important issues with respect to general equilibrium are how households respond to changes in market prices and income in the presence of transaction costs. In order to focus on these issues, these variables will be eliminated from the model.

One might follow Pollak & Wachter (1975) and define a commodity utility function, $W_h: \mathbb{R}^{2j} \rightarrow \mathbb{R}$:

$$W_h(x,e) = \max \{ u \mid \exists \text{ exists } z \text{ so that } u \leq U_h(z), \quad F(-x, e - z) \leq 0 \} \quad (16)$$

When this assignment is not defined, $W_h(x,e) = -\infty$. However, specification of the functions, $W_h$, is not straightforward because of their discontinuities. Alternatively, vector valued functions, $G_h: \mathbb{R}^{2j+1} \rightarrow \mathbb{R}^L$, can be specified so that
\begin{align*}
W_h (x,e) > -\infty & \iff G_h(x,e, W_h (x,e)) \leq 0 \\
\end{align*}

After all, it is only the graph of \( W_h \) that matters. By inserting \( G_h \) in (15), it simplifies to:

\[
\max \left\{ \sum \alpha_h u_h + r^* \sum \gamma_h x_h \right\} \quad 0 \geq x_0 + \Sigma_h x_h, \\
F(-x_0, y_0) \leq 0, \\
G_h(x_h, e_h, u_h) \leq 0 \right\} \tag{17}
\]

This model has almost exactly the structure of the Negishi program (9). The main contrast is the role of the endowments which now enters as arguments of the functions \( G_h \), not as entries of the market balance relation.

If \( U_h \) is concave and \( F \) convex, is necessarily \( G_h \) convex. However, non-convexities and transaction costs is not an unlikely combination. It is not expected that \( G_h \) is linearly homogeneous. Decreasing marginal utility of income implies that the possibility set specified with \( G_h \) has decreasing returns to scale. Certain elements of this vector valued function may be independent of the argument, \( u_h \). Moreover, may certain commodities appear only in such elements. The net demand of these commodities will then not affect the possibility of a certain level of \( u_h \). In an implemented model should of course this eventual separability structure be specified in accordance with empirical observations. At the present theoretical level is separability an issue that do not interfere with the structure of the model.

4 Concluding comments

By returning to the basic relationships between general competitive equilibrium and mathematical programming it has been possible to explore the precise character of the equilibrium that comes out of a price endogenous programming model.

The formal appearance of PEP models for closed economies is simple - "fitting the back of an envelope". This makes them convenient as a starting point for more complex models. This article has moved in two directions. First in the direction of a partial equilibrium sector model - a class of models with many applications for the agricultural sector. Second, in the direction of a model with transaction costs and household production.

With respect to partial equilibrium sector models with endogenous demand, a flaw is discovered in conventional models and reasoning. Such models are said to have no income effects on consumption as income is fixed. The analysis reveals that income necessarily is endogenous and that some income effect is inescapable. The mistake probably stems from the fact that the PEP model has no explicit income equation. Rather, the appropriate income balance need to be established with some exogenous adjustment of the policy distortions (tax rates). The trade balance with the rest of the world less the net tax expenditure should be kept constant in all scenarios. This is so both in general and partial equilibrium versions. If one does not undertake this adjustment, the income of the model will not be comparable across scenarios.

The fact that partial sector models cannot account for the feed-backs between the sector and the remaining economy, are arguments for making partial sector models nation-wide. This can be done without any sacrifice of detail and rigor in the sector model. With a theoretically correct welfare function of the representative consumer as starting point, one can roughly add merely four constraints in the PEP model: Market constraints for labour, capital and an aggregate external consumer commodity, and technical constraints with regard to the production of this commodity from labour and capital. The agricultural economists may feel he lacks competence in determining these technical constraints with regard to an artificial...
aggregate, but in this respect he is no worse off than any economist constructing CGE models. The same tricks will do. Subsequent solves of the PEP with adjustment of tax rates so that an optimum is reached with satisfied tax and trade balances respectively, is then a partial equilibrium within the constraints of general equilibrium. In this way the step from a partial equilibrium price endogenous programming model to one of general equilibrium is rather short. One need not adapt to some special CGE methodology to incorporate the missing feedbacks.

The weak part of the PEP approach is the adjustment of tax rates towards satisfied tax and trade balances. One needs to find and specify an appropriate adjustment mechanism. With a complementarity specification of the model, the software will presumably ensure that a solution is found provided it exists. How the equilibrium actually is calculated is, however, a matter of taste and available software. The message here has been that one can go all the way with PEP.

The way towards the transaction cost equilibrium model goes via the classic multi-consumer Negishi-program, which basically is a PEP model. This program illustrates clearly the fundamental laws of welfare economics: A competitive equilibrium without distortions is a Pareto optimum and visa versa. However, the PEP approach is not restricted to first best solutions. It works just as well in economies with distortions, calculating competitive equilibrium as a second best optimum.

With a specification of transaction technology incorporated in the Negishi program, we have a model where general equilibrium with household production can be calculated. Transaction costs are strongly associated with institutional economics, but here it is framed in rather neo-classical terms. The fact that agriculture to a considerable extent is run as family enterprises makes this transaction cost model promising. There is a long way from this theoretical outline to an implemented model however. The function determining the "utility possibility set" of the household need to be estimated and various specifications need to be tested.

References
The Multi-Output and Multi-Input
Symmetric Positive Equilibrium Problem

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Abstract
The PMP methodology is extended in two directions: The inclusion of market prices of limiting resources and the definition of a total cost function which replaces the variable cost function in the original version of PMP. The inclusion of market prices of limiting resources prevents the formulation of a consistent and meaningful optimization problem. The new version of PMP takes on the structure of a Symmetric Positive Equilibrium Problem (SPEP) with the advantage of removing the last vestige of normative programming represented by the need for an explicit optimization. With the definition of a total cost function, SPEP also removes the matrix of fixed production coefficients that implies constant yields. The SPEP structure can be easily adapted to deal with either one or multiple observations. This paper also demonstrates an application of the SPEP methodology to measure the impacts of the European Union agricultural policy.

Keywords: PMP, Symmetric Positive Equilibrium Problem, Maximum Entropy, Calibration

Introduction
The methodology of Positive Mathematical Programming (PMP), originally developed by Richard Howitt (AJAE 1995), has found many applications at the level of individual farms as well as at the regional and sectoral levels. From the beginning, the objective of PMP was that to bridge the gap between the traditional econometric approach---that has always been regarded as a positive approach---and the mathematical programming framework, that has always been characterized as a normative approach. Since the structural relationships in econometric models have a basis in optimizing behavior, it is the need to explicitly optimize an objective function that distinguishes normative models. The dichotomy between the two approaches was based upon a simple fact: The econometric approach uses the observed decisions of economic agents as a means to infer the structure of their decision process, while the normative mathematical programming approach postulates the structure of an economic agent's decision process and generates the decisions that the economic agent ought to take. In reality, neither approach is either purely positive or purely normative.

The conventional mathematical programming approach cannot use the information contained in the decisions taken by economic agents. This simple observation lead to the incorporation of those decisions in the PMP specification as calibrating constraints. In turn, these constraints make the marginal cost of those decisions explicit and make it possible to estimate a nonlinear cost function capable of reproducing the base period results. This step opens the way for economic predictions characterized by a large degree of substitution between activities that liberates the PMP approach from the restrictions of a fixed production coefficient technology.
The use of maximum entropy methods in the reconstruction of the PMP functions (Paris and Howitt, 1998) has enabled more flexible specifications. Maximum entropy (ME) has been applied to both cost and production function specifications. Previous cost functions applications model the interdependency of crop output and cost, but have had to assume fixed proportions for the limiting inputs used in each type of crop production (Paris and Arfini, 1995). An alternative approach is to use ME to reconstruct the production function on a regional or farm basis. This approach (Howitt et al., 1999) expresses the substitution of limiting inputs, but has to assume that the cost and production interdependency between the different crop and livestock outputs is captured by resource constraints and a matrix of land allocation costs.

Hence, PMP is a methodology that is inspired only by economic theory and uses all the available empirical information to its maximum extent. Contrary to the traditional econometric approach, it can use any amount of information, making good use of the fact that the first sample observation contains the largest amount of information. Any subsequent observation of the studied phenomenon contains a decreasing amount of information.

The initial presentation of the PMP methodology, however, encountered many critics because the skeptical reader focussed excessively upon the details used to implement the original idea without grasping the overall meaning of the novel approach. In this paper, we present an expanded framework of the PMP methodology that overcomes residual criticisms raised against the original version: In particular, the fixed coefficient technology and the zero marginal product for one of the calibrating constraints.

The new version of PMP will appear substantially different from the original specification but it follows the same inspiration and goal. First, the explicit maximization of net revenue is no longer postulated. In place of the LP maximization/minimization objective characteristic of the traditional phase 1, we introduce the notion of equilibrium problem. Second, the calibrating phase 3 no longer includes the fixed-coefficient technology appearing in phase 1. Also this phase is expressed as an equilibrium problem between demand and supply functions of inputs and marginal cost and marginal revenue of the output activities. This more general scenario has inspired the name of Symmetric Positive Equilibrium Problem (SPEP) for the new structure (Paris, 1999).

**Description of the Economic Problem**

The problem discussed in this section presents multiple outputs and multiple limiting inputs. The objective is to estimate a generalized cost function that will calibrate the observed levels of output production and input use. The estimation phase is followed by a prediction phase based upon the estimates of the calibrating cost function. The available information concerns an agricultural region of California where \( J \) crop activities are operated using \( I \) limiting inputs. The symbols \( \bar{x}, \bar{h}, \bar{w}, \bar{o}, \bar{c}, \bar{p}, \bar{b}, \bar{r} \) refer, respectively, to vectors of observed activity levels, crop acreage, water levels (for each crop), operating capital (for each crop), accounting cost per unit of activity, output prices, limiting input quantities, and rental market prices for limiting inputs. In other words, we hypothesize that limiting inputs such as land, irrigation water, and operating capital are associated with their observable market prices which may prevail over a larger area than the region under analysis. The matrix of technical coefficients \( A \) is generated by dividing each observed limiting input by the corresponding output level. The objective is, then, to estimate the latent variables that are identified as the marginal costs of output and of the limiting inputs.

In the original version of PMP, this goal was fulfilled by means of a linear programming model that takes on the following specification:
subject to
(2) $\mathbf{A} \mathbf{x} \leq \mathbf{b}$
(3) $\mathbf{x} \leq \bar{\mathbf{x}}$
with the following associated dual problem
(4) $\min_{\mathbf{y}, \mathbf{\lambda}} \{ \mathbf{b}' \mathbf{y} + \mathbf{\lambda}' \bar{\mathbf{x}} \}$
subject to
(5) $\mathbf{A}' \mathbf{y} + \mathbf{\lambda} + \mathbf{c} \geq \mathbf{p}$

where $\mathbf{y}$ and $\mathbf{\lambda}$ are the Lagrange multipliers of constraints (2) and (3), respectively. In the expanded scenario discussed in this paper, however, the presence of the vector $\mathbf{r}$ of rental prices of the limiting inputs prevents the formulation of a consistent maximization-minimization structure. The reader can verify that there is no place in a traditional linear programming model for the available information on market rental prices of limiting inputs contained in the $\mathbf{r}$ vector. This important piece of information which is always part of the basic farm or regional data, on the other hand, must be utilized if we wish to reproduce the decision generating process that most likely underlies the observed regional information.

The Phase 1 of SPEP: Estimation of Marginal Costs

In place of the traditional dual pair of linear programming models we specify an equilibrium problem with the following structure: Four types of constraints are shown with their associated dual variables.

(6) $\mathbf{A} \mathbf{x} + \mathbf{\beta} \leq \mathbf{b}$, $\mathbf{y} \geq 0$
(7) $\mathbf{x} \leq \bar{\mathbf{x}}$, $\mathbf{\lambda} \geq 0$
(8) $\mathbf{A}' \mathbf{y} + \mathbf{\lambda} + \mathbf{c} \geq \mathbf{p}$, $\mathbf{x} \geq 0$
(9) $\mathbf{y} \geq \mathbf{r}$, $\mathbf{\beta} \geq 0$.

The above four constraints have a clearly symmetric formulation: The first two constraints are quantity constraints representing, respectively, the demand and supply of limiting inputs and output calibrating constraints. We will refer to these two constraints as primal constraints. The last two constraints represent marginal costs and marginal revenues of outputs and inputs, respectively. The constraints of this second set are regarded as dual constraints. Notice the symmetric position and role of the two variables designated with Greek symbols, $\mathbf{\lambda}$ and $\mathbf{\beta}$. Both vectors have the meaning of dual variables of the corresponding constraints. When the $\mathbf{\lambda}$ dual variables appear in the marginal cost constraint, together with the $\mathbf{c}$ vector, they take on the meaning of variable marginal costs. The $\mathbf{\beta}$ dual variable appearing in the input constraint is a new introduction to sectoral modeling. It defines the effective supply of the limiting inputs ($\mathbf{b} - \mathbf{\beta}$), as opposed to the usual nominal fixed input supply represented by the vector $\mathbf{b}$. The vector $\mathbf{\beta}$ enables a generalization of the limiting input supply that allows for a more realistic and flexible specification of allocatable inputs. The vector $\mathbf{b}$ can be thought of as an upper limit on the quantity of allocatable inputs that does not imply a zero implicit marginal cost for quantities of allocatable inputs used in amount less than $\mathbf{b}$, as in the usual asymmetric specification of $\mathbf{A} \mathbf{x} \leq \mathbf{b}$. Furthermore, the vector $\mathbf{\beta}$ is not to be regarded as a slack variable. The symbols to the right of the four constraints are their corresponding dual variables. In order to complete the specification of the equilibrium problem we must state the associated complementary slackness conditions:

\[\mathbf{A} \mathbf{x} + \mathbf{\beta} = \mathbf{b}, \quad \mathbf{y} = 0\]
\[\mathbf{x} = \bar{\mathbf{x}}, \quad \mathbf{\lambda} = 0\]
\[\mathbf{A}' \mathbf{y} + \mathbf{\lambda} + \mathbf{c} = \mathbf{p}, \quad \mathbf{x} = 0\]
\[\mathbf{y} = \mathbf{r}, \quad \mathbf{\beta} = 0.\]
The Multi-Output and Multi-Input Symmetric Positive Equilibrium Problem

(10) \[ y'(b - Ax - \beta) = 0 \]
(11) \[ \lambda'(\bar{x} - x) = 0 \]
(12) \[ x'(A'y + \lambda + c - p) = 0 \]
(13) \[ \beta'(y - r) = 0. \]

The solution of the above Symmetric Positive Equilibrium Problem represented by the set of constraints (6)-(13) generates estimates of the output levels, \( x \), the effective supply of limiting inputs \( (b - \beta) \), the total marginal cost of crop activities \( A'y + \lambda + c \), and the marginal cost of limiting inputs \( y \).

In order to solve the above SPEP by means of a suitable computer code such as GAMS (see Brooke et al.), it is convenient to introduce slack vector variables in each of the constraints (6)-(13). Let \( v_{P1}, v_{P2}, v_{D1}, v_{D2} \) be the nonnegative slack vectors of the primal and dual constraints. Then, the computable version of the SPEP can be stated as

\[
\begin{align*}
\text{(14) } & \min \{ v'_{P1} y + v'_{P2} \lambda + v'_{D1} x + v'_{D2} \beta \} \\
\text{subject to} & \\
\text{(15) } & Ax + \beta + v_{P1} = b \\
\text{(16) } & x + v_{P2} = \bar{x} \\
\text{(17) } & A'y + \lambda + c = p + v_{D1} \\
\text{(18) } & y = r + v_{D2}.
\end{align*}
\]

In this specification of the SPEP, the complementary slackness conditions (10)-(13) have been added together to form the auxiliary (artificial) objective function (14). All the variables are nonnegative. The target of finding an equilibrium solution \( (x, y, \lambda, \beta) \) is achieved when the objective function value is equal to zero and the solution vector \( (x, y, \lambda, \beta) \) is feasible. In the appendix, a fictitious, auxiliary LP problem is presented whose Karush-Kuhn-Tucker conditions are equivalent to the SPEP specification.

Phase 2 of SPEP: the Total Cost Function

In previous versions of the traditional PMP methodology, phase 2 of the estimation process dealt with the recovery of a variable cost function. In this paper, however, we are concerned with the estimation of a total cost function. Notice that total marginal cost is represented by \( (A'y + \lambda + c) \), with the component \( (\lambda + c) \) representing the variable marginal cost while \( A'y \) has the meaning of marginal cost due to limiting inputs. We prefer to avoid the terminology of "fixed" inputs because inputs are rarely fixed. Rather, we refer to the constraining inputs such as land, water and operating capital as limiting inputs.

By definition, total cost is a function of output levels and the input prices. In our case, this total cost function is represented as \( C(x, y) \). The properties of a cost function require it to be concave and linearly homogeneous in input prices. The functional form selected to represent the inputs is a generalized Leontiev specification with nonnegative and symmetric off diagonal terms. For the outputs, the functional form is a quadratic specification in order to avoid the imposition of a linear technology. Furthermore, we must allow sufficient flexibility to fit the available empirical data. For this reason we add an unrestricted intercept term. Finally, we must guarantee that the cost function is homogeneous of degree one in input prices. All these considerations lead to the following functional form:

\[
\begin{align*}
\text{(19) } & \quad C(x, y) = u'y(f'x) + u'y(x'Qx)/2 + y^{1/2} S y^{1/2}.
\end{align*}
\]
where $\mathbf{u}$ is a vector of unit elements. Many different functional forms could be selected. The matrix $\mathbf{Q}$ is symmetric positive definite while the $\mathbf{S}$ matrix is symmetric with nonnegative off-diagonal terms.

The marginal cost function is the derivative of equation (19), that is

$$\frac{\partial C}{\partial \mathbf{x}} = (\mathbf{u}' \mathbf{y} \mathbf{f} + (\mathbf{u}' \mathbf{y}) \mathbf{Q} \mathbf{x}$$

whereas, by Shephard's lemma, the limiting input derived demands are

$$\frac{\partial C}{\partial \mathbf{y}} = (\mathbf{f}' \mathbf{x} \mathbf{u}) + \mathbf{u} \left( \frac{\mathbf{x}' \mathbf{Q} \mathbf{x}}{2} + \Delta \mathbf{y} - \frac{1}{2} \mathbf{S} \mathbf{y} \right) = \mathbf{Ax} = \mathbf{b} - \mathbf{\beta}.$$

The matrix $\Delta \mathbf{y}^{-1/2}$ is diagonal with elements of the vector $\mathbf{y}^{-1/2}$ on the diagonal.

The objective of Phase 2 is to estimate the parameters of the cost function, $\mathbf{f}, \mathbf{Q}$ and $\mathbf{S}$. This estimation will be performed using the maximum entropy formalism. Economic theory requires that the $\mathbf{Q}$ matrix be symmetric positive semidefinite. In order to guarantee this condition during the estimation process, we will use the Cholesky factorization (Benoit)

$$\mathbf{Q} = \mathbf{LDP}'$$

where $\mathbf{L}$ is a unit lower triangular matrix and $\mathbf{D}$ is a diagonal matrix with nonnegative elements. It can be shown that the $\mathbf{Q}$ matrix is positive semidefinite (definite) if and only if the diagonal elements of $\mathbf{D}$ are nonnegative (positive). These diagonal elements are called the Cholesky values (Lau). Following Golan et al., all the parameters to be estimated will be defined as a convex combination of a corresponding set of predetermined support values and where the weights are regarded as probabilities. Hence, it is assumed that for each $(j,j')$ parameter

$$L_{jj'} = \sum_{s} Z_{L}(j,j',s) P_{L}(j,j',s), \quad j,j' = 1,...,J$$

$$D_{jj} = \sum_{s} Z_{D}(j,j,s) P_{D}(j,j,s), \quad s = 1,...,S$$

where $\mathbf{Z}_{L}$ and $\mathbf{Z}_{D}$ are the matrices of the known support values for the probability distribution of the $\mathbf{L}$ and $\mathbf{D}$ matrices, respectively, while $\mathbf{P}_{L}$ and $\mathbf{P}_{D}$ are the corresponding probability matrices. In matrix notation, equations (23) and (24) correspond to $\mathbf{L} = \mathbf{Z}_{L} \mathbf{P}_{L}$ and $\mathbf{D} = \mathbf{Z}_{D} \mathbf{P}_{D}$, respectively, where the multiplication is performed only with respect to the index $s$, $s = 1,...,S$. A similar specification involves the vector $\mathbf{f}$ and the matrix $\mathbf{S}$, that is $\mathbf{f} = \mathbf{Z}_{f} \mathbf{P}_{f}$, and $\mathbf{S} = \mathbf{Z}_{S} \mathbf{P}_{S}$. The curvature conditions for the $\mathbf{S}$ matrix require nonnegative off-diagonal coefficients.

The maximum entropy objective, therefore, can be stated as the problem of finding positive values of all the probabilities, $\mathbf{P}_{L}, \mathbf{P}_{D}, \mathbf{P}_{f}, \mathbf{P}_{S}$, such that

$$\max H(\mathbf{P}_{L}, \mathbf{P}_{D}, \mathbf{P}_{f}, \mathbf{P}_{S}) = \sum_{j,j',s} P_{L}(j,j',s) \log(P_{L}(j,j',s)) - \sum_{j,s} P_{D}(j,j,s) \log(P_{D}(j,j,s))$$

$$- \sum_{j,s} P_{f}(j,s) \log(P_{f}(j,s)) - \sum_{i,i',s} P_{S}(i,i',s) \log(P_{S}(i,i',s))$$

subject to
In the above formulation, the total marginal cost \( A'\hat{y} + \hat{\lambda} + c \), the limiting input demand \( A\hat{x} \), the realized level of activities \( \hat{x} \), and the shadow prices of limiting inputs \( \hat{y} \), are known elements of the specification. The parameters to be estimated are the probabilities, \( P_x, P_d, P_f, P_s \). The solution probabilities of problem (25)-(27) allow the recovery of all the parameters of the total cost function, \( f, Q, \) and \( S \) using their support values.

**Phase 3:** the Calibrating Symmetric Positive Equilibrium Problem

With knowledge of the parameters of the total cost function it is possible to set up a calibrating specification that takes on the structure of an equilibrium problem for the same reasons explained during the discussion of the phase 1 specification. In this case, however, we are interested in reproducing the base year results in terms of output quantities, effective limiting input supplies and their shadow prices without requiring a linear technology. Furthermore, we want variations in output prices to affect both the shadow price and the quantity of the limiting inputs. Because the specification in question conforms to the structure of an equilibrium problem, we utilize the complementary slackness conditions as an auxiliary objective function as is done in the first phase calibration problem (14)-(18). Given these stipulations, the calibrating symmetric positive equilibrium problem of phase 3 has the following specification

\[
\begin{align*}
\text{(28)} & \quad \min \{v_{p1}y + v_{d1}x + v_{d2} \beta \} \\
\text{subject to} & \quad (\hat{f}'x)u + u(x'Qx)/2 + \Delta_{y\rightarrow x} \hat{y}^{1/2} + \beta + v_{p1} = b \\
\text{(29)} & \quad (u'y)\hat{f} + (u'y)\hat{Q}x = p + v_{d1} \\
\text{(30)} & \quad y = r + v_{d2},
\end{align*}
\]

where all the decision variables are nonnegative. The linear technology in equation (15) is now replaced by the Shephard lemma’s equation (21) in constraint (29). Similarly, the marginal cost terms in equation (17) are replaced by the marginal output cost equation (20). In addition, since the calibration of output levels is now guaranteed by the cost function, the calibration constraints in equation (16) are removed. Constraint (29), when rearranged as \( (f'x)u + u(x'Qx)/2 + \Delta_{y\rightarrow x} \hat{y}^{1/2} \leq b - \beta \), states the quantity equilibrium condition according to which the demand for limiting inputs must be less than or equal to the effective supply of those inputs. The quantity \( b - \beta \) is the effective supply by virtue of the endogenous parameter \( \beta \) that is part of the solution. Constraint (30) states the economic equilibrium conditions according to which the total marginal cost of the activities must be greater than or equal to the marginal revenue that, in this case, corresponds to the output market price. The SPEP specification given above neither implies nor excludes an optimizing behavior. Hence, it removes from the original PMP methodology the last vestige of a normative behavior. Furthermore, the nonlinear cost function implies a nonlinear technology and, therefore, it removes the restriction of a fixed production coefficient matrix.
Table 1. Base year information

<table>
<thead>
<tr>
<th>Activities</th>
<th>$\bar{h}$, land</th>
<th>$\bar{w}$, water</th>
<th>$\bar{o}$, capital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>242.0000</td>
<td>738.1000</td>
<td>997.0400</td>
</tr>
<tr>
<td>Fodder crops</td>
<td>13.1800</td>
<td>52.7200</td>
<td>18.9792</td>
</tr>
<tr>
<td>Field crops</td>
<td>112.9900</td>
<td>282.4750</td>
<td>126.5488</td>
</tr>
<tr>
<td>Grains</td>
<td>34.4100</td>
<td>44.7330</td>
<td>9.2907</td>
</tr>
<tr>
<td>Fruits</td>
<td>21.3500</td>
<td>68.3200</td>
<td>117.4250</td>
</tr>
<tr>
<td>Vegetables</td>
<td>82.1700</td>
<td>180.7740</td>
<td>1388.6730</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Activities</th>
<th>$c$, variable unit cost</th>
<th>$p$, output price</th>
<th>$x$, output level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>256.3457031</td>
<td>418.6000</td>
<td>619.5200</td>
</tr>
<tr>
<td>Fodder crops</td>
<td>50.9890110</td>
<td>95.6000</td>
<td>107.9442</td>
</tr>
<tr>
<td>Field crops</td>
<td>77.1022727</td>
<td>108.4000</td>
<td>497.1560</td>
</tr>
<tr>
<td>Grains</td>
<td>72.6321070</td>
<td>138.5000</td>
<td>102.8859</td>
</tr>
<tr>
<td>Fruits</td>
<td>102.4205000</td>
<td>235.1000</td>
<td>166.5300</td>
</tr>
<tr>
<td>Vegetables</td>
<td>182.5818182</td>
<td>264.8000</td>
<td>858.6765</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Activities</th>
<th>land</th>
<th>water</th>
<th>capital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total inputs, $b$</td>
<td>506.1000</td>
<td>1367.1220</td>
<td>2658.0000</td>
</tr>
<tr>
<td>Input prices, $r$</td>
<td>60.0000</td>
<td>3.0000</td>
<td>30.0000</td>
</tr>
</tbody>
</table>

Elasticities

The specification of the above cost function allows the derivation of a series of important elasticity measures such as the matrices of demand elasticities of limiting inputs, the supply elasticities of output crops, Allen and Morishima's partial elasticities of substitution. The output supply function can be derived by inverting the Q matrix in the marginal cost function after it has been set equal to the output price. The various elasticity formulas can be found in any good textbook of production economics.

Application to an Agricultural Region of California

The application involves an agricultural region of California that produces six crop activities using three limiting inputs. The crops are: cotton, fodder crops, field crops, grains, fruit crops, and vegetable crops. The limiting inputs are: land, irrigation water, and operating capital. The year selected as a base period is 1989. The information on the required components of the problem, $\bar{h}, \bar{w}, \bar{o}, c, p, b, r$, is given in table 1. In order to insure a better convergence of the computational algorithm, all the elements of table 1 were divided by 100. Scaling is extremely important when using numerical algorithms such as GAMS. The recommendation is to scale the data series around unity as much as possible avoiding large differences within the same data series.

The estimates in tables 2 and 3 below were obtained by specifying two sets of support intervals: One set for the coefficients expected to be nonnegative (the D matrix in the Cholesky factorization and the off diagonal elements of the S matrix) and one for those coefficients that are unrestricted. Three support values were selected. The nonnegative supports were (0,1.5,2.5). The unrestricted supports were (-4.5,0,4.5). A sensitivity analysis was performed by enlarging the support intervals by hundred percent: (0, 2.5, 5) and (-8.5,0,8.5). The impact of this increase was to expand the principal parameters (on the main diagonal of the Q and S matrices) by roughly 80 percent.
Table 2. Estimates of the Q matrix and supply elasticities

<table>
<thead>
<tr>
<th>Q matrix</th>
<th>cotton</th>
<th>fodder crops</th>
<th>field crops</th>
<th>grains</th>
<th>fruits</th>
<th>vegetables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>0.8792</td>
<td>-0.0267</td>
<td>0.0552</td>
<td>-0.0382</td>
<td>-0.0569</td>
<td>0.0266</td>
</tr>
<tr>
<td>Fodder crops</td>
<td>-0.0267</td>
<td>1.2852</td>
<td>0.0167</td>
<td>-0.0215</td>
<td>-0.0331</td>
<td>0.0021</td>
</tr>
<tr>
<td>Field crop</td>
<td>0.0552</td>
<td>0.0167</td>
<td>0.3370</td>
<td>0.0293</td>
<td>0.0459</td>
<td>0.0321</td>
</tr>
<tr>
<td>Grains</td>
<td>-0.0382</td>
<td>-0.0215</td>
<td>0.0293</td>
<td>1.7950</td>
<td>-0.0644</td>
<td>0.0000</td>
</tr>
<tr>
<td>Fruits</td>
<td>-0.0569</td>
<td>-0.0331</td>
<td>0.0459</td>
<td>-0.0644</td>
<td>1.7672</td>
<td>0.0013</td>
</tr>
<tr>
<td>Vegetables</td>
<td>0.0266</td>
<td>0.0021</td>
<td>0.0321</td>
<td>0.0000</td>
<td>0.0013</td>
<td>0.5343</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>supply ela.</th>
<th>cotton</th>
<th>fodder crops</th>
<th>field crops</th>
<th>grains</th>
<th>fruits</th>
<th>vegetables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>0.7213</td>
<td>0.0040</td>
<td>-0.0315</td>
<td>0.0061</td>
<td>0.0154</td>
<td>-0.0182</td>
</tr>
<tr>
<td>Fodder crops</td>
<td>0.1011</td>
<td>0.6378</td>
<td>-0.0430</td>
<td>0.0134</td>
<td>0.0345</td>
<td>-0.0041</td>
</tr>
<tr>
<td>Field crop</td>
<td>-0.1516</td>
<td>-0.0082</td>
<td>0.6110</td>
<td>-0.0148</td>
<td>-0.0384</td>
<td>-0.0846</td>
</tr>
<tr>
<td>Grains</td>
<td>0.1116</td>
<td>0.0097</td>
<td>-0.0558</td>
<td>0.6956</td>
<td>0.0486</td>
<td>0.0046</td>
</tr>
<tr>
<td>Fruits</td>
<td>0.1020</td>
<td>0.0091</td>
<td>-0.0529</td>
<td>0.0177</td>
<td>0.7440</td>
<td>0.0024</td>
</tr>
<tr>
<td>Vegetables</td>
<td>-0.0208</td>
<td>-0.0002</td>
<td>-0.0201</td>
<td>0.0003</td>
<td>0.0004</td>
<td>0.5366</td>
</tr>
</tbody>
</table>

It is well known that, under the entropy framework suggested by Golan et al., the parameter estimates are sensitive to the width of the support interval, especially in an ill-posed problem. Since both sets of estimates of the cost function calibrate the base period decisions with any desired precision, it seems more interesting to measure the sensitivity of the predictions with respect to the variations of the support intervals.

Table 3. The S matrix, demand, Allen and Morishima elasticities of substitution

<table>
<thead>
<tr>
<th>S matrix</th>
<th>land</th>
<th>water</th>
<th>capital</th>
</tr>
</thead>
<tbody>
<tr>
<td>land</td>
<td>-8.1097</td>
<td>4.6819</td>
<td>5.2890</td>
</tr>
<tr>
<td>water</td>
<td>4.6819</td>
<td>-16.2768</td>
<td>10.7159</td>
</tr>
<tr>
<td>capital</td>
<td>5.2890</td>
<td>10.7159</td>
<td>3.9377</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>demand elast.</th>
<th>land</th>
<th>water</th>
<th>capital</th>
</tr>
</thead>
<tbody>
<tr>
<td>land</td>
<td>-0.6117</td>
<td>0.2455</td>
<td>0.3662</td>
</tr>
<tr>
<td>water</td>
<td>0.3226</td>
<td>-0.8401</td>
<td>0.5174</td>
</tr>
<tr>
<td>capital</td>
<td>0.1420</td>
<td>0.1527</td>
<td>-0.2946</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Allen elastic.</th>
<th>land</th>
<th>water</th>
<th>capital</th>
</tr>
</thead>
<tbody>
<tr>
<td>land</td>
<td>-2.6549</td>
<td>1.4002</td>
<td>0.6162</td>
</tr>
<tr>
<td>water</td>
<td>1.4002</td>
<td>-4.7910</td>
<td>0.8707</td>
</tr>
<tr>
<td>capital</td>
<td>0.6162</td>
<td>0.8707</td>
<td>-0.4958</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Morishima elas</th>
<th>land</th>
<th>water</th>
<th>capital</th>
</tr>
</thead>
<tbody>
<tr>
<td>land</td>
<td>1.0856</td>
<td>0.6608</td>
<td></td>
</tr>
<tr>
<td>water</td>
<td>0.9343</td>
<td>0.8121</td>
<td></td>
</tr>
<tr>
<td>capital</td>
<td>0.7537</td>
<td>0.9927</td>
<td></td>
</tr>
</tbody>
</table>

We performed a parametric variation of the prices of cotton and grains choosing to reduce them by 20 percent together with a reduction of 10 percent of the land price. The equilibrium problem (28)-(31) was resolved using the two sets of support intervals described.
above. The results are reported in table 4. Notice that a change in prices induces a change in the quantities of limiting inputs mediated precisely by the novel variable $\beta$. This result is a principal feature of the SPEP methodology that allows for a better evaluation of agricultural and environmental policies that was not admissible under the original PMP methodology.

Furthermore, the difference between the two sets of predictions is contained within a maximum error of 7.7 percent. Hence, an enlargement of the support interval by 100 percent induces, in this specific case, a discrepancy no larger than 7.7 percent. This difference is much smaller than the corresponding variation in the parameter estimates evaluated at an average of 80 percent.

Table 4. Prediction results under two sets of support intervals for a 20\% reduction of the price of cotton and grains and a 10\% reduction of the land market price

<table>
<thead>
<tr>
<th>Output levels</th>
<th>base period</th>
<th>support set 1</th>
<th>support set 2</th>
<th>% difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>6.1953</td>
<td>5.5963</td>
<td>5.9029</td>
<td>5.194</td>
</tr>
<tr>
<td>Fodder crops</td>
<td>1.0795</td>
<td>1.1232</td>
<td>1.1049</td>
<td>1.629</td>
</tr>
<tr>
<td>Field crops</td>
<td>4.9716</td>
<td>5.2895</td>
<td>5.1307</td>
<td>3.000</td>
</tr>
<tr>
<td>Grains</td>
<td>1.0289</td>
<td>0.9222</td>
<td>0.9722</td>
<td>5.143</td>
</tr>
<tr>
<td>Fruits</td>
<td>1.6653</td>
<td>1.7431</td>
<td>1.7194</td>
<td>1.360</td>
</tr>
<tr>
<td>Vegetables</td>
<td>8.5868</td>
<td>9.0022</td>
<td>8.6663</td>
<td>3.731</td>
</tr>
<tr>
<td>Input shadow prices</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>0.6109</td>
<td>0.5400</td>
<td>0.5400</td>
<td>0.000</td>
</tr>
<tr>
<td>Water</td>
<td>0.1721</td>
<td>0.1549</td>
<td>0.1595</td>
<td>2.884</td>
</tr>
<tr>
<td>Capital</td>
<td>0.3000</td>
<td>0.3000</td>
<td>0.3000</td>
<td>0.000</td>
</tr>
<tr>
<td>Effective input supply</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>5.0610</td>
<td>4.6357</td>
<td>5.0230</td>
<td>7.710</td>
</tr>
<tr>
<td>Water</td>
<td>13.6712</td>
<td>13.6712</td>
<td>13.6712</td>
<td>0.000</td>
</tr>
<tr>
<td>Capital</td>
<td>26.5800</td>
<td>25.0394</td>
<td>24.5434</td>
<td>1.981</td>
</tr>
</tbody>
</table>

A SPEP Representation of the European Agricultural Policy

The Agricultural policy of the European Union has been formulated by a complex set of instruments. We wish to give a stylized illustration of a SPEP specification that articulates many aspects of that policy. We assume that the principal instruments are:

1. direct crop subsidies per hectare, $s_h$,
2. set-aside subsidies per hectare, $s_{sa}$,
3. market price supports per unit of output, $mps$,
4. output price supports per unit of output, $ops$.

Let $h \equiv$ vector of crop hectarage, $x_{sa} \equiv$ vector of set-aside hectarage, $p_w \equiv$ vector of world prices, and $u \equiv$ vector of unit elements. The set-aside area cannot be larger than 5 percent of any given crop hectarage. With these stipulations, the corresponding phase 1 of the SPEP specification can be stated as follows:
The Multi-Output and Multi-Input Symmetric Positive Equilibrium Problem

Primal constraints

land input \[ A_L'x_u + u'y_{sa} + \beta_L \leq b_L \]
non-land inputs \[ A_{NL}'x + \beta_{NL} \leq b_{NL} \]
crop hectarage \[ -\Delta_{A_L}x + h = 0 \]
realized output \[ x \leq x \]
set-aside output \[ x_{sa} \leq .05h \]

Dual variables

\[ y_L \]
\[ y_{NL} \]
\[ \eta \]
\[ \lambda \]
\[ \rho \]

Dual Constraints

primal variables

\[ x \]
\[ x_{sa} \]
\[ h \]
\[ \beta_L \]
\[ \beta_{NL} \]

The first dual constraint is interpreted as the marginal cost of the crop activities that must be greater-than-or-equal to the marginal revenue of those activities. The second dual constraint states that the marginal cost of set-aside hectarage must be greater-than-or-equal to the marginal subsidy. The third dual constraints states that the marginal cost of the crop acreage must be greater-than-or-equal to the direct crop subsidy plus 5 percent of the shadow price on the set-aside constraint. The fourth and fifth constraints state that the marginal cost of the limiting inputs must be greater than or equal to their market price.

The solution of the above SPEP specification can be obtained by inserting slack variables and minimizing the sum of the corresponding complementary slackness conditions. The Phase 2 of this SPEP policy model proceeds with the estimation of the cost function as described above. The phase 3 takes on the following structure:

\[ (f'x)u + u(x'\hat{Q}x) / 2 + \Delta_{Y_{sa}}\hat{y}^{1/2} + \beta + Ux_{sa} \leq b \]
\[ (u'y)'\hat{f} + (u'y)\hat{Q}x \geq p + \Delta_{A_L}\eta \]
\[ -\Delta_{A_L}x + h = 0 \]
\[ x_{sa} \leq .05h \]
\[ \rho + uy_L \geq s_{sa} \]
\[ \eta \geq s_h + .05\rho \]
\[ y \geq r \]

The domestic farm price vector \( p \) is related to the world price vector by the additional relation:

\[ p \geq p_w(1 + mps + ops) \]

In this way all the policy instruments can be adequately modeled into the SPEP specification. It is interesting to note that this SPEP formulation can verify whether the levels of the various policy instruments are consistent with each other and with the structure of the agricultural sector. In fact, if the set-aside subsidies or the direct crop payments are set too high the SPEP model may become infeasible signifying that that the level of subsidies is economically inconsistent. The solution of the phase 3 SPEP model proceeds as explained in previous sections.
Conclusion

Agricultural production on a regional or farm scale is characterized by both rotational interdependency between crops and limiting input substitution within given crop and livestock production processes. A flexible representation of the whole range of substitution and interdependency effects requires a flexible multi-output, multi-input cost function that is able to capture the limiting input substitution and the rotational effects on crop output. The specification of the regional production problem via the SPEP model presented above enables the modeler to capture the full range of cost and substitution elasticities, usually restricted to dual econometric models. This ability to model the substitution effects within agricultural production and limiting input use is increasingly important as agricultural policy in Europe and the US become dominated by environmental concerns rather than by the definition of direct price supports.

The SPEP model presented in this paper can be extended to include the relevant policy instruments normally used to express the agricultural policy in western countries. The SPEP specification is flexible enough to allow the articulation of direct subsidies at the production level as well as price and output subsidies at the market level.

References


Appendix A: An Alternative, Fictitious LP Problem to Solve the SPEP

The structure of the Symmetric Positive Equilibrium Problem arose from the desire to take into account the available market information regarding the price of limiting inputs, \( r \). This vector is related to the vector of dual variables, \( y \) which is interpreted as the effective cost of limiting inputs. The components of the vector \( y \) may often be greater than those of the vector \( r \). The correct "profit" level of the given economic agent whose behavior is represented by the SPEP model is stated as \( (p'x - y'b) \). However, in order to guarantee the generation of the
Karush-Kuhn-Tucker (KKK) conditions corresponding to the SPEP specification, one alternative is to state the following LP problem:

\[(A1) \quad \max \{p'x - r'(b - \beta)\}\]

subject to
dual variables
\[(A2) \quad Ax + \beta \leq b, \quad y\]
\[(A3) \quad x \leq \bar{x}, \quad \lambda.\]

Notice that the objective function states that the limiting inputs will be paid only in the amount of their effective utilization and using the market price \(r\) instead of \(y\). It is unlikely that a supplier of, say, land would agree to be paid only for the amount of land effectively used by the entrepreneur. The above specification, however, produces the desired KKK conditions as the following development shows. Let the Lagrangean function corresponding to problem (A1)-(A3) be

\[(A4) \quad L = p'x - r'(b - \beta) + y'(b - Ax - \beta) + \lambda'(\bar{x} - x).\]

Then, the KKK conditions are:

\[(A5) \quad \frac{\partial L}{\partial x} = p - A'y - \lambda \leq 0\]
\[(A6) \quad \frac{\partial L}{\partial \beta} = r - y \leq 0\]
\[(A7) \quad \frac{\partial L}{\partial y} = b - Ax - \beta \geq 0\]
\[(A8) \quad \frac{\partial L}{\partial \lambda} = \bar{x} - x \geq 0.\]

Relations (A5)-(A8), together with the corresponding complementary slackness conditions are precisely the relations of the SPEP specification. There are other alternative and equally fictitious specifications that can reproduce the SPEP relations.

**Appendix B: SPEP with Many Observations**

The SPEP approach can easily be adapted to handle many observations whether in spatial or time series samples. Let us assume that the information about a sample of \(N\) farms is available for analysis. The type of information is similar to the data presented for the single economic agent as explained in previous sections. In order to simplify the presentation, we assume away any self-selection problem arising when some farms do not produce all the crops in the sample. For a solution of this problem see Paris (1999). Under these circumstances, phase 1 of SPEP consists in solving \(N+1\) equilibrium problems of the type presented in equations (14)-(18). The number of \(N+1\) problems arise from the \(N\) farms plus an aggregate equilibrium problem for the sample as a whole. The information about marginal costs derived for all the \(N\)
farms and the sample will be utilized simultaneously in phase 2 of SPEP in order to estimate a
total cost function as follows:

\[
\text{(B1)} \quad \max H(P_L, P_D, P_f, P_s) = - \sum_{j,j',s} P_L(j,j',s) \log(P_L(j,j',s)) - \sum_{j,s} P_D(j,j,s) \log(P_D(j,j,s)) \\
- \sum_{j,s} P_f(j,s) \log(P_f(j,s)) - \sum_{i,i',s} P_s(i,i',s) \log(P_s(i,i',s)) \\
- \sum_{n,j,s} P_{fn}(j,s) \log(P_{fn}(j,s))
\]

subject to

sample aggregate marginal cost and input demand

\[
\text{(B2)} \quad A\hat{\gamma} + \lambda + c = (u'\hat{\gamma})f + (u'\hat{\gamma})Q\bar{x} \\
\text{(B3)} \quad A\bar{x} = (f'\bar{x})u + u(\bar{x}Q\bar{x}) / 2 + \Delta_{\gamma}^{\frac{1}{2}}S\hat{\gamma}^{\frac{1}{2}}
\]

\(n\)-th farm marginal cost and input demand

\[
\text{(B4)} \quad A_n\hat{\gamma}_n + \lambda_n + c_n = (u'\hat{\gamma}_n)f_n + (u'\hat{\gamma}_n)Q\bar{x}_n \quad n = 1, \ldots, N \\
\text{(B5)} \quad A_n\bar{x}_n = (f_n'\bar{x}_n)u + u(\bar{x}_nQ\bar{x}_n) / 2 + \Delta_{\gamma}^{\frac{1}{2}}S\hat{\gamma}_n^{\frac{1}{2}} \quad n = 1, \ldots, N
\]

where the matrices \(Q, S, f, f_n\) should be replaced by their GME representation such as
\(Q = LDL' = (Z_LP_L)(Z_LP_L)'\), \(S = Z_SP_S\), \(f = Z_LP_f\), and \(f_n = Z_LP_{fn}\). The above
specification defines a total cost function for all the \(N\) farms and the sample. Each farm has
common \(Q\) and \(S\) matrices. The individual farm’s cost function is identified by a different
intercept \(f_n\).

The calibrating and policy analysis phase 3 of SPEP is similar to that one described in
the text of this paper. The researcher has the option to calibrate every farm and the sample and
to conduct policy analyses either on the sample aggregate or on every farm, or both.
An Integrated Multi-phase Model for Evaluating Agricultural Policies Through Positive Information

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Abstract
The aim of this paper is to propose a theoretical model for analysing in dynamic terms the territorial impact of agricultural and environmental policy measures. This model should also allow to evaluate the adjustment capacities of the farms as a function of the characteristics and opportunities of each territory, through a “multi-phase” approach. In the first step, a multivariate statistical analysis (MSA) leads to the identification of homogeneous clusters of territorial units. The territorial mapping is conditional to a predetermined set of indicators, that covers different aspects of agricultural development. In a second step, Positive Mathematical Programming (PMP) allows to introduce the impact of agricultural policies (compensatory payments, price changes etc.) returning different scenarios of land use and agricultural profitability. According to the outputs of the PMP, the third step consists in a new MSA for detecting any change in the territorial mapping.

Keywords: Principal Components, Positive Mathematical Programming, Integrated Policy Analysis

1 Introduction
The recent CAP development highlighted some issues that should be considered when modelling with the objective of simulating the impact of agricultural policy measures. As a matter of fact, the agricultural sector is less and less isolated from the rest of the economic systems in the different member countries. Indeed, it is increasingly integrated with them for different aspects. Under an economic point of view, it is at the core of the agri-food chain; under the environmental perspective, it is the key sector for the environmental measures; under a social perspective, the rural families are more and more sensible to the social and economical dynamics of the territory, due to more flexible organisational systems. In other words, the pluri-functionality of agriculture and the adjustment capacity of the rural family are now considered as key issues for the rural development policies. Under this perspective, the agricultural policies are not limited to the interaction with agriculture, but also concern the environment and – more broadly – all those production activities that allow the development of rural areas, especially the less favoured ones.

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The authors share the responsibility for the contents of this paper. However section 1 and 6 where jointly written by all the authors, section 2 by Mario Mazzocchi, section 2.1 and 5 by Elisa Montresor, section 3 by Quirino Paris and Filippo Arfini, section 4 by Filippo Arfini and section 4.1 by Filippo Arfini and Mario Mazzocchi.
Hence, the policy maker is required to define policies whose effect is rarely limited to the concerned sector, but goes beyond by interesting other related sectors, in economic, environmental and social terms. As the characteristics of the social and economic systems in Europe are different in each country and also vary from Region to Region, the same policy instruments can lead to extremely different results. Consequently, in order to define better the agricultural policy tools, the policy-makers need to preliminarily know the effects that the new measures can induce on the territory, considered as a set of production activities, not limited to the agricultural ones.

The aim of this paper is to propose a theoretical model for analysing in dynamic terms the territorial impact of the adopted agricultural and environmental policy measures and evaluating the adjustment capacities of the farms as a function of the characteristics and opportunities of each territory through a “multi-phase” approach.

The proposed theoretical model is based on the assumption that farmers and families are able to find in their own environment some form of adjustment to the impulses generated by the different EU policies. Then, the achieved equilibrium represents the starting point to articulate new strategies. For this reason, the model aims to combine two approaches that are different under a theoretical and methodological perspective, but they are both able to employ the largest amount of “positive” information. These information should reflect the structure, the behaviour and the production strategies of the rural families in their economic environment.

From a methodological perspective, the aim is to overcome some of the limits of the analyses that carried out exclusively with macro-economic or micro-economic tools. In facts, by construction, these do not consider respectively (1) the socio-economic issues characterising the territory and (2) the variables at farm level that determine the farmer’s choices.

The combination of the two proposed methodologies inside a single decision model leads to a “micro-macro” model and allows to evaluate the policy action under a dynamic point of view. The objective is to evaluate whether the changes in agricultural income and land allocation are able to modify the output of the cluster analysis, with respect to the initial mapping. This last indication will supply a measure of the likely success and/or failure of the new policy measures, keeping into account not only the agricultural sector, but all the economic and social components existing on the territory.

Hence, this contribution is structured in two part: in the first one (section 2 and 3) the employed methodologies and their characteristics will be summarised, the second (section 4) will explain how these two different methodologies are employed together in order to set-up a new dynamic model. An application to the Northern Italy agricultural systems is proposed in section 5, whereas some conclusion are drawn in section 6.

2 The multivariate statistical approach for territorial analysis (MSA)

The first methodology proposed is a mixture of Principal Components Analysis (PCA) and Cluster Analysis (CA) to be applied on territorial data. The aim is to detect areas with homogeneous characteristics with respect to the production activities, to the adjustment patterns to the policies adopted through time and to other specific features (such as economic, social and demographic variables) of each territorial unit. The output of this first step is a mapping of the territory, tracking the areas that show homogeneous characteristics with respect to a pre-defined set of indicators. Such a methodological approach has appeared in economic literature since the early 1970s [Davies, 1972] and has been frequently employed.
for the Italian agriculture [see for example Anania and Tarsitano, 1995; Boccafogli and Brasili, 1998; Cannata and Forleo, 1998; Mazzocchi and Montresor, 1999 and references therein].

As widely known, the PCA technique allows to summarise the variability of the original data matrix into a reduced number of non correlated components. A good recent formalisation of this classical multivariate methodology is given by Krzanowsky (1988). Starting from a wide set of indicators which is assumed to be complete to describe the territorial agricultural system, the PCA allows to synthesise this set into a reduced number of components, sufficient to describe the local systems. These components are then employed in the CA to identify the agricultural systems on the territory, getting to the agricultural mapping itself. The PCA may be simply a preliminary tool to the actual mapping through the cluster analysis, but it can also become itself an useful explicative tool for the territorial analysis and for a hierarchical evaluation of the relevance of the single original indicators [Mazzocchi, 1999].

Once the principal components have been detected, one can proceed to the actual aggregation of the territorial units through the cluster analysis. However, also in the CA there are a number of different approaches, that may lead to extremely different results [see Aldenderfer and Blashfield (1984)]. Hence it is important to preliminarily identify the methodology more suitable to the research objectives. An essential problem, that has not yet been solved in an univocal way, is the one related to the identification of the optimal number of clusters. The aggregation method can not ignore the principle of informativeness with respect to the original objectives of the analysis: any technique considered statistically correct should always be confirmed by a satisfying results in terms of economic interpretation. Summarising the above considerations, the identified approach is the following:

1. The locally optimal number of clusters is identified through the hierarchical clustering method of the average linkage, according to the values of the pseudo-F statistic and Cubic Clustering Criterion.

2. Given the number of clusters, the actual clustering was based on the non hierarchical aggregative method of the k-means.

2.1 The indicators of agricultural and rural development

The analysis can be carried out at different territorial levels (municipalities, provinces and/or regions) in order to detect the homogeneous areas, conditional to the level of territorial disaggregation. Here one important problem, from the methodological point of view, is also to identify the indicators more relevant to explaining the territorial differences.

In other words, the proposed technique does not solve the problem of defining rural and agricultural development, but just allows to deal with large amounts of information. The pursued objective is to subdivide the territory into homogeneous systems. Hence it is necessary utilise a wide range of indicators than can reflect shades and situations. The indicators described by Mazzocchi and Montresor (1999) constitute a suitable analytical basis, as they are capable of “measuring” (1) the level of agricultural development as well as other development characteristics; (2) the main demographic and social trends; (3) agricultural concentration and specialisation and finally (4) a tentative measurement of the degree of integration between farming and the food industry. The specialisation levels (in terms of land use) constitute the starting point to simulate the evolutionary dynamics at work, in relation to regional and national supply. They will also allow to assess the impact of extensification measures and measures concerning farming, environment, as well as land use itself. The list of the indicators employed for mapping the territory at Nuts3 level is reported in table 1.
### Table 1: Variables for the territorial multivariate analysis

<table>
<thead>
<tr>
<th>Group</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main social and demographic indicators and territorial morphology</td>
<td>% change in population 1981-91; female activity ratio, dependency ratio, ageing index, population density, % hilly areas, % mountain areas.</td>
</tr>
<tr>
<td>Economic structure</td>
<td>Employees per km²: agriculture, industry, services; ratio of industry employees; ratio of services employees; per capita GDP; unemployment ratio.</td>
</tr>
<tr>
<td>Agricultural structure</td>
<td>Avg. UAA per farm; % UAA of farms under 2 ha; % UAA of farms above 50 ha; tractors per 100 ha UAA; AWU per 100 ha UAA; % UAA on total agricultural surface; % change in number of farms; % change in UAA.</td>
</tr>
<tr>
<td>Agricultural activities and land use</td>
<td>Soft wheat; durum wheat; barley; maize; rice; dried leguminous vegetables; potatoes; beet; sunflower; soya beans; horticulture; grapes; oilseeds; apples; pears; peaches; kiwi; chestnuts; feeding crops; meat; milk; woods; pastures.</td>
</tr>
<tr>
<td>Crops as UAA %</td>
<td>Standard gross margin per ha of UAA; marginal price of land; gross saleable production per ha (vegetables), GSP per ha (animal production); variable costs for saleable production per ha; variable costs for re-used production per ha; variable costs for animal production per ha.</td>
</tr>
<tr>
<td>Animal production: heads/UAA</td>
<td>% food firms on total manufacturing firms; employees per food firm; employees in the food sector per km².</td>
</tr>
</tbody>
</table>

### 3 PMP and FADN data for Policy analysis

As previously stated, agricultural activities appear more and more integrated with the rest of the economy, or better, with the rest of society; also, agriculture and the action of the individual farmers are increasingly conditioned by the choices made by the public decision-makers, both at EU level and at national/regional level, with respect to the procedures of implementation of the various EU policies.

In such a scenario the instruments which can be employed to evaluate the future effects of new policies are multifold (both at a macro and micro level), but when the object of the analysis is the farmer behaviour according to a micro-economic approach, the methodologies can be restricted to the fields of econometric and mathematical programming models. The limits and the capacities of the two approaches are well known. Recently, thanks to the works of Howitt and Paris (1998), mathematical programming tried to assume many of the typical features of the policy analysis models, even when the quantity of available information is limited with respect to the parameters to be estimated. Such a methodology is the Positive Mathematical Programming (PMP), well fitted for the micro-economic data of the European FADN.

The theoretical and methodological issues that are at the core of the PMP, widely discussed in the works of the Howitt and Paris, are widely employed by European researchers. These contributed themselves to deepen the current debate on this methodology, both at theoretical (Heckelei 1997, Heckelei, Britz 1999) and empirical level, as shown by the outputs of the EU projects Capri and Eurotools².

This paper tries to underline how the PMP can be also adapted to face the problems of the animal farms, where the marketed crop processes (Jv) are considered together with the feeding crops processes re-used for breeding (Jr) and animal processes such as meat and milk production (Jz). Starting from the information available in the Italian FADN, the PMP model in the so-called “first phase”, corresponding to the LP model, is structured as follows:

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² See project web pages for more details and working papers: http://eurotools.stat.unibo.it (Eurotools) and http://www.agp.uni-bonn.de/agpo/rsrch/capri/caprin1.htm (Capri)
An Integrated Multi-phase Model for Evaluating Agricultural Policies Through Positive Information

(1) \[ \sum_{v} A_{v} x_{v} + \sum_{r} A_{r} x_{r} \leq b \]

(2) \[ \sum_{z} A_{z} x_{z} - x_{r} \leq 0 \]

(3) \[ x_{v} \leq x_{Rv} \]

(4) \[ x_{r} \leq x_{Rr} \]

(5) \[ x_{z} \leq x_{Rz} \]

(6) \[ \sum_{v} A_{v} x_{v} - x_{Hv} = 0 \]

(7) \[ \sum_{r} A_{r} x_{r} - x_{Hr} = 0 \]

(8) \[ \sum_{z} DA_{z} x_{z} = 0 \]

Max Obj = \[ \sum_{v} \left( x_{v} * p_{v} \right) - \sum_{r} \left( x_{r} * c_{r} \right) + \sum_{z} \left( x_{z} * p_{z} - c_{z} \right) - \sum_{r} \left( x_{r} * c_{r} \right) + \sum_{v} \left( x_{Hv} * s_{v} \right) + \sum_{z} \left( x_{Na} * s_{z} \right) + \sum_{r} \left( x_{Hr} * s_{r} \right) + \sum_{v} \left( x_{Hv} * .05 * s_{av} \right) + \sum_{r} \left( x_{Hr} * .05 * s_{ar} \right) \]

where the notation is the following:

- \( x_{v,r,z} \) are the unknown quantities for each process;
- \( x_{Hv,v} \) are the unknown surfaces for marketed processes and re-used feeding crops;
- \( x_{Na} \) is the unknown number of animal heads for breeding typology, expressed in ABU;
- \( x_{Rv,v} \) are the outputs for each process;
- \( p_{v,z} \) is the prices’ vector;
- \( c_{v,r,z} \) is the costs’ vector;
- \( s_{v,r,z} \) is the vector of the compensatory payments according to Reg. 1765/92;
- \( s_{av,v} \) is the vector of the compensatory payments for Set-aside;
- \( A_{v,r} \) are the matrices of the technical coefficient for the marketed and re-used crop (Hv/xRv and Hr/xRr);
- \( A_{z} \) are the matrix of the technical coefficient for feeding crops consumption (xRr / xRz);
- \( DA_{z} \) is the matrix of the technical coefficient for the animal production (ABU / xRz);

Of course, the model proposed in the so-called “third phase” of the PMP model does not contain the positivity constraints \( x_{v,r,z} \leq x_{Rv,v} \) given by the equation (3), (4), (5).

The model has the same methodological structure described by Howitt and Paris (1998) and the Maximum Entropy formulation is employed in order to get to the estimation of the Total Variable Cost matrix “\( Q_{R} \)” (three in this model, one for each process typology: marketed, reused, animal production), allowing first the model calibration and then the agricultural policy analysis.

For the purposes of this paper, the FADN data concerning costs, yields and sale prices were added to the structural data taken from the 1990 Italian agricultural census. For each of the 41 provinces of Northern Italy, a model was generated keeping into account of the existing processes in terms of surface and animal heads as reported by the census. More specifically, in order to consider the actual structural and productive characteristics, in each province, 4 farm typologies for each altimetric class were detected.

4 An integrated model for policy analysis

Given the specificity of the two methods, a possible integration between them is suggested. The objective of a link between them is twofold, and tries to answers two questions addressed by the policy makers in developing agricultural policies based on a decoupling logic. The potential output is a tool for identifying homogeneous areas where different compensation levels should be applied, which could overcome the logic simply based on administrative subdivision (Regions and Provinces) and propose some horizontal qualitative and quantitative criteria. Moreover this model could constitute a tool for policy evaluation: are compensations sufficient to reach the objective of the policy makers? Or better, what will be the
consequences on the income of the farmer’s family, on the supply structure and on the economic-social organisation of the rural areas as a whole?

To answer these questions one should start from the consideration that each area (Region) has economic, productive and structural characteristics that are connected directly with the capability of the local farmers to adapt to varying market situations, to current policies and, more generally, to the characteristics of the environment in which they operate. Therefore, it is necessary - or essential - to resort to a “positive” model rather than to a “normative” model, capable of reproducing the situations observed in a realistic way and then simulate the impacts that can be produced by the same agricultural policy measures on Regions that differ considerably in their characteristics.

The integration of the multivariate statistical approach (MSA) with the PMP could give some answer to these problems, as both methods are based on the use of positive information and reflect the behaviour of the farmers. More precisely, the MSA generally uses information at territorial level of macroeconomic, social and demographic type, whilst the PMP is based on information on the production strategy of individual farms within the same territory, hence at micro-economic level.

Whilst the MSA is a ‘static’ instrument – its main objective being the identification of homogeneous areas for a given reference in time – the PMP can be considered as a ‘dynamic’ instrument, since its main objective is to develop agricultural policy analyses. On the other hand, a limit of the PMP is that it focuses its analysis at farm level and does not identify homogeneous areas beforehand. It is the researcher that applies this method to areas regarded as homogeneous, however without the support of objective analysis. Besides, when the PMP models are calibrated, the results obtained by the policy analysis evaluation (elasticity of supply, processes, costs and incomes) are unlikely to be useful for wider-spectrum considerations to allow for observing the “secondary” effects induced by the changes occurred in the farms life.

A new multi-phase model can be worked out in these terms to combine the “positive” components of the two approaches described before. In practice, the model proposed is organised in three phases:

**Table 2: Phases of the MSA-PMP integrated model**

<table>
<thead>
<tr>
<th>Phases</th>
<th>Inputs</th>
<th>Approach</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1</td>
<td>Use of micro-economic (FADN), macro-economic, social and demographic indicators.</td>
<td>PMP and MSA</td>
<td>Model Calibration and identification of homogeneous areas and corresponding clusters</td>
</tr>
<tr>
<td>Phase 2</td>
<td>Policy Analysis</td>
<td>PMP</td>
<td>Agricultural Policy Analyses and Indexes of Elasticity</td>
</tr>
<tr>
<td>Phase 3</td>
<td>Updating macro-economic indicators using the indexes of elasticity</td>
<td>MSA</td>
<td>New re-organisation of homogeneous areas corresponding to the new clusters</td>
</tr>
</tbody>
</table>

**4.1 The connection between MSA and PMP**

The preceding part of the work indicated clearly that both approaches use “positive”-type information. This final phase represents the connection element between the two methods; in fact, certain necessary input of the MSA model can be “updated” using the results of the PMP model applied to the homogeneous areas deriving from the previous application of the MSA. Considering this in the short term, not all variables would undergo changes, but only those directly connected with the agricultural sectors such as the indicators of agricultural specialisation and those linked with productivity in agriculture. More precisely, with respect to the indicators listed in table 1, all those classified under the group “agricultural activities and land use” will be modified by the PMP projections, together with some indicators concerning land use and productivity: crop distribution, standard gross margins, the marginal
price of land, variable costs and saleable production per hectare. An important aspect of this approach that needs to be considered is that the UAA for each individual process and the total UAA must coincide in the two phases of the model (MSA and PMP). Unfortunately, the FADN data do not allow for satisfactory statistical inference from the sample to the universe, thus restricting considerably the potential of the model. The solution to this problem can be identified by connecting the unit data (yields) and economic data (prices and unit costs) by process, obtained from FADN, to the structural data (UAA and animal heads) drawn from the official statistics (i.e. ISTAT/Eurostat). More precisely, to reflect the average behaviour of the farmers, the production and economical data by process contained in the FADN will be organised by type of farm, according to the physical size of the farm (up to 10 Ha, from 10 to 20 Ha, from 20 to 50 Ha, over 50 Ha). Within each farm type identified in each homogeneous area, all processes present will be considered after organising them – for sake of simplicity – under the following groups of processes: a) **COP crops**: cereal, corn, split and waxed corn, protein cereals and flax; b) **other open field crops**: horticultural, industrial plants, tobacco; c) **fodder**: alfa-alfa, fodder plants, grass meadows; d) **permanent crops**: grape, apple, pear, peach, other fruits; e) **breeding**: milk cows, meat cows, meat male cattle, meat female cattle.

In brief, the PMP model consists of identifying 4 types of farms (T=4), each representing one “virtual” farm with a maximum number of 20 activities (J=20), whilst the statistical sources required to collect the input differ between each other, as FADN supplies yields, prices and variable costs and surfaces and number of animal heads are taken from agricultural censuses (or official statistics). The data relative to the individual processes, in the policy evaluation phase, should be completed with other data connected directly to the individual policies to be implemented at regional level, such as the compensatory payments for each individual process or any possible measures for production reduction, such as quotas and set-aside.

The PMP model in the policy (scenario) analysis phase will lead to an overall representation of the behaviour of the farmers represented in the individual types of firms present in the region. In other words, the specific characteristics of each type will be dropped, and the “homogeneous territorial universe” considered by each specific model will be employed.

### 5 An example: evaluation of policy impact on agriculture in Northern Italy

With the aim of giving an example of the possible application of the integrated dynamic model described in the previous sections, the analysis was applied on data at Nuts3 level for the 41 provinces of Northern Italy\(^3\). The results are summarised in figure 1. The left map represents the initial situations in the early Nineties (data drawn from the 1990 agricultural census and 1991 population census, ISTAT, and Italian FADN for animal processes as milk and meat). The scenario illustrated in the central map derives from the application of PMP as illustrated in section 3, considering steady prices, but allowing for compensatory payments and set-aside fixed by Reg. 1762/92. In the third (right) map, the scenario considers both the compensatory payments and changes in prices up to 1997 as taken from FADN.

\(^3\) More informative results about the Italian territorial agricultural system and their integration with the social and economical background can be found in Montresor, Mazzocchi, Zanchini (1999), who used a different (and more specific) set of indicators.
The MSA identifies in the initial situation 8 clusters. The territorial structure does not change significantly over the two scenarios, so the clusters definition can be held for the whole analysis and is reported in table 3.
In the scenario where just the compensatory payments are introduced, the land use situation does not change drastically if one considers Northern Italy as a whole. There is a slight decrease in the area under durum wheat (-0.8%), beet (-0.4%), soya beans (-3.1%) and feeding crops (-1.6%), whereas there is an increase in the areas under barley (+0.8%) and maize (+1.3%). Also, the standard gross margin per hectare show a slight increase (+5.6%), thanks to a reduction in the variable costs (-0.6%). Under this scenario the detected systems mainly correspond to the initial situation (four provinces move from one cluster to another and cluster 3 disappears. Inside the new clusters one can also detect some changes in the land use, including the mountain and hilly ones, where there is an increase of the area under maize, but also in the provinces where agriculture is more productive, where the portion of land under grapes or fruits raises.

In the second scenario, where prices’ changes are considered together with the compensatory payments, the Northern Italian agriculture as a whole changes more consistently. There is an increase in both the gross saleable production (+2.5%) and in the variable costs per hectare (+1.8%), whereas the profits as a whole show a rise of 7.7% in terms of SGM per hectare with respect to the initial situation. If one considers the crops concerned by the CAP reform, there is a general increase in the areas under maize (+1.8%) and soya beans (+1.4%). However there are no sharp changes in the clusters with respect to the initial situation, with just two provinces that change cluster. But even if the initial differences in the agricultural systems seem to ‘survive’ to the reform, there are some relevant changes inside each system, as summarised in table 4.

6 Conclusions
The objective of this paper is to propose a model which – although with the limits imposed by the approaches and statistical sources used – allows for simulating the effects of certain policies on a territorial scale, while taking into account not only the variations connected with the agricultural sector, but also the influences generated by other sectors present at territorial level. Thanks to the combination of the two approaches, in practice a double evaluation of the proposed policies can be obtained: a quantitative and a qualitative one. The first stems from the quantification of how the utilisation of the land and the supply of the main products of the food sector will vary. The value obtained will add to the quantification of the EEC expenditure that may be generated by individual agricultural policy measures and the overall economic effects on the income of the farmer’s family. From a quality point of view, one can find whether the production and economic variations will change the “status” characterising each individual area. In other words, it is possible to see whether the change in progress will have a positive or negative impact keeping fixed the other social-economic components of the territory, thus providing a tool to change the condition of the area with respect to the cluster to which it belonged originally. The last aspect is particularly relevant for the policy makers since it allows to verify if the agricultural policies envisaged are going to be beneficial and, if so, whether this benefit is in line with the objectives expected.

References


Abstract

Traditional food demand models lose their consistency when significant structural changes occur over the considered time period, especially when those changes are due to sudden food scares. Demand systems need to be modified in order to consider such changes. The structural approach suggested in this paper, once the hypothesis of parameter stability has been rejected by the opportune tests, is based on the stochastic specification of some or all of the model coefficients. Maximum likelihood estimation is based on the EM algorithm and the Kalman filter. An application on meat demand in Italy and the BSE crisis is proposed.

Keywords: Structural Demand Systems, Structural Change, BSE, Food Consumption, Kalman Filter

1 Introduction

The occurrence of relevant food scares throughout Europe and their impact on demand have recently led many researchers to further develop the analysis of consumer response towards information about food safety. This is not an easy task, especially when the information is related to the failure of the food safety market, as in the case of food scares. As a matter of fact, the consumer does not seem to be rational any more, at least under the traditional definition of “rationality”. A food scare can modify the consumption habits of families and individuals, not only in terms of food expenditure allocation, but the different risk perception also modifies the prices and income elasticities. This is why traditional demand modelling becomes usually inadequate, the models being affected by a clear structural break that changes the relationship between the dependent variable (food expenditure) and the explanatory ones (basically prices and income). Even more difficult is to determine “how structural” is the impact of a scare and the adjustment of demand models often require some assumptions on the crisis time pattern.

The analysis of structural change in food demand has always been a relevant task for agricultural economists, long before the problems due to large scale food scares. Improving demand modelling and making it more sensitive to sudden or slow structural changes can help the policy-makers to organise an adequate response to the new consumer needs. Recent food scares in the meat sector have also shown that they do not only affect the single concerned products, but the loss in consumer trust leads to crisis that concern all the closer products (that cease to be substitutes) and the entire sector. Hence a demand system that allows for structural change can also help identifying and quantifying the cross-effects. A brief literature review on the analysis of structural change in food demands is reported in section 2, together with the discussion of the most common tests for detecting structural instability in the parameters of an econometric model. The specification of a structural demand system is proposed in section 3, whereas section 4 describes the estimation method based on the Kalman filter. An illustrative
application to meat demand in Italy is proposed in section 5. Some conclusions are drawn in section 6.

2 Testing and analysing structural change in food demand

An excellent review of the parametric and non-parametric methods employed for analysing structural change in food demand has been given by Moschini and Moro (1996). Meat seems to be the food category that is the most sensitive to structural change in consumer habits. Smalwood et al. (1989) identify and discuss eleven works focusing on the structural analysis of meat demand. Among these, Chavas (1983) employ a model specification with time-varying parameters (TVP). The most widely used approach to model demand systems with changing parameters is probably the one given by Moschini and Meilke (1989), who employ a switching system for meat and find a significant switch in the intercept and expenditure coefficients. The same approach with some modifications is also proposed by Rickertsen (1996), Burton and Young (1996) and, more recently, by Mangen and Burrel (1999). These last two works concern the BSE crisis. A special issue of the European Review of Agricultural Economics in 1996 was dedicated to structural change. Among the papers included, Yen et al. and Burton et al. employ a double-hurdle model. A single meat demand equation with stochastic parameters was estimated by Al-Kahtani and Sofian (1994) through the Kalman filter. Bertail and Combris (1998) also discuss the filtering techniques for studying the evolution of a parameter through repeated samples, referring to a rolling panel on consumption. Under a non-parametric perspective, Moro (1997) discusses the existing methods and focuses on testing the Generalised Axiom of Revealed Preferences (GARP).

However one should avoid the risk to adopt a TVP demand model when the usual stability tests fail to reject the hypothesis of parameters’ constancy. The most known, and still the most effective tests for structural breaks are those formalised by Chow (1960). Fisher (1970) reproposed these tests and extended them in order to deal with limited degrees of freedom, as it often happens when the break is recent and there are not many observations after the exogenous shock. The tests (named after Chow) are based on the availability of information about the time period when the break occurs and in such a situation are the most powerful ones. Another relevant assumption behind the Chow test is that the model’s residual should be homoscedastic, otherwise one could employ an alternative test based on the Wald statistics (see Greene, 1993). When the main requirement of the Chow test is missing, i.e. the exact period when the break occurs is not known, the most appropriate tests are the so-called Cusum and Cusumsq tests based on recursive residuals, as introduced by Brown, Durbin and Evans (1975).

The approach suggested here, once the hypothesis of parameter stability has been rejected by the above tests, is based on the stochastic formulation of some or all of the model coefficients. Of course, this opens the way to a wide range of problems, that this paper does not pretend to overcome. First of all, many different stochastic specifications could be adopted for the model parameters and they could lead to different results. These however do not seem to be unsolvable problems and further testing and simulations could lead to more general models.

3 A structural demand system: specification

The structural approach to time series modelling gained growing attention in the last decade for several reasons. It is based on simple and intuitive basic principles, but it opens the way to a wide range of applications of different complexity. Moreover structural models have built a bridge between classical time series analysis (Box & Jenkins ARIMA modelling) and econometrics. The increased interest towards this method is also due to the very quick
progress of the IT tools, that now allows one to carry out a large amount of computation in a relatively short time, as sometimes structural modelling requires. The most complete and detailed work on time series structural models is certainly the book by Harvey (1989), where they are defined as models formulated in terms of interest components that cannot be directly observed, but have a direct interpretation. The structural (or unobserved components) approach is strictly linked to the Gaussian state-space models and to the Kalman filter (see section 5). It derives from control engineering applications (Kalman, 1960, Anderson and Moore, 1979) and has started to interest economists and econometricians after turning from the numerical optimisation application to its use for maximum likelihood estimation. The milestones of this path are the works by Rosenberg (1973), Garbade (1977), Engle (1978) and Harvey and Phillips (1979). From the Eighties, the structural approach became more popular thanks to the work of Harvey et al.1

The basic structural model (BSM) is based on the consideration that a time series can be decomposed into three structural (stochastic) components: a time trend, a seasonal and an irregular component. These components are driven by random errors as in the following BSM specification:

\[ y_t = \mu_t + \phi_t + \epsilon_t \]  

(1)

where \( \mu_t \) is the trend component, \( \phi_t \) is the seasonal one and \( \epsilon_t \) is the irregular one. Clearly the model (1) is not complete without defining a functional form for each component. Generally \( \mu_t \) is specified as a local linear trend with the following notation:

\[
\begin{align*}
\mu_t &= \mu_{t-1} + \delta_{t-1} + \upsilon_t \\
\delta_t &= \delta_{t-1} + \zeta_t
\end{align*}
\]

(2)

where \( \zeta_t \) and \( \upsilon_t \) are independently distributed and follow a white-noise distribution. While \( \upsilon_t \) has effects on the trend levels, the changes in \( \zeta_t \) affect its slope. Seasonality can be introduced in different ways. Here we assume the seasonal dummies specifications, constraining to 0 the sum of the seasonal effects over a one year period. The seasonal component at time \( t \) is defined as follows:

\[ \phi_t = -\sum_{j=1}^{s-1} \phi_{t-j} + \omega_t \]

(3)

where \( s \) is the periodicity (\( s=12 \) for monthly data, \( s=4 \) per quarterly data etc.) and \( \omega_t \) is the white-noise stochastic term. Other seasonal patterns can be defined (Harvey, 1989, 41-44).

The BSM model is then completed by the irregular component, a traditional white-noise error. A further assumption requires that the error terms of each equation and the irregular component are uncorrelated between them. The BSM can now be extended by adding exogenous variables, given that they are (weakly) exogenous (Engle, Hendry and Richard, 1983):

\[ y_t = \mu_t + \phi_t + x_t'\gamma + \epsilon_t \]

(4)

where \( x_t \) is a \( k \times l \) vector containing the exogenous variables and \( \gamma \) contains the respective coefficients. A further extension can be made by allowing the coefficients in \( \gamma \) to change stochastically over time. Returning to demand analysis, one could express (for instance) the linear approximation of the Almost Ideal Demand System by Deaton and Muellbauer (1980) in structural terms, according to the following specification:

1 For a rich reference list see Harvey (1989).
where \( \overline{w}_{it} \) is the average (per family) expenditure share for product \( i \) at time \( t \), \( p_{it} \) is the price of product \( i \) at time \( t \), \( \overline{x}_t \) is the average expenditure for all products at time \( t \), \( P_t^* \) is the Stone price index and the other variables are those defined for the BSM model. All the coefficients in (5) are allowed to be time-varying. Generally, one assumes a random walk specification for \( \gamma_{ijt} \) and \( \beta_{it} \) but, as mentioned, any time series specification is possible (e.g. autoregressive patterns).

As any demand system, the structural demand system can be constrained in order to respect the theoretical assumption of consumer economics, with the difference that the constraints are time-varying (Doran and Rambaldi, 1997). So, the adding up constraints become

\[
\sum_{k=1}^{n} \mu_{kt} = 1 \quad \sum_{k=1}^{n} \beta_{kt} = 0 \quad \sum_{k=1}^{n} \gamma_{kjt} = 0 \quad \forall t
\]

the homogeneity condition is

\[
\sum_{j=1}^{n} \gamma_{kjt} = 0 \quad \forall t
\]

and symmetry is respected if

\[
\gamma_{ijt} = \gamma_{jit} \quad \forall t
\]

A certain degree of complexity would be added if one wishes to impose (locally) the negativity condition, as it is often done in recent works (see for example Ryan and Wales, 1996 and Moschini and Rizzi, 1997 for Italy). The unresolved debate between imposing these conditions and verifying them through specific tests goes beyond the purpose of this paper. Here the theoretical conditions (6-8) are imposed just to show that they do not create any complication in the structural approach.

### 4 Estimation

The maximum likelihood estimates of the unknown parameters in the structural demand system can be obtained by rewriting it in the state space form (one equation is dropped as usual to avoid the singularity problem), by deriving the log-likelihood function through the Kalman filter and applying a maximisation procedure. The state-space form (SSF) for the demand system (5) is formed by a measurement equation (9) and a transition equation (10) as follows:

\[
\overline{w}_t = A_t z_t + \xi_t
\]

\[
A_t = A_{t-1} T + \eta_t
\]

The vector \( \overline{w}_t \) contains the \( n-1 \) expenditure shares for each good at time \( t \). The measurement equation (9) represents its relationship with all the \( m \) unknown parameters of the system in the same period, contained in the \((n-1)\times m\) state matrix \( A_t \). The \( m\times1 \) vector \( z_t \) is formed by the values of the exogenous variables and other known fixed values, so that (9) becomes equivalent to (5). In the transition equation (10), the state matrix is expressed as a function of its lagged values through the \( m\times m \) transition matrix \( T \), whose values are known and depend upon the specification of (2) and (3). The stochastic specification is completed by the error vectors \( \xi_t \) and \( \eta_t \), both with 0 mean and with covariance matrices equal respectively to \( h_t \) and \( Q_t \). For simplicity sake, we will refer to a single equation of the system (univariate case), but the generalisation regarding the multivariate model is straightforward. Referring to the
generic \( i \)-th equation of an \( n \) goods system and considering monthly time series, the state vector can be defined as follows:

\[
\alpha'_t = [\mu_t, \delta_t, \phi_t, \phi_{t-1}, \ldots, \phi_{t-9}, \gamma_{1t}, \ldots, \gamma_{n-1,t}, \beta_t] \quad t:1, \ldots, T
\]

In the state vector, there are the parameters of the local trend component (\( \mu \) and \( \delta \)), eleven parameters \( \phi \) for monthly seasonality\(^2\), \( n-1 \) price coefficients \( \gamma \) and the \( \beta \) coefficient for total expenditure. Once the state vector is defined, from the original specification (5) it is a simple task to derive the transition matrix \( T \):

\[
\begin{bmatrix}
\mu_t \\
\delta_t \\
\phi_t \\
\phi_{t-1} \\
\vdots \\
\phi_{t-10} \\
\gamma_{1t} \\
\vdots \\
\gamma_{n-1,t} \\
\beta_t
\end{bmatrix} = 
\begin{bmatrix}
1 & 0 & 0 & \ldots & 0 & 0 & \ldots & 0 \\
0 & 1 & 0 & \ldots & 0 & 0 & \ldots & 0 \\
0 & 0 & 1 & \ldots & -1 & 0 & \ldots & 0 \\
0 & 0 & 0 & \ldots & 0 & 1 & \ldots & 0 \\
\vdots \\
0 & 0 & 0 & \ldots & 1 & 0 & \ldots & 0 \\
0 & 0 & 0 & \ldots & 0 & 1 & \ldots & 0 \\
\vdots \\
0 & 0 & 0 & \ldots & 0 & 0 & \ldots & 1 \\
0 & 0 & 0 & \ldots & 0 & 0 & \ldots & 0
\end{bmatrix} 
\begin{bmatrix}
\mu_{t-1} \\
\delta_{t-1} \\
\phi_{t-1} \\
\phi_{t-2} \\
\vdots \\
\phi_{t-11} \\
\gamma_{1,t-1} \\
\vdots \\
\gamma_{n-1,t-1} \\
\beta_{t-1}
\end{bmatrix} + 
\begin{bmatrix}
0 \\
0 \\
0 \\
0 \\
\vdots \\
0 \\
\gamma_{1,t} \\
\vdots \\
\gamma_{n-1,t} \\
\beta_t
\end{bmatrix} \quad t:1, \ldots, T
\]

A further simplification can be introduced by assuming the time invariance of the error covariance matrices \( h \) and \( Q \). It can be helpful to notice that in the multivariate formulation the symmetry constraints can be introduced by inserting twice the same coefficient in the state matrix.

The state space form specification opens the way to the application of the Kalman filter algorithm. Basically, it is a recursive procedure for computing the optimal estimates of the state vector at time \( t \) using all available information at time \( t \). The filter needs to be started by specifying some initial values\(^3\). On the other hand, the Kalman smoother is a backward procedure starting from the state vectors computed through the Kalman filter and producing ‘smoothed’ estimates. The complete formulations of the Kalman filter and smoother are omitted here; all details can be found in Harvey (1989, ch. 3). Through the Kalman filter, the log-likelihood function can also be derived as a function of the unknown parameters in the system and of the other parameters appearing in the state space representation, namely the error covariance matrices \( h \) and \( Q \).

Now it is possible to compute the maximum likelihood smoothed estimates through an iterative procedure, the EM algorithm by Dempster et al. (1977), whose application to the estimates of TVP models is illustrated by Shumway and Shoffer (1982) and Watson and Engle (1983). The EM (estimation + maximisation) algorithm starts with the definition of the initial values for the state vector, for its covariance matrix and for \( h \) and \( Q \). Then the following steps are repeated iteratively:

---

\(^2\) The twelfth is given by difference, as the sum of 12 consecutive values is constrained to be 0.

\(^3\) This is probably the biggest issue in the application of the Kalman filter. Under a bayesian perspective one can form reasonable assumptions on the initial values and the covariance matrices (e.g. the values estimated through a non structural system). The other solution is to start the filter with a diffuse prior, that is setting the starting values to 0, but with an infinite (or extremely large) covariance matrix. The efficiency of this last solution widely depends on the number of available observations. For more details see de Jong (1988 and 1991), Ansley and Kohn (1990) and more recently Koopman (1997).
1. A passage through the Kalman filter returns filtered estimates of the state matrix (and its covariance matrix);
2. Starting from the state matrix at time $T$, a passage through the Kalman smoother returns the smoothed estimates for all time periods (including the initial matrices at time 0);
3. By maximising the log-likelihood function conditional to the smoothed estimates, the algorithm computes new estimates of $h$ and $Q$;
4. With the latest estimates of the initial state matrix and of $h$ and $Q$, the algorithm goes back to step 1 until convergence, which is reached when the increase in the log-likelihood function value (computed at step 3) and the differences in parameter estimates are negligible.

5 An application to meat demand in Italy: BSE impact and structural change

The proposed application refers to demand for four meat products and fish using monthly expenditure data taken from the Istat Households Expenditure Survey, from January 1986 to December 1996. Besides being the foods traditionally more affected by the changes in consumption habits, these were also affected by the BSE shock of March 1996. A conditional LA/AIDS system was estimated for five goods (beef, poultry, pork meat, other meats, fish) according to the formulation by Deaton and Muellbauer (1980). Adding up, homogeneity and symmetry were imposed, negativity was verified ex post through the Slutsky matrix. The parameters were initially estimated through an iterative maximum likelihood method based on Zellner GLS for SURE systems. The fish equation was dropped for avoiding singularity. Parameters’ stability was then tested through the Chow, Cusum and Cusumsq tests and all of them led to the rejection of the constancy hypothesis for the beef and poultry equations. The Chow test clearly identified the significance of the BSE scare, whereas from the Cusum and Cusumsq other patterns of structural change emerged.

Then a structural demand system of type (5) was estimated, holding constant through time the price and expenditure coefficients $\gamma_{ij}$ and $\beta_i$. Better results were obtained by introducing an intervention (dummy) variable on the level for keeping into account the BSE shock. The constant coefficient estimates are reported in Table 1, whereas the patterns of the time-varying level and trend components are illustrated in Figure 1. It may be interesting to notice how the sudden break of March 1996 is accompanied by a sign inversion in demand trends. This suggests that the initial shock tends to be reabsorbed, but there are no sufficient observations to determine in what measure demand recovers. The results also show how the BSE shock is relevant. The intervention variable on the intercept is significant and necessary to eliminate the effects of the BSE structural break. Considering the structural system without any a priori intervention, the intercept estimates clearly identify some BSE impact (figure 3), but this is not sufficient to completely absorb the break effects. The limit is due to the algorithm characteristics, which smoothes any strong variation in the parameters on the basis of the whole time series. Hence, if information about a sudden structural break exists, it cannot be ignored and should be embodied either through a simple intervention or – if enough post-event data is available – through shifts as in the Moschini-Meilke (1989) model.

Only for demonstration purposes, a single equation for beef demand was estimated and all the prices and expenditure coefficients were also allowed to change over time. The time-varying Marshallian own-price elasticity and the expenditure elasticity computed through the time-varying coefficients are reported in figure 4. This example could help to understand consumer response. Without pretending to draw general conclusions, the fall in expenditure elasticity and the rise in the own-price elasticity suggest some effects due to the loss in consumer trust towards beef. Just after the food scare, prices tend to become a quality-proxy,
so consumers avoid the low-price beef. On the other hand, the demand for food safety is income-elastic (Henson and Traill, 1993) and as beef is perceived as a less safe food, the expenditure elasticity decreases. This is just one interpretation to the ‘lack of rationality’ emerging from the data if the BSE crisis is not explicitly considered.

Figure 1. Level component for each equation in the structural demand system with intervention on the level.

Figure 2. Trend component for each equation in the structural demand system with intervention on the level.
Table 1. Parameter estimates of the structural demand system (standard error in parentheses)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Equation</th>
<th>Beef</th>
<th>Poultry</th>
<th>Pork</th>
<th>Other meats</th>
<th>Fish</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \gamma_1 ) Beef</td>
<td>-0.061 (0.056)</td>
<td>-0.163 (0.061)</td>
<td>-0.053 (0.048)</td>
<td>0.243 (0.104)</td>
<td>0.034</td>
<td></td>
</tr>
<tr>
<td>( \gamma_2 ) Poultry</td>
<td>-0.163 (0.061)</td>
<td>0.047 (0.031)</td>
<td>-0.056 (0.029)</td>
<td>0.030 (0.044)</td>
<td>0.141</td>
<td></td>
</tr>
<tr>
<td>( \gamma_3 ) Pork</td>
<td>-0.053 (0.048)</td>
<td>-0.056 (0.029)</td>
<td>-0.001 (0.032)</td>
<td>-0.020 (0.037)</td>
<td>0.129</td>
<td></td>
</tr>
<tr>
<td>( \gamma_4 ) Other meats</td>
<td>0.243 (0.104)</td>
<td>0.030 (0.044)</td>
<td>-0.020 (0.037)</td>
<td>0.060 (0.029)</td>
<td>-0.314</td>
<td></td>
</tr>
<tr>
<td>( \gamma_5 ) Fish</td>
<td>0.034</td>
<td>0.141</td>
<td>0.129</td>
<td>-0.314</td>
<td>0.010</td>
<td></td>
</tr>
<tr>
<td>( \beta_1 ) Expenditure</td>
<td>-0.022 (0.020)</td>
<td>-0.030 (0.009)</td>
<td>-0.029 (0.013)</td>
<td>0.071 (0.015)</td>
<td>0.011</td>
<td></td>
</tr>
<tr>
<td>( \beta_2 ) Intervention</td>
<td>-0.044 (0.005)</td>
<td>0.018 (0.003)</td>
<td>0.009 (0.003)</td>
<td>0.010 (0.003)</td>
<td>0.008</td>
<td></td>
</tr>
<tr>
<td>( \bar{R}^2 )</td>
<td>0.86</td>
<td>0.69</td>
<td>0.83</td>
<td>0.86</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( D.W )</td>
<td>1.80</td>
<td>1.95</td>
<td>2.14</td>
<td>2.09</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3. Level components in the structural demand system without intervention.
6 Conclusions

This paper suggests a structural approach to demand modelling, where some or all the parameters of the demand function are allowed to change stochastically over time. This should help to better catch the modifications in consumer habits towards foods and identify sudden changes as those due to the release of information on food safety. However, the application to meat demand in Italy showed that the approach is not sufficient to avoid the econometric problems due to structural breaks. Hence, when this information is available, the structural system should still be completed by the opportune shifts on the parameters. In general, the possibility to have time-varying estimates opens the way to acquire information about the time patterns of food consumption habits, such as changes in trends or changes in price and expenditure elasticities. The limits of the suggested approach mainly lie in the large amount of data required by the estimation method, in order to avoid undesirable effects linked to the choice of the initial values. This problem could be solved by valuing the individual information and estimating the models on time series of cross section data. Another development for improving the analysis of consumer behaviour could derive from using pseudo-panel observations, where demographic characteristics are also considered.

References


Briefs on Further Research
Updating and Prediction of Sectoral Models: A Bayesian Entropy Approach

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The information associated with sectoral models is invariably limited to a few years. However, it is often as important to disaggregate the model in its temporal dimension as the spatial dimension. In addition, trends in productivity and prices influence the ability of sectoral models to make short run predictions. For these reasons it is desirable to have a formal method to link the model parameters and realizations without the necessity of solving the problem simultaneously for the entire horizon. In this presentation, we show how the spatially disaggregated modeling approach shown in Paris & Howitt can be extended to annual model disaggregation. We use the concept of Kullback cross entropy to sequentially update the annual model parameters, despite the ill posed nature of the problem. Zellner (1988) shows that the cross entropy criterion is an efficient information processing rule, and yields an equivalent representation of Bayes theorem.

The Multi-output, Multi-input SPEP model presented in Paris and Howitt is reconstructed from seven annual data sets of regional crop production and input allocation in California from 1985 to 1991. The eighth year of data (1992) is used to assess the accuracy of a one year out-of-sample prediction. The Kullback cross-entropy measure used to reconstruct the parameters has the following form:

\[
\text{Min } \sum p_i \ln \left( \frac{p_i}{q_i} \right)
\]

where \( p_i \) are the probabilities over "I" support values for the particular parameter, and \( q_i \) are "I" prior probabilities over the same support set. In the first year we assume that there is no prior knowledge about the parameters, and the \( q_i \) for 1985 have the uniform value of \( 1/I \). In subsequent years, \( q_i \) follow the usual Bayes updating rule in which the prior for the current year is the posterior probability for the previous year. The prior \( q_{it} \) is therefore set equal to \( p_{i,t-1} \). The resulting cross-entropy probability \( p_{it} \) is the value that minimizes the distance between the prior and posterior distributions. Essentially, the new probability, and thus the parameter value, is a Bayes weighted combination of the distribution in the previous time period, and the maximum entropy distribution based on the current data and restrictions. The Kullback criterion puts equal weight on the prior and current data to reconstruct the posterior, and thus in each year, the posterior is derived from the current year's data and a declining weight of the data in previous years. The next step in this research is to incorporate a formal equation of motion and an error term in the updating procedure.

Results for a single region in California with nine crops and three inputs show that the model has an average out-of-sample prediction error for individual crop production of 15.17%. The Leontief matrices and the eigen values for the cost matrix show significant changes over time, thus justifying the annual updates of the parameters.

Keywords: Positive Mathematical Programming, Kullback-Leibler Cross-Entropy, Time-Series.
MECOP: A Regionalised European Arable Crops’ Sector Model

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The MECOP model, where MECOP stands for Maximum Entropy on Cereals, Oilseeds and Protein crops, has been developed in order to analyse and evaluate the effects of agricultural policy measures related to the European sector of arable crops. There already exist several models focused on this agricultural sector. They mainly differ in terms of product coverage, behavioural relations and calibration process. Simulation results are thus not easily comparable. One main objective of the MECOP project is therefore to apply a common framework to the main crop-producing EU member states, facilitating comparisons for policy makers.

The model describes the behaviour of crop producers with respect to the supply of cereals, oilseeds and protein crops as well as their land allocation decisions. Crop producers are profit-maximizers. They choose the levels of output and land used by maximising their profit subject to market and technical constraints. The two main distinctive features of the model MECOP are firstly the representation of technical constraints, secondly the calibration process of behavioural parameters by the Generalised Maximum Entropy (GME) approach.

Many programming models have been recently developed at the farm level or at an aggregate level using the so-called Positive Mathematical Programming (PMP) methodology. This recent trend can be partly explained by the fact that, compared to the linear programming approach, the PMP methodology perfectly calibrates the model solution to observed data and generates smooth (or non-jumpy) responses. Technically, the main innovation of the PMP lies in the specification and the calibration of a non-linear objective function. To date and as far as the crop sector is concerned, non-linear terms have been mainly introduced via the cost function assuming that yields are constant. This specification implicitly imposes particular restrictions on the crop producing technology (constant marginal productivity of the land factor and decreasing marginal productivity of other production factors). Our approach is more flexible in that non-linear profit functions are specified for each crop. Per-crop profit functions depend on output price and land allocated to the particular crop. In that context, supply responses, obtained by applying Hotellings’ lemma, may differ from land allocation decisions. In other words, yields are no longer constrained to be exogenous. Per-crop profit functions are represented by the normalised quadratic functional form. They include a time trend to capture exogenous technical changes effects.

The second main innovative feature of the MECOP model concerns the calibration of behavioural parameters (per-crop profit function parameters). Using time series data from Eurostat, it is theoretically possible to estimate these parameters, using “traditional” econometric estimators, like Full Information or Least Squares Estimators. However, high collinearity between explanatory variables, in particular between crop prices, leads to unstable parameter values and rules out this calibration strategy as an efficient one. In such ill-conditioned problems, GME estimators are appropriate. We therefore take benefits of these now widely used estimators, paying particular attention to the choice of necessary prior information.

Keywords: Generalised Maximum Entropy, Calibration, Non Linear Programming Model, CAP

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The objective of this paper is to analyse the main structural changes in the agrofood system in the EU countries in the last 25 years. The aim is to measure if there exist evidence of process of convergence towards a more homogeneous structure among the EU countries. In this paper we will analyse the long run structural change in the agrofood system, focusing on the main components and variables for each European country. In particular the analysis will consider the relative importance of the main components of agrofood systems (agriculture, food industry and food consumption) and how they change over time. The starting point of the analysis will be the definition of models that describe the structure of the national agrofood systems starting with the simple formulation of Malassis (1992). We will suggest more complete models that consider explicitly, besides agriculture and food consumption, the food industry and the degree of openness in terms of exports and imports. The descriptive models will be based on appropriate joint structural variables available in the European National Accounting Data (from the SEC2 Database of Eurostat). The analysis consider the period from 1970 to 1995 in twelve EU countries. These models will show how the structure of the agrofood systems are different in the EU countries and how the structural variables follows different trends and patterns in the period considered.

In the second part of the paper we will further verify, on the basis of the main variables of the models, whether convergence or similarity is present in the structural changes in the agrofood systems of the EU countries. In this section, we attempt to test the hypothesis that the various countries are converging towards the same structure of agrofood system. In ordered to do this, we have used three different statistical tests based on the variance of the structural components of the previous models described. We will make us of three statistics proposed by Lichtemberg (1991) and Carree, Klomp (1997) to test the convergence over the 22 OECD countries.

The results show there are important processes of convergence among the EU countries as regards the variables of the agrofood system that are more linked to the economic development, such as the importance of agriculture and food consumption in GDP. On the other hand there are divergences on the variables more linked to the openness degree and to the competitiveness of the agrofood system. The analysis will lead to a better understanding of the process of development of the agrofood system in the presence of market and policy intervention.

Keywords: Agrofood System, Sigma-convergence, Structural Change, Food Industry, Food Consumption, Gross Domestic Product, Agricultural Value Added.

References
Modeling Discrete Technology Choice: An Application to Standard and Organic Farming in Finland

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Finland has a long experience in implementing a public policy program to promote organic farming. Farmers’ choice alternatives under the Finnish incentive program are characterized as follows. A farmer, who is currently applying the standard production technology, is facing a choice between two mutually exclusive alternatives. At the beginning of each year he decides whether to sign a five-year contract and switch to organic farming or to continue standard farming while retaining the option to switch later. Similarly, a farmer currently farming organically decides whether to switch back to standard farming, or to continue farming organically while retaining the option to switch later.

These discrete choices are solutions to a multi-period, dynamic optimization problem in which the future returns are stochastic. Therefore, estimating the farmer’s choices in the structural form requires a solution to two distinct problems: (1) the solution to the stochastic dynamic optimization problem on which these choices are based; (2) the estimation of choice probabilities together with the underlying structural parameters of the behavioral equations.

In this study, the dynamic optimization problem is solved by first defining choice specific value functions that obey the Bellman equation and next numerically iterating on the Bellman equation backwards, starting from the terminal period. The maximized random return streams are simulated using crude Monte Carlo simulation. These maximized return streams then determine the next period optimal value functions. A Probit-type endogenous switching model using Maximum Likelihood Estimation (MLE) is used to estimate the choice probabilities.

The results suggest that decreasing output prices and increasing direct subsidies have been triggering switches to organic farming. Therefore, income neutral policy reforms, which decrease price support and compensate the resulting income losses by direct income transfers, increase incentives to switch into organic farming. It is also found that the switch is more likely on farms having large land areas and low yields and less likely on farms with intensive livestock or either labor or capital intensive production.

Keywords: Technology Choice, Organic Farming, Dynamic Programming, Switching Model

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1 A preliminary paper on this work has been presented on the 65th EAAE Seminar. The revised final version is forthcoming in the European Review of Agricultural Economics, Volume 28.
Chapter IV

Applied Analysis:

Models for Agricultural Supply and Environment
ESMERALDA – A Regionalised Econometric Model of the Danish Agricultural Sector

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Abstract
ESMERALDA (Econometric Sector Model for Evaluating Resource Application and Land use in Danish Agriculture) is an economic model describing the relationships between prices on agricultural products and inputs on the one hand, and agricultural production, input uses and agricultural incomes on the other hand. The model is based on duality theory and estimated on farm-level account data spanning the period 1974-96, using panel data econometrics. The structure of model paves the way for a micro-based regional description of the Danish agricultural sector. Hence, the impacts of e.g. changed prices can be assessed for each individual in the data set, and subsequently aggregated to a relevant sector level (e.g. national, regional, local community etc.) using a set of aggregation factors. The paper provides a brief outline of the methodology used for constructing the regionalised ESMERALDA-model and discusses the “state-of-the art” for the model, as well as directions for further developments.

Keywords: Duality Theory, Panel Data Econometrics, Regionalisation

1 Introduction
ESMERALDA (Econometric Sector Model for Evaluating Resource Application and Land use in Danish Agriculture) is an economic model describing the relationships between prices on agricultural products and inputs on the one hand, and agricultural production, input uses and agricultural incomes on the other hand. This paper provides a brief introduction to the model with emphasis on the most recent developments of the model, addressing regional and environmental issues. Readers interested in details of the model are referred to Jensen et al. (2000).

ESMERALDA has been developed at the Danish Institute of Agricultural and Fisheries Economics since 1992. The first version of the model is described in Jensen (1996) and is based on aggregate data for different lines of production in Danish agriculture. This model version has been applied for various economic analyses. For example, Schou et al. (1998) use the model for analysing the impacts of different nitrogen regulation instruments, whereas Andersen et al. (1999) use the model for analysing the combined impacts of a recently introduced tightening of Danish aquatic environmental policy and major parts of Agenda 2000. Given the increasing focus on regional aspects and site-specific environmental issues in agriculture-related policies, the model has been under reconstruction in the recent years, in an attempt to address these issues. As opposed to the first model version, the new version is based on farm level economic data.

The new version of ESMERALDA is an econometric model describing the impacts on agricultural production, input use, land use, agricultural incomes etc. of changes in output price, input prices, quantitative restrictions etc. The model is mainly static-comparative and
covers 13 of the most significant lines of production in Danish agriculture (spring barley, winter barley, wheat, pulses, rape, potatoes, sugarbeets, fodder beets, green fodder, milk, beef, pork and poultry), of which 11 are marketed products.

In the model, economic optimisation takes place at the farm level in three different stages: 1) composition of variable inputs, 2) determination of yield levels, and 3) determination of land allocation, as well as animal and capital density. Whereas stages 1) and 2) are purely static and could be considered as short-run optimisations, stage 3) is partly dynamic and yields the medium- to long-run aspects of the model.

In the following, a brief outline of the methodology used for constructing the regionalised ESMERALDA-model is given and some key behavioural aspects of the model are shown. Furthermore, use of the model for simulation purposes is described and discussed. The paper concludes by discussing the “state-of-the art” for the model, as well as directions for further development of the model.

2 Methodology
In the model, farmers are assumed to exhibit cost minimisation behaviour. The theoretical formulation of ESMERALDA is based on duality theory, representing farmers’ optimisation problem in terms of translog cost functions (see e.g. Chambers, 1988, for the principles of duality theory). Combining the assumption of cost minimisation with an assumption of profit maximisation in the short run and the long run, respectively, yields the possibility for deriving equations for profit maximising yield levels for individual lines of production, as well as profit maximising land allocation and animal and capital densities.

The data material underlying the model consists of farm-level account data spanning the period 1974-96 (with 1000-2000 anonymous individual observations per year). Variables in the data material include numbers of hectares in various crop sectors, numbers of animals in different categories, agricultural product sales revenues, input costs, labour use, capital endowments, agricultural input and output prices, farmer’s age, municipality code, and various other variables. Around 80 per cent of one year’s farm sample is reselected in the preceding year, whereas the remaining 20 per cent of the sample is replaced. Hence, the data material provides the opportunity of constructing a “rolling panel” data set (where farms on average are represented in five subsequent years) and panel data techniques (see e.g. Baltagi, 1995) can be used in the econometric estimations.

The three steps in the model formulation and estimation procedure are described briefly in the following, and in more detail in Jensen et al. (2000).

2.1 Input composition
Given the assumption of cost minimisation at the farm level, and due to duality theory, the optimisation problem can be represented by a cost function. From the cost function can be derived demand equations for input demands by means of Shephard’s lemma. A dual short-run cost function is specified due to the translog functional form. The cost function is specified conditional on 7 input prices, 15 activity levels, 11 yield levels, amount of capital, and a number of additional explanatory variables in order to take into account differences in farm size, time period etc. From the translog cost function, we can derive expressions for input demands, expressed as the respective inputs’ shares of variable costs.

From the cost share expressions, expressions for own- and cross-price elasticities can be derived for each of the variable inputs considered in the variable cost term. As the yield and activity levels (and hence output level and composition) underlying these elasticity expressions are assumed constant, the elasticities have a Hicksian interpretation, i.e. they
express the price-induced changes in input demands for fixed output and hence represent pure input substitution effects.

For the empirical estimation, farms in the data material are divided into 8 groups: 4 farm types (part time farms and full time crop, cattle and pig farms) on two soil types (loam and sand), in order to allow for possible differences in behavioural parameters depending on production structure and soil type. Cost functions for the eight farm types have been estimated using panel data econometrics (where “slope” parameters are restricted to be equal across farms, while constant terms are allowed to be farm specific), yielding 8 sets of behavioural parameters – one for each farm type. Results in terms of price elasticity estimates for the group of crop farms on loamy soils are shown in table 1.

Table 1. Own- and cross-price Hicksian input demand elasticities, crop farms on loamy soils, 1994/95.

<table>
<thead>
<tr>
<th>Quantity/Price</th>
<th>Energy</th>
<th>Labour</th>
<th>Fertiliser</th>
<th>Pesticides</th>
<th>Services</th>
<th>Roughage</th>
<th>Con.feeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>-0.275</td>
<td>-0.138</td>
<td>0.373</td>
<td>-0.042</td>
<td>0.065</td>
<td>0.005</td>
<td>0.012</td>
</tr>
<tr>
<td>Labour</td>
<td>-0.014</td>
<td>0.019</td>
<td>0.043</td>
<td>-0.031</td>
<td>0.065</td>
<td>0.005</td>
<td>-0.087</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>0.140</td>
<td>0.156</td>
<td>-0.561</td>
<td>0.323</td>
<td>0.065</td>
<td>0.046</td>
<td>-0.169</td>
</tr>
<tr>
<td>Pesticides</td>
<td>-0.019</td>
<td>-0.138</td>
<td>0.389</td>
<td>-0.883</td>
<td>0.065</td>
<td>0.029</td>
<td>0.556</td>
</tr>
<tr>
<td>Services</td>
<td>0.053</td>
<td>0.518</td>
<td>0.141</td>
<td>0.117</td>
<td>-0.149</td>
<td>-0.232</td>
<td>-0.448</td>
</tr>
<tr>
<td>Roughage</td>
<td>0.053</td>
<td>0.518</td>
<td>1.299</td>
<td>0.686</td>
<td>-3.017</td>
<td>0.259</td>
<td>0.202</td>
</tr>
<tr>
<td>Con.feeds</td>
<td>0.006</td>
<td>-0.445</td>
<td>-0.236</td>
<td>0.644</td>
<td>-0.288</td>
<td>0.010</td>
<td>0.309</td>
</tr>
</tbody>
</table>

Source: Jensen et al. (1999)

Similar results could be presented for the other 7 farm types. In general, Hicksian input price elasticities vary across farm types, but there also seems to be some general characteristics. For example, the own-price elasticity of labour seems to be relatively small (in absolute terms) on all farm types, whereas the own-price elasticity of pesticides in general is relatively large (in absolute terms).

2.2 Yield levels

If the assumption of cost minimisation is supplemented by an assumption of profit maximisation, short-run equilibrium conditions for the yield levels in the different agricultural lines of production can be derived, because profit maximisation implies that the marginal cost of increasing the yield level in a given agricultural sub-sector should equal the product price, if the activity level is fixed. Hence, the equilibrium conditions determine the short-run profit maximising yield levels in the respective sub-sectors, and from the conditions, we can derive expressions for the price elasticities related to yield levels and output prices. Having derived these elasticities, we can derive expressions for short-run Marshallian price elasticities (i.e. elasticities which in addition to the above-mentioned “Hicksian” effect also include the effects of adjustments in the optimal yield levels).

The equilibrium conditions for yield levels are estimated econometrically on the above-mentioned “rolling panel” data, for each line of marketed production on each of the eight farm types, and output-related price elasticities are calculated based on the estimated parameters.

2.3 Land allocation and livestock density

The two preceding steps represent adjustments in the short run, i.e. with land use, livestock and capital fixed. In the medium to long run, these factors can be considered endogenous, because they can be adjusted in accordance with profit maximising behaviour. The condition for profit maximising capital and livestock density is that the marginal returns on an investment in capital or livestock yields the same marginal return as an alternative investment.
outside agricultural production. As agricultural land is assumed to have no relevant opportunity cost, the conditions for profit maximising land allocation is that the marginal returns to land are equal (and positive) in all relevant land uses. As land allocation as well as capital and livestock densities may be more rigid than the use of e.g. fertilisers, these parts of the model are formulated in a dynamic specification, more specifically as error correction models, allowing for short-run disequilibrium in these variables, but reflecting movements towards a long-run equilibrium.

For this part of the model, the above-mentioned data material has been supplemented by sub-sector specific average revenue and cost data, which are used to provide estimates of economic returns in the respective lines of production. The model equations are estimated simultaneously for each farm type. Combining the results of these estimation with those in the previous two steps yields the possibility for calculating short-, medium- and long-run Marshallian price elasticities.

3 Model simulation

The database and the estimated cost functions, equilibrium yield equations, equations for land use, livestock density and capital use pave the way for a micro-based regional description of the Danish agricultural sector. For the most recent years, the model consists of approximately 2000 sample farms, representing the entire population of Danish farms. When using the model for simulations, the 8 sets of estimated parameters are combined with the farm-level account data, applying the most relevant set of parameters for each of the 2000 farms in the model/dataset. For example, if farm no. i is a crop farm located in a municipality with predominantly loamy soils, the behavioural parameters for crop farms on loamy soils are used for simulating economic behaviour on farm no. i. Hence, the impacts of e.g. changed prices can be assessed for each individual in the data set.

The impact assessment on a given model farm is composed of three steps, corresponding to the steps in the estimation procedure, as illustrated in figure 1. Thus, first step is to calculate the impacts on the cost minimising input composition. Second step is to calculate the adjustments in profit maximising yield levels, and the derived further impacts on input use. Third step is to calculate the adjustments in profit maximising land use, livestock density etc. for the relevant time horizon – and the derived effects on optimal yield levels and input uses. This 3-stage procedure is repeated for each farm in the model.

To each sample farm belongs a multiplication factor, which could be interpreted as the number of farms in the population represented by the individual sample farm. Hence, the results of farm-level simulations can be aggregated to the national sector level using these multiplication factors. Based on information on the observed regional farm structure (including numbers of farms in different categories, land use, animal use etc.), a regional disaggregation of the national aggregation/multiplication factors has been carried out. The main principle in this disaggregation is to obtain regional multiplication factors, which provide the best possible correspondence between the aggregated and the observed structural variables at the regional level. Hence, the vector of national multiplication factors is replaced by a matrix of multiplication factors, where the sum of regional factors attached to a specific model farm equals the model farm’s national multiplication factor. A precondition for this approach is that the farm structure is exogenous and not affected by e.g. changed relative profitabilities on different farm types. However, as the price of land is endogenously determined and is farm specific in the model, endogenous determination of farm structure may be a future improvement of the model.
Linkage with other models

At present, ESMERALDA is linked with various other types of quantitative models, including macro-economic models (and CGE models), regional economic models, and environmental satellite models. Some principles related to these model linkages have been discussed by Frandsen et al. (1997). Furthermore, linking ESMERALDA to agricultural sector models for other countries might be considered. The principles in different model linkages are illustrated in figure 2.

The link between ESMERALDA and a macroeconomic model is based on the following two-way procedure. First, behavioural parameters for the agricultural sector in the macroeconomic
model are derived from the econometric estimations underlying ESMERALDA. This step ensures (approximate) consistency in the behavioural descriptions in the two models, and a procedure for this step has been developed by Jensen et al. (1999). Second, in a specific scenario price information to ESMERALDA is given from the macro-economic model. The linked model system can be applied for analysing the impacts of general economic changes (e.g. a carbon dioxide tax or changes in national economic growth) on the agricultural sector or to assess the effects of agriculture-related policies, taking into account the feedback from other sectors in the economy, i.e. scenarios where price formation is assumed endogenous.

The integrated agricultural sector-macro model system is linked to a set of regional economic models in analyses focusing on the impacts of agricultural policies on the regional economy, for instance in rural regions. In this setup, model results from ESMERALDA (e.g. agricultural incomes and employment) as well as from a macroeconomic model (production, employment, imports, exports etc.) in the remaining sectors in the economy) are fed into the regional economic model, where the macroeconomic effects are general for all regions (but may vary according to differences in the regions’ industrial structures), whereas agriculture-economic effects differ due to regional differences in behavioural parameters and farm structure.

ESMERALDA is also linked to various environmental satellite models used for assessing environmental impacts (e.g. nitrate and pesticide leaching, carbon emissions etc.) of changes in agricultural or environmental policies. The link is uni-directional in that results from ESMERALDA are fed into the environmental models, but no feedback is assumed. This type of model system can be used for integrated analyses of economic and environmental impacts of various policies – as long as the policy changes do not affect the economic conditions for other economic sectors significantly. One specific task in establishing the link between ESMERALDA and environmental models has been to ensure sufficient correspondence in variable definitions in the two types of model. As ESMERALDA is based on accountancy data, the distinction between various components of fertilisers (nitrogen, phosphorus and potassium) or pesticides (herbicides, fungicides etc.), which is necessary for environmental interpretation of the results, cannot be based on these data. A methodology for solving this problem has been developed by Jørgensen et al. (2000).

In relation to analyses of EU policy changes and their impacts on agricultural markets, a link between ESMERALDA and national models for the other EU countries would be relevant. Such links have not been established so far, and would involve participation by agricultural model specialists from the respective countries. One way to do it would be similar to the link between ESMERALDA and a macroeconomic model, cf. above. Hence, relevant behavioural parameters can be extracted from ESMERALDA (and the other national agricultural sector models) and used in a EU-market simulation model, which then provides equilibrium prices to be used in the respective national models. Other methodologies may however be considered as well.

5 Perspectives

This paper has described a micro-based econometric model of the Danish agricultural sector - ESMERALDA. The model represents a further development of an earlier ESMERALDA-version based on aggregate agricultural sector data, thus widening the range of analytical possibilities. The new model can be applied for analysis of various policy scenarios. The micro-level foundation for the model enables analysis of relatively detailed policy instruments, e.g. instruments addressing the farm level such as animal density restrictions, individual fertiliser quotas etc. The model farm results can be aggregated to any level of aggregation, including local, regional or national levels, and they can be linked to Geographic
Information System (GIS) data, in order to assess spatial impacts of changes in the agricultural sector.

Although the new model version provides a large range of detailed analyses, it still has some limitations. One limitation is that the level of detail is more or less restricted by the data available for econometric estimation. Although efforts have been made to overcome these problems in relation to fertilisers and pesticides, there is still work to be done in this field, and for some purposes the level of detail in other agricultural inputs is also insufficient. Another limitation is the absence of crop-specific price elasticities on e.g. nitrogen use, which may be relevant for environmental assessments such as nitrogen leaching. A third limitation is that the model is mainly static comparative (although it contains some dynamic behavioural equations), and hence less suitable for projection purposes and analyses of adjustment processes.

Most of these limitations may however be overcome by further research. For instance, the lack of dynamic specification can be remedied by devoting effort to a more sophisticated dynamic structure of the model, thus paving the way for e.g. projection applications of the model. The level of detail in the model may be expanded by incorporating information from other sources (e.g. mathematical programming models). Although such an approach would imply that data are not strictly consistent with those underlying the above econometric estimations, it may still provide reasonable approximations. A third route of further development could be to incorporate more lines of production or farm types (e.g. organic farming). Moreover, linking ESMERALDA with other national agricultural sector models in the respective EU-countries in order to get an integrated system of models could be an interesting task.

References
Production Decisions under Price Uncertainty for Irish Wheat and Barley Producers

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Abstract

A standard criticism of duality based supply response models has been the relative lack of studies which incorporate risk aversion and uncertainty into the analysis. The presence of greater price volatility due to successive reform of EU agricultural policy exacerbates this point. This study follows on from previous work by applying a supply response model within a mean variance framework to a panel data set of Irish wheat and barley producers. Under this specification, Irish producers are actually found to be risk neutral in their production behaviour.

Keywords: Duality, Uncertainty, Risk Preferences

1 Risk Aversion and Price Risk in Duality Models of Production

A recurring criticism of applied duality theory has been the relative lack of duality studies, which have incorporated producer risk aversion and uncertainty. In response, Coyle (1992) developed a duality model of production under risk aversion and price uncertainty within the context of a mean-variance model of utility maximisation. If the mean-variance model is linear, Coyle (op cit) demonstrated that the advantages of standard duality models for econometric estimation, hypothesis testing, and policy inference are maintained. Furthermore, linearity results in the objective function of the mean-variance model assuming a particularly simple form. Therefore, the resulting duality models can be easily estimated in applied research. In addition, standard price certainty models are nested within these duality models as a special case. Oude Lansink (1999) has expanded Coyle’s model to simultaneously determine multiple input demand, multiple output supply and the optimal area allocation across crops.

This paper seeks to apply the Oude Lansink (op cit) model to a sample of Irish wheat and barley producers. In addition, complexity of the data allows for cost functions for both cereals to be specified. As with the Coyle and Oude Lansink studies, output price uncertainty is assumed to be the only source of income uncertainty.

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2 See for instance the review of duality theory by Lopez and Pope (1982) and a subsequent review by Shumway (1995)

3 This allows for variable input equations to be specified for both barley and wheat.
1.1 Mean Variance Framework with Output Price Uncertainty

With the linear mean-variance (LMV) framework, the producer's utility function $U$ is defined in terms of expected income $E(\tilde{Y})$ and income variance $V(\tilde{Y})$ by the following

$$U = E(\tilde{Y}) - \frac{\alpha}{2} V(\tilde{Y}) \quad (1.1)$$

The underlying risk structure imposed is constant absolute risk aversion (CARA). Therefore $\alpha$ is the coefficient of absolute risk aversion with $\alpha > 0$, $\alpha = 0$ implying risk aversion or risk neutrality respectively. Random and expected income are defined in the following manner:

$$\tilde{Y} = p^T q - C(n,q,B) \quad (1.2)$$

$$E(\tilde{Y}) = p^T q - C(n,q,B) \quad (1.3)$$

Random and expected output price vectors are given by $\tilde{p}$ and $p$ respectively. Vectors of output quantities and cereal areas are denoted by $q$ and $B$ while $n$ is an input price vector. A cost function $C(n,q,B)$ is defined as $n^TX$. As output prices are the only source of uncertainty then the variance of the producer's random income is

$$V(\tilde{Y}) = q^T V_p q \quad (1.4)$$

where $V_p$ is the (symmetric, positive definite) covariance matrix of output prices.\(^4\) Using (1.2) and (1.3) the indirect utility function corresponding to (1.1) is:

$$U^*(p,n,V_p,B) = \max_{q,B} \left( p^T q - C(n,q,B) - \frac{\alpha}{2} q^T V_p q \right) \quad (1.5)$$

The corresponding first order condition is given by:

$$p - C_q (n,q,B) - \alpha V_p q = 0 \quad (1.6)$$

If $\alpha V_p q$ is brought to the left hand side then the standard result of price equaling marginal cost is achieved if either $\alpha = 0$ or if the price variance is zero.

$$p - C_q (n,q,B) = \alpha V_p q \quad (1.7)$$

If $\alpha > 0$, then the output price exceeds marginal cost (providing $V_p$ is diagonal). Using the first order condition (1.6), $q^*$ is solved for in terms of $n$, $B$, expected output price and the covariance matrix of output prices.

$$q^* = q^*(p,n,V_p,B) \quad (1.8)$$

Coyle (op cit) demonstrates that by using the envelope theorem and the first order condition (1.6), input demand equations can be obtained by differentiating either $U^*(p,n,V_p,B)^5$ or $C(n,q^*,B)$ with respect to input prices $n$.

$$X(p,n,V_p,B) = - \frac{\partial U^*(p,n,V_p,B)}{\partial n} = \frac{\partial C(n,q^*,B)}{\partial n} = X(n,q^*,B) \quad (1.9)$$

Oude Lansink (op cit) derives the area demand equation by setting the first derivative of $U^*(p,w,V_p,B)$ to $B$ to zero. Again using the first order condition (1.6) the following is obtained:

\(^{\text{4}}\) with $V_{p_{ij}}$ representing the (co)variance of prices $i$ and $j$.

\(^{\text{5}}\) The curvature properties for $U^*(p,n,V_p,B)$ have been derived by Coyle (1992), Saha (1996) and Saha and Just (1996) and are presented in Oude Lansink (1999).
\[
\frac{\partial U^* (p, n, Vp, B)}{\partial B} = \frac{\partial C (n, q^*, B)}{\partial B} = 0 \quad (1.10)
\]

### 1.2 Empirical Application

For computational purposes two short term Normalised Quadratic cost functions are initially specified. Total costs can be defined in the following manner

\[
C(n, q, B) = n_3 \ C_1 (s, q_1, t_1) + n_3 \ C_1^* (s, q_1^*, t_1^*),
\]

where \( t_1 + t_1^* = B \) and

\( C_1 = \) normalised barley costs, \( C_1^* = \) normalised wheat costs,
\( s = \) normalised input prices,
\( q_1 = \) barley output quantity, \( q_1^* = \) wheat output quantity,
\( t_1 = \) barley area, \( t_1^* = \) wheat area.
\( n_3 = \) input price of the numéraire input - "other inputs".

Normalised costs for barley are given by the following: \(^6\)

\[
C_1 = \alpha \phi_0 + \sum_{i=1}^{2} \phi_i s_i + \beta \sum_{i=1}^{5} \pi_i t_i + \lambda \theta_1 q_1 + \frac{1}{2} \sum_{i=1}^{2} \sum_{j=1}^{2} \phi_{ij} s_i s_j + \frac{1}{2} \sum_{i=1}^{5} \sum_{j=1}^{5} \beta \pi_{ij} t_i t_j + \frac{1}{2} \lambda \theta_1 q_1^2 + \sum_{i=1}^{2} \gamma \omega_i s_i t_i + \sum_{i=1}^{5} \xi_{ii} s_i q_i + \mu \sum_{i=1}^{5} \psi_i q_i t_i
\]

\( (1.11) \)

where:
\( s_i = \) normalised input prices, with \( i = 1 \) (nitrogen), \( 2 \) (crop protection),
\( t_i = \) fixed inputs and other variables, with \( i = 2 \) (labour), \( 3 \) (capital) \( 4 \) (trend) and \( 5 \) (soil dummy).

Note that two individual cost functions are specified for both barley and wheat owing to the complexity of the data source. \(^7\) The underlying technology therefore, is assumed to be highly separable in variable inputs. \(^8\) This permits the derivation of cereal specific input demand functions, which distinguishes this work from that of Coyle (op cit) and Oude Lansink (op cit). For identification purposes the following is assumed: \( \pi_{ij} = \pi_{ji} \) and \( \phi_{ij} = \phi_{ji} \). The first order condition corresponding to (1.6) is:

\[
p_i - \theta_i - \lambda \theta_1 q_i - \sum_{i=1}^{2} \eta \xi_i s_i - \mu \sum_{i=1}^{5} \psi_{ii} t_i - \alpha \sum_{j=1}^{2} q_j V_{pj} = 0 \quad (1.12)
\]

where \( p \) is the normalised expected output price. To get the output supply equation, \( q_1 \) is isolated on the left-hand side:

\[
q_1 = \frac{1}{\lambda \theta_1 + \alpha V_{p11}} \left( p_i - \lambda \theta_1 - \sum_{i=1}^{2} \eta \xi_i s_i - \mu \sum_{i=1}^{5} \psi_{ii} t_i - \alpha q_2 V_{p12} \right) \quad (1.13)
\]

---

\(^6\)Only the barley cost function, output supply, input demand and area allocation equations are presented here.

\(^7\) Data on expenditure and quantity applied of variable inputs for both cereals is available.

\(^8\) This assumption can be made particularly in an Irish case given that Irish wheat production is essentially of a winter variety whilst most barley tends to be a spring crop. Note also that total fixed inputs are included in both cost functions however they are not allocated out to the individual cereals as per Oude Lansink & Peerlings (1996).
By differentiating (1.11) with respect to the normalised price of inputs the non-numéraire input equations are:

$$x_i = \phi_i + \sum_{j=1}^{2} \phi_j s_j + \gamma \sum_{i=1}^{4} \omega_i t_j + \eta \xi_i q_i, \quad i = 1, 2$$

(1.14)

Normalised costs for barley are defined as $C_1 = s_1 x_1 + s_2 x_2 + x_3$. Thus, the numéraire input equation is:

$$x_3 = \phi_0 + \sum_{i=1}^{5} \pi_i t_i + \lambda \theta q_i - \frac{1}{2} \sum_{i=1}^{2} \sum_{j=1}^{2} \phi_j s_j + \frac{1}{2} \beta \sum_{i=1}^{5} \sum_{j=1}^{5} \pi_{i,j} t_{i,j} + \frac{1}{2} \theta_1 q_i^2 + \mu \sum_{i=1}^{5} \psi_i q_i t_i$$

(1.15)

The demand equation for barley is derived using equation (1.10). The data used here is taken from specialised Irish cereal producers. Thus the assumption is made that the area going to both barley and wheat is fixed in the short run. The land allocation decision in the short run therefore is solely between the two cereals barley and wheat. The decision to focus exclusively on the area allocation decision between barley and wheat simplifies the analysis somewhat in that the policy payments to both crops are the same. Thus one can argue that the planting decision is purely a function of the market returns. Equation (1.10) is solved for in the following manner

$$\frac{\partial C_i(s, q_i, t_i)}{\partial t_i} = \frac{\partial C_i^*(s, q_i^*, t_i^*)}{\partial t_i^*} = 0$$

subject to the restriction that $t_i + t_i^* = B$. Barley area $t_i$ can be estimated in the following manner (1.16) with wheat area being obtained through subtraction ($B - t_i$).

$$t_i = \frac{1}{(\pi_{ii} + \beta \pi_i)} \left[ (\pi_i^* - \beta \pi_i) + \beta \pi_{ii} B + \sum_{i=2}^{5} (\pi_{i,i} - \pi_{ii}) t_i \right]$$

(1.16)

Note because of the restriction above, the presence of parameters and variables from the wheat cost function in (1.16).

2 Empirical Illustration

The data on specialised tillage farms covering the period 1984-1998 is taken from a stratified sample of Irish farms which forms part of the Teagasc conducted National Farm Survey. In order to avoid the problem of corner solutions which would require the use of censored regression techniques the data set was confined to those producers who simultaneously planted both wheat and barley. This will of course give biased results for the population as a whole. The total area going to both cereals on the farms accounts for 75% of the total farm area.

The three variable input demand equations solved for both cereals are nitrogen, crop protection and other inputs. Other inputs which is the numéraire input consists of potassium and phosphate fertilisers, seed, machinery and transport costs. Quantities of the crop protection and other inputs are obtained by dividing total expenditure for these items on both cereals by the aggregate relevant Central Statistics Office (CSO) cost indices. Given the relative close geographical proximity of specialist Irish cereal producers the assumption is

9 Farms with more than 75% of the gross margin coming from tillage crops.
10 For a complete description of the sample see National Farm Survey (1998)
made here that output and input price indices vary over the years but not over farms. Areas’ going to the two cereals are measured in acres.

The question of generating the appropriate expected output price will itself constitute a chapter of this study, however for the present paper expected output prices are generated by applying an AR(1) filter to both wheat and barley CSO aggregate output prices. The variance \( \text{var}(p^i) \) and covariance \( \text{cov}(p^i, p^j) \) for producers' subjective probability distributions of output prices are generated in a similar fashion to Coyle (op cit), Oude Lansink (op cit) and Chavas and Holt (1990):

\[
\text{var}(p^i) = 0.50(p^i_{-1} - E_{-2} p^i_{-1})^2 + 0.33(p^i_{-2} - E_{-3} p^i_{-2})^2 + 0.17(p^i_{-3} - E_{-4} p^i_{-3})^2 \\
\text{cov}(p^i, p^j) = 0.50(p^i_{-1} - E_{-2} p^i_{-1})(p^j_{-1} - E_{-2} p^j_{-1}) \\
+ 0.33(p^i_{-2} - E_{-3} p^i_{-2})(p^j_{-2} - E_{-3} p^j_{-2}) + 0.17(p^i_{-3} - E_{-4} p^i_{-3})(p^j_{-3} - E_{-4} p^j_{-3})
\]

(1.17) (1.18)

The presence of price support for the sample period (1984-1998) leads to a truncation of the price distribution faced by producers. An intervention floor effectively reduces the potential downward price variability, which the producer can experience. This study adopts the methodology advanced by Chavas and Holt (op cit) to adjust the expected price level, the variance and the covariance of the output prices accordingly. As a consequence, the expected price of barley is increased and its variance is reduced. Intervention prices are not applicable to Irish wheat produce after 1993.11

The system of equations (1.13), (1.14), (1.15) and (1.16) were estimated jointly in SAS using nonlinear 3 stage least squares. The nonlinear component was necessary owing to the nonlinear nature of the output supply equation (1.13). The 3 stage least squares was required because of the presence of endogenous variables on the right-hand side of some of the equations and also to allow for cross correlation of the errors.

### 3 Results

Three different sets of instrumental variables were used in the estimation of the output supply, input demand and area allocation equations. The results obtained using these different sets were compared and evaluated using a series of first-stage R\(^2\) (FSRSQ) which were calculated in SAS. Only the results of the chosen estimation are presented here. The coefficient of absolute risk aversion \( \alpha \) was found not to be significant (at the 5 per cent level) and negative which would suggest that farmers in the set actually have a preference for risk. This result is not compatible with the inherent assumption made in relation to the structure of the risk preferences i.e. that the underlying risk structure is one of CARA. By definition this assumes that the utility function is concave in nature resulting in expected income being greater then the certainty equivalent of income. The risk premium as defined in (1.7) must be non-negative under the CARA assumption. For this reason a second model was estimated which imposed a restriction on the equations (1.13) through (1.16) which required the \( \alpha \) coefficient to have a positive sign.12

Elasticities from the estimated equations (1.13) through (1.16) are presented. They are obtained in an analogous manner to Lansink (op cit) i.e. price elasticities and elasticities of intensities were derived implicitly by solving the system of equations for different sets of

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11 Intervention prices for wheat post 1993 are for milling wheat. Most Irish wheat produced is of a "feed" variety.

12 A chi-square test performed on the restriction using the “probchi” command in SAS suggests however that the null hypothesis of the restrictions not applying cannot be rejected.
price levels\textsuperscript{13}, using the solution algorithm for nonlinear simultaneous systems of equations available in SAS. The elasticities presented in Table 1 represent both the intensity and area effect of a price change. 58 per cent of the parameters were found to be significant at the 5 per cent level.\textsuperscript{14}

\textbf{Table 1. Total Price Elasticities at the Sample Mean (Restricted Model)\textsuperscript{15}}

<table>
<thead>
<tr>
<th></th>
<th>Nitrogen (Barley)</th>
<th>Crop Protection (Barley)</th>
<th>Expected Barley</th>
<th>Expected Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output (Barley)</td>
<td>-0.14</td>
<td>0.01</td>
<td>0.06</td>
<td>-0.04</td>
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<td>Output (Wheat)</td>
<td>-0.58</td>
<td>0.00</td>
<td>0.00</td>
<td>0.05</td>
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<tr>
<td>Nitrogen (Barley)</td>
<td>0.19</td>
<td>0.00</td>
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</tr>
<tr>
<td>Crop Protection (Barley)</td>
<td>0.60</td>
<td>-0.83</td>
<td>0.00</td>
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<td>Other Inputs (Barley)</td>
<td>2.23</td>
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<td>0.05</td>
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<td>Nitrogen (Wheat)</td>
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<td>0.00</td>
<td>0.00</td>
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<tr>
<td>Crop Protection (Wheat)</td>
<td>0.60</td>
<td>-1.36</td>
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<td>Other Inputs (Wheat)</td>
<td>0.57</td>
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<td>-0.05</td>
</tr>
<tr>
<td>Area (Barley)</td>
<td>0.22</td>
<td>0.00</td>
<td>0.02</td>
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</table>

The own price elasticities conform with the properties of the hessian\textsuperscript{16} except for the response of nitrogen applied to barley to its own price increase. The cross price effects of an increase in the price of nitrogen on other inputs are more elastic for both cereals. An increase in the price of crop protection only really affects quantities applied of crop protection. Its effects on nitrogen usage and other inputs are negligible. Increases in the expected output prices bring about inelastic responses. An increase in the expected output price of wheat sees a reduction in the output of barley, which is mainly brought about again by a reduction in the barley area.

The coefficient of absolute risk aversion $\alpha$ is found to be significant (at the 5 per cent level) and non-negative which conforms to the assumed underlying risk structure. The coefficient is approximately equal to 0 – the risk neutral case. Thus the risk premium calculated as $0.5\alpha Q VpQ^T$, is found to be approximately 0 as is the coefficient of relative risk aversion (CRRA), which is defined as $Y\alpha$. Saha (1994) has presented a review of relative risk aversion results obtained in various studies. Most of these coefficients are between 1 and 4. Thus, the results achieved in this paper along with those obtained by Oude Lansink (op cit) of about 0.3 are particularly low. The policy conclusion to be drawn from these results is of course that Irish producers of barley and wheat are indifferent to price volatility and price volatility in itself has no implications for these producers’ profit levels.

\textsuperscript{13} The system was solved for exogenous variables at the sample mean, and after 1 per cent increase of the price of input or output $i$. The difference in the input and output quantities of the first and second solution can be used to calculate elasticities of outputs, inputs and areas with respect to price $i$.

\textsuperscript{14} Coefficient estimates of the restricted model are presented in Table 1 of the Appendix.

\textsuperscript{15} Elasticity results for the effects of increases in the price of other inputs are not included for presentational purposes. However these results are available from the author on request.

\textsuperscript{16} As outlined by Coyle (op cit) and Oude Lansink (op cit).
4 Conclusions and Further Work

A dual based supply response model has been presented which allows for uncertainty. The utility function adopted imposes constant absolute risk aversion. The degree of risk aversion is then tested for. Irish barley and wheat producers were found initially to actually favour risk. As this result of a negative $\alpha$ is incompatible with the risk structure imposed, a restriction was applied which confined the $\alpha$ coefficient to non-negative values. A chi-square performed on this restriction suggests however that the hypothesis that the restrictions don’t apply cannot be rejected. The coefficient again was approximately equal to 0 - the risk neutral case. The policy implication of this finding is that the larger fluctuations of cereal prices wrought by CAP reform have practically no impact on producer profit levels.

Further analysis in this area will seek to expand the current study by looking at:

- An improved specification of the price expectation generating mechanism. The price expectation mechanism utilised here although popular in the literature is rudimentary. A more comprehensive analysis of the relationship between volatility spillovers between UK and Irish cereal prices will constitute a chapter in itself of this study.
- The addition of yield uncertainty to the analysis. All uncertainty in this analysis has been assumed to exist exclusively on the price side. Coyle (1999) has expanded upon his earlier work to add yield uncertainty to the dual framework.

In conclusion therefore, the risk premia calculated in this paper constitutes an important “first step” in the incorporation of risk variables within Irish supply response models. Subsequent components of this study will seek to expand on this analysis by permitting a more flexible utility function specification, improving the price expectation mechanism and allowing for yield uncertainty to be incorporated into the overall model.

References


Pope R.D.”To Dual or Not to Dual?” Western Journal of Agricultural Economics, 7(1982): 337-352.


Table A.1 Parameter Estimates and t-Values for Restricted Model

<table>
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<tr>
<th>Parameter</th>
<th>Barley Value</th>
<th>t-Value</th>
<th>Parameter</th>
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<th>t-Value</th>
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Modelling Farmer Response to Policy Reform: An Irish Example

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Abstract
This paper presents the results of a study in which multi-period linear programming models were used to project the likely responses of dairy and cattle farmers in Ireland to policy change. Representative farms were chosen from the Irish National Farm Survey using cluster analysis. A Markov chain analysis was conducted to estimate the future representivity of farming clusters. Models were validated historically and calibrated according to their historical ability to optimise. Projected farmer response to Agenda 2000 is presented.

Keywords: Representative Farm, Multi-period Linear Programming, Markov Chain Analysis

1 Introduction
The work described in this paper has been developed under the auspices of the FAPRI-Ireland Partnership. The objective of this Partnership is to project the impact of agricultural policy scenarios on agricultural markets, farms and other related industries. The projection process begins at macro level with an econometric model of Irish agriculture. The model is comprised of a set of individually estimated commodity models, e.g. beef, dairy, sheep, pigs and cereals that are linked and solved simultaneously under different policy scenarios. The individual commodity models for Ireland are linked to the FAPRI-USA constructed EU and world models. This allows the simulation of policy changes at a national, EU, and international level. Following simulation at macro level the projected agricultural prices link into the farm level linear programming models. This allows the response at farm level to be modelled based on the projected policies and prices. This paper focuses on the farm level stage of the analysis. The following is an explanation of the methodology applied and a presentation of results of the Agenda 2000 analysis.

2 Methodology
A set of multi-period linear programming models was constructed to analyse the representative farmer response to Agenda 2000. As the models are multi-period it is possible to model the dynamics of change over the projection period. Multi-period LP models have the advantage that they can demonstrate growth and development of a farm business over a number of years. They can, for example, demonstrate the cash-flow implications of different policy development scenarios. LP models incur criticism due to their normative nature. However, Jones (1982) argues that normative models have particular value in projecting response under conditions, which are outside the range of past experience. Such models indicate the likely direction of changes in production in response to price and policy changes.

1 The FAPRI-Ireland Partnership is a joint venture between Teagasc, the Irish Universities, other groups in Ireland, and the Food and Agriculture Policy Research Institute (FAPRI) in the USA.
LP also receives criticism due to its data requirements, since a consistent set of input-output coefficients and detailed information on farm resources is required for the model. The Irish National Farm Survey (a member of FADN\textsuperscript{2}) is a rich source of such farm level data. It records sufficient data, as required by an LP model, from 1,200 farms of all systems and sizes each year representing a population of over 120,000 farms.

2.1 Representative Farms

There have been numerous studies on the correct procedure for classifying representative farms. All studies point towards the importance of classifying farms into homogenous groups. Day (1963) laid the foundations for this classification procedure. His foremost criterion for classification was \textit{- technological homogeneity}. He defines this as similar resource endowments and constraints, similar levels of efficiency and similar managerial abilities. Other classification criteria have been identified since Day's. Buckwell and Hazell (1972) emphasised the importance of groups having similar expectations of changes in constraints and similar rates of technical innovation.

Cluster and principal component analysis was carried out based on these classification procedures. Variables were chosen from the Irish National Farm Survey as proxies for the classification criteria. The variables used were three-year averages from 1994 to 1996. The motivation for this was to minimise the disturbance of inter-year variations on farms due to exogenous factors such as weather, price volatility etc. To enable historical validation and calibration at a later stage it was necessary to construct a panel of matched data from the farm survey. The required data was drawn from a balanced panel from 1992 to 1996. To ensure the unbiasedness of the panel a t-test was conducted to test the significant difference between the panel population and total population. Tests were carried out along five variables. The results showed that although the panel tended to contain slightly larger and more profitable farms the differences were not significant.

The results of the cluster analysis for dairy and cattle farms are tabulated below. The tables show the main descriptors for the farms in each cluster. The number of farms represented nationally is shown in brackets for each cluster. The clusters have been named according to their most discriminatory characteristics.

| Table 1: Description of Representative Dairy Farms\textsuperscript{3} |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
| Descriptors as per 1996         | Static          | Developers       | Large           | Typical         |
| (No. of Farms Nationally)      | (10 800)        | (7 900)          | (1 000)         | (13 200)        |
| Farm Net Margin                 | £11 150         | £14 500          | £65 750         | £22 650         |
| Milk Quota (litres)             | 95 400          | 103 725          | 425 700         | 169 200         |
| Change: Milk Sold (92-96)       | 0 +55%          | +5%              | +10%            |                 |

Source: Derived from Irish National Farm Survey

Four groups of farms emerged as homogeneous from the clustering. The first two although of similar size, differ significantly on their development path over time and also their technical efficiency. The third group is differentiated from the other three, as it is exceptionally large. Finally the last group is the centroid group. Farms remained in this group because they did not have any significant distinguishing factors.

\textsuperscript{2} Farm Accountancy Data Network

\textsuperscript{3} All monetary values are expressed in Irish Punts. The Euro/Punt rate is 0.787564.
Four groups of cattle farms emerged as homogeneous from the clustering. The first two are of similar size and have similar demographics. They are both young farmers with off farm income. However, they are differentiated easily by their levels of efficiency and profitability. The first is a minimalist because the number of hours worked on the farm is minimal. It is important to segment these two types of part-time farmers, as they may not have similar expectations for their farm. The third group is differentiated from the other three, as it is a full-time operation and it is larger and more profitable. Finally the last group is the moderate group. Farms remained in this group because they were full time but were not a large-scale operation with high technical efficiency.

### 2.2 Structural Change in Representative Clusters

The above tables show the number of farms represented by each cluster in 1996. However, the representivity of clusters may change over time. A Markov process is a useful technique for analysing such change as it is based on the assumption that transitional probabilities calculated from historical data shall continue in the future. Previous such studies carried out on the Irish farm structure have proved quite accurate, for example Keane (1991). In this application the probabilities are fixed at calculations derived from the 1992-1996 sample period, with farms in 1992 being assigned to the clusters which were identified for 1996. Calculations are based on the rate of movement of farms between clusters in this sample period. These probability calculations are projected forward to estimate the future representivity of clusters. The rate for change between 1992 and 1996, in the number of farms in different clusters, is presented in the figures below.

**Figure 1: Changing Representivity of Dairy Clusters**

![Figure 1: Changing Representivity of Dairy Clusters](image-url)
Figure 1 shows the observed movements from 1992 to 1996. Through the analysis it is assumed that the same rate of movement will continue in the future. Therefore it is projected that the representivity of the typical dairy farm will continue to decrease while the static and developer dairy farms become more representative.

**Figure 2: Changing Representivity of Cattle Clusters**

Figure 2 shows the observed movements from 1992 to 1996. Through the analysis it is assumed that the same rate of movement will continue in the future. Therefore it is projected that the representivity of farms with off farm employment will increase. By 2004 it is projected that over 60% of all cattle farmers in Ireland will have off-farm employment. As this analysis is based on a balanced panel data set it only includes farmers that remained in farming. As yet there is no provision made in the methodology for calculating or projecting exits from farming. In addition to this, projected changes are based on those occurring in the 1992-1996 period. Projections do not take account of the state of the future economic climate to the extent that future growth rates are projected to exceed those between 1992 and 1996. The dramatic increase in the growth of the overall economy means that these projections are likely to be conservative.

### 2.3 Model Construction

A multi-period LP model was constructed for each representative cluster. The arithmetic mean farm was used as the representative for each group; this is less complicated at the weighting stage than using a median farm (Hazell & Norton 1986). The majority of the data required to construct the models were derived from the farm survey, although it was necessary to include some macro-economic data from other sources. All the models were multi-period and covered 10 years. All activities that currently existed on the farms were included in the model and all likely activity options open to the farm were also included. Some of the main activities were dairying, heifer rearing on a one and two year system, cattle rearing of weanlings, stores or finishers, sheep, renting/letting land and milk quota, borrowing money, hiring labour and working off the farm. The resource constraints included, land, labour, milk quota, access to capital, livestock housing and milking facilities, living expenses and fixed costs.

### 2.4 Calibration

As LP is normative it indicates the optimal strategy for a profit maximising farmer only, it does not project actual farm strategy. There are two reasons why the optimal strategy may not replicate the actual one. The first is a methodological issue and the other a farmer-specific issue. The LP model assumes perfect certainty within the projection period with regard to prices, policies, etc. It also assumes instantaneous response to new situations. As certainty and
instantaneous response may not actually exist the optimal outcome may not mirror the actual. The farmer-specific problem relates to the willingness and ability of the farmer to implement change. Fleming (1998) identified reasons such as multiple goals, aversion to risk, lack of education and others, as reasons why farmers may not be willing/able to implement change. Many of the reasons he identified can be quantified in the model. However, others can not and therefore the actual response to a policy scenario may not be the optimal one identified by the model. This inability to reach the optimal is termed the 'response deficit factor'. Through historical validation of the model it is possible to regress the actual position of the farm against the optimal. Therefore the magnitude of the response deficit factor can be determined and projected into the future. Based on this the future optimal outcome can be deflated by the response deficit factor as a performance correction tool. This will enhance the postiveness of the projection capabilities of LP. While the magnitude of the response deficit can vary over time, the degree of variation is likely to be closely linked to the type of farm. Hence much of the change will be captured by the changing distribution of farms amongst clusters.

3 Agenda 2000

The reform of the CAP in May 1992 represented a significant shift away from price support for producers in favour of direct income support. Agenda 2000, the 1999 reform of the CAP is aimed at distancing agricultural policy even further from price support and increasing income support. The main changes agreed in prices and policies as a result of Agenda 2000 will be summarised. Following this, FAPRI-Ireland's analysis of the agreement will be presented.

In relation to dairying price reductions and compensation will not be implemented until 2005. Intervention prices for butter and skimmed milk powder will be reduced by 5% annually, in 2005, 2006 and 2007 respectively. Compensation on a per litre basis will be paid to offset price reductions. Compensation will be 0.68, 1.35 and 2.01 pence per litre in 2005, 2006 and 2007 respectively. An increase in the Irish milk quota has been secured amounting to 2.86%, this will be allocated by 2002.

Support prices for beef will be reduced by 20% by 2003. Direct payments will be introduced or enlarged to compensate for this price cut. The existing suckler-cow and special beef premia have been increased and a new slaughter premium has been agreed. Premia for extensification will be increased significantly and the conditions for qualification changed.

Although there are few cereal farms in Ireland, cereals are indirectly significant to the majority of Irish farmers through feed prices. Under Agenda 2000 intervention prices for cereals will be reduced by 15% over 2000 and 2001. Compensatory payments shall be increased by 16% to offset the reduction.

3.1 Econometric Analysis of Agenda 2000

FAPRI-Ireland has developed sectoral econometric models to simulate the behaviour of the main components of agricultural output in Ireland, under different policy scenarios. The text below outlines the FAPRI-Ireland analysis of the implications of Agenda 2000.

Under the terms of Agenda 2000, in 2001 and 2002 quota increases lead to a modest reduction in Irish producer milk prices of the order of 2% from 1998 levels. Further, more substantial, reductions in the Irish milk price occur from 2005/06 as the impact of increased quota and lower intervention prices feeds through to farm level milk prices. By 2007, the Irish milk price is projected to decline to 89p or 15% below its 1998 level (Binfield, Donnellan, & McQuinn, 2000).

Recent years have seen the gap between EU and Irish cattle prices grow. Falling prices at the EU level are reflected in the Irish market. The Irish price is projected to stabilise around 14 per cent below the 1998 level from 2002.
The main changes of concern in the cereals sector are the resultant effects on feed prices. Changes are projected in input prices due to cheaper compounds. Dairy and beef meal prices are due to fall by 2% by 2007.

4 Results
The results of just two of the representative farms are presented. The typical dairy farm and the moderate cattle farm. The results emanating from the model, i.e. dynamic results are graphed against a static situation. The static situation is a representation of what farm net margin would be if there were no farmer response to policy change. Figure 3 shows the results for the typical dairy farm. In a no response scenario farm net margin falls by approximately 20% from 1996 to 2007, in nominal terms. Through response it is possible to increase long-term farm net margin.

Figure 3: Typical Dairy Farm: Farm Net Margin and Cash Flow

Conditions governing the transfer of milk quota have been greatly deregulated in the Irish market. It is projected that this farm will avail of these new regulations and purchase the 27000 litres that are currently leased along with an additional 18000 litres. In the years 1999 and 2000 this has a negative impact on the farm net margin because of the associated investment. The purchase of quota and investment in housing requires a loan of £11000, which is repaid over 7 years.

Farm net margin recovers dramatically following 2000. However, as a large investment has been made, it may be more realistic to consider farm cash flow rather than margin. From 1996 to 2007 this farm increases total quota owned by 30% and total quota farmed by 15%. As a consequence of this increase in quota, farm net margin increases by 30% in nominal terms and 11% in real terms. To put this increase in context, farm net margin in 2007 is 10% above the average cost of rural living in that year.

For the moderate cattle farm, net margin falls by approximately 25% in nominal terms from 1996 to 2007 if there is no farmer response. The option of off farm employment is not a viable one for this farm because of the age profile. Fifty per cent of farmers represented by this group are over 60 years of age. Therefore it is projected that this farm will continue full-time farming.
When the farm responds to this new situation, it is possible to maintain margins over the period. In the base year, this farm has a stocking rate of less than 1.4 livestock units per hectare. Thus, it qualifies for the higher rate of extensification in both scenarios. It is projected that from 1996 to 1999 such a farm will reduce the number of non-premia eligible animals.

Post 2000, farm net margin increases marginally to 2004 as indicated in figure 4 due to the increasing value of premia especially extensification. Following 2004 margins begin to diminish marginally this is due to the stagnant value of premia while the product price continues to fall.

In 1996 this farm represented 28300 farms nationally. However, such a response is not projected for 28300 farms. Through a Markov analysis of the samples used it can be projected that the number of farms represented will decrease by approximately 60%. Therefore it is possible through the model to project the likely response of 11600 cattle farmers in Ireland.

5 Conclusions
This paper describes a modelling process, which estimates the effects of a policy change at both macro and micro levels. At the micro level, which is the focus of this paper, the effects of Agenda 2000 on different types of Irish farms are analysed and the likely farmer response is projected.

The results presented here should be regarded as an illustrative example of the methodology that is currently being developed by the FAPRI-Ireland Partnership for the analysis of agricultural policy scenarios. The example that was presented here is an analysis of Agenda 2000. However this methodology can be used to examine many different agricultural policy scenarios, for example modulation, effect of environmental regulations and reduced income support to mention a few. The potential effects of a policy scenario can be estimated for agricultural markets, farm incomes and inter-related industries. Such comprehensive knowledge is of great use to policy-makers, as it provides a quantitative basis for comparing the outcome of alternative policy options.
References


A Sector Consistent Farm Group Model for German Agriculture

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Abstract
This paper describes the development of a farm group model (FARMIS) which aims at enabling a sector-consistent policy impact analysis of the German agricultural sector at the farm level. To this end, an improved aggregation scheme is developed, allowing an almost complete coverage of German agriculture by representative farm groups. The structure and definitions of FARMIS are as far as possible identical to the regional agricultural sector model RAUMIS, facilitating a parallel use and the interpretation of results. First assessments of policy impacts yielded very similar sectoral results for both models, allowing the complementary interpretation of policy effects differentiated by regions and farm types. Using FADN data from the EU network, the farm group model could be extended to other member states of the European Union.

Keywords: Farm Group Model, Aggregation

1 Introduction
Agricultural and environmental policy changes often tend to include a combination of several market related policy instruments and whole sets of specific command and control measures focussing on regional or farm structural characteristics. Moreover, policy makers want to know the probable impacts of policy changes on the markets, on the allocation of production, on income and income distribution as well as on budget expenditure and perhaps even on economic welfare. Unique economic models complying with all these questions are not available. Therefore, model-based policy impact assessment has often been restricted to either market or regional or farm aspects. By limiting the models and the scenarios to some narrowly defined segments of economic reality, however, essential interdependencies sometimes get out of sight. Inconsistencies and quantitative differences of model results may be due to a variety of factors, e.g. differences in databases, methodological approaches and aggregation levels, and significantly complicate not only explanation and interpretation of the differences in model outcomes, but especially the communication to policy makers.

To overcome these problems a system of complementary models has been established at the FAL. It takes into account different decision levels and allows larger flexibility at both regional and farm levels while also observing a certain market equilibrium. The regional and sectoral analysis is based on the agricultural sector model RAUMIS. As a programming model being regionalised on county level it is not able to represent the variance of the different farms in each region, and a considerable aggregation error due to the regional modelling approach might occur. Nevertheless, results of the farm models currently used at
the FAL (BEMO and TIPI-CAL) cannot be extrapolated to the agricultural sector due to a lack of representativeness. The development of the farm group model (FARMIS) carried out during the last years by Jacobs (1998) and Schleef (1999) therefore had two objectives:

- to improve the representativeness of farm data to establish a farm model for complementary use to RAUMIS
- to as far as possible ensure identical model structure and definitions to enable a parallel use of the models, such that differences in results can largely be ascribed to the different levels of aggregations, thus permitting an assessment of the extent of the aggregation error and facilitating interpretation.

This paper provides an insight into the determination of aggregation coefficients for a more representative projection, the calculation of input-output coefficients being consistent with farm accounts, the optimisation and aggregation modules, and documents an example of recent parallel model applications for policy assessment.

## 2 Main components of the farm group model

### 2.1 Structure of the model

The farm group model has been developed during the last years by Jacobs (1998) and Schleef (1999). Like RAUMIS, FARMIS is a partial supply model, which represents the major part of the German agricultural sector. It is structured in a similar way to RAUMIS in order to facilitate the parallel use and the comparison of results of both models. The model includes three main components: a basic data system, a process analysis system and a presentation system. Within the **basic data system**, improved aggregation factors for farms of the FADN (farm accountancy data network) are calculated regarding indicators for income, land use and livestock. Data from different sources is used to derive complete input-output-tables of agricultural production (see chapter 2.2 and 2.3). The **process analysis system** including an optimisation model enables ex-ante simulations for different farm groups. The analysis comprises agricultural production, input use, farm income and environmental indicators. For the calibration of the base year situation, the simulation of a future baseline and alternative policy scenarios, a positive quadratic programming (PQP) approach is used (see chapter 2.4). The **presentation system** transforms the output of the optimisation model into clearly arranged graphs and tables, which afterwards can be discussed with policy makers and experts. During this discussion process, assumptions can be modified recursively in order to integrate expert knowledge and to satisfy the actual information demand of policy makers (Henrichsmeyer, 1994).

### 2.2 Database, calculation of improved aggregation factors and sample stratification

In co-operation with the German Ministry of Agriculture, national FADN data were placed at the disposal of the FAL for the underlying modelling approach. FADN data of two years is used as the main database. In a first step improved aggregation factors for the farms included in the network are calculated. Currently, in the national and EU FADN a so-called simple aggregation scheme is used to aggregate farm individual data to the sectoral account. The weighting factors for each sample farm are based on the number of sample farms within the socio-economic farm groups defined by region (German Laender), farm type, and standard farm income. A projection applying ‘simple’ aggregation factors results in significant deviations from the statistical frame data with respect to land use and livestock numbers (see Figure 1). This method is rather well suited to represent standard farm income and thus for
agricultural policy measures oriented towards farm income, but it has some deficiency to represent the levels of land use, animal stock and quantities of products.

To solve this problem, an improved aggregation scheme has been developed by Jacobs (1998), based on an approach described by Merz (1983). The object is to find new aggregation factors that are consistent with the statistical frame data, and which are still closely related to the ‘simple’ aggregation factors applied within the existing FADN. The chosen estimation method minimises the cross-entropy (as a measure of informational distance) between the new aggregation factors and the prior information supplied by the 'simple' aggregation factors, subject to the restriction that the resulting aggregated figures for twelve important variables (e.g. land use and livestock numbers) come close to the known totals. From a statistical point of view, reweighting the sample farms has the same effect as an additional stratification (Rothe and Wiedenbeck 1987).

The model is specified as follows:

\[
\min Z = \sum_{j=1}^{k} a_j \ln \frac{a_j}{b_j} \quad 0 < a_j < n, \quad 0 < b_j < n, \quad \sum_{j=1}^{k} a_j = \sum_{j=1}^{k} b_j = n, \quad (1)
\]

where

- \( a_j \) = new consistent aggregation factor of farm \( j \) (\( j = 1, \ldots, k \)),
- \( b_j \) = prior aggregation factor of farm \( j \),
- \( k \) = number of sample farms,
- \( n \) = total number of farms,

subject to:

\[
r^*(1-e) \leq S^*a \leq r^*(1+e) \quad (2)
\]

where

- \( S_{(m,k)} \) = \( (s_{ij}) \) matrix of farm specific characteristics \( i \) (\( i = 1, \ldots, m \)),
- \( a \) = \( (a_1, \ldots, a_k) \) vector of consistent aggregation factors,
- \( r \) = \( (r_1, \ldots, r_m) \) vector of the sum of farm specific characteristics of the total number of farms from the Federal Statistical Office (known totals),
- \( e \) = \( (e_1, \ldots, e_m) \) vector of factors to allow some deviation from the known totals

Aggregation factors are determined for individual farms. Individual ranges (vector \( e \)) assigned to each restriction ensure the practical feasibility of the model and help in avoiding extreme reweighting which may occur when requiring exact matches for all variables. The adjusted aggregation factors are used to build up farm groups.

Figure 1 shows that with the consistent aggregation scheme, the number of farms, land use, pigs and dairy cows are represented rather well in the German Laender (SH – TH). Deviations in most of the Laender are in between \( \pm 5 \% \). Larger deviations occur for Saarland (SL), where farms had to be aggregated together with neighbouring regions due to the small number of sample farms. Compared to this, the ‘simple’ aggregation scheme shows deviations from the base in the range of \( \pm 30 \% \) (and more) for sugar beet area and the number of dairy cows. Industrial crops are under-represented, while the total of land use seems to be over-represented.

1 A drawback is that the statistical database used as framework for the optimisation of aggregation factors excludes small farms of less than 5000 DM standard farm income, as well as farms run by legal persons in western Germany. Hence, strictly speaking, it is not possible to represent the whole agricultural sector even with an improved aggregation method.
From this follows that the consistent aggregation scheme allows a better representation of land use and animal production than the actually used system. It can also be concluded that total production, inputs and subsidies are represented much better than with the simple aggregation scheme. In accordance with the statistic frame data used for the estimation of improved aggregation coefficients, the standard stratification criteria for the establishment of farm groups are the German Laender (NUTS I level), farm type and standard farm income. Farm size in hectare has also been used.
Other criteria can be applied depending on the specific policy to be analysed. As an example, for the analysis of policies for nitrate surplus reduction, Schleef (1999) used stocking rates - as an indicator for manure production per hectare - for the determination of farm groups. In this way, homogeneous farm groups were generated for the simulation of measures linked to the amount of organic nitrogen output on the farm level.

The use of farm groups instead of single farms in FARMIS allows a better manageability. Other reasons are confidentiality of individual farm data and the reduction of errors in the accounting data. Due to such errors, the use of single farm data would result in a high variance of estimated input-output coefficients between the farms. The impact of data errors is reduced by using average data of two years and the aggregation of single farm data to groups of similar farms.

2.3 Generation of consistent matrix coefficients

For the definition of production processes, farm group specific input-output coefficients are calculated. Aim of this procedure is to provide input-output coefficients which are consistent with the farm accounts of the respective farm group. For the base situation, the extent of different agricultural processes, physical yields as well as the corresponding prices are in most cases available from the farm accounts. The intermediate use of young stock (e.g. heifers, calves, piglets) within a particular farm group is estimated by the help of simple balance calculations.

For the estimation of the use of input factors like fertiliser, feed, machinery etc., a normative approach is used in the first step. Based on information from farm management handbooks, the use of input factors of each process is determined either in relation to yields (e.g. input of feed or fertiliser) or in relation to structural characteristics (e.g. use of machinery). In a second step these normative input coefficients are adjusted according to corresponding monetary accounts in the accounting data of the respective farm group. If physical units are used in the model, like in the case of feed and fertiliser, reasonable prices have to be assumed to ensure the consistency among physical input coefficients and the monetary account provided by the book keeping data.

For example, the crop specific fertiliser use is determined on the base of assumed fertiliser prices and in accordance with accounting data like yields, manure supply, and expenses for fertiliser. As an exception, labour input coefficients of the production processes are calculated on the basis of normative farm management handbooks, taking into account farm group specific characteristics like field or herd sizes. The calculated labour input is not adjusted to labour capacities mentioned in the accounting data.

2.4 Optimisation and output generation

The core of FARMIS is a standard optimisation matrix, which contains 27 activities of crop and 15 activities of livestock production. The definition of processes and the design of the optimisation matrix is based on the methodology used in RAUMIS. Differences between RAUMIS and FARMIS arise as a result of the different data basis. FARMIS offers better possibilities to specify restrictions at farm level than it is possible within the regional approach. Therefore, the optimisation matrix of FARMIS is slightly different to RAUMIS.

Based on the consistent input-output coefficient matrix of agricultural production, a clearly arranged method of income calculation is conducted in the model (Jacobs, 1998). The net value added (farm income) is the relevant income indicator. From this, the costs of fixed factors, irrespective whether they are in the ownership of the farmer or not, have to be covered. For the objective function of FARMIS, farm income minus opportunity cost for labour and the interest on borrowed capital is used.
For optimisation, a positive quadratic programming procedure is used to calibrate the model for the base year in accordance with the ‘real world’ in the base situation. Further model development is planned in order to avoid distortions of the elasticity of supply due to the non-linear terms.

The policy simulation process (ex ante analysis) usually proceeds in two steps. In the first step a reference scenario is created for a target year in the future, assuming that the present agricultural policy will continue. Furthermore, estimates on structural changes and technical progress are used as external model input. In a second step, alternative policy measures are specified, e.g. through additional activities and restrictions or changes of matrix coefficients. The outcome of the optimisation can be compared to the result of the reference scenario and allows to derive statements on the impacts of different policy measures. The definitions of reference and alternative policy scenarios as well as assumptions are harmonised with those used in other models of the FAL working group, especially with those applied in RAUMIS. Furthermore, FARMIS output can be specified by farm classes and thus enables deeper insights into the impacts of the studied policy measures. By this way the results of the regional model are complemented.

3 First experiences with parallel model applications

First applications of the model were realised for the assessment of a reform of the arable and dairy regime (Jacobs 1998), in the area of agri-environmental policies (Schleef, 1999) and of Agenda 2000 (Kleinhanss et al, 1998). In the following, some experiences of the parallel and complementary use of FARMIS together with the regional sector model RAUMIS are described.

Schleef (1999) analysed the average agricultural nitrogen surplus per hectare in Western Germany with the farm group model. The results were similar to those calculated by Weingarten (1996) on the basis of RAUMIS. With regard to the sectoral own-price elasticity of mineral nitrogen fertiliser, Schleef came to similar results with FARMIS like Weingarten with RAUMIS. The average own-price elasticity determined with FARMIS varies between -0.38 and -0.31, while the elasticity calculated with RAUMIS was -0.28 to -0.26. The disaggregation by farm type in FARMIS obviously leads to higher adjustments and thus to a higher own-price elasticity of nitrogen fertilisers. Schleef was able to analyse impacts differentiated by farm types and stocking rates and stressed the respective effects within the different farm groups, e.g. regarding the reduction of nitrogen surplus or farm income loss.

The parallel implementation of FARMIS and RAUMIS for policy analysis showed a comparable output, e.g. for the reduction of transfer payments (Jacobs 1998) or the Agenda 2000 proposal (Kleinhanss et al, 1998). Due to the different data basis of the models, either at farm or regional level, relative income changes are not directly comparable. In FARMIS, vegetables, permanent crops and poultry production are underrepresented, although they are important for income generation. On the other hand, a comparison based on absolute income changes estimated with FARMIS and RAUMIS showed a considerable equivalence (see table 1).
Table 1: Comparison of model results of RAUMIS and FARMIS for Western Germany

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Difference between reference and Agenda 2000 ¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>RAUMIS (Western Laender)</td>
</tr>
<tr>
<td>Aggregation level / Farm type</td>
<td></td>
</tr>
<tr>
<td>Improved aggregation factor</td>
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<tr>
<td>Land use (ha)</td>
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<td>Cereals</td>
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<td>Oil seed</td>
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<tr>
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<tr>
<td>Grandes Cultures 2)</td>
<td>4.9</td>
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<tr>
<td>Crop and animal production (output)</td>
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<tr>
<td>Cereals</td>
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<tr>
<td>Oil seed</td>
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<td>Pork</td>
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<tr>
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<td>Transfer payments</td>
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<tr>
<td>Net value added (farm income)</td>
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<tr>
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<tr>
<td>Transfer payments Mio. DM</td>
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<tr>
<td>Net value added (farm income) Mio. DM</td>
<td>-957</td>
</tr>
</tbody>
</table>

¹) Agenda 2000 proposal, March 1998
2) Cereals, oil seeds, protein crops, maize.
Source: Own calculations with RAUMIS and FARMIS

The generation of similar results allows the complementary interpretation of impacts both on regional and farm group level. In general, FARMIS tends to more pronounced adaptations due to a higher variability of input-output coefficients and restrictions between the different farm groups. Furthermore, FARMIS can be applied for the modelling of measures targeted at the characteristics of individual farms which cannot be modelled with a regional approach. For example, during the discussion of Agenda 2000 farm individual ceilings for transfer payments per farm were considered. These ceilings were modelled with FARMIS especially for Eastern Germany, providing a valuable complement to the results of RAUMIS.

### 4 Conclusions

The farm group model aims at policy assessment at farm level. Depending on policy measures rather homogeneous farm groups are built up. Consistent input-output coefficients and an improved aggregation scheme allow sectoral aggregations of results and a parallel use with the regional model RAUMIS. The model can be applied for quantitative policy assessments with a differentiation by farm types. This allows a complementary use to the regional model RAUMIS. First applications show that FARMIS came out with promising results.

Currently, the model is adapted to the new farm account introduced in 1995/96. An improved database for Eastern Germany is included, too. Up to now the model can only be
used for Germany. After a period of further model development and evaluation we hope to find partners in other countries interested in the FARMIS approach. Using FADN data from the EU network, the farm group model could be extended to other member states of the European Union.

References


The Effects of Alternative Direct Payment Regimes on Ecological and Socio-Economic Indicators: Results of a Spatial Linear Programming Model for a Swiss Alpine Region

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Abstract
Differences in land productivity, input and technology requirements and production costs are functions of topographic, climatic, environmental, agronomic and infrastructural characteristics which lead to considerable variations in land use intensity. Land use also offers obvious examples of spatial environmental externalities. Policy makers concerned with regional rural development are facing an increasing need for indicators encompassing a wide diversity of attributes and environmental assets in a spatial setting. In this paper, a spatial linear programming model is described and implemented for one Swiss Alpine region. The effects of different policy assumptions for land use payments are investigated. Special reference is made to the effects of different types of direct payments on the amount of fallow land in various topographic situations. It can be shown that the ecological effectiveness can be improved by giving due consideration to spatial aspects when designing agricultural policy measures with lower costs for the tax payer.

Keywords: Land-use modelling, Linear Programming, Multi-criteria Analysis, Agricultural Policy, Direct Payments, Spatial Analysis, Scenarios, Indicators

1 Introduction
Policy makers and stakeholders concerned with regional rural land use and development find themselves facing an ever-increasing need for instruments that can improve transparency in the policy debate and enhance understanding of opportunities and limitations for development (Bouman et al., 1999). The complexity of land use requires different approaches combining the experience and methodological approaches of various disciplines. Different disciplinary contributions can be integrated with the help of multi-criteria analysis (MCA). MCA has evolved from a mechanism for the selection of the best alternative from a set of competing options to become a range of decision aid techniques (Beinat and Nijkamp, 1998). A number of land use models have been developed in the last decade based on a combination of methods of system analysis and multi-criteria and multi-objective decision models, respectively. Scenario-based programming approaches is one method which is frequently applied. De Wit et al. (1988), for example, employ multiple goal programming for regional analysis and planning of regional agricultural development. This methodology permits scenarios to be drawn up, in which biophysical, technical and economic information on potential or improved land use are combined with various objectives derived from different policy views. A common characteristic of such models is that they aim at the quantification of biophysical and economic trade-offs. Kruseman and Bade (1998), for instance, propose a bio-economic modelling framework for the assessment of the effectiveness of different agrarian policies to improve farm household income and soil fertility based on the functional combination of (1) an agricultural household model; (2) a multiple goal linear programming model; and (3) a
partial equilibrium model. Cesaro (1995) uses a Weighted Goal Programming Model for the simulation of the consequences of alternative scenarios of CAP reform in a mountain area in north-eastern Italy on land-use patterns and the economic performance of the agricultural sector. Ridgley and Heil (1998) design buffer zones around protected areas (Mexico’s Izta-Popo national park) under different scenarios combining Lexicographic Goal Programming and Geographic Information System (GIS). Tiwari et al. (1999) apply Compromise Programming to determine trade-offs between ecological and economic goals in an irrigation project in the Northern Plains of Thailand. A GIS has been used to integrate spatial aspects in the analysis. Bouman et al. (1999) and Zander and Kächele (1999) combine technical coefficient generators, a linear programming model and a GIS to quantify trade-offs among socio-economic, agronomic and environmental indicators at the field level. The widespread use of GIS illustrates the fact that nowadays spatial aspects receive a considerable amount of attention in regional land use planning.

Land use also offers obvious examples of spatial environmental externalities, which in many cases may be biased in favour of specific environmentally non-benign activities (Beinat and Nijkamp, 1998). The negative effects of land exploitation are manifested in soil erosion, loss of habitats, increased vulnerability of soils and loss of natural amenities. On the other hand, appropriate land use activities prevent the emergence of these negative externalities. There is no uni-dimensional denominator which can be used to assess and evaluate land-use changes and policies. There are many complex linkages between the economy, the social sphere and the environment in which land use and space act as vehicles for transmitting externalities. Consequently, there is a need for a clear formulation of indicators encompassing a wide diversity of attributes and environmental assets in a spatial setting. This is particularly true when there is a wide degree of divergence between topographic, climatic, environmental and agronomic and infrastructural characteristics. To a large extent, differences in land productivity, input and technology requirements and production costs are functions of these characteristics and lead to considerable variations in land use intensity: production sites with good access and high productivity are often used in an ecologically unsustainable way, in the sense that, for instance, an excessive amount of fertiliser is applied. In contrast, remote areas with high transportation costs, areas with difficult access for machines or low productivity may be laid fallow. These types of spatial aspects are particularly pronounced in mountain regions where, for example, fallow land may cause negative external effects such as increased danger of avalanches or soil erosion on steep slopes.

In this paper, a land use model is described for the Swiss Alpine area. It gives due consideration to the type of spatial aspects described before. The purpose and structure of a spatial linear programming model are described in the following section. The model is implemented for one Swiss Alpine region. The effects of different policy assumptions for direct payments are investigated in Section 3. Special reference is made to the effects of different types of direct payments on the amount of fallow land in various topographic situations. Conclusions are drawn and an outlook is presented in the last section. One principal conclusion drawn from the model calculations reveals that the ecological effectiveness (reduction of fallow land on steep slopes) can be improved by giving due consideration to spatial aspects when designing agricultural policy measures with, at the same time, lower costs for the tax payer.

2 Purpose and description of the model

The model described in this section is developed within the scope of the multidisciplinary research project ‘PRIMALP — Sustainable primary production in the Alpine region’ at ETH Zurich (see www.primalp.ethz.ch). Production methods and policy concepts for sustainable
land use in agriculture and forestry in the Swiss Alpine region are developed via an association of engineering with natural sciences, social sciences and humanities (Gotsch et al., 1999). A synthesis of the results is structured, formalised and communicated with the aid of a multiple goal linear programming model. The individual projects of PRIMALP provide important contributions to the model. Model results and policy recommendations are communicated to the policy decision-makers.

Trade-offs among socio-economic and ecological indicators are included in the model. Since the relevance of the same indicator varies at different spatial scales, three separate levels of aggregation are included in the model: farm, sub-regions as an aggregate of characteristic farms, the overall Swiss Alpine region as an aggregate of sub-regions. Table 1 presents selected indicators for these three levels which are included in the model (some of them are the result of specific PRIMALP projects and will therefore be implemented in the model at a later stages). The model includes five different farm types cultivating grassland for different types of cattle (milk or nursing cows, beef or calf production, cattle rearing) and sheep. Full-time and part time farms are included with two different types of barn each. The area available can be used by various types of grassland at two different levels of intensity. The model includes the following spatial information from different geographic information systems and statistical databases:

- Subdivision of the overall model region (Swiss Alpine region) into 48 sub-regions based on the legislation governing regional investment aid. These sub-regions belong to six different types of regions according to regional economic structure — contribution of the three sectors to overall sectoral income, commuter balance and according to their economic power (see Bätzing et al., 1995).
- Agricultural land and forest land available in each sub-region subdivided into six altitude levels (<600 m, 600-1800 m in steps of 300 m, >1800 m above sea level) and in four categories of slope (<16%, 16-32%, 32-51%, >51%) in a per-hectare grid (Bundesamt für Statistik, 1999).
- Distance of each hectare to the next road (Bundesamt für Landestopographie, 1999).

Table 1: Selected indicators included in the model at different levels of aggregation

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Farm Level of aggregation</th>
<th>Sub-region Level of aggregation</th>
<th>Alpine region Level of aggregation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ecological</strong></td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Nutrient balance (nitrogen and phosphorus)</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Amount of organic and mineral fertiliser applied</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Share of fallow land</td>
<td>x</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Greenhouse gas emissions (CO₂, CH₄, N₂O)</td>
<td>x</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td><strong>Social</strong></td>
<td>x</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Number of farms</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Number of labour force</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workload per worker</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Farm revenue per worker</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td><strong>Economic</strong></td>
<td></td>
<td>x</td>
<td>X</td>
</tr>
<tr>
<td>Opportunity for off-farm revenue</td>
<td></td>
<td>x</td>
<td>X</td>
</tr>
<tr>
<td>Factor revenue (labour)</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Farm revenue</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Sectoral revenue</td>
<td></td>
<td>x</td>
<td>X</td>
</tr>
</tbody>
</table>
• Physical yields for each hectare and for different land use activities (grassland, hay, silage, pasture) based on digital information of the cultivation suitability map (Bundesamt für Statistik, 1999) and on expert judgement obtained within the scope of specific sub-projects of PRIMALP.
• Input requirements (labour, mechanisation, fertiliser) are a function of land use activity (grassland, hay, silage, pasture) and topographic situation (altitude, slope).

Figure 1 illustrates an example of the implementation of spatial aspects of land use in the model. The figure is compiled from the statistical sources described above for one of the 48 sub-regions of the model, the region of Praettigau, Canton of Grisons. For each of the six altitudes above sea level, the figure depicts (a) the relative share of agricultural land in the total area of agricultural land (Area); (b) the relative share of the number of farms in the total number of farms (Farms); (c) the relative share of agricultural land belonging to the farms located at that specific altitude in the total of agricultural land (Farm area). A positive difference between the value for Farms and Farm area at a specific altitude signifies that the area of all farms located at that specific altitude is larger than the area of agricultural land available. This means that these farms use land at other altitudes. For example, between 900-1200 m, 26 percent of the agricultural land available in the overall sub-region is located at that particular level, whereas farms located at that altitude use 41 percent of the total agricultural land available. Hence, within the actual context of that specific sub-region, 15 percent of the area used by those farms located at that altitude is located at other levels. The model also grants farms the possibility to use land at altitudes which do not correspond to their actual locations, whereby the additional costs for overcoming distances and differences in altitude are taken into account during the optimisation process.

The model is implemented for two of the 48 sub-regions. Results for one sub-region (Praettigau, see preceding paragraph) are presented in the following sub-section.

Figure 1: Relative shares of farm area and agricultural land at different altitudes
3 Results

The validity of the model is evaluated in Section 3.1 comparing structural data for the sub-region with base-run model results. The effects of a variation in two different types of direct payments on the development of fallow land at different altitudes and different slope, the number of farms and sectoral revenue is discussed in Section 3.2.

3.1 Validity of the model

The first column of Table 2 (Actual) shows the values for structural variables of the sub-region Praettigau in the year 1996. Relative values for these variables (compared with Actual) resulting from model runs with different assumptions on opportunity costs for labour are depicted in the following three columns. Assuming no opportunity cost for labour (Labour 0) represents a short-term situation where farmers have no possibility to take up employment outside their farm business. In contrast, taking into account full opportunity cost for labour (Labour 100, corresponding to sFr. 19.15/hour) reflects a longer time horizon where farm labour becomes mobile. Labour 50 reflects an intermediate position. Prices, costs and policy measures correspond to the situation in 1999.

Comparison of the first and second columns of Table 2 shows that the model provides a reasonable reflection of the structural reality for the sub-region. Labour use is ten percent lower which can be explained by the fact that it is used more effectively in the model than in reality. There is no fallow land (Agricultural land=100) which is in keeping with the actual situation. The number of farms remains constant because no increase is allowed in the short term. More sheep exist in the model result which may be due to traditional barriers towards sheep production in that area.

Increasing the opportunity costs for labour results in plausible values of the structural variables both in direction and extent. Changes are more pronounced when opportunity costs for labour amount to 100 percent: labour input decreases to 76 percent; there is six percent fallow land; a considerable reduction in the number of sheep from 138 to 97 percent can be observed because steep, outlying areas — which are the areas preferred for sheep production — become fallow land when labour cost increases.

Table 2: Structural data for the sub-region Praettigau in 1996 (Actual) and model results under three different assumptions for labour opportunity costs (Labour 0: no opportunity costs for labour; Labour 100: full opportunity costs for labour (sFr. 19.15/hour); Labour 50: 50 percent of full opportunity costs for labour)

<table>
<thead>
<tr>
<th></th>
<th>Actual</th>
<th>Labour 0</th>
<th>Labour 50</th>
<th>Labour 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of standard labour units</td>
<td>1060</td>
<td>90</td>
<td>82</td>
<td>76</td>
</tr>
<tr>
<td>Agricultural land (hectares)</td>
<td>6372</td>
<td>100</td>
<td>100</td>
<td>94</td>
</tr>
<tr>
<td>Number of farms</td>
<td>606</td>
<td>100</td>
<td>93</td>
<td>88</td>
</tr>
<tr>
<td>Livestock units of cattle</td>
<td>7201</td>
<td>99</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>Livestock units of sheep</td>
<td>497</td>
<td>138</td>
<td>143</td>
<td>97</td>
</tr>
</tbody>
</table>
3.2 The effects of a variation in direct payments

All farmers in the Swiss Alpine region receive base payments of sFr. 1200.- per hectare. The motivation for these payments is, firstly, to ensure farmers’ income in view of decreasing commodity prices and, secondly, to reduce the immediate structural pressure resulting from the commitment taken by the Swiss government to liberalise agricultural markets within the scope of the GATT Uruguay Round. The political motivation behind these base payments is therefore essentially transitional and is designed to prevent structural change taking place too rapidly and causing an increase in fallow land and social hardship. In contrast, direct payments granted for the cultivation of steep slopes can be justified exclusively from the point of view of environmental policy: the cultivation of steep slopes has the character of a public good reducing the risk of avalanches and landslides through the prevention of fallow land.

Figure 2 serves as a basis for discussing the effects resulting from the elimination of base payments on the relative shares of fallow land at four different altitudes and on four categories of slope. The left side of the figure depicts the situation with base payments and slope payments (Table 3, assumption Actual). The right side gives the same information when only slope payments continue unchanged but base payments are no longer granted (assumption No base payments in Table 3). Full opportunity costs for labour are assumed in all the results discussed in this subsection. When base payments are granted, there is no fallow land below 1200 metres above sea level. At 1200-1500 metres above sea level, five percent of the agricultural land lies fallow (Fallow land). This share increases to twenty percent at altitudes over 1800m. Most fallow land accrues on the steepest slopes: land with a slope of over 51 percent is no longer cultivated above the 1500 metre mark. Mechanical harvesting of these steep slopes is not possible thus making their cultivation unprofitable when full opportunity costs for labour must be taken into account. Furthermore, the entire area above 1800 metres with a slope less than 16 percent is fallow land. This can be explained by the fact that no slope payments are granted for this slope category. Therefore, land use is uneconomic because physical yields are low at such a high altitude. When base payments are no longer granted (right side of Figure 2) the entire agricultural area in the steepest category lies fallow. This also applies at lower levels where no fallow land (900-1200 metres above sea level) or comparatively little fallow land existed before (1200-1500 metres above sea level).

Fallow land on very steep slopes is particularly hazardous from the point of view of avalanche and landslide prevention. The elimination of fallow land in these steep locations is a matter of public interest. By using a sensitivity analysis we identified the amount of slope payments necessary for the complete elimination of fallow on land with more than 51 percent slope. They increase from sFr. 1100.-/hectare for land at 900-1200 metres above sea level to sFr. 2600.-/hectare for land over 1800 metres above sea level (see Table 3, column Increasing slope payments). The corresponding payments for the two slope categories in between (1200-1500 and 1500-1800 metres above sea level) amount to sFr. 1500.- and sFr. 2100.- per hectare.

The effects of varying assumptions on direct payments on selected ecological and socio-economic indicators depicted in Table 1 are presented in Table 4. The first column (Labour 100) shows the results in absolute values for the situation with opportunity costs for labour as discussed in Section 3.1. The results depicted in the second and third columns of Table 4 (No base payment and Increasing slope payments) are obtained from model calculations assuming direct payments as presented in Table 3 under the identically named columns.
As discussed with the help of Figure 2, fallow land increases considerably when base payments are no longer forthcoming. This can be seen in the second column of Table 4 (No base payment) which shows that fallow land increases by approximately 450 percent under this assumption. When slope payments for the steepest category are increased as shown in the last column of Table 3 (Increasing slope payments) it can be seen from the identically named column of Table 4 that there is a considerable reduction in fallow land to 280 percent (with no more fallow land in the ecologically sensitive steepest slope category, which is the specific purpose of these payments). The taxpayer pays for the provision of this public good with an increase in the amount of direct payments from 19 percent to 31 percent. Only a minor proportion of these additional direct payments contributes to an increase in sectoral revenue which rises from 73 to 75 percent. The substantial share is absorbed by the remuneration of the additional (manual) labour needed for the cultivation of steep land. The need for this additional labour is reflected in an increase in the number of farms from 82 to 91 percent.

Table 3: Types of direct payments, their actual levels (Actual) and variations for the model calculations (No base payment and Increased slope payments)

<table>
<thead>
<tr>
<th>Type of payment</th>
<th>Assumption on direct payment category (sFr/hectare)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Actual</td>
</tr>
<tr>
<td>Base payments</td>
<td>1200</td>
</tr>
<tr>
<td>Slope payments &lt;16%</td>
<td>0</td>
</tr>
<tr>
<td>Slope payments 16-32%</td>
<td>370</td>
</tr>
<tr>
<td>Slope payments 32-51%</td>
<td>510</td>
</tr>
<tr>
<td>Slope payments &gt;51%</td>
<td>510</td>
</tr>
</tbody>
</table>

*) for explanations see text
Table 4: Effects of varying assumptions on direct payments on ecological and socio-economic indicators

<table>
<thead>
<tr>
<th>Assumption on direct payment category</th>
<th>Labour 100 (absolute)</th>
<th>No base payment</th>
<th>Increasing slope payments (percent of Labour 100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fallow land (hectares)</td>
<td>413</td>
<td>444</td>
<td>280</td>
</tr>
<tr>
<td>Direct payments (1000 sFr.) *)</td>
<td>9591</td>
<td>19</td>
<td>31</td>
</tr>
<tr>
<td>Sectoral revenue (1000 sFr.)</td>
<td>27945</td>
<td>73</td>
<td>75</td>
</tr>
<tr>
<td>Number of farms</td>
<td>531</td>
<td>82</td>
<td>91</td>
</tr>
</tbody>
</table>

*) Base payments and payments for steep slopes only

4 Conclusions and outlook

Policy decision-makers and stakeholders face a growing need for tools which facilitate the assessment and evaluation of different policy options on a range of policy objectives. The complexity of this task demands an amalgamation of the experience and methodological approaches of different disciplines. Various disciplinary contributions are integrated with the help of multi-criteria models. There are many complex linkages between the economy, the social sphere and the environment, in which land use and space act as the vehicles for transmitting externalities. This is particularly true when there is a wide degree of divergence between the topographic, climatic, environmental, agronomic and infrastructural characteristics as exhibited by mountain regions such as the Swiss Alpine area. In this paper, a land use model is described for this area and implemented for one sub-region. The effects of a range of policy assumptions for direct payments are investigated. Special reference is given to the consequences of alternative regimes of direct payments on the amount of fallow land in different topographic situations. One principal conclusion which can be drawn from the model calculations is that ecological effectiveness (reduction of fallow land on steep slopes) can be improved by giving due consideration to topographic aspects when designing agricultural policy measures with, at the same time, lower costs for the tax payer.

The model approach presented in this paper will be extended which allows the assessment and evaluation of agricultural policy measures on the sustainability of agriculture. For this purpose, three aspects will be taken into account in the future development of the model: (1) further indicators of sustainability will be incorporated; (2) dynamic aspects will be taken into account to allow the modelling of adjustment paths towards sustainability; (3) trade-offs among different indicators of sustainability will be assessed under varying policy scenarios. Furthermore, the model will be extended to the Swiss Alpine region as a whole. This will allow it to be used as a tool for the evaluation of alternative production systems and as a means for the development and communication of consistent concepts for a resource-efficient and sustainable agriculture and forestry in mountain regions within the scope of the integrated project PRIMALP.

References


The Swiss agricultural model SILAS – an example of quantitative decision support systems for policy makers

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Abstract
The Sector Information and Prognosis System for Swiss Agriculture (SILAS) serves as a decision support system (DSS) for policy measures introduced by the Swiss Federal Office for Agriculture. SILAS is a highly differentiated sector model which takes into account different regional conditions, thereby simulating and forecasting the impacts of different policy measures on agricultural production and income (re.: the economic agricultural accounting system (EAA)) as well as the environment and Federal expenditures for agriculture. SILAS is based on the regional farm concept and takes into special consideration environmental measures in plant and animal production. The supply model is calibrated by means of positive mathematical programming. Based upon the model SILAS a decision support system is implemented by means of the Object Manager Environment (OME) which combines Decision Support Objects (DSO) containing model and data modules.

Keywords: Decision Support System (DSS), Programming Model, Swiss Agriculture.

1 Introduction
A fundamental reform of Swiss agricultural policy was introduced at the beginning of the nineties. In order to steer and evaluate the reform, agro-political decision-makers demanded models and information systems to simulate the effects of alternative agro-political measures on the value added, the environment, and Federal expenditures for direct payments as well as price and market support. At the beginning of 1997, in order to meet these information requirements, the Swiss Federal Office for Agriculture (BLW) commissioned the Swiss Federal Research Station for Agricultural Economics and Engineering (FAT) with the development of a sectoral information and prognosis system for the Swiss agriculture (SILAS).

SILAS delivered first results for the Federal Council's financing address (1998) for the period from 2000 to 2003. The model is currently being developed further at the FAT, in cooperation with the Institute of Informatics of the University of Fribourg (IIUF), the goal consisting in defining a prognosis system which can be implemented and up-dated constantly.

2 The agricultural policy reform in Switzerland
From the Second World War up until the end of the eighties, Swiss agricultural policy focussed on ensuring food supply by introducing corresponding market measures. Since the beginning of the nineties, Swiss agricultural policy is in the process of being fundamentally reformed. This is largely due to the gradual liberalisation of agricultural trade as agreed upon with the WTO, the increasing price differences in comparison to foreign markets, the high costs of using surplus products as well as growing consumer interest in environmentally sound food production.
New agricultural policy, as in effect since 1993, stipulates distinguishing between price and income policy, implementing ecological measures thanks to direct payments, and loosening state interventions (Burger, 2000). Moreover, new direct payments which should serve to compensate for simultaneously reduced administrated prices were also introduced. At the same time, direct payments should also promote ecological production on a voluntary basis. As of 1999, only those farms able to furnish proof of their ecological endeavours will be entitled to receive direct payments.

Table 1: Federal expenditures for agriculture

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Expenditures in millions of CHF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Market support</td>
<td>1'626</td>
<td>1'152</td>
<td>787</td>
</tr>
<tr>
<td>Direct payments</td>
<td>870</td>
<td>2'126</td>
<td>2'419</td>
</tr>
<tr>
<td>Structural improvements</td>
<td>148</td>
<td>118</td>
<td>272</td>
</tr>
<tr>
<td>Total</td>
<td>2'644</td>
<td>3'396</td>
<td>3'478</td>
</tr>
</tbody>
</table>

In 1998, Federal expenditures for agriculture amounted to approx. 3.4 billion Swiss Francs (table 1, Burger, 2000). The total expenditures should remain about the same in the following years; whereas market support will be reduced and the amounts set aside will be used for direct payments.

Thanks to the incentives to encourage environmentally-sound agricultural production, in 1998, approx. 84% of the utilised agricultural area was cultivated according to ecological criteria (of which 7% comprised organic farming). Today, ecological compensation surfaces account for more than 8% of the utilised agricultural area. The use of plant crop protection agents has dropped by almost one fourth since 1993; the use of commercial fertilisers by approx. one third. 45% of all animals are kept in animal-friendly housing systems (Burger, 2000).

3 Policy-makers’ need for informations

For the duration of the reform in progress, agro-political decision-makers will remain highly interested in an information and prognosis system able to simulate the effects of different agro-political measures. The effects of Federal expenditures on agriculture, agricultural production and income as well as ecological impacts are of particular interest. Among the typical questions SILAS has been able to answer to date are the following:

- Simulation the effects of individual measures, e.g.:
  - The introduction of direct payments for roughage consuming animals (with the exception of dairy cows), combined with a restriction of the intensity of the usage of meadows, according to the different regional conditions.
  - The introduction of direct payments for ecological compensation surfaces in crop farming areas.

4 The Sector Model for Swiss Agriculture (SILAS)

SILAS is in course of being further developed by the FAT. In its methodology, it is based mainly on the RAUMIS (Heinrichsmeyer 1996) and the CAPRI models. In the following, we shall discuss certain model characteristics.
4.1 Model Overview

Basically, SILAS is a regionalised supply model for the Swiss agriculture. The regional differentiation corresponds to eight different zones according to which the majority of agro-political measures are categorised. All eight regions will be optimised simultaneously with due respect to the sectoral sales limitations of agricultural final products. The model simulates the Economic accounts for Agriculture (EAA) for a period of eight to ten years.

Regions may exchange young cattle and concentrates. The quantity and demand in other agricultural intermediate products (roughage, organic fertilisers) are assessed regionally because of their limited tradability.

The reform of Swiss agricultural policy is marked by a strong shift from ensuring agricultural income by means of market interventions towards making direct payments. The majority of direct payments are linked to product-engineering or ecological requirements. The specific requirements of the various direct payments have been defined within the scope of the supply model. To this effect, a detailed illustration of different forms of farming (conventional, integrated, organic), of crop rotation requirements, of nutrient balances and regulations governing fertilisation, of various plant protection strategies and of different types of ecological compensation surfaces (fallow land, lean meadows, hedges, etc.) has become necessary.

4.2 Plant production

37 cultures, that can be cultivated according to the different farming systems, were defined in the plant cultivation model (figure 1). Up to four different degrees of production intensity are possible within a farming system. The differentiation of farming systems and production intensities follow the conditions of direct payment programs.

Figure 1: Differentiation of plant production activities

Other combinations are possible, according to agronomic characteristics and geographical occurrence. The model illustrates 1046 plant production activities which differ according to input / output coefficients, direct payments, machine and labour costs as well as ecological restrictions.

4.3 Animal production

17 different animal species which can be kept in all regions were defined in this model (figure 2). Given the high prices of organically produced products, a distinction was made between animals kept on such farms and those housed on others. In addition, because of the relevance with regard to direct payments, the model distinguishes between animals allowed to exercise outdoors regularly and those kept in especially animal-friendly indoor housing systems. The model illustrates 272 activities with regard to animal production.
Within the scope of the model, the composition of feed rations is optimised according to the performance of the animals, to the consumption of dry matter as well as according to energy and protein requirements. This allows to take into consideration changes in animal performance and feed production intensities, in context with the use of concentrates. Furthermore, the differences in summer and winter feed were also taken into account.

The form and extent of farmyard manure is determined with due regard to the housing system. The interrelation between the nutrient requirements of the cultures, the amount of farm manure produced by the animals, and the purchase of additional manure is defined by means of regional nutrient balances. Only manure produced by animals kept on organically managed farms may be used for the production of organically cultivated plants. This principle also applies for feeding. Specific restrictions limit the use of fertilisers and prevent excess fertilisation according to the stipulations of various direct payment programs.

Figure 2: Differentiation of animal production activities

4.4 Technology module
Labour time requirements and machine costs for production activities are determined by means of the technology module. The FAT's Work Budget and its machine costs catalogue serve as the basis here. Due to a lack of corresponding statistics, the current state of agricultural engineering for each production activity is defined by experts. Labour time requirements of the production activities are reported over the course of eight periods; regionally, and according to family manpower available. This allows to determine manpower requirements.

In addition to the machine costs, the machine types and the extent to which they are used, the technology module also informs of fuel and lubricant consumption. Within the scope of the CAPRI project (FAIR3-CT96-1849), this model helped us to develop a partial model serving to record and determine the consumption of non-renewable forms of energy in agriculture (Fischer, 1999). In future, the technology model will also serve to establish life cycle assessments.

4.5 Positive mathematical programming
If the model results for the base years were to reflect the known statistical values, politicians and the authorities would most certainly be much more receptive to model calculations. Since 1996, the Federal Office for Statistics registers agricultural surface utilisation and livestock yearly. These statistics allow to determine plant and animal production activities for the base years most precisely. To date, within the scope of the model, the traditional method of positive mathematical programming according to Howitt (1995) was applied to determine the dual values of the production activities for the base years. These dual values serve to
transform the linear costs of the production activities into quadratic functions. In order to simulate the prognosis year, the marginal costs curves were shifted according to assumptions made with regard to cost development.

5 The Decision Support System (DSS-SILAS)

Based upon the model SILAS a decision support system (DSS) is being built at the IIUF by means of the 'Object Manager Environment' (OME). This environment was developed as well at the IIUF and serves to create domain specific DSS. It allows both a data driven bottom up setup and a design driven top down setup. The basic concept of OME consists in breaking down decision support into so-called Decision Support Objects (DSO), which have their individual functionality. By means of their correspondent DSO Managers the DSS user can easily create, customize, combine and apply such DSOs (Schroff, 1998, Hättenschwiler et al., 1998).

The DSS-SILAS is the fourth application being implemented with OME - the first one was the DSS-ESSA (Food Security Strategy of Switzerland). In fact, OME was developed in order to build, based upon ESSA, all the components of an interface, necessary for the DSS user - normally a decision assistant - to deal with the quite vast decision space in the food supply sector. From its beginning, OME had to meet the high demands of a complex DSS.

All data being input of the model is stored in one Facts base DSO. Such a DSO contains a complete set of statistical data, like crop areas and livestock, expert knowledge, e.g. yields, reproduction rates of animals, processing coefficients or various contents of feedingstuff (energy, protein, fat, etc.), and finally data referring to assumed evolutions of various parameters in the future. A Facts base DSO is created by means of the Data Manager, which calls the import routine of the fully integrated meta-database application. Once the data is imported, it has to be preprocessed in order to obtain a complete data set of a base year. This is done by evaluating several sub-models and includes the computation of all data necessary for the input of the PQP-model (dual values). It is one of the capabilities of a Facts base DSO to execute and control these processes.

Figure 3: DSS-SILAS: Data Manager

At least once a year the Facts base has to be updated. In order to maintain the reproducibility of former evaluations, an update is usually done on a newly created Facts base DSO. Figure 3
gives an overview of the DSS-SILAS, with its manager objects focusing on the open Data Manager folder, which contains two Facts base DSOs.

The data belonging to a Facts base DSO refers to the normal situation at a given date and will be output when starting an evaluation. In order to reflect an anomaly of this situation, whether an observed or a prognosticated one, this output will be overwritten. The user captures such an anomaly simply by creating a new Scenario DSO, selecting the respective data domain and its aggregation level, and finally specifying the Influence Factor DSO. He would normally specify influence factors, that refer to general deviations from the assumed evolution of a parameter, within a basic scenario, from which he can deduce variants of different scenarios reflecting specific deviations from the assumptions. The technique of basing one scenario on another one is also applicable and indicated when there is a need to group influence factors by themes, dates of observation or whatever. An example of such a hierarchical structure is shown in figure 4. The basic scenario ‘Pessimistic assumptions on prices’ consists of one influence factor (‘General price reductions of 30% until 2003’), which is inherited by the scenario ‘Assumptions on prices of cereals’. The latter has the additional influence factor ‘Price reductions for cereals of 25% until 2003’.

Figure 4: DSS-SILAS: Scenario Manager

The LP-model underlying SILAS is written in LPL - a model description language (Hürlimann, 1997) similar to the better known GAMS - and is hierarchically structured in sub-modules. By means of specific interfaces, which are addressed by Switch DSOs and set by the corresponding Option DSOs, they are alternatively selected.

In the same manner, objective functions can be packed into singular sub-modules, each of them consisting of the optimization, the computation of the relaxation, and the setting of the respective bounds. Thanks to this encapsulation, the objective functions can be combined in any sequence, which again is addressed by an interface. The user is free to determine his own sequence, depending on the priorities he gives the different goals.

Every Switch DSO consists of at least two Option DSOs, one of them being the default option. When creating a new Task DSO, all default options will be set. The user can then configure this task simply by selecting other options. In figure 5 two Task DSOs are shown, ‘Task 1’ having the default option ‘Labour module: active’ of the first Switch DSO and the
non-default option ‘Fertilization module: inactive’ of the second Switch DSO selected (different shapes of the icons). It is subject of future work to define and design further Switch DSOs in order to enhance the flexibility of the DSS-SILAS.

Figure 5: DSS-SILAS: Task Manager

Once an anomaly has been captured by a Scenario and a Task has been specified, these two DSOs will be combined together with a Facts Base DSO in order to create an Evaluation DSO. Such a DSO together with the selected Facts base, Scenario and Task DSOs is shown in figure 6.

Figure 6: DSS-SILAS: Evaluation Manager

By means of the Evaluation Manager, one can add several Exogenous Decision DSOs to this object, either by simply activating archived ones or by specifying new ones. A possible
exogenous decision in the context of the DSS-SILAS would be to set milk production quota in the different regions.

Before running an evaluation the DSS user has to select the base year and the year of the prognosis. The output of the model is automatically imported into the database of the Evaluation DSO.

The content of this DSO as well as the content of a Facts base DSO can be accessed either directly by an integrated OLAP-Tool (On-Line Analytical Processing) or by means of the Report Manager. The user has the possibility to create and design Report DSOs, which he can put into a hierarchical structure of folders (Category DSOs) belonging to the Report Manager.

Every DSO can be exchanged between DSS users by copying and pasting it into the Exchange Manager and transferring the whole Exchange Manager Object to the new location.

6 Further Developments

An earlier version of the supply model has already supported the federal budget process at the end of 1998 for the time period 2000 until 2003. During 1999 the supply model has been improved and the standard PMP-approach introduced.

The aim for the next year is to make the SILAS system operable by means of the new Object-Manager-environment. Including market models for different products (cereals, meat) will help to improve the simulation results in forecasted periods. The simulation behaviour of the model is effected by the PMP formulation too. Testing and discussing the simulation results obtained with experts and policy-makers will be a main task this year together with new formulations of the PMP approach.

A further step of the model development will be the use of life cycle assessments (LCA). For LCA’s detailed informations about the physical product-flows and all inputs for production are needed. Most of the informations are already included in the database and the technology-modul. The use of LCA will give an overall view of energy use, material flows and emissions in agriculture.

References

Analysing the Effects of Agenda 2000 Using a CES Calibrated Model of Belgian Agriculture

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Abstract

This paper models the agricultural sector in the agricultural loam region of Belgium and simulates the economic effects of the agricultural policy reform as set forth in Agenda 2000 using different calibration methods and production functions. To achieve exact calibration, the model uses, first, the standard positive mathematical programming approach to derive the underlying non-linear activity cost function and, second, a maximum entropy technique to recover the full set of parameters of the quadratic activity cost matrix. To allow for input substitution, a nested constant elasticity of substitution (CES) production function replaces the Leontief production function in the objective function. Compared with a reference scenario in 2005, the net farm income available for family labour and equity of the region falls by 12% under the modelling method that is the most flexible in terms of activity competitiveness and input substitution.

Keywords: Positive Mathematical Programming, Maximum Entropy, Constant Elasticity of Substitution, Agenda 2000, Belgium

1 Introduction

This paper combines different calibration methods and production function specifications to model the agricultural sector in the agricultural loam region of Belgium and simulate the economic effects of the agricultural policy reform as set forth in Agenda 2000. The positive mathematical programming (PMP) calibration method and the maximum entropy (ME) estimation used in this model are drawn from Howitt (1995a) and Paris and Howitt (1998). The introduction of a nested constant elasticity of substitution (CES) production function to allow for input substitution in the model is drawn from Howitt (1995b) and Edwards et al. (1996). Combinations of these modelling methods are evaluated and compared. The novelty of this study compared with the previous applications is combining the maximum entropy estimation with the PMP calibration method and the CES specification.

The agricultural sector model is calibrated according to 1995 farm and regional data and validated for 1997. A reference scenario is simulated with the policy parameters of 1995 and yield and price projections for 2005. The Agenda 2000 scenario with its intervention price cuts, compensatory payment increases, compulsory set-aside and livestock extensification premiums is then simulated for 2005. Differences in activity levels and yields and net regional farm incomes between the reference and Agenda 2000 scenarios are examined. The agricultural area of the Belgian loam region covers 24% of the country’s agricultural area. This area includes 7,000 commercial farms that are mainly involved in the production of cereals, sugar beets, potatoes, forage and silage crops as well as milk and bovine meat.

The next section reviews the PMP and ME methods used in this paper. Section 2 specifies the structure and the different modelling methods. Section 3 presents the results
from the simulation runs, interprets and compares them according to the different modelling methods. Section 4 concludes.

2 Calibration methods

The standard positive mathematical programming (PMP) method is first used to calibrate the agricultural sector model of the Belgian agricultural loam region. Applied to the supply side of farm models, the PMP method is able to achieve exact calibration of linear programming problems in activity levels by calculating either non-linear yield or non-linear cost functions (Howitt, 1995a). The parameters of these non-linear functions are derived from the allocation of fixed resources that is realised and observed for a reference period as a result of an implicit optimisation rule. Since these parameters are derived from observed data rather than normative assumptions, this calibration method is termed "positive". This method not only automatically and exactly calibrates the model to observed activity levels but also avoids adding ad-hoc constraints and over-specialised responses of the model to policy changes. This method has been used by many applied modellers on several policy models at the sectoral, regional and farm level (House, 1987; Kasnakoglu and Bauer, 1988; Bauer and Kasnakoglu, 1990; Hatchett, 1991; Horner et al., 1992; Rosen and Sexton, 1993).

The PMP calibration method adopted in this model infers a non-linear cost function for each production activity from the land and livestock allocation observed at the regional level during a reference period. The non-linearity of this activity cost function reflects increasing marginal costs due, for example, to decreasing land or livestock quality as the proportion of an activity in the region is increased. The method is articulated in three stages. In the first stage, calibration constraints are added to the initial base-year linear program to limit the solution of this program to the observed activity levels. In addition to dual values for the limiting allocable resources \( \lambda_1 \), this constrained program generates dual values \( \lambda_2 \) for each activity except for the marginal activity. These activity dual values \( \lambda_2 \) are viewed here as the components of the marginal costs attributed to heterogeneous land or livestock quality. Together with the activity accounting costs, they define the variable marginal costs of the activities. In the second stage, the activity dual values are used along with the base-year data set to derive the parameters of the non-linear total activity variable cost functions. A quadratic cost functional form is used here for simplicity. In the third stage, the derived cost parameters and the base-year data set are used to specify a PMP non-linear program that includes the original constraints except the calibration constraints. This calibrated non-linear model is consistent with the choice of the non-linear activity cost function derived in the second stage and exactly calibrates to the base-year solution. This calibrated model can be used for policy change simulations.

Formally, the calibration stages lead to the following model structure adapted from Howitt (1995a):

\[
\text{Maximise } \text{TNR} = p' y - \alpha' x - x'Qx / 2 \tag{1}
\]

subject to:
\[ A x \leq b \]
\[ y = f(x) \]
\[ x \geq [0] \]

\( \text{TNR} \) is the total net revenue, \( p \) is the \((n \times 1)\) vector of output prices, \( y \) is the \((n \times 1)\) non-negative vector of output levels, \( x \) is the \((n \times 1)\) non-negative vector of activity levels, \( \alpha \) is the \((n \times 1)\) vector of derived parameters associated with the linear term of the activity cost function, \( Q \) is the \((n \times n)\) symmetric positive semi-definite matrix of derived parameters \( \gamma_{ii} \) associated with the quadratic term of the activity cost function, \( A \) is the \((m \times n)\) matrix of
technical and policy coefficients in resource constraints and \( b \) is the \((m \times 1)\) vector of available resource levels.

Deriving the \( n(n+1)/2 \) parameters of the \( Q \) symmetric matrix from the \( n \) observations on the differential activity marginal costs \( \lambda_{2i} \) is, however, an ill-posed problem. One solution to this problem is to assume that the \( Q \) symmetric matrix is diagonal implying that the change in marginal cost of activity \( i \) with respect to the level of activity \( i' \) \((i' \neq i)\) is null. In this PMP specification, diagonal element \( \gamma_{ii'} \) of the \( Q \) matrix equals \( (2\lambda_{2i}/x_{oi}) \) and element \( \alpha_i \) of the \( \alpha \) vector equals \((c_i - \lambda_{2i})\) with \( \lambda_{2i}, x_{oi} \) and \( c_i \) being respectively the dual value, the observed level and the unit accounting cost of activity \( i \).

Another solution is to use the maximum entropy approach to recover all the \( n(n+1)/2 \) elements of the \( Q \) matrix as well as the Cholesky factorisation of this \( Q \) matrix to guarantee that the recovered \( Q \) matrix is symmetric positive semi-definite. After factorising \( Q \) in \((L \cdot D \cdot L')\) where \( L \) is a \((n \times n)\) unit lower triangular matrix and \( D \) is a \((n \times n)\) diagonal matrix with non-negative diagonal elements to guarantee a symmetric positive semi-definite \( Q \) matrix, the maximum entropy technique applied to the PMP calibration of our model consists in recovering the positive \( P_\alpha \), \( P_L \) and \( P_D \) probability vector and matrices with the following model structure adapted from Paris and Howitt (1998):

\[
\text{Maximise } H(P_\alpha, P_L, P_D) = \\
- \sum_{i,k} P_\alpha (i,k) \ln [P_\alpha (i,k)] - \sum_{i,j,k} P_L (i,i',k) \ln [P_L (i,i',k)] - \sum_{i,j,k} P_D (i,i',k) \ln [P_D (i,i',k)] \tag{2}
\]

being strictly concave in the unknown variables \( P_\alpha, P_L \) and \( P_D \), subject to:

\[
\sum_k P_\alpha (i,k) = 1 \quad \text{for } i = 1, \ldots, n
\]

\[
\sum_k P_L (i,i',k) = 1 \quad \text{for } i, i' = 1, \ldots, n
\]

\[
\sum_k P_D (i,i',k) = 1 \quad \text{for } i, i' = 1, \ldots, n
\]

with \( c_i \) the \((n \times 1)\) vector of accounting costs of the limiting resource \( l \) and \( \lambda_2 \) the \((n \times 1)\) vector of activity dual values. \( Z_\alpha, Z_L \) and \( Z_D \) are the known support-space vector and matrices for the probability distributions of the \( \alpha \) vector and the \( L \) and \( D \) matrices respectively with the elements of the \( \alpha \) vector centred around the likely \( \alpha_i \) value, the off-diagonal elements of the \( L \) matrix centred around the likely zero value and the diagonal elements of the \( D \) matrix centred around the likely \( \gamma_{ii'} \) value.

The unique estimated probability vector \( P_\alpha \) and matrices \( P_L \) and \( P_D \) are used to recover the elements \((i)\) and \((i,i')\) of the vector \( \alpha \) and Cholesky \( L \) and \( D \) matrices such that:

\[
\alpha_i = \sum_k Z_\alpha (i,k) \cdot P_\alpha (i,k)
\]

\[
L_{ii'} = \sum_k Z_L (i,i',k) \cdot P_L (i,i',k)
\]
The maximum entropy technique in combination with the PMP calibration allows recovering a quadratic activity variable cost function accommodating complementarity and substitution relations between activities.

3 Model structure

3.1 Modules and modelling methods

Figure 1 schematically depicts the CES calibrated model of the Belgian loam agricultural region. The model adopts the structure of the Common Agricultural Policy Regional Impact Analysis model (Heckelei and Britz, 2000) and includes 6 modules:

1. a base module comprising the balance equations between agricultural production and agricultural input consumption and the constraint on agricultural area availability,
2. a feed module describing the animal activity needs in energy, protein and dry matter, as well as their maximum intake capacity,
3. a policy module representing agricultural policy instruments: milk and sugar quotas, animal density constraints to benefit from cattle premiums, set-aside requirements, the minimum grassland rate in total fodder acreage, crop and animal premiums and the intervention CAP prices,
4. an objective function maximising the net farm income available for family labour and equity, whose cost function is linear in the initial optimisation problem and quadratic in the calibrated optimisation problem,
5. a CES module allowing substitution between input categories in the production of the main crop outputs using a nested CES production function to which a linear shift term is applied to account for technical progress in the projections,
6. a ME module maximising the entropy when estimating the quadratic cost function parameters.

Output and input prices are taken as exogenous given the small agricultural supply of the region with respect to the other European regions.

Figure 1: Structure of the CES calibrated regional model
Calibrations in 1995, validations in 1997 and simulations of the reference and Agenda 2000 scenarios in 2005 are implemented using four different modelling methods. As reported in Table 1, the first two methods called “pmp” and “pmpces” use the standard PMP calibration method implying a diagonal cost matrix. The last two methods called “me” and “meces” combine the PMP and ME calibration methods implying a symmetric cost matrix. The “pmpces” and “meces” methods use in addition a CES production specification instead of a Leontief specification. Accordingly, Table 1 shows the cost functions for each corresponding modelling method.

### Table 1: Modelling methods with their respective regional cost function

<table>
<thead>
<tr>
<th>Modelling method</th>
<th>Module combination</th>
<th>Quadratic cost function $^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>pmp</td>
<td>1, 2, 3, 4</td>
<td>$C = \sum_{ij} (\alpha_{ij} x_{ij} + 0.5 \gamma_{ij} x_{ij}^2)$</td>
</tr>
<tr>
<td>Pmpces</td>
<td>1, 2, 3, 4, 5</td>
<td>$C = \sum_{ij} (\alpha_{ij} x_{ij} + 0.5 \gamma_{ij} x_{ij}^2)$</td>
</tr>
<tr>
<td>Me</td>
<td>1, 2, 3, 4, 6</td>
<td>$C = \sum_{ij} (\alpha_{ij} x_{ij} + 0.5 x_{ij} \gamma_{ij} x_{ij})$</td>
</tr>
<tr>
<td>Meces</td>
<td>1, 2, 3, 4, 5, 6</td>
<td>$C = \sum_{ij} (\alpha_{ij} x_{ij} + 0.5 x_{ij} \gamma_{ij} x_{ij})$</td>
</tr>
</tbody>
</table>

$^a$ where $x_{ij}$ is the total use of input $j$ by the $i$th activity, $l$ denotes the activity level expressed in ha or LU, $\alpha_{ij}$ and $\alpha_{ij}'$ are respectively the linear term of the quadratic cost function in BEF per unit of $x_{ij}$ and $x_{ij}$, $\gamma_{ij}$ is the $ii$th entry of the symmetric matrix of the quadratic cost function in BEF per unit of $x_{ij}$ and $x_{ij}$. To allow for input substitution between pairs of input categories, the CES production specification includes two input nests with different elasticities of substitution. The first nest corresponds to the substitution between land and other inputs, while the second nest the substitution between capital and chemicals. The CES production function for a single crop $i$ is as follows in the programme (1):

$$y = (1 + r)^t \left[ \beta_{land} LAND^{\eta_1} + \beta_{var} \left( SP_1 \left( \beta_{chem} CHEM^{\eta_2} + \beta_{cap} CAP^{\eta_2} \right) \right)^{\eta_2} \right]^{\gamma_i}$$

where $y$ is the total output in tons from crop $i$, $t$ denotes the time horizon in years, $r$ is the projected annual yield growth rate, $SP_1$ and $SP_2$ are the scale parameters of the first and second nests, $\beta$ is the share parameter, $LAND$ is the total land use in ha, $CHEM$ the total chemical use in tons, $CAP$ the total capital use in capital units, $\eta = 1/\gamma$ with $\gamma = (\sigma-1)/\sigma$ and $\sigma$ is the elasticity of substitution. Elasticities of substitution of 0.5 and 0.8 are respectively chosen for the first and second nests.

The CES share and scale parameters are estimated according to Howitt (1995b) and Edwards et al. (1996) by using the following first-order conditions for input allocation:

$$P_y \frac{\partial y}{\partial LAND} = \omega_{LAND} \quad P_y \frac{\partial y}{\partial CHEM} = \omega_{CHEM} \quad P_y \frac{\partial y}{\partial CAP} = \omega_{CAP}$$

where $P_y$ is the output price and $\omega$ the resource shadow price. This resource shadow price includes the market input price and the shadow costs of constrained resources as follows:

$$\omega_{LAND} = P_{LAND} + \lambda_1 + \lambda_2 \quad \omega_{CHEM} = P_{CHEM} \quad \omega_{CAP} = P_{CAP}$$
where $\lambda_1$ is the dual value of the allocable land constraint and $\lambda_2$ the dual value of the calibration constraints.

The entropy problem (2) is maximised using a support-space $Z_\alpha$ vector and $Z_D$ matrix defined over a $(k \times 1)$ vector of weights $(0.0, 0.75, 1.5, 2.5, 3.0)$ and a support-space $Z_L$ matrix defined over a $(k \times 1)$ vector of weights $(-1.0, -0.5, 0.0, 0.5, 1.0)$. Because no cross cost effects are expected between crop and animal activities, the linear vector $\alpha$ of the quadratic activity cost function is partitioned into a vector including the crop activities and a second vector including the animal activities. Similarly, the quadratic matrix $Q$ is partitioned into a matrix including the crop activities and a second matrix including the animal activities. To this maximum entropy problem, lower and upper bounds are added to the values that can take the supply elasticities calculated from the recovered quadratic activity marginal cost functions. The minimum expected supply elasticity is 0.2 for the crop activities and 0.1 for the animal activities while the maximum expected supply elasticity is 2.0 for both crop and animal activities.

### 3.2 Activities and data

The model includes the principal 14 crop and 9 animal activities of the Belgian loam region (see table 3). The CES production specification is introduced for the main crop activities, i.e., soft wheat, barley, sugar beet, potatoes, chicory, maize silage, grass silage and grassland. In the feed module of the model, cattle is allowed to consume grain maize, maize silage, grass silage, pulses, fodder beet, other fodder silage, fresh grass, straw and milk that are regionally produced, as well as cereal and energy and protein rich fodder that are bought from the market. Pork is allowed to consume cereal and energy and protein rich fodder bought from the market, but also grain maize, potatoes, fodder beet and milk that are regionally produced. Following the European official regulation, livestock unit (LU) is defined as follows: 0.0 LU for calves younger than 6 months, 0.6 LU for cattle between 6 months and 2 years, and 1.0 LU for cattle older than 2 years.

Farm data of 1995 from a regional farm management agency, the Centre pour la Recherche, l’Economie et la Promotion Agricole (CREPA), and regional data of 1995 from the national statistics office, the Institut National de Statistiques (INS), and from the national agricultural economics institute, the Centre d’Économie Agricole (CEA), are used to calibrate the model. The farm accounting costs from CREPA are aggregated over seven input categories: land including rent and seeds, fertiliser, pesticides, capital depreciation and operating costs for machinery and buildings, home-grown feeds, purchased feeds and herd replacement.

Yields and output prices to simulate the reference and Agenda 2000 scenarios in 2005 are projections from 1995 using a linear trend. Reflecting technical progress, the yield trends are estimated from the 1980-98 regional yields. Output price trends from the forecasting and simulation system for agricultural world market (WATSIM) are used when they give a price higher than the foreseen intervention price. Accounting costs in 2005 are those of 1995 because it is observed that accounting costs for four main crop activities stay in one percent range of variation between 1990 and 1997. The policy parameters used in the calibration, the reference and the Agenda 2000 scenarios are reported in Table 2. All input and output prices are expressed in nominal terms.

1 CPU time is shortened.
Table 2: Policy parameters

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Cereal price</td>
<td>5.6 BEF/kg</td>
<td>4.8 BEF/kg (-15 %)</td>
</tr>
<tr>
<td>Set aside rate</td>
<td>minimum 12%, maximum 33% of fodder and grass area</td>
<td></td>
</tr>
<tr>
<td>Cereal and set aside premium</td>
<td>14,735 BEF/ha</td>
<td>16,860 BEF/ha</td>
</tr>
<tr>
<td>Pulse premium</td>
<td>21,280 BEF/ha</td>
<td>19,400 BEF/ha</td>
</tr>
<tr>
<td>Milk price</td>
<td>11.3 BEF/litre</td>
<td>11.0 BEF/litre (-5 %)</td>
</tr>
<tr>
<td>Milk quota</td>
<td>405 million litres</td>
<td>407 million litres (+0.5 %)</td>
</tr>
<tr>
<td>Beef price</td>
<td>44,400 BEF/LU</td>
<td>35,520 BEF/LU (-20 %)</td>
</tr>
<tr>
<td>Slaughter premium</td>
<td>0</td>
<td>3,200 BEF/animal older than 8 months &amp; 2,000 BEF/calve younger than 7 months</td>
</tr>
<tr>
<td>Eligible animal density</td>
<td>maximum 2.5 LU/ha</td>
<td>maximum 1.8 LU/ha</td>
</tr>
<tr>
<td>Extensive animal density</td>
<td>maximum 1.4 LU/ha</td>
<td>maximum 1.4 LU/ha</td>
</tr>
<tr>
<td>Suckler cow premium, including national premium</td>
<td>6,900 BEF</td>
<td>10,000 BEF</td>
</tr>
<tr>
<td>Fattening cattle premium</td>
<td>4,440 BEF/animal</td>
<td>8,400 BEF/animal</td>
</tr>
<tr>
<td>Extensification premium</td>
<td>1,470 BEF/animal</td>
<td>4,000 BEF/animal</td>
</tr>
</tbody>
</table>

1 EURO = 40.34 BEF

4 Results and interpretation

Table 3 shows changes in activity level as a result of simulating Agenda 2000 compared with the 2005 reference scenario using the four modelling methods. As expected, changes in the levels of most activities are lower when cross cost effects with the maximum entropy technique and input substitutions with the CES specification are allowed. Results from this most flexible modelling method are used.

Besides the set aside activity which is the marginal activity in the first stage of the program, the suckler cow and breeding and fattening activities are the most affected by Agenda 2000. With a 20% reduction in beef price, the suckler cow activities shrink by 10% and the breeding and fattening activities by 11%. As expected, within these animal activities, the activities not subsidised by a premium are the most affected. As a result, the more costly fodder activities such as fodder beet and other silage and rye grass also decrease by 22% and 19% respectively. In contrast, pulses and fodder maize activities expand by 17% and 9% respectively. With a 15% reduction in the cereal intervention price not fully compensated, cereal activities decrease by 1% to 7%. The profitable potato activity increases by 8% while the sugar beet activity stays constant since a quota limits its production.

Table 4 shows the change in activity yields as a result of simulating Agenda 2000 with a CES production specification compared with the 2005 reference scenario. As a consequence of the 15% reduction in the cereal intervention price, yields of barley and wheat respectively decrease by 13.4% and 11.4%. Yields of fodder maize, grass and rye grass decrease by a couple of percentages. Restricted by a quota in production, the yield of sugar beet decreases in yield by one percent while the area of sugar beet increases by one percent. Only yields of high added value commercial crops of potatoes and chicory slightly increase.
Table 3: Impact of Agenda 2000 on activity levels in 2005

<table>
<thead>
<tr>
<th>Activity</th>
<th>Agenda 2000 Level (ha or LU)</th>
<th>Change in level a (%)</th>
<th>Modelling method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>meces</td>
<td>pmp</td>
<td>pmpces</td>
</tr>
<tr>
<td>Soft wheat</td>
<td>95,827</td>
<td>-10</td>
<td>-6</td>
</tr>
<tr>
<td>Barley</td>
<td>20,631</td>
<td>-9</td>
<td>-2</td>
</tr>
<tr>
<td>Other cereals</td>
<td>2,867</td>
<td>-9</td>
<td>-9</td>
</tr>
<tr>
<td>Grain maize</td>
<td>4,821</td>
<td>-16</td>
<td>-16</td>
</tr>
<tr>
<td>Potatoes</td>
<td>17,708</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Sugar beet</td>
<td>49,226</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Chicory</td>
<td>7,711</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Fodder maize</td>
<td>22,796</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Pulses</td>
<td>2,469</td>
<td>155</td>
<td>155</td>
</tr>
<tr>
<td>Fodder beet &amp; other silage</td>
<td>2,882</td>
<td>-10</td>
<td>-12</td>
</tr>
<tr>
<td>Grassland</td>
<td>48,307</td>
<td>-4</td>
<td>-4</td>
</tr>
<tr>
<td>Rye grass</td>
<td>7,481</td>
<td>-48</td>
<td>-20</td>
</tr>
<tr>
<td>Set aside</td>
<td>24,882</td>
<td>56</td>
<td>39</td>
</tr>
<tr>
<td>Milk cow</td>
<td>81,637</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Breeding &amp; fattening from milk herd</td>
<td>62,798</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Suckler cow without premium</td>
<td>19,525</td>
<td>-34</td>
<td>-34</td>
</tr>
<tr>
<td>Suckler cow with premium</td>
<td>48,358</td>
<td>-10</td>
<td>-10</td>
</tr>
<tr>
<td>Extensive suckler cow</td>
<td>7,127</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Breed. &amp; fatt. from suckler cow herd w/o premium</td>
<td>17,279</td>
<td>-50</td>
<td>-50</td>
</tr>
<tr>
<td>Breed. &amp; fatt. from suckler cow herd w/ premium</td>
<td>42,795</td>
<td>-10</td>
<td>-10</td>
</tr>
<tr>
<td>Extensive breeding &amp; fatt. From suckler cow herd</td>
<td>11,118</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Pork</td>
<td>51,500</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

a with respect to the reference scenario in 2005.

Table 4: Impact of Agenda 2000 on activity yields in 2005

<table>
<thead>
<tr>
<th>Activity</th>
<th>Agenda 2000 Yield (T/ha)</th>
<th>Change in yield a (%)</th>
<th>Modelling method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>meces</td>
<td>pmp</td>
<td>pmpces</td>
</tr>
<tr>
<td>Soft wheat</td>
<td>7.383</td>
<td>-11.4</td>
<td>-11.4</td>
</tr>
<tr>
<td>Barley</td>
<td>6.100</td>
<td>-13.4</td>
<td>-13.4</td>
</tr>
<tr>
<td>Potatoes</td>
<td>49.297</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Sugar beet</td>
<td>67.048</td>
<td>-1.2</td>
<td>-0.9</td>
</tr>
<tr>
<td>Chicory</td>
<td>44.268</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Fodder maize</td>
<td>43.035</td>
<td>-1.9</td>
<td>-1.9</td>
</tr>
<tr>
<td>Grassland</td>
<td>33.416</td>
<td>-2.1</td>
<td>-2.1</td>
</tr>
<tr>
<td>Rye grass</td>
<td>30.590</td>
<td>-3.8</td>
<td>-3.8</td>
</tr>
</tbody>
</table>

a with respect to the reference scenario in 2005.

Table 5 gives the changes in total net farm income as a result of simulating Agenda 2000 using the four modelling methods. Compared with the reference scenario in 2005, the falls in the net regional farm income vary from 12.5% to 14.5% according to the modelling method. As expected, the fall in the net regional farm income is the lowest with the most flexible modelling method, i.e., the maximum entropy combined with the CES production specification. These falls in the net farm income are of the same order of magnitude of the
reductions in gross margins calculated in Burny et al. (1999) with simulated farm budgets. Their estimates range from 5% to 17% depending on the representative farm for no substitution in inputs and activities and technical progress.

The reduction in net income from the milk activity as a result of the reduction in beef price combined with the reduction in milk price explains 53% of the 12% fall in the net regional farm income. The milk activity in the Belgian loam region is not highly specialised and, hence, its level is sensitive to price changes. Burny et al. (1999) conclude as well that dairy farms would suffer the most under Agenda 2000. Reductions in net income from the suckler activities, the cereal activities and the industrial crop activities respectively explain 24%, 19% and 4% of the fall in the net regional farm income.

Table 5: Impact of Agenda 2000 on the net regional farm income in 2005

<table>
<thead>
<tr>
<th>Modelling method</th>
<th>Agenda 2000 net income (millions BEF)</th>
<th>Change in income (^a) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pmp</td>
<td>11,100</td>
<td>-14.5</td>
</tr>
<tr>
<td>pmpces</td>
<td>11,414</td>
<td>-13.0</td>
</tr>
<tr>
<td>me</td>
<td>11,901</td>
<td>-13.9</td>
</tr>
<tr>
<td>Meces</td>
<td>12,263</td>
<td>-12.5</td>
</tr>
</tbody>
</table>

\(^a\) with respect to the reference scenario in 2005.

5 Conclusions

Results from the Agenda 2000 simulation indicate that compared with a reference scenario in 2005 the regional farm income available for family labour and equity falls by 12%. This simulation also indicates that Agenda 2000 has a greater negative impact on net incomes from animal than crop activities. Drops in net incomes from milk and suckler activities explain 53% and 24% of the fall in the net regional farm income respectively while drops in net incomes from cereal and industrial crops explain 19% and 4% of the fall in the net regional farm income respectively. The levels of the suckler cow activities and the breeding and fattening activities decrease by 10% and 11% respectively while the levels of the wheat and grain maize activities decrease by 5% and 7% respectively. The levels of some fodder crops increase while the levels of some others decrease according to their relative costs. The level of the profitable potato activity increases by 8%. Yields of wheat and barley are the most responsive to intervention price decrease.

Among the different calibration methods and production function specifications used in this model, the maximum entropy approach combined with the PMP calibration and the CES production function specification gives the most flexible response to policy changes. The maximum entropy method has the advantage of adding cross cost effects between activities and the CES specification of allowing substitution between inputs. As a result, responses of activity levels and net farm incomes to the Agenda 2000 simulation are smoother with this more flexible modelling method than with the others. These cross cost effects and, to a lesser extent, the net farm incomes, however, depend on the support-space points chosen in the entropy maximisation problem (Paris and Howitt, 1998; Heckelei and Britz, 1999). The selection of these support-space points can be refined by exploiting additional information on marginal costs from additional base-years. The Kullback cross-entropy approach, for example, is able to incorporate prior information in the entropy problem and update sequentially the recovered probability distributions (Golan et al., 1996).

Because the recovered total activity variable cost function also depends on the selection of the functional form, the robustness of the results could be tested by using other functional forms than the quadratic form used in this model. For example, Paris and Howitt (1998) test
the weighted-entropy and the generalised Leontief cost functions in addition to the quadratic cost function.

To take into account the eventual competitiveness between joint outputs, a constant elasticity of transformation (CET) specification can increase even more the flexibility in the farm response to policy changes, particularly in the optimal combination of milk and meat outputs from the milk activities. Both elasticities of substitution and transformation can be directly estimated from farm data of the loam region instead of relying on elasticities from the existing literature.

The environmental impact from Agenda 2000, such as nitrate leakage, has not been addressed in this paper but could easily be measured. Because the CES production specification allows relative input uses to vary with relative input shadow prices, the environmental and income effects of, for example, taxation on chemicals or pesticides could also easily be measured.

References

Dynamic agricultural and environmental policy analysis using KRAM, a sector model of Danish agriculture

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Abstract
This paper describes KRAM (KVL’s Regional Agricultural Model), and demonstrates it using a nitrogen tax scenario. KRAM is a dynamic, spatial, programming sector model based on representative farms describing the actions of professional farmers in the Danish agricultural sector. The model assumes profit maximising behaviour, and describes the allocation of agricultural production, economic outcomes and the effects on certain environmental indicators.

The main strengths of KRAM are the detailed description of manure application in combination with crop yield functions; the detailed determination of optimal feeding strategy for cattle and pigs based on minimum and maximum demands to the feed components; its dynamic structure; and finally its spatial construction, which allows environmental indicators to be calculated on a regional level.

The results of the scenario considered indicate that KRAM is capable of estimating changes in manure application techniques as a response to changed fertiliser nitrogen prices. Furthermore, the results appear reasonable.

Keywords: Agricultural Sector Model, Econometric Model, Programming Model, Nitrogen, GAMS, Production Economics, Denmark

1 Description of the KRAM framework

KRAM is a model of the Danish agricultural sector that is being developed to carry out analyses of the interactions between agricultural and environmental policy, markets, production and the environment. KRAM has been developed in a research project at KVL financed by the Danish Research Councils from 1997 to 2000. The present model design is new, but has been inspired by a number of earlier models, especially Day (1963), Bauer (1989), Helming (1997), Andersen et al. (1979) and Andersen et al. (1974). KRAM was first described by Wiborg (1998), and has later been described in Wiborg (1999) and Asmild and Wiborg (1999). Currently, a detailed manual describing all the functions and data is in press (Wiborg, 2000).

KRAM can be used for policy analysis and forecasting. The output from KRAM is a time path of the regional production and resource use, and the influence on the environment. The model is a micro based programming model, and the foundation is a relatively detailed modelling of production processes on representative farm firms.

KRAM is a recursive dynamic model. An iteration of the model uses a three year mathematical programming model to solve for the optimal production in year $t$, and – as a by-product – prior plans for the production in year $t+1$ and $t+2$. After solving this problem, the
resource vector generated as a result of production in year $t$ is stored and used as the basis for the next iteration, which solves for the optimal production in year $t+1$ etc. This means that although model output for only one year is used in each iteration, the planning horizon is always three years. The advantage of this model structure is that expected changes in external factors up to three years ahead are taken into account when planning the first year’s production.

KRAM consists of several optimisation models and some econometric modules utilising the results from the optimisation. The different parts of KRAM have very different structures, characteristics and scopes. The optimisation criterion is maximisation of expected NPV of the gross margin plus the salvage value of the stocks at the end of period three.

**Figure 1: Graphical overview of the structure of KRAM**

In KRAM, the Danish agricultural sector is divided into 12 regions and 7 different production types, giving a total of 84 representative farm types. The division into regions is relevant due to differences in soil types and limitations on the transport of manure etc. The different production types are arable farming, dairy farming, pork production and mixed farming, with the first three types further divided into two groups according to size measured by standard gross margins (above or below 140 European Size Units (ESU)). All the farms in a region are assumed to have the same proportion of loamy soils, irrigated sandy soils and non-irrigated sandy soils. For each crop three different yield functions are formulated and are weighted together using these proportions.

There are two levels of iterations in KRAM. The overall model is solved once for each year, and when it has finished the next year is considered. Within any given year, the manure and fertilisation submodel is solved iteratively with the sector model. The manure and fertilisation submodel is first solved using a guess on prices, manure production and crop mix, and the output is provided to the sector model. After solving the sector model the results are compared to the assumptions used in the manure and fertilisation submodel, and if a convergence criterion has been satisfied the iterations end and the model proceeds with the market module, which serve the purpose of preparing the main models for the next period.
Otherwise, the manure and fertilisation submodel is solved again. This is illustrated in Figure 1 above.

1.1 The manure and fertilisation submodel

The manure and fertilisation submodel is a non-linear programming model (NLP-model) with the per hectare revenue minus manure and fertilisation costs as the objective function. Non-linear yield functions in nitrogen are used for most crops. 27 different crops are considered in KRAM. The model explicitly considers fertiliser nitrogen, three different kinds of manure and dung. A formal description of this submodel is provided in appendix 1.

In solving the manure and fertilisation submodel, all manure and dung must be allocated. Manure may be applied on the crops using three different application techniques: traditional spreading, trailing pipes, and direct injection into the soil. The utilisation rates for manure vary with the application technique and the crop to which the manure is applied. The same factors influence the manuring costs, which are measured per kg of nitrogen usable for crops. This means that the price can be compared to the price of nitrogen fertiliser including transport and distribution. Furthermore, the farm has a fertiliser nitrogen quota, which is calculated as a function of the crop mix and the animal stock.

It is important to notice that the crop mix is determined in the sector model, and is therefore exogenous to the manure and fertilisation submodel. At the same time the fertilisation costs are determined in the manure and fertilisation submodel, and these are exogenous to the sector model. In reality the crop mix is a function of the fertilisation costs, and the fertilisation costs are a function of the crop mix, and they should in principle be solved simultaneously.

In order to solve this problem an iterative procedure is applied, where the manure and fertilisation submodel is solved - the first time using last year’s crop mix as a preliminary guess on the crop mix. The optimal manure and dung allocations, crop yields and fertilisation costs are then forwarded to the sector model as exogenous variables. Now the sector model is solved, and the optimal use of manure is compared to the production. If they are not sufficiently close the manure and fertilisation submodel will be solved again using the new crop mix from the sector model. These results are again forwarded to the sector model. This process will continue until the production and consumption of manure is equal, i.e. the convergence criterion is satisfied.

Since the manure and fertilisation submodel is a one-period model it needs to be solved for each of the three periods relevant to the farm optimisation model. A separate manure and fertilisation submodel is formulated for each of the 84 farm types in KRAM. Thus 252 different NLP models are solved in each iteration.

1.2 The sector model

In its final form the sector model will probably be a Positive Mathematical Programming (PMP) model (Paris and Howitt, 1998). An interesting development of the original PMP method proposed by Heckelei and Britz (1999) is currently being evaluated. In this proposal maximum entropy (ME) recovery techniques are used to estimate the regionalised PMP cost functions so that they ensure exact calibration to the observed regional crop mix, and describe the full PMP cost matrix. This discussion is further described in McCarl et al. (2000).

---

1 These crops cover 98-99% of the arable land in Denmark, but since KRAM only simulates the effects for full-time farmers only 74% of the total arable land is represented in KRAM. The full-time farmers run 44% of the total number of farms, but they own 98% of the milking cows, 97% of the breeding pigs and 95% of other pigs (SJFI, 1998).

2 The current version of the model is not calibrated yet.
As mentioned above, KRAM is a recursive dynamic model, where three periods are considered when solving for the optimal production in one period. Several factors motivate this approach, which admittedly is more complex than a one-period model. The main one is the wish to simulate the farmers' decisions as closely as possible, and to take into account that adjustments in agriculture often take several years to carry out. An example is the growth of perennial crops like clover grass silage, where growth of 2nd year grass silage is not possible unless grass seed was laid down in a cover crop two years ahead. Another example is winter crops, which may not be grown if last year crops were late harvested crops such as beets or maize. In a one-period model similar restrictions could be introduced, either by demanding the crop mix must be repeatable, or in a recursive manner by restrictions based in last period's crop mix. But it would not be possible to follow the adjustment process.

Investments are another example. An investment is by definition (in KRAM) decided upon between periods (between runs of the sector model). KRAM does not allow the investment to take effect immediately, but rather one full year after the investment decision was made. Take the example of an investment in a new cowshed. Using the period labels above, in (the end of) period \( t-1 \) the decision is made, and during period \( t \) the building is constructed, while at the same time the farmer increases his stock of breeding heifers. At the beginning of period \( t+1 \) the new building is ready, and at the same time the dairy herd can be increased, since heifers of the correct age and in the correct number are ready\(^3\). These decisions, which have medium term planning horizons, are made clearly visible in a three-period model set-up.

### 1.3 The econometric modules

When the optimisation models have been solved, the iterations have ended and equilibrium has been established, KRAM proceeds to the econometric modules. The econometric modules include the market module, the price expectation module, and the investment module.

The market module uses the optimal supplies estimated in the farm optimisation model, and a demand function to estimate the market clearing prices. These prices are then used to calculate the resulting gross margins for each farm type.

The price expectations module uses an adaptive price expectations model (Nerlove, 1958) together with farmers' a priori expectations regarding policy changes to estimate their expected prices for the next three periods. Farmers' a priori expectations to policy-induced price changes are set exogenously as a part of the scenario. This part of the generation of price expectations is very important in KRAM.

Take the example of a simulation of farmers' reactions to politically induced changes, which have been planned several years ahead, such as Agenda 2000. Agenda 2000 defines changes in the EU Common Agricultural Policy until 2006. If the farmer has knowledge of this kind of change, he should start planning his adjustment early. This might include growing other crops or investing differently. The alternative would be equivalent to the assumption that the farmer is constantly taken by surprise by new policies, even when they have been common knowledge for a number of years. An interesting effect of this approach is that KRAM yields different results to otherwise identical scenarios, if one scenario assumes that farmers have pre-knowledge of policy changes, while the others assume the changes to be unexpected.

The last of the econometric modules is the investment module. This module estimates net investment in land, sow sties and dairy cow sheds. Furthermore, the number of farms in

\(^3\) To clarify, in figure 7 the feeding submodel, the manure and fertilisation submodel and the sector model is solved “in the beginning of” period \( t \), while the other submodels are solved in “the end of” period \( t \) or “between” period \( t \) and \( t+1 \).
the groups is estimated (structural development). In the current version of KRAM this module has not yet been completed, and some preliminary functions are used.

2 Applying KRAM to a nitrogen tax

Nitrogen taxes have been evaluated in a number of agricultural sector or farm firm models, for example Feinerman and Choi (1993), Jacobsen, et al. (1998), Simmelsgaard and Djurhuus (1998) and Linddal (1998). In the event of a simple tax on fertiliser nitrogen being introduced it is expected that crops with the smallest derivatives of the yield function with respect to nitrogen will increasingly be grown. Furthermore, a lower intensity of production is to be expected for all farms, which were using nitrogen fertiliser before the tax introduction. Finally, farms with a fertiliser nitrogen quota would have an incentive to change the manure application technology so that the manure is better utilised.

2.1 Results

The scenario considered here is very simple. The price of nitrogen fertiliser is simply changed from the current market price (the base line scenario) to twice (scenario 1) and three times that price (scenario 2), corresponding to a 100% and 200% tax on nitrogen fertiliser.

The change in output is measured by two variables: the amount of fertiliser nitrogen applied, and the average utilisation rate of the manure. For each scenario the following procedure has been used: First the manure and fertilisation submodels are executed, and then the sector model. If the convergence criterion has not been satisfied, another iteration is initiated. The convergence criterion is that the absolute difference between the amount of manure used in the manure and fertilisation submodel and the manure produced in the sector model should be less than a small number, epsilon.

The results given below are the optimal levels after equilibrium has been established. Only selected farm types and the national figures are given. The farms reported here are the KRAM farm types in Funen County. The national level results are given in thousands of tons rather than hkg for the use of fertiliser nitrogen.

Table 1: Results from KRAM.

<table>
<thead>
<tr>
<th></th>
<th>Fertiliser nitrogen used, hkg</th>
<th>Average utilisation rate of nitrogen in manure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Base line</td>
<td>Scenario 1</td>
</tr>
<tr>
<td>Small arable</td>
<td>113.69</td>
<td>41.29</td>
</tr>
<tr>
<td>Large arable</td>
<td>439.57</td>
<td>121.00</td>
</tr>
<tr>
<td>Small dairy</td>
<td>14.07</td>
<td>11.18</td>
</tr>
<tr>
<td>Large dairy</td>
<td>41.76</td>
<td>29.41</td>
</tr>
<tr>
<td>Small pork</td>
<td>14.02</td>
<td>13.18</td>
</tr>
<tr>
<td>Large pork</td>
<td>157.27</td>
<td>48.30</td>
</tr>
<tr>
<td>Mixed</td>
<td>71.19</td>
<td>54.93</td>
</tr>
<tr>
<td>National level</td>
<td>142.51</td>
<td>72.22</td>
</tr>
</tbody>
</table>

The results from the model runs seem to correspond with theory and other model results, although the reduction in fertiliser use is somewhat larger than expected. As the nitrogen price increases the use of fertiliser nitrogen is reduced, and the utilisation rate of manure increases as some farmers change the application method. However, the results are very preliminary. The current version of KRAM is not completely debugged yet, the PMP calibration method has not yet been introduced and the dynamics in KRAM are not utilised in these calculations.
The value of these results thus lies more in the direction of demonstrating the manure and fertilisation submodel.

3 The future development of KRAM

The KRAM model is expected to provide far more interesting results when the rest of the model framework has been completed. This includes, for example, results for more years, and a direct link to environmental indicators, such as nitrogen leaching functions.

It is obvious that very essential parts of KRAM have not yet been modelled. The investment module is expected to have a major influence, because the investment module will determine the production capacity. With the typical problem of “sunk cost” in agriculture, investment decisions will therefore have a major influence on future production. The intention is to base the investment module on results from the literature. But further estimation of investment behaviour will have to be carried out to make the investment module as realistic and updated as possible.

References

Appendix 1. Equations in the manure and fertilisation submodel

\[
\text{MAX}_{\eta_{frij}, \eta_{ijr}, P, M_{rfij}} \left\{ \sum_{i=1}^{I} X_{fri} \left( Y_{fri} S_{in} P_{r} - \sum_{j=1}^{J} \sum_{l=1}^{L} \eta_{frij} C_{frijl} - \eta_{frij,j=1}^{P} P_{r,2} - \eta_{frij,j=1}^{K} P_{r,3} \right) \right\}
\]

\[
Y_{fri} = \sum_{k=1}^{K} \left( Y_{ik}^{\text{min}} + \left( Y_{ik}^{\text{max}} - Y_{ik}^{\text{min}} \right) \left( \sum_{j=1}^{J} \eta_{frij}^{N} N_{ijr}^{N} - \eta_{frij,j=1}^{N} N_{opt}^{N} \right) \right) A_{jk}
\]

\[
\eta_{frij}^{N} = U_{ijr}^{N} M_{rfij}^{N} C_{frij}^{N}, \text{ for } j = 2...J
\]

\[
\sum_{i=1}^{I} F_{rfij} \leq \sum_{i=1}^{I} X_{fri} Q_{ri} - \sum_{j=2}^{J} H_{rfij} U_{ijr}^{N} C_{frij}^{N}
\]

\[
\eta_{frij}^{P} = \sum_{l=1}^{L} U_{ijr}^{P} M_{rfij}^{P} C_{frij}^{P}, \text{ for } j = 2...J
\]

\[
\sum_{j=1}^{J} \eta_{frij}^{P} \geq \text{MIN}_{i}^{P}, \text{ for all } f, r, i
\]

\[
\eta_{frij}^{K} = \sum_{l=1}^{L} U_{ijr}^{K} M_{rfij}^{K} C_{frij}^{K}, \text{ for } j = 2...J
\]

\[
\sum_{j=1}^{J} \eta_{frij}^{K} \geq \text{MIN}_{i}^{K}, \text{ for all } f, r, i
\]

\[
\sum_{i=1}^{I} \sum_{k=1}^{K} M_{rfijl} = H_{rfij}, \text{ for } j = 2...J
\]

with the symbols collected in the following table:
Indexes

|\( r \) | Region (1…12) |
|\( f \) | Farmtype (1…7) |
|\( i \) | Crops (1…30) |
|\( j \) | Nitrogen source (1…5), 1 is fertiliser, 2-5 are manure and dung types |
|\( k \) | Soil type (1…3) |
|\( l \) | Manure application methods |
|\( n \) | Goods, \( n=1 \) is fertilizer N, 2 is fertiliser P, 3 is fertiliser K, others are other goods |

Parameters

| \( X_{rfi} \) | Crop acreage |
| \( P_{rn} \) | Prices |
| \( Y_{ik}^{\min} \) | Yield without nitrogen |
| \( Y_{ik}^{\max} \) | Highest yield |
| \( N_{ik}^{\text{opt}} \) | Amount of N that supports \( Y_{ik}^{\max} \) |
| \( U_{ijl}^{N} \) | Utilisation rate of N |
| \( U_{ijl}^{Nq} \) | Demanded utilisation rate of N |
| \( U_{ijl}^{P} \) | Utilisation rate of P |
| \( U_{ijl}^{K} \) | Utilisation rate of K |
| \( CT_{rfj}^{N} \) | Manure’s content of N |
| \( CT_{rfj}^{Nq} \) | Manure’s content of N according to law |
| \( CT_{rfj}^{P} \) | Manure’s content of P |
| \( CT_{rfj}^{K} \) | Manure’s content of K |
| \( H_{rfj} \) | Manure available |
| \( S_{in} \) | Matrix with 1’s and 0’s giving the correspondences between crop yields and goods. |
| \( A_{jk} \) | Share of soil type |
| \( Q_{ri} \) | Nitrogen quota |
| \( Min_{i}^{P} \) | Minimum phosphorus application |
| \( Min_{i}^{K} \) | Minimum potassium application |

Variables

| \( Y_{rfi} \) | Crop yield |
| \( \eta_{rfij}^{N} \) | Nitrogen applied |
| \( \eta_{rfij}^{P} \) | Phosphorus applied |
| \( \eta_{rfij}^{K} \) | Potassium applied |
| \( M_{rfij} \) | Manure applied |

All prices are expected prices. The costs of distributing manure, \( C_{rfij} \), are calculated in the equations below, and are determined immediately before solving the submodel (Hasler and Wiborg, 2000):

\[
C_{rfij} = \frac{9.65 + 3.2D}{U_{ijl}^{N} CT_{rfj}^{N}}
\]

\( D \) is the farm’s average distance from the manure storage place to the centre of the fields. It is assumed that all farms have \( D = 0.5 \) km. This is probably true for smaller farms, and for larger farms the increase in transport costs is assumed to be paralleled by the negotiation power exercised when purchasing the manure distribution and by utilising economies of size.
Briefs on Further Research
The Economic Role of the Portuguese Wine Co-Operatives

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Agricultural markets are characterised by thinner margins, and greater price and income volatility. Despite these changes, agricultural raw material markets are increasingly characterised by vertical co-ordination between farmers and processors. The organisational form of a marketing co-operative is a common means adopted by farmers to achieve vertical co-ordination. The core aim of this paper is to analyse the contribution made to the economic performance of Portuguese wine co-operatives (PWCs) both by the skills of the human resources and the technology employed.

The database was collected through a survey of 116 PWCs, an organisational form responsible for 50% of Portuguese wine production. This survey showed that 11.4%, 45.7% and 42.9% of PWCs paid prices that were, respectively, smaller than, equal to and higher than those paid by competitive private firms.

To analyse the effects of labour skills and technology on the economic role of PWCs, a multinomial logit model was estimated using: Y, a qualitative dependent variable, with values 0, 1 and 2, respectively, if the co-operative pays smaller, equal or higher prices; X, a vector of independent variables related to the skills of the labour employed (managers with delegated powers, production experts, economists/managers, sales staff, administrative staff employed) and technology with stainless steel vinification.

The results of this model show that PWCs would indeed be able to improve their economic performance through the application of integrated management strategies, increasing the recruitment of skilled professionals in the areas of management and wine production, and by the adoption of new technologies of production.

Keywords: PWC, Economic Role, Labour Skills, Technology, Multinomial Logit
A method for determining future perspectives of arable farmers in The Netherlands based on a regional approach

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Arable farmers look for alternative activities to increase or at least to maintain their income level. This paper describes a method for determining and screening future perspectives of arable farmers in the Netherlands. The method determines financial and organisational consequences of alternative activities at farm level. It is used in the four most important arable regions of the Netherlands (Krikke a.o., 1994) (Smid, 1997) (Smid a.o., 1999). The method consists of three aspects. Firstly representative farm types are defined. Secondly alternative scenarios are compiled, based on a SWOT analysis and judgement of experts and farmers. These alternatives are categorised in different groups such as (1) cost price reduction, (2) more crops with a high gross margin, (3) widening of activities and (4) organic farming. Application of alternatives is limited by different preconditions regarding environment, policy, production techniques and farm-economics. Thirdly a judgement of the present production plan and plans of alternative scenarios takes place by simulating farm budgets (Schoorlemmer a.o., 1997). Two different models were used: a linear programming model and a simulation model (Smid a.o., 1996). In all calculations organic farming shows an improvement of the Net Farm Result. Of all calculations regarding cost price reduction 86% result in an improvement of the Net Farm Result. Of the calculations regarding more crops with a high gross margin and widening of activities respectively 69% and 54% result in an improvement of the Net Farm Result. In all regions about 70 to 80% of all the alternative activities improve the Net Farm Result.

The developed method contributes to the process of searching future perspectives and supports farmers and extension officers. The four arable regions in The Netherlands have a number of alternative activities to maintain or to improve the actual income level. As well within a region as between regions there are differences in possibilities mainly caused by the farm structure and the availability of labour.

Keywords: Method Development, Regional Approach, Farm Economic Perspectives

References
In recent years increasing apprehension has been felt concerning the effects of agricultural policies on the environment. They often comprise measures in which environmental issues are under regulation. Limitations on nitrogen leaching, pesticide use and soil erosion levels are examples of such policies. Moreover, agricultural and environmental policies have increasingly become specific to a particular type of farm or group of farms requiring detailed insight at the level of the decision making unit, i.e. at farm level. Consequently, a farm-level model integrating agronomic and economic disciplines is the most appropriate approach to simulate the behaviour of individual farms under different agricultural policies, and to evaluate the interaction between the agricultural practices and the environment.

This paper presents a farm-level agri-environmental economic model. Using a plant-growth environmental model and the multi-period linear programming technique, the model is developed so that it is able to investigate, at farm level, the impact of agricultural policies on the environment. It includes not only the relationship between livestock and crop activities, but also the effect of weather conditions and variability on these production activities. Farmers' attitude to risk is also incorporated in the model to evaluate its effect on farmers' decisions relating to farming practices. The characteristics of the model allow it to take into account the inter-temporal effects of soil erosion on crop yields during and beyond the planning horizon.

An empirical application of the model is presented to illustrate its appropriateness in analysing and predicting the levels of soil erosion under alternative agricultural policies. The characteristics of the model also allow it to take into account the inter-temporal effects of soil erosion on crop yields during and beyond the planning horizon.

*Keywords: Agri-Environmental Economic Model, Soil Erosion, Agricultural Policies*
Application of a Model of Positive Mathematical Programming to Analyse the Effects of the Measures of Agenda 2000 in Spain


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The first part of this work describes the structure of the model known as PROMAPA ("PROgramación Matemática para el Análisis de Políticas Agrarias"), a mathematical programming model developed to analyse agricultural policies in Spain.

This model represents different farm types (according to a typology based on Type of Farming (TF) and Size class) by means of a set of linear constraints, a non-linear economic function and integer decision variables for modelling the different agricultural policy options. The parameters of the non-linear economic function are estimated by using Positive Mathematical Programming (PMP) technique developed by HOWITT (1995). It is shown that the verification of a single condition for each non-zero activity is enough to accomplish calibration and that, in contrast to the considerations of HOWITT, no auxiliary linear programming is required to obtain the opportunity costs that calibrate the model. Most of the coefficients of the model are estimated from data of the Spanish Farm Accountancy Data Network (FADN).

The second part of the work presents the results of an application of the model to the analysis of the effects of the Agenda 2000 measures, approved at the Berlin European Council, on the Spanish farms most likely to be affected by the measures: those oriented to arable crops and cattle. The data for modelling these farms in the base year were taken from the Spanish FADN for the following TF: 111 (Specialist cereal, other than rice), 1245 (Various field crop) and 421 (Specialist cattle-rearing). The Autonomous Regions included are: Andalucía, Aragón, Asturias, Castilla-La Mancha, Castilla-León, Extremadura, Galicia, Madrid, Navarra and La Rioja.

In general, results show that in spite of the increase in compensatory payments and premiums, this would not offset a possible decrease in market prices, and therefore the economic results worsen for all of the agricultural farm types considered.

The two parts of the work are developed more fully in a background paper, available upon request from the authors.

Keywords: Positive Mathematical Programming, CAP, Agenda 2000, Spain
Positive Mathematical Programming and agricultural supply within EU under Agenda 2000

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In this work, we use the 1995 European Farm Accountancy Data Network (FADN) database and the Positive Mathematical Programming (PMP) approach to simulate the impacts of Agenda 2000 (Berlin agreement) on the field crops sector supply at the European Union regions level.

The standard PMP method is used to calibrate each regional model. The simulations reveal some problems for small activities where we observe high deviations. In many regions the variable cost for small activities became negative. This problem is treated by using a quadratic form for the variable cost per hectare instead of a linear form. Price and technical progress effects on crop yields and variable costs per hectare are taken into account by introducing yield functions.

We projected the impact of Berlin agreement on field crops sector supply by the year 2005. All results are evolutions compared with 1995 (the calibrating year). According to the simulations, cereal production will increase sharply (+28.6 %) and oilseed production will decrease (-23.9 %) in the case the 15% intervention price cut is integrally transmitted to market price.

The Berlin agreement measures would thus have a considerable impact on respective balance sheets for cereals and oilseeds, with a jump in cereals production and a drop in oilseeds production. The maintain of the compulsory set-aside stresses the oilseed deficit. It reduces the cereal excess to export but with the risk that the European price will be higher than the word price. So we can ask for the logic behind the maintain of the compulsory set-aside. However, this situation is only possible if the intervention price for cereals is set below or close to the world market price. Adversely, export is only possible with subsidy but its volume will no longer respect the Marrakech agreement constraints.

Keywords: CAP reform, Programming Model, Positive Mathematical Programming
Chapter V

Applied Analysis:

National Models
Liberalisation of a non-competitive market - Lessons from a forward looking general equilibrium model for Bulgaria

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Abstract
We present a dynamic general equilibrium model with oligopsonistic market structure in one of the sectors. Buyers of inputs can set the price of inputs by being involved in rent seeking activities. The framework developed is applied to the Bulgarian economy in particular to the agro-food chain. From the application to the Bulgarian economy we find that if there are market imperfections, such as oligopsonistic behaviour in the economy, there are no significant welfare gains from free trade. Significant welfare gains from trade are observed only when a competitive structure prevails. We show that eliminating this market imperfection can bring about important welfare implications and an efficient reallocation of resources.

Keywords: Imperfect Competition, General Equilibrium Model, Growth and Development, Transition Economics, Rent Seeking

1 Introduction
The once mighty agricultural sector of Bulgaria is in a deep crisis today. Having liberalised nearly all prices at the beginning of the transition process in the early nineties, most of these measures have soon been revoked. Instead, ceiling prices for main agricultural products were introduced in order to keep food prices on a low level. However, combined with restrictions on exports, allowable price margins and the cost-plus pricing practices of food processors, this policy neither created production incentives in agriculture nor did it provide incentives for food processing enterprises to decrease costs and to increase efficiency (Davidova 1994). As a result, the sector is locked in an unfavourable organisation of production and trade. Food retailers and processors have controlled nearly all the relevant channels for market oriented agricultural production. Price uncertainty, criminal business attitudes, strategic low pricing as well as weak land property rights and weak jurisdiction helped them to establish market power over primary producers (Hanisch and Pavel 1999). As a consequence, farmers leave the market and continue to produce subsistence food in small-scaled household plots. This situation, with its consequences for resource allocation and production structure, tends to protect retailers and traders at the expense of primary producers (Gorton et al. 1999, Swinnen 1997, Ivanova et al. 1995).

In this paper we examine the question whether standard “Getting the Prices Right” policies that aim at the elimination of tariff and tax distortions can potentially create significant gains in welfare for an economy such as Bulgaria, given the unfavourable organisation of production and trade in the food sector. Therefore, we include market power

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and rent seeking activities of food processors and the choice of primary producers between market and subsistence production into a dynamic general equilibrium model. Using this model, we estimate welfare losses caused by tariff and tax distortions on an economy wide level and compare them with the social costs of market imperfections. Based on these results we discuss in how far a sufficient increase in welfare can be achieved by eliminating tax and tariff distortions only and derive implications for the design of an appropriate reform policy for the Bulgarian case.

From a policy makers’ point of view, the paper provides a discussion on the relative priority of different aspects of reform policies. From modeller's view, it develops an approach, which includes oligopsonistic competition and rent seeking activities into a neo-classical growth model. This aspect has rarely been addressed in applied work yet, but appears to be of strong interest not only for the specific case of Bulgaria but also with respect to other transition and developing economies. Additionally, it contributes to the modelling of subsistence production as non-separable farm-household decisions. The paper is organised in four parts. In the first section, we describe the assumed market arrangements in the model. It follows a brief description of the underlying data and the calibration procedure. The third part explains the design of our policy experiments and discusses the results. In the last part we conclude and derive some policy implications.

1.1 The Model

We describe a small open economy. There is an infinite number of discrete time periods \( t=1,2,\ldots, \infty \). In each period \( t \), there is an infinitely lived representative consumer, government agent, and three sectors: primary agriculture, food and non-food manufacturing. These sectors produce respectively agricultural products, food products and non-food products. Additionally, there are imports and exports of each commodity.

In each period, the production of each output requires fixed proportions of intermediate inputs as well as labour and capital. Industries are assumed to produce one principal output with the exception of agricultural farmers, who produce agricultural raw products, which they sell to food processors, and subsistence food. Agriculture and non-food industries of this economy are competitive, taking the prices of their respective output and inputs as given, and choosing nonnegative values of factor inputs to maximise profits. In contrast, food processors are oligopsonists, as they can set the agricultural good’s price. In addition to the costs of using labour, capital and intermediate agricultural inputs, food processors face an additional cost. This cost is an exogenous expense faced by each firm in the sector, and is an expense that allows food processors to have market power. Following Shleifer and Vishney (1998) we think of it as costs for financing a rent seeking system, such as expenditures for bribes etc. Food processors, then, maximise profits by choosing their input value and set the price for agricultural goods by choosing output.

The representative consumer is endowed with labour (\( \bar{L} \)) at each period \( t \) and capital at time 0 (\( K_0 \)). In each period, he/she receives income from labour payments, and from renting out capital. He/she allocates this income to savings and consumption of non-food and two types of food products, marketed and subsistence food, to maximise an intertemporal utility function subject to an intertemporal budget constraint. The government receives income from taxation of labour income, capital income and consumption as well as tariffs on imports in each period. It pays transfers to the representative consumer and additionally, consumes a fix amount of non-food products.

---

1 We are aware of just three empirical studies that analyse the effect of rent seeking on growth and development: Rama (1993), Shleifer and Vishney (1998) and Brumm (1999).
Since the formal presentation of representative consumer, government and competitive industries follows the standard neo-classical growth framework as described for instance by Barro and Sala-i-Martin (1999) and Obstfeld and Rogoff (1998) or, for an application, by Diao, Yelden and Roe (1997), we focus the following discussion on the presentation of the non-competitive industry, the real contribution of our modelling work (for simplicity, we suppress the time subscripts). For a more detailed formal presentation of our model see Gaitan and Pavel (2000).

1.2 Non-competitive Industry

The production of processed food \( (Y_F) \) uses as inputs agricultural goods \( (I_F) \), labour \( (L_F) \) and capital \( (K_F) \). The technology to produce \( Y_F \) is represented by a Leontief technology of the form:

\[
Y_F = \min \left\{ \theta_F K_F^{\alpha_F} L_F^{1-\alpha_F} , AI_F \right\} \quad \text{with} \quad 0 < \alpha_F < 1
\]

We assume that, due to the imperfect market structure, food processors have market power over the price of agricultural goods \( (p_a) \) which they use as intermediate inputs. To keep this market imperfection, firms have an exogenous expenditure denoted by \( rse_g \) used for rent seeking activities. Adding an exogenous cost into the profit function of an individual firm introduces a wedge between total unit and marginal costs of production. This leads to increasing returns to scale in production. We have, therefore, firm level differentiation. Thus, there are \( n \) food processors indexed by \( g \) operating in the market.

The problem of firm \( g \) is to choose non negative values of \( I_{F,g}, K_{F,g} \) and \( L_{F,g} \) given prices of food \( (p_f) \), capital \( (p_k) \), interest rate \( (r) \) and wage rate \( (w) \) and to set a value of \( p_a \) by choosing \( Y_{F,g} \), taking the output of other food processors as given to solve:

\[
\begin{align*}
\max & \left( p_f Y_{F,g} - rp_k K_{F,g} - w L_{F,g} - p_a I_{F,g} - rse_g \right) \\
\text{s.t.} & \quad Y_{F,g} = \min \left\{ \theta_F K_{F,g}^{\alpha_F} L_{F,g}^{1-\alpha_F} , AI_{F,g} \right\} \\
\text{or:} & \quad \max \left( \left( p_f - MC_{K,L}^{F,g} \right) Y_{F,g} - p_a I_{F,g} - rse_g \right) \\
\text{s.t.} & \quad MC_{K,L}^{F,g} = \min w L_{F,g} + rp_k K_{F,g} \\
& \quad \theta_F K_{F,g}^{\alpha_F} L_{F,g}^{1-\alpha_F} = 1
\end{align*}
\]

where \( MC_{K,L}^{F,g} \) denotes the labour and capital minimising cost of producing a unit of the food commodity. Solving for the cost minimising factor demand for labour and capital from (1) is just a standard exercise in microeconomics. For solving the remaining part of the profit maximisation problem, the choice of the price of agricultural goods \( (p_a) \), we need to modify the profit function. Leontief technology and cost minimisation imply that the intermediate demand of firm \( g \) for agricultural goods for a given level of output \( (Y_{F,g}) \) is given by

\[
I_{F,g} = \frac{Y_{F,g}}{A} .
\]

Total supply of agricultural goods \( (Y_A) \) equals intermediate demand of food processors and therefore:

\[
Y_A = \sum_{g=1}^{n} I_{F,g} = \frac{1}{A} \sum_{g=1}^{n} Y_{F,g} \quad \text{(2)}
\]
Assuming symmetry among firms it follows:

\[ I_{F,g} = \frac{Y_g}{n} = \frac{1}{n} \sum_{g=1}^{n} Y_{F,g} \quad (3) \]

Substituting (3) into the profit function (1) of firm \( g \) we get:

\[
\max \left( p_f - MC_{F,g}^{K,L} Y_{F,g} - p_a \frac{1}{nA} \sum_{g=1}^{n} Y_{F,g} - rse_g \right) \quad (4)
\]

Similar to the \textit{Cournot} specification of imperfect competition (see for instance Kehoe and Kehoe 1994) we assume that firms choose their output \((Y_{F,g})\) given the output of other firms to maximise profits. From the first order condition for this problem we can solve for \( p_a \):

\[
p_a = (p_f - MC_{F,g}^{K,L}) nA \quad (5)
\]

Assuming free entry and exit, the number of firms \( n \) adjust such that sectoral profits equal to zero. This is consistent with Posner’s Rent Dissipation Axiom that the total expenditure by firms to obtain the rent is equal to the amount of the rent \( \sum_{g=1}^{n} rse_g = RSE \), Tirole 1988).

Substituting the profit maximising price (5) into the profit function (4), setting profits equal to zero and using \( I_{F,g} = \frac{Y_{F,g}}{A} \) we solve for the number of firms \( n \):

\[
n = \frac{rse_g + MC_{F,g}^{K,L} Y_{F,g} - p_f Y_{F,g}}{MC_{F,g}^{K,L} Y_{F,g} - Y_{F,g} p_f} \quad (6)
\]

Since profits (4) equal to zero, this is equivalent to:

\[
n = \frac{p_a I_{F,g}}{Y_{F,g} p_f - MC_{F,g}^{K,L} Y_{F,g}} = \frac{p_a I_{F,g}}{p_a I_{F,g} + rse_g} \quad (7)
\]

Equation (7) is the ratio of remuneration to intermediates over the sum of intermediates remuneration plus rent seeking expenditures. When \( n \) equals one (that is \( rse_g = 0 \)) perfect competition prevails and the closer \( n \) to zero, the higher the degree of imperfect competition. Thus, \( n \) can not necessarily be interpreted as the number of firms, but rather as an index that measures the degree of imperfect competition. Also, from (5), the price for intermediates \((p_a)\) increases the closer \( n \) goes to one. This is consistent with the \textit{Lerner condition} under \textit{Cournot competition}, where and increasing number of firms also reduces the degree of imperfect competition.

1.3 Equilibrium and Steady State

The equilibrium for this model is a price and allocation sequence such that the consumer’s and the firms’ problem are satisfied and factor and commodity markets clear\(^2\). The steady state is an equilibrium such that prices and allocations are constant for all \( t \).

\(^2\) Rents from rent seeking are allocated to the capital stock.
2 Data

The model is based on 1994 national accounts data. We assume that return to capital, as given by original data, includes both, the costs of using capital in production and for rent seeking activities. Therefore, we estimate the return to capital from production by subtracting the sectoral expenditure for rent seeking activities (RSE) from the value given in the data.

Some recent studies estimate producer and consumer subsidy equivalents (PSE/CSE) as indicator for the level of protection in the Bulgarian agro food chain (Ivanova et al. 1995, Gorton et al. 1999). Assuming, that positive levels for food processors and traders are in part due to the market power over the price for agricultural raw products and that these rents are used for covering rent seeking expenditures, we use this information for quantifying RSE. According to Gorton et al. (1999), in 1994 processing and retail firms of five main food products received rents between 8 and 41 percent of their domestic sales value, whereas primary producers were taxed by about 26 percent. In our model, we initially assume an income transfer of 15 percent of the domestic sales value of food processors (RSE=0.15 \sum_{g=1}^{n} Y_{F,g})^5.

3 Scenario Experiments

3.1 Design of the Experiments

In benchmark equilibrium, both non-uniform tax rates and tariffs, as well as oligopsonistic competition distort the economy. We simulate three different scenarios: First, we liberalise the economy by removing import tariffs and introducing a uniform consumption tax (policy). This studies the effects of pure ”Getting the Prices Right” policies and sheds light on how far this strategy is reliable to overcome the problems of the agro food chain. Second, we study the impact of eliminating rent seeking activities by simulating perfect competition in the food sector (market). Third, we assume a reform where the elimination of rent seeking supports liberalisation (totReform). In all scenarios we replace tariff revenue by consumption tax such that the real value of public consumption remains constant.

3.2 Simulation Results

Table 1 shows an insignificant gain in welfare for the policy scenario. Moreover, GDP in the new steady state remains by almost one percent below the benchmark. However, when oligopsonistic competition is removed, welfare increases by 8.8 percent in the market scenario and GDP by 6.3 percent at the new steady state level ("long run GDP"). Combining both scenarios, that is simulating a completely undistorted economy, leads to a slightly lower long run level of GDP than under the market scenario and a welfare increase of about 9.1 percent. The results suggest that given non-competitive behaviour of some agents in the economy, the

---

3 Data include adjustments for hidden economy activities and subsistence production of food products accounting for 26 percent of private food consumption (see OECD, 1996). Sales as well as demanded values are converted into consumer price levels and thus, include trade margins such that food processors in our model consist of both, processors and retailers.

4 Wheat, milk, pork, beef and chicken.

5 This corresponds with a taxation of agriculture of about 10.2 percent of the domestic sales value. Note that the higher estimations in literature also include income transfers due to trade policies, whereas in our model RSE is defined as rent from oligopsonistic competition only.

6 In particular, there are import tariffs of 5.2% on agricultural products, 16.3% on food, 3.6% on non-food; indirect tax rates on consumption of agricultural products (6.3%), food (23.1%) and non-food (12.6%) as well as a 3.2% subsidisation (non-food) and 0.1% taxation (food) of labour input.
reduction of policy distortions does not necessarily lead to a significant improvement in welfare. Although the number of firms \( n \) goes up slightly\(^7\), suggesting a small increase in the level of competition, the price setting behaviour of food processors and traders still has strong implications for the economy as a whole. In the following, we will describe the results of our simulations, from where we are able to give a reason for the low impact of liberalisation on welfare.

Table 1. Welfare and long run GDP (percent deviation from base values)

<table>
<thead>
<tr>
<th></th>
<th>policy</th>
<th>Market</th>
<th>TotReform</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welfare</td>
<td>0.3</td>
<td>8.8</td>
<td>9.1</td>
</tr>
<tr>
<td>GDP (long run)</td>
<td>-0.8</td>
<td>6.3</td>
<td>5.8</td>
</tr>
</tbody>
</table>

\(^a\) measured as equivalent variation in representative consumer’s income

Figure 1 in the appendix shows selected variables under the three scenarios. Since consumers discount late consumption, it jumps up in the early periods under the policy scenario. Over time, consumption decreases and the new steady state level is below the benchmark\(^8\). Thus, this scenario does not lead to a significant increase in welfare. Moreover, for the entire model horizon, investment and capital are below the initial level, indicating that a “liberalised” economy (that still has non-competitive markets) requires a smaller capital stock. Accordingly, GDP also decreases, yet to a small extend (1 percent). However, when the reform focuses on eliminating imperfect competition (market), we observe a huge income effect. Consumption jumps up significantly and remains stable on the new level indicating the positive effect of increasing competition on the representative consumers’ income. Without market imperfections, GDP increases in the new steady state leading to an expansion of investment and a raising capital stock.

Table 2. Output Levels in the new Steady State (benchmark=1)

<table>
<thead>
<tr>
<th></th>
<th>policy</th>
<th>market</th>
<th>TotReform</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>0.99</td>
<td>1.15</td>
<td>1.16</td>
</tr>
<tr>
<td>Food</td>
<td>1.09</td>
<td>1.57</td>
<td>1.71</td>
</tr>
<tr>
<td>Nonfood</td>
<td>0.98</td>
<td>0.96</td>
<td>0.93</td>
</tr>
</tbody>
</table>

Under the policy scenario, non-food output decreases and agricultural output remains almost constant, whereas food processors increase production by 9 percent in the new steady state level (table 2). Food products have the highest initial tariff rate. Cancelling these tariffs in the policy scenario reduces the price of marketed food. With the lower price, food processors increase especially exports by 20 percent and therefore, food production raises, although prices are below the initial level. However, agricultural production does not match the expansion of food production. Instead, food processors meet their increasing demand for intermediate inputs by expanding imports. The shift to perfect competition (market) has a significant impact on the price for agricultural output (figure 1) since it is no longer set by food processors. This favours production of agricultural raw products and reduces incentives for producing subsistence food. With declining amount of subsistence production, corresponding prices increase relative to marketed food prices. This change in price ratio

\(^7\) From 0.4 in the benchmark equilibrium to 0.42 in the new steady state.

\(^8\) The discounting of late consumption is also the explanation for the seemingly contradictory increase in welfare in line with an decreasing GDP: while in the new steady state both, consumption as well as GDP are below the benchmark, consumers derive a (slightly) higher utility from the increased consumption in the early periods than they loose from lower consumption in the new steady state.
shifts consumer's demand towards marketed food where prices go down with increasing demand. Additionally, decreasing food prices expand food exports, however to a lower extend than under the policy scenario (figure 1).

The strong reactions of the model on shocks introduced in our scenarios indicate that the economy is initially very distorted. The reduction of distortions (partially or completely) reduces output of non-food significantly. Furthermore, cancelling all distortions increases the price of labour relative to the rental rate of capital (figure 1). Thus, the economy has a comparative advantage in labour intensive (agriculture), rather than in capital incentive (non-food) production. Having this in mind, we can explain the drop in GDP and the insignificant welfare gains following the policy scenario. The removal of all tariffs lowers domestic prices of all products including agriculture. From the Stolper-Samuelson theorem, this also reduces the factor prices for the most intensively used factor, labour. Since the labour endowment is by far the biggest source of private income, this eventually results in a significant drop in income, which almost offsets the positive income effect resulting from lower domestic prices. The same logic explains the huge welfare gains under the market scenario. Due to oligopsonistic behaviour of food processors and traders, from equation (5) the initial price for agricultural raw products is below the competitive level. Thus, if policy enforces a shift to perfect competition, the price of agricultural raw products goes up and, again by the Stolper-Samuelson theorem, the wage rate increases relative to the rental rate of capital. This leads to a significantly positive effect on consumers income and enhances welfare. Moreover, relative consumption of food products shifts toward marketed products and thus, the decline in subsistence production increases the efficiency of factor allocation, too.

4 Conclusions

In this paper we provide a formal explanation, of why the Bulgarian food sector is locked in an unfavourable organisation of production and trade. We argue that the equilibrium, which the economy has achieved within the transition process, is not a competitive one. We develop a dynamic general equilibrium model, where non-competitive industries have oligopsonistic market power over their intermediates. We apply this model to Bulgaria and simulate two shocks, the removal of all price distortions caused by policy and the elimination of oligopsonistic competition. Our results show that the initial distortions are very high and that they push resources out of activities where the economy has a comparative advantage. Results also show that among the policies analysed in this paper, only the reduction of oligopsonistic competition in the food sector leads to a significant improvement in the allocation of resources and thus, to a positive effect on welfare. Furthermore, we found that for the given level of policy distortions, there is almost no impact of liberalisation on welfare and growth. We explain this by the behaviour of oligopsonistic competitors who are able to set a low price for intermediates. With this practice being kept in a liberalised economy, there will be no price incentive on production for the sector that suffers under market imperfection and thus, an efficient allocation of resources can not be achieved.

Our model provides an idea about the priority of different aspects of reform policies based on a formal framework. However, for a more appropriate consideration of dynamic gains from liberalisation, an additional scenario should simulate the liberalisation of the capital account (see Barro and Sala-i-Martin 1999 or Diao, Yelden and Roe 1997). Furthermore, for the discussion of implications on economic growth, an extension of the model can focus on the issue of who receives the benefits from rent seeking. Two cases come to mind: one, where the rents from rent seeking leave the country, maybe because they are deposited on a foreign bank account, and the other, where the rents are kept in the economy, as we assume in the present model.
From policy makers’ view, our results underline that for the case of Bulgaria, improving welfare and efficiency requires a much deeper reform than just cancelling tax and tariff distortions. Instead, policy should focus on the elimination of non-competitive behaviour and market imperfections. Some possibilities of how this could be achieved have been discussed in the literature already. North (1981) provides a general introduction into anti-rent seeking ideology. Shleifer and Vishney (1998) discuss this issue related to transition economies and strengthen the importance of property rights protection. The World Bank (1997) suggests concrete measures for transition economies such as expediting privatisation and liquidation of state-owned enterprises, establishing a stable enabling environment and improving market transparency. What our results contribute to this discussion is that they underline the high importance of this aspect of reform by showing that improving welfare and efficiency and achieving positive growth rates requires a more sophisticated reform package than just eliminating tax and tariff distortions.

References
Figure 1: selected variables of the model

- **benchmark**
- **market**
- **totReform**
- **policy**
Effects of the Common Agricultural Market and Accession to the WTO on the Russian Agricultural Sector

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Abstract

The collapse of the Soviet Union led to a sharp decline of trade in agricultural products between its successor states. The Russian Federation is following a dual strategy to revive and intensify its foreign trade. On the one hand, it is persistently trying to revitalise trade relations with the other member countries of the Commonwealth of Independent States by means of bilateral and regional trade agreements. Among these, the Common Agricultural Market has the most importance for the agricultural sector. On the other hand, Russia has applied for accession to the World Trade Organisation. This paper analyses the impact of these two trade policy options on Russia’s agricultural sector. Scenarios are modelled using a partial equilibrium Armington approach.

Keywords: Partial Equilibrium Model, Agricultural Trade, Armington Approach, Russian Federation

1 Introduction

The Russian Federation has undergone fundamental changes in both its foreign trade relations and its trade regime since the beginning of the transformation process. To counterbalance the disintegration process resulting from the breakdown of the Soviet Union and the Council for Mutual Economic Assistance, the Russian Federation concluded free trade agreements or similar agreements of this kind with all of the successor states of the Soviet Union in 1992 and 1993. Not least to give the regional integration process a new impetus the Commonwealth of Independent States (CIS) was founded in 1992 and in 1998 the states of the CIS established the Common Agricultural Market (CAM).

Besides this policy of revitalising traditional trade relations, the Russian Federation has tried to foster the integration of the Russian economy into the world trading system. In June 1993 the Russian Federation applied for accession to the General Agreement on Tariffs and Trade (GATT). This has been interpreted as a commitment to follow a more liberal trade policy in the future. However, both of these strategies have been put into question by the actual developments. While the regional integration efforts lack determined enforcement, the process of accession to the World Trade Organisation (WTO) has been delayed several times for various reasons.

The paper first analyses this parallel approach of the Russian trade policy. Then a multi-commodity partial equilibrium model is used to evaluate the effects of this strategy on the

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1 The three Baltic states are not members of the CIS. Georgia was not a founding member but jointed later.
2 Azerbaijan and Turkmenistan did not sign the agreement. Georgia, Kazakhstan, Uzbekistan and Ukraine added individual amendments to this agreement, in which they stated that they did not accept certain parts of it and/or its provisions.
Russian agricultural market and trade as well as on Russia’s welfare. In doing so we try to test the claim of some Russian politicians that in the current situation a further liberalisation of Russia’s foreign trade in agricultural and food products would have adverse welfare effects. It is argued that rather the deepening or re-establishment of the trade relations which prevailed under the Soviet regime would lead to welfare improvements.

2 Russia’s Agro-Food Trade and Trade Policy

2.1 Agro-food Trade

Russia’s agro-food imports have traditionally accounted for a high percentage of its total imports, while the share of agro-food exports has been of minor relevance. In 1996 the share of agro-food imports in total imports amounted to 24%, having declined from a peak of 42% in 1993. However, this decline in relative importance is not due to an absolute decline in the value of food imports in the considered period, but to an increase in the value of non-food imports (Eiteljörge and Hartmann 2000).

The value of agro-food exports amounted to only 2% of all merchandise exports and to 15% of the total agro-food import value. Thus, Russia’s agro-food deficit has been considerable, attaining about 9.4 billion US dollars in 1996. With a share of about 0.3% of world trade in agro-food products, the weight of Russia as an exporter of these products is negligible. Russia is more important as an importer of agro-food products. Its share in world imports was about 3% in the period 1992 to 1996.

With respect to the geographical structure of agro-food trade, several trends can be observed. On the import side Russia’s trade links with its traditional trade partners in the CIS are still very strong. Their relative importance in Russia's imports even increased to 30% in 1996. These data confirm that Russia continues to be a significant market for agricultural exports from other CIS countries. The by far most important source of Russia’s imports is the Ukraine, which accounted for 16% of total Russian agro-food imports in 1996. However, the importance of the CIS as a destination for Russia’s agro-food exports is declining. Its share dropped to 29% in 1996 (Eiteljörge and Hartmann 2000).

2.2 Trade Policy

Russia’s trade policy generally appears to be in a state of flux, with considerable uncertainty about its overall direction. However, it is apparent that progress has been considerable. An important new characteristic of Russia’s trade policy in recent years has been a tendency to concentrate on WTO-conform measures. Progress has been made in introducing a regulatory framework typical of that in market economies. The Russian tariff schedule comprises four levels depending on the source of imports. The basic rates for countries with Most-Favoured-Nation (MFN) status for the most important agricultural products range between 5% and 10%, although some rates are much higher.

The Soviet Union became an observer to the predecessor of the WTO, GATT, in 1990. The Russian Federation as the legal successor of the Soviet Union requested accession in June 1993, and presented the GATT Secretariat with a memorandum describing its trade policies in

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3 Nevertheless, for some products Russia is an important exporter on world markets; this holds e.g. for sunflower seed, where Russia has an export share of up to 32% in world trade in recent years.

4 Due to a lack of data it was not possible to include Belarus in the analysis. Thus the CIS-related data exclude import and export data for this country in trade with Russia.

5 When interpreting these trade data one has to keep in mind that this is only registered trade. The volume of unrecorded barter and shuttle trade between the CIS countries seems to be increasing.

6 ‘MFN status’ means that the respective trade partner will not be treated less favourably than any trade partner from any other country.
February 1994. In the same year a working party was established for negotiations between the Russian Federation and GATT. With the foundation of the WTO, this working party was transformed into a WTO working party. Negotiations between this working group and the Russian Federation are still in progress; bilateral talks on market accession between Russia and WTO members have also started.

To make a country’s trade regime more predictable, an important part of the accession procedure to WTO is the binding of its tariff rates. WTO members will be anxious to convince the Russian Federation to bind its tariffs to levels not much higher than the rates currently applied. An offer on the market access of goods in general and on such tariff bindings in particular was made by the Russian Federation in February 1998.

For agricultural goods, the Russian Federation offered a reduction in the bound level of customs import tariffs by about 36% during the implementation period, including a minimum reduction of 15% for each individual tariff item (Russian Federation 1998). Initial bound tariff rates range between 15% and 68%, while the final bindings at the end of the seven-year transition period are set between 10% and 53% with an average of 26%. If one compares these rates with the tariff rates actually applied, most of which range between 5% and 15%, it becomes obvious that even the proposed final bound tariff levels are in most cases much higher. Thus, it seems very unlikely that the reductions will lead to any effective liberalisation. However, Russia has justified the high levels of binding with its low level of tariffs on average and the need to provide for some leeway to be prepared to react to disequilibria in its foreign trade during the transformation process.7

3 The Common Agricultural Market

Despite its high flying objectives the achievements of the Commonwealth of Independent States (CIS) in liberalising trade among its member countries are very poor. With the establishment of a Common Agricultural Market (CAM) its member countries try to give the CIS as a whole a new impetus. The agreement was signed by Armenia, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, the Russian Federation, Tajikistan, Uzbekistan and Ukraine in March 1998.

The parties to the agreement state their intention to intensify trade in agricultural and food products as well as in means of production and services for agro-industrial complexes among the member countries. This should be achieved using a step-by-step approach. In a first step, the CAM should be “based on agreed-upon agricultural policies, and further on the basis of a common agricultural policy” (Art.3). Parties shall “step-by-step create the CAM with the simultaneous formation of a free trade area, and then (...) (the) formation of (a) common customs territory within the framework of the Customs Union” (Art.5).

Such a CAM would go far beyond just being a free trade area or a customs union. The outline of the agreement reveals many similarities with the Common Agricultural Policy (CAP) of the EU. In some points the provisions of the CAM are even more regulative and administratively complicated, whereas the technical infrastructure to administer such a policy is worse and financial resources are scarcer than in the EU (Fock et al. 2000).

Thus, while it seems very unlikely that the CAM becomes a proper common market it might at least lead to the implementation of a free trade area for agricultural products among its members. This prospect together with the restriction to the agricultural sector, leads us to analyse the possible effects of the CAM agreement on the one hand and of non-preferential trade liberalisation as it might result from WTO membership on Russian agricultural market

7 Other important topics during the negotiations concerning agro-food trade are quantitative restrictions, like quotas, licensing and trading monopolies, as well as internal support and export subsidies.
and trade as well as on Russia’s welfare. Although this procedure resembles the standard analysis in integration theory with well known results it is of special interest to analyse whether the economic structure inherited from the command economy might justify at least a temporal sticking to these trading relations in order to facilitate and soften the transition process.

The potential impact of a membership in a free trade area like the CAM on a specific sector crucially depends on the initial level of protection for products of this sector and on the structure of comparative advantage in its member countries. Trade creation can be expected if the trade advantage of - in this case - Russia on the one hand, and the other member countries on the other hand, is of a complementary nature. If it is of a similar nature, trade diversion is more likely to occur. This, however, only holds if the establishment of a free trade area really does lead to preferences for the member countries. Since Russia’s import tariffs for agricultural products range between 5% and 30% for non-CIS countries, while they are set to zero for imports of most agro-food products originating in the CIS, this seems to be the case indeed.

4 Description Of The Russian Agricultural Trade Simulation Model

The Russian Agricultural Trade Simulation Model (RATSIM) used for the following analysis has been developed at the Institute of Agricultural Development in Central and Eastern Europe (IAMO).

RATSIM is a static partial equilibrium model for the Russian agricultural sector. It consists of a system of output supply and input demand functions derived from profit maximisation, and a system of food demand functions derived from expenditure minimisation. This structure is extended to incorporate bilateral trade flows with the other CIS countries and the rest of the world using the Armington (1969) approach. Welfare is measured in terms of producer surplus, equivalent variation, and the federal budget. The model covers 12 primary agricultural commodities and 5 intermediate inputs as well as labour input.

Policy analyses are of a comparative static nature, i.e. independent of the time path. The behaviour of economic actors follows from the assumptions of neo-classical economic theory. In addition, it is assumed that markets are perfect and that the small-country assumption holds. Especially these last two assumptions are controversial. While Russia’s share in world agro-food exports is rather small and will probably not influence world market prices to a greater extent the opposite might be true for some agro-food products which Russia imports

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8 Due to data restrictions in the following simulations we do not differentiate between CIS and CAM membership. However, since Russia’s most important agricultural trading partners are CIS- as well as CAM-members the resulting error will most probably be not very large.

9 The stated tariff rates give the range of the tariff rates in the Russian tariff schedule. However, during this year several tariff rates have been raised and various additional duties introduced. For a closer analysis of the comparative advantage of Russia vis-a-vis the other CIS countries see Eiteljörge and Hartmann (2000).

10 For a more detailed description of the model as well as the methodology used in the empirical analysis and a discussion of the data and elasticities used in the simulation model as well as a critical discussion see Eiteljörge and Wall (1999) and Fock et al. (2000).

11 RATSIM is a further development of the Central European Agricultural Simulation model (CEASIM) (see Frohberg et al. 1997).

12 Wheat, coarse grain, potatoes, vegetable oil, refined sugar, milk, beef, pork, eggs, poultry meat, mutton, rest, feed wheat, feed coarse grain, feed potatoes, fertiliser and rest of variable input. “Coarse grain” comprises all coarse grain but wheat.
heavily. Furthermore, markets in Russia are in general far from being perfect. However, this assumption has been made to simplify the analysis.

Figure 1 shows the basic structure of the model with its three-step decision process. The supply system is derived from the Symmetric Generalised McFadden Profit Function (SGMPF) (Diewert and Wales 1987) which fulfils all theoretical conditions of profit maximisation. A system of food demand functions is directly specified using a Normalised Quadratic Expenditure Function (NQEF) (Diewert and Wales 1988). The characteristics of the functional form on the demand side correspond with those of the McFadden profit function on the supply side.

**Figure 1: Structure of the Russian Agricultural Trade Simulation Model (RATSIM)**

The Armington approach treats products from different sources not as perfect but as imperfect substitutes. In other words, for every commodity producers and consumers differentiate according to the country of destination or origin respectively. Producer (consumer) decisions whether to sell (buy) on the domestic market or to export (import) are represented by a constant elasticity of transformation (CET) function (constant elasticity of substitution (CES) function). The link to the respective trading partners is modelled in the same way. The use of this pragmatic device allows to analyse gross trade flows and thus to project and illustrate the effects of policy changes on trade patterns.

Due to a lack of statistical time series data the parameters of the supply and demand system are calibrated using 1996 data on prices and quantities and initial assumptions about

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13 Even on the export side Russia might have an influence on world market prices. See footnote 3 above.
As a starting point for the supply and demand systems, own and cross price elasticities have been predetermined. The parameters of the supply and demand functions used are determined so as to minimize the (weighted) square of deviation between the set (full matrix) of predetermined elasticities and those finally implied in the model. The calibration procedure adjusts the elasticity sets to the microeconomic requirements.

5 Scenarios and Results of the Ex Post Analyses

5.1 Scenarios

The simulation period for all scenarios is 7 years. We assume throughout this period a decrease in food expenditures per capita of 1% per year and a negative population growth of 0.3%. It is further assumed that technical progress in the production (use) of each output (input) commodity is modest (0.5% to 2.2% p.a.) and that feed efficiency is increased by 0.9% to 1.8% p.a. Admittedly, due to the lack of reliable estimations these are rather ad-hoc assumptions about the development of incomes and efficiency gains.

According to Russia’s possible alignment in international trade three scenarios are defined:

- The base scenario assumes that all policy parameters (e.g. direct, input and general subsidies) remain unchanged during the simulation period. The only policy measure applied are tariffs against imports from the rest of the world. Trade among CAM members is assumed to be duty free. This scenario aims at representing the status quo “de jure”. As stated already in the CIS agreement and again in the CAM agreement agricultural trade among the respective member countries should be free while outside tariffs remain in the responsibility of the individual countries. Therefore, it is assumed that the 1996 MFN tariff levels apply against non-CIS countries.

- The liberalisation scenario reflects a possible development in which the Russian trade policy is determined by liberal forces. It assumes that the Russian Federation increases its efforts to integrate in the world trading system by setting minimal uniform import tariffs of 2% on all imports (Table 1). All other policy measures remain constant. In this scenario the preferential treatment of CAM members vanishes.

- The protection scenario assumes the contrary: The protectionist lobby in the agricultural sector succeeds in its demand for higher protection. The Russian government gives preference to regional integration and increases tariffs against imports from the rest of the world to the levels that were offered to the WTO in February 1998 as “final bound tariff rates” after a transition period (Table 1).

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14 Tariff data also relate to 1996. The data were taken from FOCK et al. (2000), who used data from Goskomstat and Gosudarstvennyi.

15 The assumed elasticities of transformation and substitution both heavily influence the results of the simulation analyses. A sensitivity analysis for a similar model has been carried out by Fock et al. (2000).
Table 1: Tariff rates in the simulation scenarios (in %)

<table>
<thead>
<tr>
<th>Commodity:</th>
<th>Base scenario</th>
<th>Liberalisation</th>
<th>Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CIS</td>
<td>ROW</td>
<td>CIS</td>
</tr>
<tr>
<td>Wheat</td>
<td>0</td>
<td>5.0</td>
<td>2</td>
</tr>
<tr>
<td>Coarse Grains</td>
<td>0</td>
<td>5.0</td>
<td>2</td>
</tr>
<tr>
<td>Potatoes</td>
<td>0</td>
<td>25.0</td>
<td>2</td>
</tr>
<tr>
<td>Oil</td>
<td>0</td>
<td>10.4</td>
<td>2</td>
</tr>
<tr>
<td>Sugar</td>
<td>0</td>
<td>25.0</td>
<td>2</td>
</tr>
<tr>
<td>Milk</td>
<td>0</td>
<td>15.0</td>
<td>2</td>
</tr>
<tr>
<td>Beef</td>
<td>0</td>
<td>15.0</td>
<td>2</td>
</tr>
<tr>
<td>Pork</td>
<td>0</td>
<td>15.0</td>
<td>2</td>
</tr>
<tr>
<td>Eggs</td>
<td>0</td>
<td>15.0</td>
<td>2</td>
</tr>
<tr>
<td>Poultry</td>
<td>0</td>
<td>30.0</td>
<td>2</td>
</tr>
<tr>
<td>Mutton</td>
<td>0</td>
<td>15.0</td>
<td>2</td>
</tr>
<tr>
<td>Rest</td>
<td>0</td>
<td>13.5</td>
<td>2</td>
</tr>
</tbody>
</table>


5.2 Results

When analysing the results of the simulations, it is important to always keep in mind that the liberalisation and protection scenarios are compared not with the 1996 data, but with the results of the base scenario, and that all changes are expressed in percentages.16

Since the model is mainly demand driven, we start our analysis at this point. In the base scenario, the primary effect on domestic demand is negative: The reduced income per capita and the declining population result in an adverse effect on total demand. This in turn leads to a decline in consumer prices and subsequently to reduced import volumes. Against these depressing effects works the improvement in technological efficiency which enables producers to increase production and sales despite the decline in prices. Since the income decrease is smaller than the price decrease induced by positive technical change this leads to an increase in sales on domestic markets of all products but coarse grains which obviously is partially replaced by wheat. Finally there is also a rise in exports resulting from the higher relative price compared to the domestic market. Total welfare deteriorates since losses in producer and consumer welfare are higher than the gains for the government. Consumer welfare declines because of lower consumption levels. Budget expenditures decline as subsidies paid to the producers are reduced.17 This effect overcompensates the loss in tariff revenues. The negative effect on the producer surplus is a result of the decrease in both prices and received subsidies (Table 2).

Despite rising tariffs on imports from other CAM members the liberalisation scenario results in a decrease in Russia’s average import prices for all products but wheat. These price reductions in turn lead to an increase in net food imports for most commodities. In the case of wheat, coarse grains and sugar higher tariffs for the other CAM members induce a slight reduction in total imports. The decline in import prices results in an increase in real income, inducing an increase in demand for most products. A second effect is a substitution of

16 For interpretation one has to keep in mind that, due to the homogeneity conditions, only relative prices matter. More detailed figures on the results are presented in Eiteljörge and Wahl (1999).
17 Up to now, producer subsidies are calculated as a percentage mark-up on the production value. That is, an increase in product prices or quantities leads to higher expenditures. Obviously, this effect is unsatisfactory.
domestic production by imports. In particular domestic animal production is reduced, since this subsector is most affected by low-price imports from the 'rest of the world'. In general, however, the effect on overall domestic production is relatively low since the increased import competition is met by the increase in technological productivity. Therefore, the overall reduction of tariffs affects producers less than consumers. However, the pattern of production changes to some extent. Producers react with higher exports on a reduced demand for domestically produced goods. Summarising, Russia’s agricultural trade increases in the liberalisation scenario. While exports to all countries increase slightly, only the rest of the world benefits from the relatively high import growth. All other effects are relatively minor.

The substitution in demand leads to a slight decline in producer surplus, while consumers profit highly from the tariff reductions. The reduced tariff revenues result in a deterioration of the federal budget. Overall welfare, is higher than in the base scenario (Table 2).

Table 2: Welfare Effects compared to the Base Scenario, in bn Roubles

<table>
<thead>
<tr>
<th>Scenarios:</th>
<th>Base</th>
<th>Liberalisation change to base</th>
<th>Protection change to base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welfare components:</td>
<td>absolute change to 1996</td>
<td>absolute change</td>
<td>relative to GAO* (%)</td>
</tr>
<tr>
<td>Change in producer surplus</td>
<td>-25037</td>
<td>-1343</td>
<td>-0,5</td>
</tr>
<tr>
<td>Equivalent variation</td>
<td>-5132</td>
<td>5588</td>
<td>2,2</td>
</tr>
<tr>
<td>Change in federal budget</td>
<td>27822</td>
<td>-1765</td>
<td>-0,7</td>
</tr>
<tr>
<td>Change in total welfare</td>
<td>-2348</td>
<td>2481</td>
<td>1,0</td>
</tr>
</tbody>
</table>

*Gross agricultural output

Source: Own calculations.

The protection scenario assumes higher discriminatory tariffs against the rest of the world than in 1996. For all products but potatoes prices of imports from the rest of the world increase against the base run. Accordingly quantities imported from the rest of the world decrease sharply for most products. The slight increase in imports from the CIS cannot compensate this sharp reduction, so that total imports decrease considerably. The rise in domestic prices for food forces domestic consumption to decline.

Higher protection has more or less exactly the opposite effect on consumers as trade liberalisation. Higher prices lead to a reduction in consumption and consumer surplus. Producers benefit from reduced imports and higher prices but not to the same extent as consumers loose since reduced real incomes and the imperfect substitutability of imports for domestic products restrict such a trend. As domestic demand and exports decline the reduction of imports does not necessarily result in increases in domestic production of all products. Therefore, since the decline in consumer welfare is larger than the positive effects on producer surplus and the federal budget, total welfare deteriorates (Table 2).

6 Conclusions

As already mentioned above first assessments of the CAM were very sceptical. Although only of preliminary nature, our simulation results point in the same direction. They indicate that an increase in tariffs against non-CIS countries would lead to considerable losses for Russia’s domestic food consumers and the Russian economy as a whole. This result points to negative effects of increased protection within the CAM. Trade liberalisation between Russia and the

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18 In the case of potatoes the decline in the tariff rate leads to a lower price and a higher import quantity.
rest of the world on the other hand has positive welfare effects for the economy. Despite the fact that net welfare effects are relatively modest they can be seen as an indicator of the positive (negative) effects of reducing (increasing) tariff and non-tariff barriers, both at the border and within the domestic market.

Furthermore, accession to the WTO is seen as a necessary condition for consolidating the liberalisation efforts Russia has made in recent years. In the short to medium run, enhanced credibility of governments and the expected impetus to further market-oriented systemic reform may well be the most important benefits of WTO accession. Besides these direct effects WTO membership offers a number of further advantages like MFN treatment, securing access to the WTO dispute settlement mechanism, and a seat at the table for further negotiations. Russia’s producers as a group would probably gain from an elimination of state intervention and a more reliable trade policy. Russia’s trading partners would mainly gain from improved market access and from the integration of the Russian Federation into a multilateral rule-oriented system.

Thus, deeper integration into the world economy via accession to the WTO could help to enhance the efficiency of the Russian economy in the long run through an improvement of the allocation of resources at the national and international levels, and to support structural adjustment and institutional change through a stabilisation of the trade regime.

The prospects of the CAM are much less optimistic. Although further steps towards a more protectionist common market and state intervention are not unlikely to be implemented, a CAP-like agricultural policy however is very unlikely due to arising conflicts between the CIS, its financial costs given the scarce resources, and the regulations of the WTO. They are also not advisable from an economic point of view.

It seems therefore neither in the short run nor in the medium to long run advisable to the Russian Federation to stick to the “old dreams”. The temptation to at least partially restore the old Soviet system which seems promising at the first glance does not provide any perspective nor is it capable of softening the transition process significantly.

References
Agricultural Policy Analysis in Transition Countries with CEEC-ASIM: who will lose, who will gain by EU-accession?

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Abstract
This paper discusses the results of a partial equilibrium model on the effects of EU accession for agriculture in ten CEECs. The model is based on duality theory and is calibrated to the base year 1997. The convexity property of the producer’s profit function and the concavity of the consumer’s expenditure function are imposed. The model depicts besides price support other relevant policy instruments of the CAP as area payments, animal premiums, quotas and set-aside. Implementing the CAP changes the pattern of price and income support leading to substitutions on the supply and on the demand side. For production these substitutions are, however, limited by the quantity control regimes of the CAP. Farm income in CEECs will rise mainly due to area payments and animal premiums. The impact on consumer welfare is small since prices increase for sugar, milk and beef but fall for pork, poultry and eggs.

Keywords: Partial Equilibrium Model, CEEC, CAP

1 Introduction
The farming sectors in the Central and Eastern European Countries (CEECs) were subject to rapid and far reaching changes of their institutional, political and macro-economic environment during the last ten years as it has never happened to their Western European counterparts. In the ten candidates for EU accession (Poland, Czech Republic, Hungary, Estonia, Slovenia, Latvia, Lithuania, Slovakia, Bulgaria and Romania) agriculture will face a second phase of adjustment. Current national agricultural policies of most of them are less protective than the Common Agricultural Policy (CAP) is. Farmers in the CEECs are nevertheless concerned about growing competition from the EU-15. After accession CEEC agriculture must stand stronger competition within the Common Market, but, perhaps, will be granted higher protection against third countries' imports. Furthermore, it is often argued that consumer welfare will decrease because of higher food prices after accession.

In the EU-15 it is feared that an implementation of the CAP's agricultural price and income support will boost CEEC's agricultural output and reduce their food demand. This could result in incompatibilities with the WTO commitments concerning the quantitative restrictions on subsidised exports. An alarming question for EU politicians is the potential burden for the EU budget arising from an implementation of the CAP in the CEECs.

The partial equilibrium model ‘Central and Eastern European Countries Agricultural Simulation Model (CEEC-ASIM)’ ¹ is used to address some of these questions. In particular, the impacts of a CAP implementation on agricultural output, food demand and farm incomes in the potential accession countries and on the EU budget are analysed.

¹ This model is the successor of the model CEASIM described by Frohberg et al. (1998).
2 Brief description of the modelling approach

CEEC-ASIM is a partial equilibrium model with rational and perfectly informed economic agents and perfect markets. By assumption, domestic production and demand have no influence on international prices (small-open-economy-hypothesis). The system of supply and input demand equations is derived from a Symmetric Generalised McFadden Profit Function (Diewert and Wales, 1987), which fulfils all theoretical conditions implied by the assumption of profit maximising producers using a multi-input-multi-output-technology. Assuming a utility maximising consumer, the system of demand equations is derived from a Normalised Quadratic Expenditure Function (Diewert and Wales, 1988), which meets all theoretical micro-economic conditions.

The parameters of the supply and demand equations are calibrated so as to reproduce the base year 1997. The calibration procedures (see also Fock, 2000, pp. 103-104, 110-111) start from initial elasticity sets borrowed from expert knowledge or specialised econometric studies. The initial sets need not be consistent with micro-economic theory but point to the magnitude of supply and demand reaction on changing prices and income. During the calibration they are adjusted in order to make them comply with theory, i.e. to ensure that the matrices of second order derivatives of the profit and expenditure functions with respect to prices are symmetric and fulfil the curvature conditions. The micro-economic constraints are implemented within a non-linear programming approach, which minimises the squared relative deviations of the final elasticity sets from the initial ones. The strong foundation of the model on duality theory is an advantage for modelling agricultural policy impacts in CEECs where long and reliable statistical time series are lacking and where it is difficult to refer to historical experience and informal analyses. Into the calibration approach for the model's supply side also information on technical relationships can be taken into account. For example, the objective function to be minimised is expanded by terms for the squared deviations between aggregated animal output elasticities and aggregated feed input elasticities. This ensure that animal output changes are reflected properly in feed input changes.

Price transmission equations establish links between the various price definitions at the different levels of the market chain (external trade, farm gate, retail). Nominal protection rates and minimum prices enter as agricultural policy variables the specification of the price transmission equations determining farm gate prices. Retail prices are linked to farm gate prices by exogenous processing and retail margins.

Domestic support and quantity control policies like quotas and set-aside are also implemented. Subsidies (for example the per-output-unit equivalents of area payments and animal premiums) are added to the farm gate prices in order to arrive at producer incentive prices which drive the model’s supply reaction.

Quotas enter the model as upper bounds on the production quantities. If a quota is binding the model computes a quota rent so as to ensure compliance with the quota by reducing the producer incentive price. The quota rent is thus interpreted as the price for the right to produce. Set-aside is modelled in a two-step procedure: firstly, a negative shift representing the set-aside rate is added to the supply functions and secondly, the resulting supply quantities are treated as ‘quotas’. The resulting ‘quota rents’ reduce the producer incentive prices and capture by that also the impact of set-aside on other production and input demand via the cross-price terms in the supply and input demand functions.

The model is specified for the 10 EU accession candidates from Central and Eastern Europe (CEEC-10). It covers supply of 12 primary agricultural commodities. Also the use of 5 intermediate inputs as well as labour input in agriculture are determined. The data are from FAO, OECD and national statistical services.
3 The scenarios
In this paper a scenario of EU accession under full application of the EU market regulations is compared to a base run scenario of unchanged national agricultural policies. In addition, a scenario of complete liberalisation of agricultural policies is a second point of reference with which the EU accession scenario is contrasted.

3.1 Base run: unchanged national agricultural policies (BA)
The base run serves as a reference for comparison assuming that the national agricultural policies in the CEEC-10 observed for the base year 1997 do not change until 2007.

The nominal rates of protection are defined as the policy induced percentage gaps between farm gate and border prices. These rates are assumed to be those observed for 1997. The changes in border prices between 1997 and 2007 are exogenous and are based on world market price projections of FAPRI (1999). Any other support like direct subsidies, input subsidies and general subsidies are kept at their 1997 levels per unit of output.

Assumptions on autonomous technical progress are derived from European Commission (1998) and reflect per-hectare-yield changes and per-animal-output changes respectively. The annual growth rates of technical progress are mainly in the range of 1 to 3 %. Retail margins in absolute real values per quantity unit are kept at their base year levels. Population and income growth are based on FAPRI (1999) projections.

3.2 EU accession scenario: Agenda 2000 (AG)
In the EU accession scenario it is assumed that by 2007 the CEEC-10 have fully implemented the CAP market regulations as reformed by the Agenda 2000 decisions of the European Council (European Commission, 1999) and that economic adjustments to these policy changes are completed.

For farm gate prices of cereals, sugar, beef and milk it is assumed that policy induced price gaps between the accessing countries and the EU are abolished. The price cuts of the Agenda 2000 of 15 % for cereals and milk and 20 % for beef are taken into account. If the farm gate prices calculated according to these assumptions are lower than the border prices, the latter are used as farm gate prices. This implies that negative protection is not allowed. For all other products no border protection is in effect after EU accession (zero nominal protection rates).

The area payments for cereals amount to 63 Euro/t. The reference yields used to calculate the payments per hectare are the average expected yields for wheat and coarse grains in 2001. For oilseeds and set-aside the same premium is received. Farmers are obliged to set aside 10 % of the area for 'grandes cultures'\(^2\). This rate is modified to a lower effective one to reflect the small producer regulation exempting non professional producers from the obligation. E.g., for Poland the 10 % obligatory set-aside reduces to an effective one of 2 %.

For the accession scenario production quotas on sugar are implemented. Sugar production is not allowed to exceed the 1997 output levels augmented by the expected rise up to 2001 of per-hectare-yields.

The premium in the beef sector is equivalent to Euro 290 per slaughtered male adult cattle (special premium plus slaughter premium). The upper limit for the number of eligible animals is assumed to correspond to the base year's number of animals.

The quotas for milk production are equivalent to the 1997 output levels plus an additional amount reflecting the expected rise up to 2001 of per-cow-yields as well as the 1.5 % increase of the Agenda 2000 decisions. For milk, a premium of Euro 17.24 per ton is paid. This premium is tied to the quota rights.

\(^2\) 'Grandes cultures' include cereals and oilseeds, while protein crops are not explicitly covered by the model.
All national subsidies of the base run are abolished. The assumptions on border prices, technical progress, retail margins, income and population growth of BA are maintained in AG. Thus, only those accession impacts attributed to agricultural policy are examined.

3.3 Liberalisation scenario: dismantling of agricultural protection (LI)

A scenario in which any agricultural protection is dismantled serves as a second point of reference with which the EU accession scenario is compared.

In this scenario border protection is abolished, i.e. the nominal rates of protection are set to zero value. Also domestic support is cut. This leads to a change in the ratios between the producer incentive prices for the different commodities. It is further assumed that a global dismantling of protection leading to lower surpluses for agricultural commodities in the developed market economies would increase world market prices for all agricultural products by 10% against BA. The latter assumption induces a further change in the price ratios between output and input commodities. The assumptions on technical progress, retail margins, income and population growth of BA are maintained in LI.

4 Results

4.1 Prices

Table 1 shows producer incentive prices relative to wheat for the base year 1997 and of the different scenarios for the year 2007. With unchanged national agricultural policies as assumed for the base run (BA) producer price ratios for the average of the CEEC-10 develop between 1997 and 2007 more favourable for meat production, whereas they decrease for crops and milk. Since in BA nominal protection rates are assumed to stay at their 1997 levels, farm gate prices change between 1997 and 2007 with the same rate as world market prices.

Implementing the CAP in the CEEC-10 (scenario AG) has impacts on the level and pattern of support. Farm gate prices for wheat, potatoes, oilseeds, vegetables, pork, eggs and poultry fall to border price levels or come close to them, whereas for sugar, milk and beef the gaps between domestic and border prices become higher due to EU price support. In addition, producers of cereals, oilseeds, beef and milk would receive direct subsidies in the form of area payments and livestock premiums. This leads to relative producer incentive prices turning less favourable for potatoes, vegetables, pork, eggs and poultry and becoming more favourable for coarse grains, oilseeds, sugar beet, milk and beef (see AG vs. BA in Table 1).

In comparing AG with the scenario of completely liberalised agricultural policies (LI), the changes in the relative producer incentive prices show the same signs but different magnitudes than in comparing AG with BA. In particular for sugar there is a stronger increase in its relative producer incentive price. This is attributed to the fact that current national policies (BA) in CEECs often tend to mimicry the CAP and protect sugar producers. For beef, on the contrary, the increase in its relative price following a CAP implementation is smaller if compared with LI than with BA. This shows that national policies distort relative price incentives for beef production negatively. For white meats and eggs relative producer prices fall less for AG compared with LI than with BA. This is a result of the protection granted to producers of these products in BA, but dismantled in LI and in AG.
Table 1. Relative producer incentive prices\(^1\), CEEC-10

<table>
<thead>
<tr>
<th>Product</th>
<th>1997 (Wheat = 1)</th>
<th>2007 (Wheat = 1)</th>
<th>2007 (Wheat = 1)</th>
<th>2007 (Wheat = 1)</th>
<th>(AG) vs. BA</th>
<th>(AG) vs. L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Coarse grains</td>
<td>0.80</td>
<td>0.70</td>
<td>0.75</td>
<td>0.83</td>
<td>19</td>
<td>11</td>
</tr>
<tr>
<td>Potatoes</td>
<td>0.49</td>
<td>0.48</td>
<td>0.48</td>
<td>0.37</td>
<td>-23</td>
<td>-23</td>
</tr>
<tr>
<td>Oilseeds</td>
<td>1.61</td>
<td>1.32</td>
<td>1.45</td>
<td>1.63</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td>Sugarbeet</td>
<td>1.85</td>
<td>1.60</td>
<td>1.23</td>
<td>2.30</td>
<td>44</td>
<td>87</td>
</tr>
<tr>
<td>Vegetables</td>
<td>1.47</td>
<td>1.46</td>
<td>1.44</td>
<td>1.11</td>
<td>-24</td>
<td>-23</td>
</tr>
<tr>
<td>Milk</td>
<td>1.44</td>
<td>1.30</td>
<td>1.28</td>
<td>1.81</td>
<td>40</td>
<td>41</td>
</tr>
<tr>
<td>Beef</td>
<td>13.20</td>
<td>15.49</td>
<td>17.46</td>
<td>21.96</td>
<td>40</td>
<td>26</td>
</tr>
<tr>
<td>Pork</td>
<td>11.22</td>
<td>13.30</td>
<td>13.16</td>
<td>10.21</td>
<td>-23</td>
<td>-22</td>
</tr>
<tr>
<td>Poultry</td>
<td>10.28</td>
<td>10.44</td>
<td>7.47</td>
<td>5.81</td>
<td>-44</td>
<td>-22</td>
</tr>
<tr>
<td>Rest of agric. output</td>
<td>8.31</td>
<td>8.27</td>
<td>9.38</td>
<td>7.25</td>
<td>-12</td>
<td>-23</td>
</tr>
<tr>
<td>Fodder wheat</td>
<td>0.90</td>
<td>0.90</td>
<td>0.91</td>
<td>0.70</td>
<td>-22</td>
<td>-22</td>
</tr>
<tr>
<td>Fodder coarse grains</td>
<td>0.72</td>
<td>0.63</td>
<td>0.68</td>
<td>0.57</td>
<td>-10</td>
<td>-17</td>
</tr>
<tr>
<td>Fodder potatoes</td>
<td>0.32</td>
<td>0.32</td>
<td>0.31</td>
<td>0.24</td>
<td>-23</td>
<td>-23</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>2.03</td>
<td>1.69</td>
<td>1.74</td>
<td>1.48</td>
<td>-12</td>
<td>-15</td>
</tr>
<tr>
<td>Rest of intern. input</td>
<td>8.31</td>
<td>10.12</td>
<td>10.44</td>
<td>8.90</td>
<td>-12</td>
<td>-15</td>
</tr>
<tr>
<td>Labour</td>
<td>1.35</td>
<td>2.35</td>
<td>2.42</td>
<td>2.06</td>
<td>-12</td>
<td>-15</td>
</tr>
</tbody>
</table>

\(^1\) In this table quota rents are no yet taken into account.

Sources: OECD, national statistics, own calculations carried out with CEEC-ASIM

4.2 Production, input use and demand

In the base run (BA) technical progress leads to growing output quantities for all products between 1997 and 2007 (see Table 2). Also in the EU accession scenario (AG) and in the liberalisation scenario (LI) this is the main reason for output growth. Due to different policies the output quantities differ, however, between BA, AG and LI.

In AG, output of ‘grandes cultures’ is restricted by the set aside requirement and the base area exceeding of which would reduce area payments. Within ‘grandes cultures’ wheat is substituted by coarse grains and oilseeds. Compared to BA, wheat output is reduced by 7%, whereas output of coarse grains and oilseeds fall by 1% only. This substitution is caused by the increase in the price ratios for coarse grains and oilseeds vis-à-vis wheat. This also reflects the assumption of unchanged national policies in BA under which wheat production is more heavily protected than coarse grains and oilseeds.

Although the relative price for sugar rises substantially under the CAP, production is lower than in BA because of the quota system. Nevertheless, the CAP fosters sugar production. This becomes obvious when LI is employed as a yardstick. Then the CAP increases sugar output by 5% (AG vs. LI in Table 2).

In the livestock sector the CAP's impacts on relative prices and the milk quotas lead to significant adjustments in production structures. Output of pork and poultry fall in AG when compared with BA (Table 2). This is due to the fading out of price support for these products under the CAP. For beef this is different: with the EU’s price support and the premiums beef output rises by 27%. The growth in beef production would be even higher if no milk quota
would exist: since milk and beef are partly joint in production the milk quota restricts also beef output. The higher beef production quantities in LI than in BA indicate that current national agricultural policies tend to discourage beef producers of the CEEC-10.

Price support and direct subsidies of the CAP are incentives also for milk producers to increase output. But the milk quota has a dampening impact on production. This becomes clear when we look at the results of LI in which no milk quotas are in effect. In this scenario milk production is higher than in AG even though the relative milk price is much lower.

Table 2. Production quantities¹, CEEC-10

<table>
<thead>
<tr>
<th></th>
<th>Base run (BA)</th>
<th>Liberalisation (LI)</th>
<th>Agenda 2000 (AG)</th>
<th>AG vs. BA (%)</th>
<th>AG vs. L (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1997 (1000 t)</td>
<td>2007 (1000 t)</td>
<td>2007 (1000 t)</td>
<td>2007 (1000 t)</td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>27718</td>
<td>34401</td>
<td>33801</td>
<td>31916</td>
<td>-7</td>
</tr>
<tr>
<td>Coarse grains</td>
<td>48045</td>
<td>56984</td>
<td>57654</td>
<td>56281</td>
<td>-1</td>
</tr>
<tr>
<td>Potatoes</td>
<td>22056</td>
<td>25961</td>
<td>26026</td>
<td>25074</td>
<td>-3</td>
</tr>
<tr>
<td>Oilseeds</td>
<td>3227</td>
<td>4398</td>
<td>4448</td>
<td>4363</td>
<td>-1</td>
</tr>
<tr>
<td>Sugarbeet</td>
<td>3755</td>
<td>4159</td>
<td>3783</td>
<td>3983</td>
<td>-4</td>
</tr>
<tr>
<td>Vegetables</td>
<td>10596</td>
<td>12251</td>
<td>12784</td>
<td>12191</td>
<td>0</td>
</tr>
<tr>
<td>Milk</td>
<td>25216</td>
<td>28570</td>
<td>28951</td>
<td>27407</td>
<td>-4</td>
</tr>
<tr>
<td>Beef</td>
<td>1139</td>
<td>1227</td>
<td>1282</td>
<td>1569</td>
<td>27</td>
</tr>
<tr>
<td>Pork</td>
<td>4341</td>
<td>4752</td>
<td>4591</td>
<td>4511</td>
<td>-5</td>
</tr>
<tr>
<td>Eggs</td>
<td>1243</td>
<td>1316</td>
<td>1305</td>
<td>1310</td>
<td>0</td>
</tr>
<tr>
<td>Poultry</td>
<td>1565</td>
<td>1635</td>
<td>1480</td>
<td>1376</td>
<td>-16</td>
</tr>
<tr>
<td>Rest of agric. output</td>
<td>16436</td>
<td>19476</td>
<td>19807</td>
<td>19308</td>
<td>-1</td>
</tr>
</tbody>
</table>

¹) Production is calculated net of waste and seed, for milk net of waste and feed use.

In the accession scenario (AG) consumption of cereals and potatoes as fodder input declines compared to the base run (BA) because of lower livestock output (see Table 3). Wheat gains higher importance within the feed mix since its price ratio vis-à-vis coarse grains is reduced. The lower output levels also lead to reduced input use of fertiliser, other intermediate inputs and labour.

The impact of EU accession on non-agricultural demand for crop products is modest. Only for sugar a strong drop in consumption is calculated (AG vs. BA in Table 4) which is due to the price increase. Effects with opposite sign are expected for pork, poultry and eggs for which the price cuts lead to higher consumption levels. Milk and beef consumption, on the other hand, strongly decline because of higher retail prices after CAP implementation. When interpreting these demand effects one has, however, to bear in mind that no attempt has been made in this analysis to capture the potential impacts of EU accession on consumer incomes as well as on the margins between prices at consumer and at farm gate level. Changes in these variables that are exogenous to the partial model would probably have impacts on the level and composition of food consumption. Therefore, the model results have to be interpreted as representing the impacts of implementing the CAP under ceteris-paribus conditions concerning the processing and retailing sectors and the general economic situation of the countries.
Table 3. Agricultural input use, CEEC-10

<table>
<thead>
<tr>
<th></th>
<th>Base run (BA)</th>
<th>Liberalisation (LI)</th>
<th>Agenda 2000 (AG)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1997 (1000 t)</td>
<td>2007 (1000 t)</td>
<td>2007 (1000 t)</td>
</tr>
<tr>
<td>Fodder wheat</td>
<td>10235</td>
<td>10677</td>
<td>11000</td>
</tr>
<tr>
<td>Fodder coarse grains</td>
<td>37336</td>
<td>42765</td>
<td>41773</td>
</tr>
<tr>
<td>Fodder potatoes</td>
<td>11593</td>
<td>12865</td>
<td>11491</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>3119</td>
<td>3123</td>
<td>3127</td>
</tr>
<tr>
<td>Rest of intern. Input 1)</td>
<td>18384</td>
<td>17824</td>
<td>17983</td>
</tr>
<tr>
<td>Labour 2)</td>
<td>9694</td>
<td>9527</td>
<td>9467</td>
</tr>
</tbody>
</table>

in 1000 Euro at 1999 prices
in 1000 employees
Source: FAO, OECD, national statistics, own calculations carried out with CEEC-ASIM

Table 4. Demand1) for agricultural products, CEEC-10

<table>
<thead>
<tr>
<th></th>
<th>Base run (BA)</th>
<th>Liberalisation (LI)</th>
<th>Agenda 2000 (AG)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1997 (1000 t)</td>
<td>2007 (1000 t)</td>
<td>2007 (1000 t)</td>
</tr>
<tr>
<td>Wheat</td>
<td>13301</td>
<td>14078</td>
<td>14091</td>
</tr>
<tr>
<td>Coarse grains</td>
<td>6121</td>
<td>6640</td>
<td>6537</td>
</tr>
<tr>
<td>Potatoes</td>
<td>10988</td>
<td>11432</td>
<td>11507</td>
</tr>
<tr>
<td>Oilseeds</td>
<td>3927</td>
<td>4874</td>
<td>4652</td>
</tr>
<tr>
<td>Sugar</td>
<td>3400</td>
<td>3660</td>
<td>3755</td>
</tr>
<tr>
<td>Vegetables</td>
<td>10698</td>
<td>11798</td>
<td>11662</td>
</tr>
<tr>
<td>Milk</td>
<td>24706</td>
<td>28072</td>
<td>28100</td>
</tr>
<tr>
<td>Beef</td>
<td>1125</td>
<td>1140</td>
<td>976</td>
</tr>
<tr>
<td>Pork</td>
<td>3991</td>
<td>4073</td>
<td>4143</td>
</tr>
<tr>
<td>Eggs</td>
<td>1192</td>
<td>1450</td>
<td>1570</td>
</tr>
<tr>
<td>Poultry</td>
<td>1503</td>
<td>1828</td>
<td>2238</td>
</tr>
<tr>
<td>Rest of food expend. 2)</td>
<td>28826</td>
<td>40142</td>
<td>36834</td>
</tr>
</tbody>
</table>

1) human consumption, processing and industrial use
2) in 1000 Euro at 1999 prices
Source: FAO, national statistics, own calculations carried out with CEEC-ASIM

The adjustments in output, agricultural input use and demand quantities described above lead to changes in the product balances. After implementation of the CAP net exports of the CEEC-10 as a whole rise for coarse grains, sugar, milk and beef compared to the base run. For wheat and pork net exports would be reduced. For poultry and eggs a greater import potential opens additional export chances for current EU Member States.

4.3 Welfare effects
In the EU accession scenario price support and direct subsidies increase real income from agricultural activity by 39 % for the aggregate of the ten Central and Eastern European Countries (Figure 1). Only Slovenia's farms are worse off since protection is lower after
accession. The gains in producer welfare for the other countries are in the range of 31% for Romania and 92% for Latvia.

Figure 1. Producer and consumer welfare, CEEC-10 (AG vs. BA, in %)

Negative impacts of the CAP on consumers resulting from price increases for sugar, milk and beef are balanced by price cuts for pork, poultry and eggs. The total (relative) impact on consumer welfare, which is measured by the equivalent variation, is small compared to the change in producer welfare. This is also due to the low value share of agricultural products in food retail prices and the re-orientation of the CAP from price support towards direct subsidies. In some countries consumers are even better off with the CAP. This is the case in Slovenia where price support under the national agricultural policy is higher than under the CAP. In Hungary the price reductions for pork, poultry and eggs more than outweigh the negative impacts on consumer welfare of price increases for the other commodities.

The gains in producer incomes mainly stem from transfers financed by the EU. The model estimates these additional budgetary costs at Euro 7.5 billion at prices of 1999, of which Euro 6.6 billion is direct payments for ‘grandes cultures’, set aside and livestock premiums. Expenditure on export subsidies amounts to Euro 0.9 billion. The largest share of these export subsidies is paid to the beef and milk sector, where the gaps between domestic and international prices remain substantial also after the Agenda 2000 reform.3

5 Conclusions and model outlook

Implementing the EU market regulations in the CEEC-10 will change their levels and patterns of agricultural protection. In most of these countries higher protection would raise farm incomes. On the consumer side, a low value share of agricultural products in retail prices and the further re-orientation of the CAP from market price support towards direct income support reduce negative welfare impacts. The main source for producer welfare gains is direct subsidies financed by the EU. Total welfare in the CEEC-10 increases provided that by far the greatest share of the budgetary burden is paid by the old Member States. In particular for milk and beef EU surpluses would become higher by an enlargement to the East.

The results show that a CAP implementation is attractive for the CEEC-10 since it is a vehicle for financial transfers from the EU without co-financing. This is not to say that this is an efficient way to support them in their efforts to attain standards of living in their rural areas

3 For a more detailed analysis of the budgetary implications see Weber et al. (2000).
comparable to those in the EU. The budgetary burden for the EU to pay the reformed direct subsidies also to the farmers of the CEEC-10 is high. Therefore it is questionable whether the EU Member States will agree to grant farmers of the accession countries the same level of support. However, is it politically feasible and economically sound to establish further distortions of the competitive environment across the agricultural sectors of an enlarged Union? The quantitative implications of this are difficult to analyse without a model also representing the EU agricultural sector. The extension of CEEC-ASIM by an EU component or its linked use with an existing EU model is therefore one option for further work on the model.

It would also be desirable to look at international trade of the CEECs not only in terms of net trade but to distinguish between exports by destination and imports by origin. Diversification of agricultural production into domestic sales and exports to different destinations (e.g. EU Member States, other CEECs, the CIS, ...) can become an important component of a strategy to overcome the CEECs’ weaknesses in competitiveness. A development of the model into this direction could improve the model's capability to analyse trade policies. Together with the analysis at EU-15 level this could provide helpful insight into the implications of enlargement for the EU’s WTO commitments. Moreover, it would allow to calculate the budgetary effects of EU enlargement with more detail and higher accuracy. Revenues from imports and exports could be treated separately whereas in the current version of the model exports are implicitly set off against imports before calculating expenditure on exports subsidies or revenues from import tariffs.

The results presented in this paper show that CEEC-ASIM is a useful tool for analysing EU accession since agricultural policy instruments like price support schemes, direct subsidies and production quotas are implemented at a highly detailed level. The strong micro-economic background of CEEC-ASIM ensures that its results have a well-founded interpretation.

References
The Econometric Modelling of Irish Agriculture

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Abstract
In this paper the econometric model that has been developed under the auspices of the FAPRI-Ireland Partnership is presented. The FAPRI-Ireland Partnership is a joint venture between Teagasc (The Irish Agriculture and Food Development Authority), the Irish universities, other interest groups in Ireland, and the Food and Agriculture Policy Institute (FAPRI) in the USA.
The overall model is comprised of a set of individual econometrically estimated commodity models e.g. beef, dairy, sheep pigs and cereals, that are linked and solved simultaneously under different policy scenarios. Typically the impact of policy changes are projected over a ten-year horizon. The individual commodity models for Ireland are linked to the FAPRI EU and world models. This allows the simulation of policy changes at a national, EU and international level. The model has already been used to assess the likely impact of the changes to the CAP under Agenda 2000.
The paper, while detailing the methodology behind the modelling exercise, also provides a critique of the strength and weaknesses of this type of model. Three important equations from the model system are used to illustrate the key points. The results of the latest simulation of the entire model which incorporates the recent Agenda 2000 reforms are also presented.

Keywords: Econometric Modelling, Irish Agriculture, Policy Analysis.

1 Introduction
Developments in computing power have facilitated a substantial expansion in the number and scale of economic models of agriculture in recent years. There are a wide variety of modelling techniques available to the potential practitioner. The choice of approach is governed by the aims of the analysis as well as practical problems such as data availability. Different models, therefore, have different strengths and weaknesses.

The FAPRI-Ireland Partnership was formed in order to provide a modelling capacity that would enable the detailed analysis of changes in agricultural policy on the sector in Ireland. This would provide information that would be of use to policy makers, industry, and producers themselves. Ireland's situation as a major exporter means that it is imperative that the model should link in with EU level projections, produced by FAPRI.

In the paper, three different equations from the model are detailed, each illustrating a different facet of the model. The beef heifer replacement equation is used to examine biological constraints, and the incorporation of policy instruments. The beef feed per head equation is an illustrative example of the inter-linkage between the individual commodity models. Finally, the derivation of the milk price presents an example of how the Irish model links to FAPRI's EU model and demonstrates how specific characteristics of the Irish product mix are incorporated. Using these examples, the wider issues of the suitability of the use of econometric models in this context is addressed. The results of the simulation of the CAP reform under Agenda 2000 produced using the model are also presented.
2 Model Methodology

With the increasing complexity of the Common Agricultural Policy (CAP) and its application in the EU, the challenges facing practitioners of agricultural policy modelling have also increased. This complexity is an important factor guiding the choice of modelling approach.

The modelling system is a standard recursive dynamic partial equilibrium model of the agricultural sector in Ireland. It is specifically designed for policy analysis and is capable of producing short, medium and long term projections up to a ten year time horizon. The model is revised annually and a baseline projection is produced, which assumes that current policy remains in place. The baseline projection is then compared with the results of alternative policy scenarios.

As far as possible the approach is to estimate autoregressive distributed lag (ARDL) models which are subsequently simplified using a testing down procedure, along with *a priori* methodological considerations (Roche 1999). This limits the chance of data mining. The models are currently estimated in Microfit and SAS and simulated in Excel.

The modelling methodology employed follows closely that which has been used by FAPRI for many years with great success. This also facilitates the use of world and EU projections to be utilised by the Irish model. At present a small country assumption is used for Ireland, which can be justified given its relatively small size.

As a multi-product modelling system, the model is well suited to reflecting the supply and demand interrelationships among agricultural products (as exemplified by the beef and grains/feed relationship detailed later). Behavioural relationships reflecting supply and demand responses can be built in. Another attraction of this model type is the flexibility it offers to incorporate exogenous variables such as weather, technical change, population growth, income and consumer preference trends.

This flexibility also means that the different policy instruments in place for the commodities can be modelled explicitly. For example, static equilibrium models, whether partial or general, that rely on supply elasticities typically taken from surveys cannot always capture the situation in the beef sector, where there are quantitative restrictions in the form of quota limits on premia payments and indirectly through the milk quota. Clearly, in order to model the sector properly, the actual number of animals has to be modelled.

The dynamic nature of the system allows the incorporation of lagged transmission and adjustment processes over time (as one would encounter in livestock breeding cycles). While static models cannot trace the accumulation of stock variables, (particularly significant in EU agriculture) there are no such problems in a dynamic framework.

In summary, the estimation of a system of single equations provides a great deal of flexibility, and allows specific policies to be modelled. Of course, all modelling approaches have weakness as well as strengths. Because of data restrictions the model is estimated using annual data, although work is also carried out in parallel using quarterly or monthly data where available. Where there have been big changes in the Common Market Organisation (CMO) for commodities, such as beef, this leaves the approach vulnerable to Lucas critique style reservations (Hallam, 1990).

In common with other partial models, the model is focused on agricultural supply, demand and trade for commodity type products and does not model higher end processed foods. The inter-linkage between the farm and food industries is therefore not examined. Also, the modelling system does not include a feedback into the macro economy that would exist in a general equilibrium. So effectively a small sector assumption is made. While this implies that the activities of agriculture represent only a small portion of the activity of the economy, this is an increasingly reasonable assumption in the Irish case.
3 Aspects of the Irish Model

In the limited space afforded here, three equations are presented in detail, each from a different commodity model and each reflecting the manner in which a particular crucial relationship is addressed in the construction of the overall model.

3.1 Dairy Model: Farm Level Manufacturing Milk Price

This equation establishes the farm level (manufacturing) milk price in Ireland. Due to its small size and because of the large proportion of its milk production which is exported, Ireland is assumed to be a price taker. Hence for modelling purposes the drivers of the Irish milk price are prices for dairy products prevailing in the EU.

In its simplest form one might attempt to establish a linkage between the average EU milk price and the milk price in Ireland. Such a relationship however would not adequately reflect the fact that individual dairy product prices within the EU do not move in lockstep and may diverge within limits depending on market conditions. This might not be a significant draw back were the Irish dairy product milk similar to that of the EU average. However the Irish dairy product mix remains heavily weighted in favour of butter and SMP (both subject to intervention) while in the EU generally cheese is the dominant product. Clearly this must be reflected in the specification of the price linkage equation.

Alternatively, one might attempt to link wholesale dairy product prices in Ireland to wholesale prices in the EU. However, there is only very limited availability of wholesale Irish dairy product prices (particularly for cheese). The course actually taken was to link EU wholesale prices to the Irish milk price. With limited degrees of freedom due to the small sample size afforded by the annual data, a parsimonious specification was desirable.

It was decided to weight the EU price for the three main Irish dairy products (butter/SMP and cheese in accordance with their relative ratios of production historically. In practice the butter and SMP prices were weighted in an approximate 2 to 1 ratio reflecting the joint nature of production involved.1 Thus, a single composite EU dairy product price was available as an explanatory variable. Additionally this composite price because of its heavy intervention product weighting should reflect the relative dependence of Irish milk prices on intervention.

Farm milk price, the dependent variable, is calculated exclusive of VAT to factor out temporal variations in the Irish milk price which are attributable to variations in the VAT refund rate applying to farm produce. A standardised 3.7% butterfat content milk price series, which removes any variation in price attributable to variations in fat content, is used. The results of the manufacturing milk price equation are shown in Table 1.

\[
\text{PRICEMLK} = f(\text{PRICEWGT})
\]

where

<table>
<thead>
<tr>
<th>PRICEMLK</th>
<th>Irish Manufacturing Milk Price 3.7% butterfat (ex. VAT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRICEWGT</td>
<td>FAPRI EU Domestic Butter/SMP price + Cheese price weighted to reflect Irish product mix</td>
</tr>
</tbody>
</table>

The equation was estimated using OLS. The coefficient on the composite EU dairy product price variable PRICEWGT is significant at the 1% level and is of the hypothesised sign. The elasticity at 1.08 conforms with expectations.

---

1 In fact this 2 to 1 ratio is not observed in Ireland since a high proportion of skimmed milk from butter production is converted to casein under the support of the Commission's casein aid programme. Due to the absence of any casein prices, either historical or projected, the assumption was made that SMP prices proxy for casein prices, although it is acknowledged that there are arguably deficiencies attached to this assumption.
Table 1: Irish Manufacturing Milk Price (PRICEMLK): 1976-1997

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>t-ratio</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-0.01</td>
<td>-1.87</td>
<td></td>
</tr>
<tr>
<td>PRICEWGT</td>
<td>0.95</td>
<td>25.78</td>
<td>1.08</td>
</tr>
</tbody>
</table>

R² = 0.97 Durbin Watson = 1.23

Source: FAPRI-Ireland Dairy Model

3.2 Beef Model: Beef Replacement Heifers

The difficulties of modelling changes in agricultural supports and changing policy instruments themselves are especially evident in the beef sector. The original CMO for the sector was primarily operated through price support, but direct payments have also been utilised since the early 1980s. Of course the MacSharry reforms saw these payments extended, a trend that has been continued in the Agenda 2000 package. Modelling these payments is made more difficult through the presence of quantitative limits on the payments.

Since imports of young animals into Ireland are very small, the number of animals that are available for the production of beef is determined by the size of the national cow herd. This herd is comprised of the dairy herd, and suckler cows. Dairy cow numbers are determined in the dairy model. The continuing existence of the EU milk quota means that the number of dairy cows is effectively institutionally determined.

The specification of the beef model includes both inflows to and outflows from the breeding herd. The beef cow herd has grown enormously over the past 10 years with a corresponding growth in the number of beef replacement heifers over the period due to the imposition of the milk quota and increases in various beef direct payments. More recently, the growth in cow numbers slows. This is due to the fact that at their peak suckler cow numbers exceeded the quota on the suckler cow premia by around 10%, hindering further expansion. All these factors need to be incorporated in the model.

Theory provides us with a particular specification and lag structures have been taken into account implicitly through the specification of the returns variable. The equation was estimated using OLS

\[
\text{BEHEIF} = f(\text{BEHEIF}(-1), \text{CWRET})
\]

where:

- **BEHEIF**: beef replacement heifers Ireland; CSO\(^2\) numbers on farms on December 1\(^{st}\) annually
- **CWRET**: a ratio of the expected gross margin from suckler cows to that from dairy. The gross margin for suckler cows includes the direct payments payable on "an average cow" including suckler premia, extensification and headage. The price of the weanlings sold is also included, as are the costs of the enterprise.

In order to capture the dairy cow quota effect the gross margin in the sector is held constant at its 1985 level. The growth in the number of replacements therefore follows the increase in the suckler gross margin.

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\(^2\) Central Statistics Office

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>t-ratio</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>11.59</td>
<td>1.60</td>
<td></td>
</tr>
<tr>
<td>BFHEIF(-1)</td>
<td>0.60</td>
<td>4.13</td>
<td></td>
</tr>
<tr>
<td>COWRET</td>
<td>40.48</td>
<td>3.85</td>
<td>0.30</td>
</tr>
<tr>
<td>DUM94</td>
<td>-25.95</td>
<td>-2.89</td>
<td></td>
</tr>
</tbody>
</table>

\[ R^2 = 0.90 \quad \text{Durbin Watson} = 2.04 \]

Source: FAPRI-Ireland Beef Model

As can be seen the fit of the estimated equation is reasonable, and the turning points are captured. The coefficients are all of the hypothesised sign and conform to a priori expectations regarding their magnitude. A complicating problem, however, is the need to capture the changes taking place under Agenda 2000.

The number of cows in 1998 and 1999 exceeded the limit of the suckler cow premia. This was resolved in the model by adjusting the level of the payment that appeared in the returns term by the extent to which the cow numbers exceeded the quota. In effect this means that whilst under the limit, replacements to the herd are determined as in the estimated equation. As the number of cows exceeds the limit, however, the number of replacements becomes increasingly determined solely by returns from the market. In the absence of Agenda 2000, therefore, numbers would effectively remain close to the suckler quota limit.

The changes made under Agenda 2000, however, introduce further complications in the form of the facility to claim suckler premia on heifers, and the changes in the extensification and stocking density regimes. These changes have lead to the rapid removal of cows held over quota. To a certain extent the 1998 and 1999 figures give us some information as to these effects, augmented from information from a number of sources. 3

In response to these, therefore, the upper bound at which the payment level starts to be reduced was dropped. Thus the model operates as if the quota limit is lower than it actually is.

3.3 Inputs Model: Beef Feed per Head

The beef feed per head equation is a good example of how the different sub-models are linked. For instance the effects of an exogenous shock to Irish cereal/feed prices influences the costs for the individual commodity sectors and this filters through to each sector’s land share. The modelling exercise is concerned specifically with commercially traded compound feed. Cattle feed is separated out into dairy rations and beef rations. All feed equations were estimated on a per head of animal basis. 4 A grass growth variable was compiled to reflect grass-growing conditions during both the spring and autumn grazing period. In this manner this variable is used as a proxy for the availability of other feeds such as dry matter fodder. 5 A beef output per hectare variable is also specified. This variable seeks to capture producers’ decisions regarding the carcass weight of their animals and secondly the intensity of producers’ production.

---

3 These included farm level modelling analysis, farmer surveys, information from the Department of Agriculture, Food and Rural Development and expert review groups drawn from a wide variety of farming related discipline.

4 Beef (beef cattle, calves and bull) rations per head were calculated by dividing the total non-dairy cow rations figure by the sum of the June enumeration of beef cattle, calves and bulls.

5 Between 80% to 90% of the diet for Irish cattle is grass based.
A lagged dependent variable is also included for most input demand equations on the basis that producer decisions concerning input use in year \( t \) is often influenced by producer behaviour in year \( t-1 \). The initial specified equation was:

\[
\text{FEEDHEAD} = f(\text{FEEDHEAD}(-1), \text{BEEFHECT}, \text{GRASS})
\]

where:
- **FEEDHEAD** Quantity of Feed Per Head Consumed Per Annum
- **BEEFHECT** Annual Beef Output Per Hectare
- **GRASS** National Autumn Grass Growth Weighted by Cattle numbers

The equation was estimated using data from 1976 to 1997 inclusive. Having tested down the final specification arrived at is detailed in Table 3.

### Table 3: Beef Feed Per Head (FEEDHEAD) Equation 1976-1997

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>t-ratio</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>112.89</td>
<td>2.69</td>
<td></td>
</tr>
<tr>
<td>FEEDHEAD(-1)</td>
<td>0.72</td>
<td>7.02</td>
<td></td>
</tr>
<tr>
<td>BEEFHECT</td>
<td>47.82</td>
<td>2.13</td>
<td>0.16</td>
</tr>
<tr>
<td>GRASS</td>
<td>-9.26</td>
<td>-3.08</td>
<td>-1.26</td>
</tr>
</tbody>
</table>

\( R^2 = 0.94 \) \quad \text{Durbin Watson} = 2.04

Source: FAPRI-Ireland Inputs Model

The three significant variables are the lagged dependent variable, the beef output per hectare variables and the grass growth variable. The coefficients on all three variables had the hypothesized signs. The negative sign on the coefficient on the weather variable captures the inverse relationship between the provision of dry matter fodder and concentrate consumption. The coefficient on the lagged dependent variable was also found to be significant.

### 4 Results

This model has already been used for policy analysis purposes (Donnellan, Binfield and McQuinn 1999). The recent Agenda 2000 reforms to the CAP system were examined and comparison made with the alternative of a continuation under the existing (MacSharry) policy of the time. European Union level analysis was conducted by our research partner FAPRI at the University of Missouri Columbia in the USA. Using the linkages already described in this paper these results were incorporated in the model of Irish agriculture. The results are quite detailed but given the limitations on space only a brief summary is presented here.

#### 4.1 Milk

In the dairy sector, the increase in EU quota and the 15% reduction in intervention prices lead to a drop in dairy commodity prices across the EU. Butter is worst effected but sizable declines in cheese SMP and WMP powder prices are also projected. Baseline analysis would indicate a decline in the EU average farm milk price of 15% relative to 1998 by 2007, with a similar percentage decline occurring in Ireland. In spite of this, the introduction of direct payments for milk production and the additional milk produced under increased quota are seen to compensate for much of the decline in milk price.

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6 Prior to this analysis the initial proposals for CAP reform, published by the European Commission in March 1998, were also analysed.
4.2 Livestock and Meat

The outlook for the beef sector shows the most substantial changes relative to the current situation, due to the impact of sizable changes in policy emanating from Agenda 2000. Beef cow numbers are set to fall substantially from their 1998 levels mainly because some heifers can now qualify for suckler cow premia and also because of changes made in stocking density criteria. Although there is a reduction in the price of beef, the EU market balances above the support level and Irish producers income is maintained through higher payments.

Agenda 2000 has only minor implications for the other meat sectors. Although reduced beef prices will result in lower pig, sheep and poultry prices, there is a countervailing decline in feed prices (and hence production costs) stemming from the crop sector reforms.

4.3 Crops and Agricultural Inputs

Under the Berlin agreement the EU is capable of exporting milling wheat without export subsidies. Therefore it is world wheat prices rather than intervention prices that place a floor on EU wheat prices.

As a result of cheaper wheat and barley prices under Agenda 2000 feed usage per head in the dairy sector increase. However, due to declining carcass weights, a decrease is projected in the beef feed usage. Dairy production becomes slightly more intensive leading to increased nitrogen application.

4.4 Agricultural Income

Table 4 presents projections for the different components of GAO and income under the baseline scenario. Overall, the value of Irish output is down 3 per cent in 2007 on its 1998 level under the baseline scenario whilst output value is down 1 per cent by 2007 relative to 1998. Consequently, GAO is also down 11 per cent relative to the 1998 level by 2007.

Due to Agenda 2000 reforms, subsidy payments are set to increase substantially. By 2007 this constitutes a 25 per cent increase on the already inflated 1998 level. Most of these increased payments occur within the beef sector where the main constituents are the special beef premia, suckler premia and the slaughter premia. The dairy sector from 2005 onwards will be in receipt of a direct payments package and cereal direct payments are also increased.

Table 4: Projections for Gross Agricultural Output Input and Income (IR £ nominal)

<table>
<thead>
<tr>
<th></th>
<th>1998</th>
<th>2007</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td>1,087</td>
<td>818</td>
<td>-25</td>
</tr>
<tr>
<td>Milk</td>
<td>1,134</td>
<td>1,005</td>
<td>-11</td>
</tr>
<tr>
<td>Other Outputs</td>
<td>1,050</td>
<td>1,098</td>
<td>5</td>
</tr>
<tr>
<td><strong>Gross Ag. Output</strong></td>
<td><strong>3,270</strong></td>
<td><strong>2,921</strong></td>
<td><strong>-11</strong></td>
</tr>
<tr>
<td>Inputs</td>
<td>1,765</td>
<td>1,689</td>
<td>0</td>
</tr>
<tr>
<td><strong>GAP</strong></td>
<td><strong>1,505</strong></td>
<td><strong>1,232</strong></td>
<td><strong>-3</strong></td>
</tr>
<tr>
<td>Subs and levies</td>
<td>1,038</td>
<td>1,296</td>
<td>25</td>
</tr>
<tr>
<td><strong>Income</strong></td>
<td><strong>1,866</strong></td>
<td><strong>1,808</strong></td>
<td><strong>-3</strong></td>
</tr>
</tbody>
</table>

Note: From 1st January 1999 IR£=1.27 EURO
Source: FAPRI-Ireland Partnership.

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7 Due to poor weather condition since 1998, many payments were brought forward from 1999 to 1998 to ease many farmers' cash flow difficulties.
Inputs expenditure is projected to remain unchanged. Despite a projected substantial fall off in the consumption of animal feed per head cost increases do occur elsewhere. Thus, when the total revenue figure calculated above is combined with the inputs figure, overall income in Irish agriculture is projected to decline by 3 per cent between 1998 and 2007 in nominal terms.

5 Conclusions and Further Work

In this paper some of the main features of the FAPRI-Ireland model for agriculture have been described, with examples from some key equations. The paper has shown that the flexibility of the approach has allowed the incorporation of a multitude of policy instruments, and also showed how the particular national characteristics of Irish agriculture can be captured. The transparency of the approach allows key behavioural relationships to be explicitly determined in a way that allows their review by academics and non-academics alike. The model is therefore able to analyse detailed changes to agricultural policy, such as the recent Agenda 2000 reforms, providing information to policy makers, industry, and farmers.

The drawbacks of the approach are that in concentrating on the agricultural sector, feedback relationships with other sectors are not incorporated. The use of annual data in the estimation of the model also provides some problems. It is hoped that in the future some of the shortcomings of the model can be addressed. Specific work currently underway includes estimation using data of a higher frequency, the simulation of the entire model in SAS, and the disaggregation of the FAPRI EU model to incorporate an Irish component. Parallel work at the farm level, and an economy wide input-output model will augment and improve the model's projections.

References


Assessing the consequences of environmental Policy scenarios in Flemish Agriculture

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Abstract
In this paper a partial equilibrium, regionalised, comparative static, mathematical programming model of the primary Flemish agricultural sector is presented. The primary agricultural sector model is linked to an input-output model (I/O-model). The mathematical programming model allows to implement the environmental policy regulations and to show in detail the consequences for production, farmer’s income, nutrient losses and other environmental emissions in eight different regions of Flanders. The input-output module allows for the assessment of the economy-wide effects in Flanders of adjustments taking place in primary agriculture.

The paper discusses in short the calibration procedure of the mathematical programming model, the environmental variables taken into account, the input-output model and the way the mathematical programming model of the primary agricultural sector is linked with the input-output model.

Keywords: Agriculture, Programming Model, I/O, Calibration, Environment

1 Introduction
The surge of animal production in Flanders, over the past few decades, has led to increasing concerns about the environmental damage caused by the abundant application of animal manure on the fields of Flanders. The damages involve decreasing qualities of soil, air and ground- and surface waters (eutrophication and acidification). This has been recognised by the Flemish government, who put abatement measures into effect in the Manure Action Plan (MAP) of 1991, which was sharpened in 1995. Recently further sharpening of the regulations related to animal production and manure applications has been proposed in the Manure Action Plan of 1999. It has been stipulated by law that an evaluation of the socio-economic consequences of alternative manure abatement measures should be available during the debate on follow-up schemes in this field. To this end a simulation tool has been built at the request of the Flemish government as an instrument to be used by the Flemish administration itself in the preparation of the socio-economic evaluation of MAP alternatives (SELES). The instrument has also been adapted at the request of the Flemish Environmental Agency to reflect the magnitude and development of other environmentally sensitive inputs and emissions related to Flemish agriculture. Here SELES is deployed as an instrument for the assessment of economic and environmental developments under alternative medium term scenarios. The findings are to be published in a Flemish environmental outlook (MIRA-S).

This paper aims to set out the main characteristics of the SELES tool, that was designed to assess the economy-wide economic and environmental consequences of Flemish policy
measures, and to report and discuss some of the experiences gathered in using this model for environmental policy analysis in Flanders.

2 The tool and its usage

At the request of the Flemish government a simulation tool, the so-called SELES model, was developed by a joint venture of two research institutes, the Institute for Applied Economic Research of the Limburg University Centre (ITEO/LUC) and the Dutch Agricultural Economics Research Institute (LEI). In conducting the research, these institutes could draw on the expertise and data available at the Belgian Centre for Agricultural Economics (CLE) and many other public Flemish and Belgian organisations. The main characteristics of the simulation tool developed are as follows.

The SELES model is a combination of two modules: (a) a mathematical programming module, describing in detail all the options available to farmers in the different subregions of Flanders, and (b) an input-output module representing the Flemish economy. The mathematical programming model allows to implement the environmental policy regulations and to show in detail the consequences for production, farmer’s income, nutrient losses and other environmental emissions in eight different regions of Flanders. The input-output module allows for the assessment of the economy-wide effects in Flanders of the adjustments taking place in primary agriculture. Both model components are integrated in a user-friendly simulation package that can be used by practitioners: (a) to define specific simulation scenarios, through the adjustment of policy parameters and other exogenous variables, (b) to simulate these various scenarios, and (c) to analyse the outcomes using the extensive reporting facilities of the package.

2.1 Primary agriculture

The general structure of the regionalised model of the Flemish primary agricultural sector is very similar to the set-up of other mathematical programming agricultural sector models. Recent examples are Horner et al. (1992), Jonasson and Apland (1997) and Lehtonen (1999). In the mathematical programming module for the Flemish primary agricultural sector, eight regions have been distinguished. A single ‘regional farmer’ represents each region. These regional farmers are maximising the net revenues of their operations, consistent with micro-economic theory. Nevertheless, the approach is basically macro-sectoral, in the sense that within each region no further breakdown at the level of specific farming types has been conducted. The choice for this sectoral approach is motivated by the following: (a) environmental policy regulations and especially those for manure applications affect almost all subsectors of the agricultural economy, (b) consistent supply-utilisation balancing accounts are automatically maintained and (c) the coupling to the rest of the Flemish economy through input-output linkages is rather straightforward. The endowments of the ‘regional farmer’ are the area available for agricultural activities and the technological production possibilities of the region he is representing. He is assumed to adjust the levels of his agricultural activities in such a way that his operation maintains maximal profits while complying with the constraints imposed by the environmental policy. Many activities have been distinguished in the model, both in arable and horticultural cropping and in animal husbandry. The ‘regional farms’ are connected by interregional transports of manure surpluses and agricultural inputs, like calves, piglets, etc. These interregional shipments are determined and priced endogenously. Output prices are exogenous, though, as they are determined at the internal EU market. These have been derived from appropriate scenario simulations with the CAPMAT model (see Keyzer and Merbis, 1998 and 2000). A more detailed description of a similar model for the Netherlands can be found in Helming (1998).
2.2 Calibration of the primary sector model

The mathematical program is of a comparative static nature and has been calibrated on a historical database for the period 1993-95, using the methods of so-called positive mathematical programming (PMP) (see Howitt (1995). The calibration approach followed for the Flemish primary sector model is somewhat different from Howitt (1995). Specifically, the calibration was accomplished through the parameterisation of upward sloping marginal cost functions at the historical reference point, keeping yields per hectare and per animal constant. Howitt (1995) explains the method from the primal side, using downward sloping yield functions and keeping variable costs per hectare constant. Furthermore, in calibrating the Flemish primary sector model prior information was used about supply elasticities to solve for the unknown marginal cost parameters.

In the Flemish primary sector model both cropping activities and livestock activities are calibrated at observed values of the base period. Furthermore, milking activities are partitioned over alternative technologies and calibrated at estimates of the numbers of milking cows per technology. PMP calibration of milking cows by technology is the main methodological difference between the model explained in this paper and the model of Helming (1999).

The basic idea behind the PMP calibration approach is that data are too scanty to reflect the production process in full. As a result some restrictions are ‘unobserved’ and the standard LP model lacks sufficient information to completely calibrate the model. Using data based average cost functions and dual values from a constrained LP model, the PMP calibration assesses the importance of these unobserved restrictions and converts these into full costs. The calibrated optimisation problem becomes.2

\[ \text{Max} \sum p_i y_i x_i - (\alpha_i + \beta_i x_i) x_i \]  
\[ \text{Subject to} \]
\[ \sum a_{il} x_i = \sum a_{il} \pi_l \]
\[ \sum \delta_i x_i \leq B_k \]
\[ x_i \geq 0 \]

Where \( x_i \) is the number of animals and acreage of land allocated to activity \( i \), \( p_i \) and \( y_i \) are respectively the price per unit and yield per unit of activity \( x_i \), \( \theta_{il} \) and \( \rho_{il} \) are respectively productivity and demand coefficients of activity \( x_i \) for the \( l \)th intermediate, \( \pi_l \) denotes the shadow value of intermediate \( l \), \( \delta_i \) is the fixed resource requirement coefficient of activity \( i \), \( B_k \) is the \( k \)th resource availability and \( \pi_k \) denotes the shadow value of resource \( k \). \( \alpha_i \) and \( \beta_i \) are the marginal cost parameters.

The PMP approach uses three stages to calibrate the PMP model in equation (1). The first stage is to construct a constrained LP model. This LP consists of a linear objective function, regional balances for intermediates (manure, roughage and youngstock) and regional balances for fixed resources (land and quota). The LP is called constrained because in the first phase of the PMP calibration approach upper bounds or constraints are put on the agricultural

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1 The authors are indebted to Bob MacGregor of Agriculture and Agri-Food Canada for his help in explaining and implementing the PMP calibration approach.
2 Equations (1) are a more general representation of the optimization problem given in Helming (1999).
activities. These constraints are observed values in the models’ base period plus a very small perturbation $\varepsilon$. This perturbation $\varepsilon$ decouples the activity constraints from the fixed resources constraints. This means that the dual values associated with the fixed resources constraints are not changed by the set of activity constraints. Now, if the intermediate balances are not binding the constrained LP model will generate dual values on constrained activities ($\lambda_i$). These dual values together with the data based average cost function and the prior information on supply elasticities are used to derive the parameters of the calibrating marginal cost function. In the third stage of the PMP calibration approach the parameters of this marginal cost function are included in the objective function and the activity constraints that were introduced in the first stage are deleted. As argued by Howitt (1995): “the resulting model calibrates exactly to the base-year solution and original constraint structure.” Our experience is that the success of the calibration depends on the dual values of the intermediate balances. These should be relatively low to calibrate the model exactly.

In the following we will show how the parameters of the marginal cost function can be derived. Consider the following linear marginal cost function for activity $x_i$.

$$\text{MC}_i = \alpha_i + \beta_i x_i$$

(2)

The supply elasticity of $x_i$ can be written as:

$$\eta_i = \frac{1}{\beta_i} \left( \alpha_i + \beta_i x_i \right) x_i$$

(3)

At the observed numbers of animals or area allocations to crops the marginal cost of activity $x_i$ equals the sum of data based average variable cost ($AC_i$) plus the unobserved costs represented by the dual of the LP calibration ($\lambda_i$).

$$MC_i = AC_i + \lambda_i$$

(4)

Equation (3) can be rewritten as:

$$\eta_i = \frac{1}{\beta_i} \left( AC_i + \lambda_i \right) x_i$$

(5)

Using this, the marginal cost slope coefficient can be solved as:

$$\beta_i = \frac{(AC_i + \lambda_i)}{\eta_i x_i}$$

(6)

Using equations (2) and (6) the intercept coefficient $\alpha_i$ can be solved from:

$$\eta_i = \frac{1}{\left( \frac{(AC_i + \lambda_i)}{\eta_i x_i} \right)} \left( \frac{\alpha_i + \left( \frac{(AC_i + \lambda_i)}{\eta_i x_i} \right) x_i}{x_i} \right)$$

(7a)

or from

---

3 Through the perturbation $\varepsilon$ the LP model will allocate more resources to the most profitable activity than actually observed in the base period. As a result the marginal activity is only restricted by the resource constraint, for example total land available in a region. The dual value on the regional land constraint equals the gross margin of this marginal cropping activity.

4 For any activity $x_i$, $\lambda_i$ equals the difference between the gross margin of that specific activity and the sum of corresponding dual values on the constraint set (both intermediate and fixed resources).
Assessing the consequences of environmental Policy scenarios in Flemish Agriculture

\[
\eta_i = \left( \eta_i \over (AC_i + \lambda_i) \right) \left( \alpha_i + (AC_i + \lambda_i) / \eta_i \right)
\]  
(7b)

as

\[
\alpha_i = (AC_i + \lambda_i)(\eta_i - 1)
\]  
\[
\eta_i = \frac{AC_i + \lambda_i}{2\lambda_i}
\]  
(7c)

Finally, the supply elasticity has to be determined. This has been done by simply assuming \(\alpha_i = AC_i - \lambda_i\) and \(\beta_i = 2\lambda_i / x_i\). Under these assumptions the supply elasticity of equation (3) can be rewritten as

In calibrating the model, an upper bound of 2 has been imposed for the value of the supply elasticity of equation (8).

2.3 The environment

SELES not only accounts for the economic decisions to be expected from Flemish farmers under changing policies, but also allows to assess, by means of nutrient accounts, the corresponding amounts of nutrient surpluses at soil level and the losses of nitrogen as ammonia. Tables 1 and 2 give insights into the importance of nutrient surpluses at soil level and the emission of nitrogen as ammonia in Flanders. These are official figures from the Flemish Environmental Agency. Table 2 shows that ammonia emissions in Flanders mainly originate from the pig sector. The data behind these tables are included in the SELES database and similar tables can be calculated from the model results. Most of the components on the nutrient accounts are based on fixed coefficients for input use and emissions per activity while the allocation of fixed resources to the activities is endogenous.

Table 1: Nutrient surpluses at soil level in 1997, Flanders, kg/hectare

<table>
<thead>
<tr>
<th></th>
<th>Nitrogen (N)</th>
<th>Phosphate (P(_2)O(_5))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply (total production and application)</td>
<td>454</td>
<td>163</td>
</tr>
<tr>
<td>Inorganic fertilisers</td>
<td>139</td>
<td>30</td>
</tr>
<tr>
<td>Animal manure</td>
<td>264</td>
<td>119</td>
</tr>
<tr>
<td>Deposition</td>
<td>38</td>
<td>2</td>
</tr>
<tr>
<td>Other</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>Biological fixation</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Removal (total uptake)</td>
<td>236</td>
<td>84</td>
</tr>
<tr>
<td>Uptake by fodder crops</td>
<td>187</td>
<td>65</td>
</tr>
<tr>
<td>Uptake by other crops</td>
<td>49</td>
<td>20</td>
</tr>
<tr>
<td>Gross nutrient balance</td>
<td>218</td>
<td>78</td>
</tr>
<tr>
<td>Emission of ammonia</td>
<td>87</td>
<td>0</td>
</tr>
<tr>
<td>Nutrient balance at soil level</td>
<td>132</td>
<td>78</td>
</tr>
</tbody>
</table>

Based on 635,000 hectare of agricultural land

Figure for 1998

Source: Flemish Environmental Agency

\(^5\) A graphical representation of these assumptions can be gained from the first author upon request.
Table 2: Emission of ammonia from different sources in 1998, Flanders, kg NH₃/hectare

<table>
<thead>
<tr>
<th>Source</th>
<th>Beef and dairy cattle</th>
<th>Pigs and sows</th>
<th>Poultry</th>
<th>Other cattle</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stable</td>
<td>15</td>
<td>30</td>
<td>5</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>External storage</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Application</td>
<td>14</td>
<td>31</td>
<td>2</td>
<td>0</td>
<td>48</td>
</tr>
<tr>
<td>Pasturing</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>36</td>
<td>61</td>
<td>7</td>
<td>1</td>
<td>105</td>
</tr>
</tbody>
</table>

Source: Flemish Environmental Agency

Recently the SELES database has been extended to other environmental inputs and emissions from agricultural production in Flanders as well. These are pesticides, energy, water, CO₂, SO₂, CH₄ and N₂O. Table 3 gives insight into the shares of agricultural activities in the use of environmental input and emissions from agricultural production.

Table 3: Shares of agricultural activities in the use of environmental input and emissions in 1998, Flanders

<table>
<thead>
<tr>
<th>Agricultural activities</th>
<th>Energy</th>
<th>CO₂</th>
<th>SO₂</th>
<th>CH₄</th>
<th>N₂O</th>
<th>Pesticides</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milking cows</td>
<td>1.2</td>
<td>1.0</td>
<td>0.0</td>
<td>37.7</td>
<td>31.8</td>
<td>11.3</td>
<td></td>
</tr>
<tr>
<td>Beef cattle</td>
<td>0.7</td>
<td>0.6</td>
<td>0.0</td>
<td>20.7</td>
<td>27.3</td>
<td>8.0</td>
<td></td>
</tr>
<tr>
<td>Veal calves</td>
<td>0.1</td>
<td>0.1</td>
<td>0.0</td>
<td>4.2</td>
<td>1.3</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Sows</td>
<td>12.1</td>
<td>9.4</td>
<td>0.2</td>
<td>11.1</td>
<td>9.8</td>
<td>7.7</td>
<td></td>
</tr>
<tr>
<td>Pigs</td>
<td>0.8</td>
<td>0.6</td>
<td>0.0</td>
<td>23.0</td>
<td>20.6</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>Laying hens</td>
<td>1.8</td>
<td>1.4</td>
<td>0.0</td>
<td>1.6</td>
<td>2.5</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Meat chicken, including parent animals</td>
<td>0.7</td>
<td>0.6</td>
<td>0.0</td>
<td>1.0</td>
<td>2.3</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>Other cattle</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.9</td>
<td>4.5</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Grassland</td>
<td>3.9</td>
<td>3.2</td>
<td>0.1</td>
<td>.</td>
<td>.</td>
<td>1.4</td>
<td>26.6</td>
</tr>
<tr>
<td>Maize</td>
<td>3.0</td>
<td>3.3</td>
<td>0.1</td>
<td>.</td>
<td>.</td>
<td>4.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Cereals</td>
<td>2.1</td>
<td>2.3</td>
<td>0.0</td>
<td>.</td>
<td>.</td>
<td>16.6</td>
<td>2.4</td>
</tr>
<tr>
<td>Potatoes</td>
<td>0.9</td>
<td>1.0</td>
<td>0.0</td>
<td>.</td>
<td>.</td>
<td>9.1</td>
<td>6.6</td>
</tr>
<tr>
<td>Sugar beets</td>
<td>0.8</td>
<td>0.8</td>
<td>0.0</td>
<td>.</td>
<td>.</td>
<td>9.0</td>
<td>2.2</td>
</tr>
<tr>
<td>Other arable and vegetable crops</td>
<td>2.8</td>
<td>3.0</td>
<td>0.1</td>
<td>.</td>
<td>.</td>
<td>16.4</td>
<td>0.7</td>
</tr>
<tr>
<td>Horticulture, including ornamental plants and fruit</td>
<td>69.1</td>
<td>72.6</td>
<td>99.5</td>
<td>.</td>
<td>.</td>
<td>42.4</td>
<td>20.0</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Source: miscellaneous, see table 4

Table 4 gives the development of total input use and emissions. Again, the model assumes that the input and emission of environmental variables per activity and technique are fixed and not reacting to relative price changes. However, at the aggregate level the input use and emission is endogenously determined as a function of the volume and composition of the Flemish agricultural production.
Table 4: Development of environmental input use and emissions, 1991-1998 (1998 = 100), Flanders

<table>
<thead>
<tr>
<th></th>
<th>1991</th>
<th>%</th>
<th>1993</th>
<th>%</th>
<th>1995</th>
<th>%</th>
<th>1998</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy in PJ</td>
<td>32.3</td>
<td>100</td>
<td>32.0</td>
<td>99</td>
<td>31.9</td>
<td>99</td>
<td>32.3</td>
<td>99</td>
</tr>
<tr>
<td>CO2-emission in mln. Kg.</td>
<td>2,214.6</td>
<td>104</td>
<td>2,148.8</td>
<td>101</td>
<td>2,117.4</td>
<td>100</td>
<td>2,123.9</td>
<td>100</td>
</tr>
<tr>
<td>SO2-emission in mln. Kg.</td>
<td>23.7</td>
<td>332</td>
<td>22.7</td>
<td>319</td>
<td>11.2</td>
<td>157</td>
<td>7.1</td>
<td></td>
</tr>
<tr>
<td>CH4-emission in mln. Kg.</td>
<td>242.2</td>
<td>102</td>
<td>243.1</td>
<td>102</td>
<td>247.3</td>
<td>104</td>
<td>238.6</td>
<td></td>
</tr>
<tr>
<td>N2O-N-emission in mln. Kg.</td>
<td>7.4</td>
<td>99</td>
<td>7.4</td>
<td>99</td>
<td>7.6</td>
<td>101</td>
<td>7.5</td>
<td></td>
</tr>
<tr>
<td>Water use in mln. m3</td>
<td>84.8</td>
<td>98</td>
<td>84.4</td>
<td>97</td>
<td>86.7</td>
<td>100</td>
<td>86.9</td>
<td></td>
</tr>
</tbody>
</table>


2.4 Flemish economy

For the description of the linkages with the rest of the Flemish economy, a Flemish input-output table was constructed, in which the primary agricultural sector, along with the upstream and downstream industries, have been desaggregated at the level of several subsectors. The construction of the SELES input-output module was based on a projected (1993) and regionalised (Flanders) version of the Belgian input-output table for 1980. The primary agriculture was subsequently disaggregated to 10 subsectors and the food industry to 8 subsectors, using, among others, the data from the Farm Accountancy Data Network of the CLE and the firm accountancy registry of the Belgian National Bank. Using the techniques available for input-output analysis, it is possible to define specific agri-food-complexes, summarising all economic activity in terms of value added, employment, etc., that is directly and indirectly linked to Flemish agricultural subsectors (like, for example, pig farming or horticulture under glass). Moreover, the overall activity of each of these complexes can be decomposed into separate parts that can be assigned to (a) primary agriculture, (b) deliveries to primary agriculture, (c) processing, (d) deliveries to processing, and (e) distribution (up to retail level). Aggregated results for the Flemish agri-food complex in 1993 are presented in table 5.

Table 5: Value-added and employment in the Flemish agri-food complex in 1993.

<table>
<thead>
<tr>
<th></th>
<th>Value-added a)</th>
<th>Employment b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agri-food</td>
<td>211</td>
<td>118</td>
</tr>
<tr>
<td>Primary, total</td>
<td>68</td>
<td>55</td>
</tr>
<tr>
<td>Primary, livestock</td>
<td>24</td>
<td>31</td>
</tr>
<tr>
<td>Primary, other</td>
<td>44</td>
<td>24</td>
</tr>
<tr>
<td>Share in Flemish economy (%)</td>
<td>5.26</td>
<td>5.69</td>
</tr>
</tbody>
</table>

in 1,000,000,000 Belgian Frank
in 1,000 Full Time Equivalent
Source: SELES
2.5 Linking the modules

When linking the modules for the primary agriculture and the complete Flemish economy, one has to realise that both modules have not been constructed from a common underlying database. In addition, there is a fundamental difference in the costing of subsectors in the two modules. The costs of farming activities in the programming module is limited to those expenditures that are directly attributable to the activity at hand, whereas the costs allocated to industries in the input-output module are covering all the costs. Therefore, the representation of costs in the two modules is not ‘one-to-one’ and as a result, the outcomes of the programming module do not fully match the data corresponding to the primary sector’s ‘block’ of the input-output table. Therefore, it was decided to apply percentage changes (with respect to the base or reference point) for linking the two modules. In other words, percentage changes were generated by the programming module and then applied to (parts) of the corresponding entries of the input-output table. These inputs from the primary sector model are percentage changes of the value of primary agricultural output per sector, value of purchased inorganic fertiliser per sector, value of other purchased inputs per sector, value of manure transportation and application per sector, value of manure processing per sector and value of other intermediates per sector. The full table was subsequently adjusted to accommodate for the changes in primary agriculture. A detailed exposition of the model’s characteristics, including a user guide for the user-friendly interface, is given in the final report of the project (Veenendaal (ed.), 2000). Linkage of the two modules enables to relate in a comparative static manner for a given policy package the economic consequences for the full Flemish economy to the savings in burdening the environment.

3 Some conclusions

The SELES model has been used by the Flemish administration itself in evaluating alternative Manure Action Plans (see Flemish government, 1998 and 1999). The applications of the model revealed that: a) coverage of the complete economy mitigates the overall economic impacts because abatement costs (e.g. involved in manure transports and industrial manure processing) lead to increased value added and employment outside the agricultural sector; and b) the variation in environmental benefits over policy scenarios seems to exceed the variation in economic consequences (see Reyns, Peeters and Veenendaal, 1999). However, it might be quite misleading to conclude that one should therefore rush for the scheme(s) that are most benign for the environment. On the one hand, it may be argued that the economic indicators in the model do only partly reflect the economic consequences for primary agriculture as the consequences for primary employment may have been underestimated. Family farms’ survival and therefore agricultural employment may crucially depend on certain threshold values for agricultural family income, and this might be affected to a much larger extent than value-added. On the other hand, the variations in environmental benefits are to a large extent due to alternative assumptions with respect to (sometimes obligatory) manure processing. As it is still an open question whether large scale manure processing will become a viable option for getting rid of the Flemish manure surplus the economic consequences may be underestimated. If industrial manure processing will not take off in the next few years to come the economic consequences for the (intensive) livestock sectors will no doubt become severe.

As there are many degrees of freedom in calibrating the primary sector model to a base period, it remains an open question whether one could improve on the ‘responsiveness’ of the model by choosing a different method of calibration. Backcasting experiments with SELES (from the base period 1993-95 to the pre-milkquota period 1982-84) showed a reasonable track record in general. Growth in subsectors with relatively high net-revenues was underestimated though. This could partly be explained from non-economic pressures leading
to a rapid expansion of pig farming in Flanders. Nevertheless, it remains an interesting research question whether one could improve the ‘dynamic’ track record of the model by calibrating it in a different way.

This issue seems to be even more important in establishing an environmental outlook for, say, a period of ten years ahead. In the outlook work for the Flemish Environmental Agency we did not, therefore, exclusively rely on an arbitrary calibration method for the base-period. Instead, the CAPMAT simulation outcomes for Belgium for Agenda 2000 (see Keyzer and Merbis, 2000) were used to derive price and volume information for Flanders for specific years of the outlook period (2002, 2005, 2010). Subsequently, SELES was calibrated to each of these points in time separately. Again, this approach is not entirely satisfactory because CAPMAT was built to address EU-wide policy questions rather than environmental issues and ignores developments in environmental policy regulations in Flanders. We conclude that the relation between specific PMP methods and the ‘dynamic’ track record of static model projections remains an issue that deserves further attention.

References
Briefs on Further Research
An Econometric Model of the Irish Beef Sector

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The FAPRI-Ireland Partnership is joint venture between Teagasc, the Irish Universities, other groups in Ireland, and the Food and Agriculture Policy Research Institute (FAPRI) in the USA. A major part of the project was the development of an econometric model that could be used to analyse changes in policies that could impact on agriculture. The model has already been used to assess the likely impact of the changes to the CAP under Agenda 2000 (Donnellan et al, 1999).

The models are estimated as a set of individual equations. An autoregressive distributed lag model is specified from which a final equation is determined through the use of the appropriate tests (Roche 1999). The strength of this type of approach is primarily that of flexibility in that it allows the various policy instruments utilised under the CAP to be fully incorporated. The final equations are also transparent and can be reviewed by a non-technical audience. The projections for key variables as simulated under a no policy change scenario are presented in Table 1 below.

Table 1: Baseline Projections for Beef Sector.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>IR£/100kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adult Cattle Price</td>
<td>170</td>
<td>147</td>
<td>-23</td>
<td>-14%</td>
</tr>
<tr>
<td>'000 Head</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beef Cows</td>
<td>1,217</td>
<td>1,061</td>
<td>-156</td>
<td>-13%</td>
</tr>
<tr>
<td>IR£ Million</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value of Output (1)</td>
<td>1,087</td>
<td>818</td>
<td>-269</td>
<td>-25%</td>
</tr>
<tr>
<td>Direct Payments (2)</td>
<td>622</td>
<td>771</td>
<td>149</td>
<td>24%</td>
</tr>
<tr>
<td>Sector Revenue (1)+(2)</td>
<td>1,709</td>
<td>1,589</td>
<td>-120</td>
<td>-7%</td>
</tr>
</tbody>
</table>

The impact of Agenda 2000 is that there is a reduction in the price of finished animals of 14 per cent, since the EU market price balances above the new support price. Since both beef and dairy cow numbers fall, there is a large drop in output numbers. There is, therefore, a substantial reduction in the (market) value of the sector's output. The increase in direct payments mainly offsets this, however.

Keywords: Beef, Econometric Model, CAP, Policy Analysis

References
An Econometric Model of the Irish Dairy Sector

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The FAPRI-Ireland Partnership is joint venture between Teagasc, the Irish Universities, other groups in Ireland, and the Food and Agriculture Policy Research Institute (FAPRI) in the USA. A major part of the project was the development of an econometric model that could be used to analyse changes in policies that could impact on agriculture. The model has already been used to assess the likely impact of the changes to the CAP under Agenda 2000 (Donnellan et al, 1999).

The models are estimated as a set of individual equations. An autoregressive distributed lag model is specified from which a final equation is determined through the use of the appropriate tests (Roche 1999). The strength of this type of approach is primarily that of flexibility in that it allows the various policy instruments utilised under the CAP to be fully incorporated. The final equations are also transparent and can be reviewed by a non-technical audience. The projections for key variables as simulated under a no policy change scenario are presented in Table 1 below.

Table 1: Main Irish Dairy Variable Projections 1998 - 2007

<table>
<thead>
<tr>
<th></th>
<th>1998</th>
<th>2007</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk Price (IR£/Litre)</td>
<td>0.23</td>
<td>0.197</td>
<td>-14.50%</td>
</tr>
<tr>
<td>Dairy Cows (’000 Head)</td>
<td>1,308</td>
<td>1,168</td>
<td>-10.70%</td>
</tr>
<tr>
<td>Milk Output/Cow (Litres/Head)</td>
<td>3,817</td>
<td>4,340</td>
<td>13.70%</td>
</tr>
<tr>
<td>Value of Output (IR£ Million)</td>
<td>1,134</td>
<td>1,005</td>
<td>-11.40%</td>
</tr>
<tr>
<td>Direct Payments</td>
<td>0</td>
<td>86</td>
<td></td>
</tr>
<tr>
<td>Sector Revenue</td>
<td>1,134</td>
<td>1,091</td>
<td>-3.80%</td>
</tr>
</tbody>
</table>

By 2007 the Agenda 2000 dairy reforms will be on stream. The Irish milk price is projected to decline to 19.7p per litre or 15% below its 1998 level. However, much of this revenue decline is counteracted by the introduction of direct payments. By 2007, sector revenue, is down by less than 4% relative to 1998. The increase in milk output per cow is anticipated of close to 1.4% per annum, with a consequential decline in dairy cow numbers. By 2007, dairy cow numbers are projected to decline 11% on 1998 levels. Agenda 2000 has only a modest impact on the dairy sector. Much of the projected reduction in milk prices is counteracted by the introduction of direct payments and increases in quota. Other changes taking place in the sector are largely unrelated to policy reform.

Keywords: Dairy, Econometric Model, CAP, Policy Analysis

References
Econometric Models of the Irish Cereals & Inputs Sector

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The FAPRI-Ireland model of the Irish agricultural sector is a multi-sectoral model (see Binfield, Donnellan and McQuinn 2000). The cereals model is one of a number of different commodity models, which provide projections of the total value of Irish agricultural output. The provision of an inputs model enables projections of total income for the overall sector.

The FAPRI-Ireland model is a partial equilibrium model. Econometrically estimated commodity models are created and these are then solved simultaneously. Ten-year projections are then provided for key variables within each sector using projected values for exogenous data. Two sets of results are typically generated. The first is the baseline or "no policy change" result. These are then compared with the results of a particular scenario performed on the model. Table 1 presents the 2000 baseline results for the Irish cereals and inputs models. The baseline results presented are fully inclusive of the Agenda 2000 reforms in March of 1999.

Table 1: Main Projections for Irish Cereals & Inputs.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed Barley Price</td>
<td>75</td>
<td>71</td>
<td>-6%</td>
</tr>
<tr>
<td>'000 Hectares</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat Area</td>
<td>84</td>
<td>71</td>
<td>-16%</td>
</tr>
<tr>
<td>Barley Area</td>
<td>191</td>
<td>179</td>
<td>-6%</td>
</tr>
<tr>
<td>'000 Tonnes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td>425</td>
<td>367</td>
<td>-13%</td>
</tr>
<tr>
<td>Beef Rations</td>
<td>1000</td>
<td>893</td>
<td>-11%</td>
</tr>
<tr>
<td>IR £ Million</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cereals Value</td>
<td>113</td>
<td>106</td>
<td>-6%</td>
</tr>
<tr>
<td>Input Expenditure</td>
<td>1765</td>
<td>1689</td>
<td>-4%</td>
</tr>
</tbody>
</table>

Owing to the assumed path of the euro/dollar exchange rate path, Agenda 2000 is envisaged to result in the price of grain falling by about 6 per cent. With setaside being kept at 10 per cent, actual cereal area planted falls for the main Irish cereals. However yield growths over the projection period ensure that production levels remain relatively static between 1998 and 2007.

Irish input consumption is generally set to fall because of Agenda 2000. With falling beef and dairy cows total feed consumption and nitrogen application falls significantly. This is also brought about by increased extensification lower carcass weights projected for the beef sector.

Keywords: Econometric Modelling, Baseline, Agenda 2000.

References
The SELES Tool for Evaluating Governmental Policies Related to Flemish Agriculture

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At the request of the Flemish government a user friendly simulation tool (SELES) has been developed to get insights into the economic importance of the Flemish agro-food complex and the trade-offs between the economic and environmental consequences of alternative abatement policies. The tool has been developed as a joint venture of two research institutes, the Institute for Applied Economic Research of Limburg University Centre (ITEO/LUC) and the Agricultural Economics Research Institute (LEI). The main characteristics of the tool developed are as follows. It is a user-friendly combination of (a) a mathematical programming model describing in detail the options available to farmers in the different subregions of Flanders, and (b) an input-output model of the Flemish economy. The tool has been specifically developed for use by the Flemish administration itself.

Both model components are integrated in a user friendly simulation package enabling the user a) to define specific simulation scenarios through adjustment of policy parameters and other exogenous variables, b) to simulate this scenario and c) to analyse the outcomes using the extensive reporting facilities of the package. The user-friendly shell has been developed according to a modular approach that facilitates the maintenance of the shell and quick adaptation of its functionality to new needs and requests. For example, the modellers can adapt their models without any changes being needed in the other modules of the shell. And conversely, the modellers won’t have to adapt if one would, e.g., adapt the graphical user interface to make it accessible through the Internet.

The simulation tool has been used in a scenario approach by the Flemish administration itself. The consequences of alternative policy measures aimed at reducing the pollution problems related to animal manure in Flanders have been analysed both in a provisional study by the Flemish government in July 1998 and in a final report to Flemish parliament in March 1999. The tool has also been extented to give it much wider coverage of environmental issues for a medium term scenario study at the request of the Flemish Environmental Agency.

Keywords: Mathematical Programming, Input-Output Analysis, Agricultural and Environmental Policy Assessment, Graphical User Interface

References
A dynamic regional sector model of Finnish agriculture (DREMFIA)

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A dynamic regional sector model of Finnish agriculture (DREMFIA) is a dynamic, partial disequilibrium model which does not assume full economic equilibrium but a gradual adjustment to changing economic conditions. The model simulates agricultural sector up to year 2010. The model is primarily intended for agricultural policy analysis but it can also be applied in other economic analyses, for example, in analysing the structural development and environmental effects of different agricultural policies. The core of the model is an optimisation model simulating the markets by maximising consumer and producer surplus subject to regional market balance, input use, and crop rotation and resource constraints. The optimisation model, which is solved for each year using the outcome of the previous as the initial value, provides an annual supply and demand pattern, which may not represent an economic equilibrium. Restrictions are imposed on the consumption and the production variables based on the previous year. The restrictions represent systems dynamics of agriculture, i.e. short term technical and biological constraints in each production line. There is some uncertainty related to these constraints, but they are not arbitrary, however. Time series of production data and expert knowledge can be used in evaluating the restrictions.

Finland is divided into four main regions in the model. Consumption, processing of milk and sugar as well as the feed use of animals are aggregated per main regions, and products can be transported between the main regions. Production is further divided into 14 subregions according to different support areas. Most products in the model are priced at the producer price level, but milk products are priced at the retail level. The model includes 18 different milk products and their regional processing activities. Armington assumption is used to differentiate between domestic and imported products which are modelled as imperfect substitutes. Export products and domestic products are homogenous and Finland cannot influence the price level in the EU. Export cost functions are used to prevent large short term fluctuations in exports. Inflation of input prices is given exogenously.

Use of feed may change endogenously because of changes in prices and agricultural subsidies. Certain energy, protein and roughage needs of animals have to be fulfilled. The application of fertilisers depends on grain and fertiliser prices through crop yield functions. The use of other inputs per hectare is exogenous each year. Crop yields, as well as some animal yields, are given exogenous linear trends in the dynamic model, representing an increase in biological production potential. A quadratic function, fitted to empirical data, is used to model the dependence between the milk yield of dairy cows and the use of feed stuffs.

Use of some inputs, like labour and capital, becomes gradually more efficient. This is due to new investments and adoption of new technology. Technological diffusion concept is used to model endogenous investments and technological change i.e. adoption of new production technologies. New efficient technologies are adopted with more or less caution. Each technology develops and the rate of development is proportional to the rate of adoption. Knowledge and skills of farmers improve and spill out if some new technology becomes increasingly popular. Capital shifts gradually to the most profitable technologies.

Keywords: Sector Model, Finnish Agriculture, Consumer and Producer Surplus, Armington-assumption, Dynamics, Production, Policy Analysis
Agricultural Policy Analysis Simulator (APAS) and Policy Analysis Matrix (PAM) for Slovenian Agriculture

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Problem and model description
Slovenian agriculture is dealing with many dimensions of European integration. Obligations from trade agreements and preparation for accession to the European union (EU) lead to reforms of national agricultural policy. Simultaneously, with the gradual reduction of market-price support, various types of budget-support measures are becoming increasingly important to compensate for declined farmers’ incomes. Adoption of direct payments is becoming a central agricultural policy question of Slovenian EU accession. Decisions in Agenda 2000 do not envisage the possibility of direct payments for candidate countries. It is expected that negotiations in this field will be most demanding. Slovenia has, due to its comparable price level for many products, a different starting point than other candidate countries. Dealing with all candidates in one package could, therefore, lead to negative results for Slovenian agriculture and may become a possible obstacle for the whole accession process.

To get some quantitative estimates of likely effects of different policy scenarios APAS and PAM models for Slovenian agriculture have been developed. The APAS is designed as econometric multicommodity, partial equilibrium model, taking into account specific features of Slovenian agro-industry and recent policy changes and it is suitable to conduct sensitivity analysis imitating different policy scenarios. On the other hand PAM has been used for analysing income, protection and competitive issues of the same policy options. Some results of APAS simulation are directly incorporated in PAM calculations both at individual producer as well as aggregate level, relaxing static nature of original PAM. Also PAM results are fed back in APAS to perform simplified welfare analysis. APAS and PAM spreadsheet model for Slovenian agriculture is prepared to cover the period until 2010.

Results and discussion
Independently of the conditions of Slovenian EU accession, it will have a negative balance for some commodities (grains, pork) and the country will remain important net importer of products which are in high surplus in EU. On the other hand milk, beef, poultry and apple production will remain export oriented. In general, positive income effects of accession in the case of equal treatment of Slovene agriculture (full package of direct and structural payments) is anticipated, with income situation for different sectors importantly determined by EU accession conditions. According to the model results no significant change can be expected in apple and sugar beet sectors. In the sectors with direct payments scheme (cereals, beef) income effects depends on the outcome of negotiations. In some less protected products (milk, pork, poultry, grape, potato) market and income situation after accession depends on the competitiveness of the whole food chain (mainly food processing sector). However, without direct (or transitional price reduction payments) we could expect significant worsening of the situation for the majority of Slovene agricultural producers. The results of the model show the importance of the pre-accession policy. If CEFTA trade liberalisation is introduced as proposed than this will determine also the accession results.

Keywords: Slovenia, Agricultural Sector Modelling, APAS, PAM, Policy Scenarios
An agricultural sector model for impact analysis of Hungary's EU-accession

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An original country model for agriculture and food processing has been developed by AKII for impact analysis and policy recommendation of Hungary's EU-accession. In the present version a static simulation model is used detailed to 60 agricultural and food products in order to attain a detailed coverage of production, consumption and trade which is relevant to policy makers. Exogenous changes in producer prices, subsidies and tariffs as consequences of accession generate impacts in the first year of EU-membership. Supply and demand equations were econometrically estimated based on time series data. Recent scenario elements are direct payments, exchange rate, period of price transmission and pre accession levels of food production and consumption. The results indicate a positive producer response to increasing prices in 2002 assumed as the year of EU-accession. Consumer responses strongly depend on length of price transmission while export earnings are indirectly influenced by direct payments. Main results of the model have been presented for experts from the Ministry of Agriculture and for a committee of the Academy of Science. A more detailed presentation may be found in Mészáros, Spitálszky, Udovecz, 2000.

Keywords: EU-Accession, Hungarian model, impact analysis, supply elasticities, demand elasticities

Reference
The econometric simulation model MESTA was developed for analyzing the effects of agricultural policy measures on Spanish agriculture. The specification follows the conventional approach that incorporates economic theory through dynamic specifications of structural equations estimated from time series data. This "ad hoc" approach was adopted because it was considered more flexible than a formal one to incorporate directly a wide variety of specific policy instruments and also because its transparence makes easier the relationship with policy makers.

The model was initially structured in two levels of aggregation: the national level and a regional one. This regional level model was completed for Navarra, an autonomous region in Northern Spain. Although the experience of modeling this regional component was very interesting, the difficulties encountered when trying to estimate equations statistically in a satisfactory way at that level led us to focus our efforts on the development of the national model.

The initial version of MESTA (1995) included 221 equations for the national level and 156 equations for Navarra. A total of 236 equations were econometrically estimated. Subsequently, several modifications have been introduced for incorporating to the model the changes in the CAP and improving the specification of the dairy and beef sub-sectors.

Functionally, MESTA is made up of four linked sub-models that are used for simulating the following aspects: i) land allocation and crop production, ii) animal production, iii) demands for inputs, and iv) input and output prices. Prices for feed, that depend on cereal prices and affect to the animal production, are the main link among the four sub-models. The competition for land establishes inter-relationships between the different agricultural sub-sectors. Econometric allocation systems, structured hierarchically from total agricultural land to individual crop land, are used for allocating land consistently to all the crops considered in the model. An important feature of this agricultural sector model is the inclusion of irrigated crops and non-irrigated crops in different crop groups. In the case of Mediterranean countries, not taking into account that irrigated and dry crop production systems are radically different is a major limitation for the agricultural policy analysis ability of a model adopting such approach.

The Spanish Ministry of Agriculture is currently using the model and financing its improvement and updating. The main analyses promoted by the Ministry till now has been on the effects of: the National Plan for Irrigated Lands, the Agenda 2000 proposal on the crop sectors, the Agenda 2000 proposal on the dairy sub-sector, and the increase of Spanish imports of citric and other fruits coming from Mercosur-Chile.

Keywords: Sector Model, Econometric Model, CAP Simulation, Spain
Chapter VI

Applied Analysis:

European and International Models
The Status of FAPRI’s EU Modeling Effort

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Abstract
The paper reviews the status of efforts by the Food and Agricultural Policy Research Institute (FAPRI) to model EU and world agriculture. FAPRI has developed multi-market, structural, dynamic, non-spatial, partial equilibrium models of international agricultural markets for use in preparing market projections and conducting policy analysis. A new experimental model for the grain, oilseed, livestock, and dairy sectors solves for quantities and prices in France, Germany, Italy, the United Kingdom, and the European Union as a whole. Model results indicate that equilibrium domestic market prices in Europe are likely to fall by smaller proportions than the institutional price reductions mandated by Agenda 2000.

Keywords: Econometric Modeling, Agricultural Trade, Grains, Oilseeds, Livestock, Dairy, European Union

1 Introduction
The Food and Agricultural Policy Research Institute (FAPRI), a joint institute of the University of Missouri and Iowa State University, provides quantitative analysis of issues related to food, agriculture, and natural resources. For the last 15 years, FAPRI has used its modeling system to develop projections of world agricultural commodity markets. From an initial focus on wheat, maize, and soybeans, FAPRI has expanded its modeling system to cover world markets for rice, cotton, barley, sorghum, sugar, meats, and dairy products. Models of EU agricultural markets have been an integral part of the FAPRI system from the start.

Recent reforms of the Common Agricultural Policy (CAP) and the potential accession of new states to the European Union have led FAPRI to make important changes in its models for European agriculture. Analysts at Iowa State University maintain the models of EU agriculture that are used as part of FAPRI’s global modeling system. These models treat the European Union as a single bloc, generating estimates of EU production, consumption, trade, and prices for important agricultural products. Recent model improvements include the incorporation of more policy variables in the EU models and the development of detailed models for several of the Central European states seeking admission to the European Union.

As part of an ongoing project in Ireland and Northern Ireland, the University of Missouri is developing a new experimental model of EU agricultural markets. The EU Grain, Oilseed, Livestock, and Dairy (EU GOLD) model covers the wheat, barley, maize, rapeseed, sunflower, soybean, beef, pigmeat, poultry, sheepmeat, milk, cheese, butter, skim milk powder, and whole milk powder sectors. Country-level estimates of production, consumption, stocks, trade, and prices are provided for France, Germany, Italy, and the United Kingdom,

* The authors would like to thank Kay Maas for her help in preparing the manuscript and the teams of researchers in the United States, Ireland, and Northern Ireland for their efforts in developing the modeling system.
with the other eleven member states treated as a bloc. Although the model is still under development, it is fully operational and was used in 1999 to conduct analysis of the Agenda 2000 reforms (Westhoff and Young, 1999).

This paper provides an overview of the global FAPRI modeling system and the EU GOLD model. The paper should be seen as a status report on an ongoing project rather than a final report on a finished product.

2 The global FAPRI modeling system

FAPRI has developed multi-market, structural, dynamic, non-spatial, partial equilibrium models of agricultural markets.

- The models provide for integrated analysis of multiple agricultural markets. Wheat and barley are substitutes in both production and in livestock rations; cereal prices affect livestock production; dairy cow numbers affect the production of both milk and beef and the demand for feed; etc.
- Model equations incorporate the most important factors driving supply and demand, with special attention to policy levers. While the models are used to generate market projections, proper reflection of market structure receives greater emphasis than forecasting ability.
- The models are dynamic, reflecting investment behavior and lags resulting from biological processes. As a result, the models are able to generate multi-period projections that reflect adjustment paths over time.
- The models generate estimates of each country’s net trade in each agricultural commodity, but do not trace bilateral trade flows.
- While the models cover multiple markets in an integrated fashion, they remain partial equilibrium models. Macroeconomic variables such as national income and exchange rates affect agricultural markets in the models, but changes in agricultural markets have no direct feedback effects on macroeconomic variables.

Econometric techniques were used to estimate many of the parameters in the model from time series data. In some cases, however, data limitations or structural change make econometric estimation of model parameters impractical or inappropriate. In these cases, model parameters are selected based on the literature, estimated parameters from similar markets, and analyst judgment. Most equations in the model are either linear or linear in logarithms.

For each commodity, major exporters and importers are modeled separately, with other countries included in regional groupings or a “rest-of-world” category. For most commodities, the model generates supply, demand, and trade estimates for the United States, the European Union, Japan, Canada, Australia, Russia, China, Argentina, Brazil, and Mexico. Additional countries important to world trade are broken out for particular commodities.

2.1 Crop sector model specification

To reflect the peculiarities of particular markets, model specification varies from country to country and from commodity to commodity. For a typical crop (e.g., wheat), the model for a particular country generally would include the following equations.

\[ \text{Area harvested} = f(\text{Lagged area, real expected prices or returns for the crop, real expected prices or returns for competing crops, government subsidy and set-aside programs}) \]  \hfill (1)

\[ \text{Yield per harvested hectare} = f(\text{Trend, area harvested, real expected prices}) \]  \hfill (2)

\[ \text{Production} = \text{Area harvested} \times \text{yield} \]  \hfill (3)
Feed use = \( f(\text{Real price of the crop, real price of other feedstuffs, index of livestock numbers or meat and dairy production}) \) \( (4) \)

Other domestic uses per capita = \( f(\text{Real price of the crop, real price of competing crops, real per capita income}) \) \( (5) \)

Ending stocks = \( f(\text{Real price of the crop, production, beginning stocks, policy variables}) \) \( (6) \)

Net exports = Production + beginning stocks - feed use - other domestic uses - waste - ending stocks) \( (7) \)

Sum of net exports across all countries and regions = 0 \( (8) \)

Trade and agricultural policies dictate the method used to determine domestic market prices. At one extreme, where prices are fixed by government policy, domestic prices are exogenous. At the other extreme, where there are no barriers to trade, domestic market prices are directly linked to a representative world market price (e.g., the U.S. Gulf price of wheat, less U.S. export subsidies) multiplied by the appropriate exchange rate. Simple modifications to the price linkage equation are made to account for fixed per-unit tariffs or export subsidies. Where there are quantitative restrictions on trade, such as tariff rate quotas or export subsidy limits, the appropriate restrictions on net trade are imposed and the model solves for domestic market prices. World market prices are those that ensure a balance of world export supply and import demand.

For particular countries and commodities, this basic model may be modified. For example, oilseed models use behavioral crush demand equations to determine the supply of meals and oils. Most crop models follow the basic structure, however.

### 2.2 Livestock sector model specification

For the livestock sector, the models reflect biological production constraints and imperfect substitution between domestic and traded meat products. The models generally would include the following equations for the cattle and hog sectors:

Breeding herd = \( f(\text{Lagged breeding herd, livestock prices, feed and other input prices, government subsidies and other policies}) \) \( (9) \)

Animals born = \( f(\text{Breeding herd, trend}) \) \( (10) \)

Slaughter = \( f(\text{Lagged animal inventories, livestock and input prices}) \) \( (11) \)

Ending animal inventories = Lagged inventories + animals born + net imports of live animals – slaughter – other death loss \( (12) \)

Slaughter weight per animal = \( f(\text{Trend, mix of breeding and market animals slaughtered, livestock and input prices}) \) \( (13) \)

Meat production = Slaughter x slaughter weight per animal \( (14) \)

Domestic consumption per capita = \( f(\text{Real price of the meat, real price of competing meats, real per capita income}) \) \( (15) \)
Ending stocks = f(Real price of the meat, production, beginning stocks, policy variables)  

Net trade = f(Price of domestically produced meat/price in international markets)  

Production + beginning stocks = Domestic consumption + ending stocks + net trade + waste  

As with the crop sector, representative international market prices are those that balance world export supply and import demand (Equation 8). Poultry models are similar in structure to the model outlined here, except production is estimated directly rather than as a function of animal inventories. For the dairy sector, behavioral equations determine both dairy cow numbers and milk production per cow. Milk is allocated to the various products based on relative prices or returns.

For the United States, meat and dairy product consumption equations are a function of retail prices, while production equations are a function of producer prices. Producer and retail prices are linked using equations incorporating the costs of processing and marketing. For most other countries, data limitations mean that the same price series is used for both consumption and production equations.

2.3 Baseline development and policy analysis

Each year, the FAPRI modeling system is used to generate ten-year baseline projections for world agricultural commodity markets (FAPRI, 1999). For purposes of the baseline projections, current agricultural and trade policies are assumed to remain in place indefinitely. Average growing conditions and rates of technological change are assumed, meaning that crop yields per hectare and other productivity measures generally grow in line with past trends. Assumptions regarding income growth, inflation, exchange rates, and other macroeconomic variables are taken from other sources, including the WEFA Group (Eddystone, Pennsylvania) and Project LINK (United Nations).

Model calibration is a critical part of the baseline development process. Each behavioral equation in the spreadsheet version of the model includes a separate line for an adjustment factor. After the most recent historical data is entered, the spreadsheets automatically calculate the adjustment factors necessary to line up the model equations to actual historical data. When historical adjustment factors are small and without serial correlation, adjustment factors may be set to zero for the projection period. When the historical adjustment factors are large and/or serially correlated, analysts may choose either to carry forward a non-zero adjustment factor, or to reestimate or otherwise modify the behavioral equation.

A preliminary version of the baseline projections is generated each November. In January, FAPRI sponsors a baseline review conference where 50-75 specialists review the baseline and offer their comments. In late January, FAPRI analysts gather to revise the baseline, incorporating the comments received and any other new information. The revision process may involve changing exogenous assumptions, modifying model equations, or changing adjustment factors. The objective is to develop a baseline that is a plausible outlook for the world agricultural economy, given the conditioning assumptions.

Once the baseline is developed, alternative scenarios can be analyzed. A principal use of the modeling system over the past 15 years has been to analyze the impact of alternative agricultural and trade policies. FAPRI researchers conduct these analyses by changing one or more exogenous assumptions, solving the model, and comparing the results to the baseline. Depending on the nature of the scenario and the time available for the analysis, preliminary results may be circulated for review. As with the baseline, FAPRI analysts use the models as
a tool, but will incorporate information from outside the model when it is relevant. One recent example of analyses conducted with the modeling system is Babcock et al. (1999), an analysis of Agenda 2000.

3 The EU grain, oilseed, livestock, and dairy (EU GOLD) model

As part of an ongoing project in Ireland and Northern Ireland, FAPRI at the University of Missouri is developing a new model of EU agricultural markets that provides country-level detail for France, Germany, Italy, and the United Kingdom. The general structure of the model follows the basic outline of the global FAPRI models described in the previous section. The new model also incorporates a number of innovations intended to reflect the unique features of European agriculture and agricultural policy.

3.1 Crop sector

The amount of land devoted to production of various crops is strongly influenced by EU set-aside policies and compensation payments. The EU GOLD model estimates crop area by means of a two-stage allocation process. In the first stage, the total area harvested for three major cereals (wheat, barley, and maize) and three major oilseeds (rapeseed, sunflowers, and soybeans) is a function of real expected returns and rates of compulsory set aside. The real expected return variables reflect a moving average of market prices, trend yields, and a portion of compensatory payments.

The total area harvested equations in most countries are relatively inelastic with respect to market prices, but react strongly to changes in the compulsory set-aside rate. Voluntary set aside is implicit; one reason that estimated area harvested falls when prices fall is that lower market prices encourage more participation in voluntary set aside. Compensation payments have some impact on area harvested, but it is assumed that a one-unit change in per-hectare compensation payments will have a smaller effect on area harvested than a one-unit change in expected returns from the market. Voluntary set-aside is implicit; one reason that estimated area harvested falls when prices fall is that lower market prices encourage more participation in voluntary set aside. Compensation payments have some impact on area harvested, but it is assumed that a one-unit change in per-hectare compensation payments will have a smaller effect on area harvested than a one-unit change in expected returns from the market. Again, part of the explanation lies with the voluntary set-aside program. Under Agenda 2000, future payments for voluntary set-aside are the same as compensation payments for production. If the voluntary set-aside program were open for all producers to idle as much land as they desired, it could be argued that future compensation payments would be largely decoupled from production, and thus should have little effect on area harvested. Limitations on the voluntary set-aside program mean that compensation payments will continue to have a significant effect on producer planting decisions.

The second stage of the area allocation process determines the share of total area that is devoted to each crop as a function of relative expected returns from the market. Once the Agenda 2000 reforms are fully implemented, compensation payments per hectare will be the same across these six crops, and so the compensation payments should not have a major effect on the share of total area devoted to each crop.

As in the global FAPRI model, feed demand in the EU GOLD model is a function of livestock production and feed prices. For each of the feeds covered in the model (wheat, barley, maize, soybean meal, rapeseed meal, and sunflower meal), a livestock index is created. The contribution of each livestock type to the index depends on assumed levels of feed efficiency and ration shares. Parameters are adjusted so the index matches reported feed demand in a recent year. While this livestock index is one argument in the model’s feed demand equations, prices are also included so ration shares can change as relative feed prices change. Symmetry is imposed on model coefficients. Own-price elasticities are slightly larger in absolute terms than the sum of the cross-price elasticities. This means that a proportional reduction in the price of all six feeds would result in a modest increase in demand for each of
the feeds, implying some substitution away from other feeds not explicitly incorporated in the model.

Equations determining ending stocks reflect both commercial stock holding and intervention agency behavior. When market prices exceed intervention levels, the model assumes a modest elasticity of demand for commercial stock holding. When prices fall to intervention levels, the elasticity of demand for stocks is assumed to be much larger. Stock levels rise rapidly when prices fall below intervention, thus ensuring that market prices never fall too far below intervention prices.

3.2 Livestock sector
As with crops, EU beef supplies are strongly influenced by policies. Dairy cow numbers are strongly affected by dairy quotas. Inventories of suckler cows and other cattle are affected by a variety of payment schemes. In the EU GOLD model, suckler cow inventories depend on cattle market prices, feed and other input prices, suckler cow payments, suckler cow payment quotas, and payments for other cattle. Parameters in the equation vary depending on the relationship between suckler cow inventories and suckler cow payment quotas. If inventories far exceed the quota, it implies that many producers are holding cows that are ineligible for suckler cow payments. In such a case, model parameters reflect the notion that market prices have a major effect on marginal production decisions, while suckler cow payments are largely irrelevant. In contrast, if inventories are near the payment quota, it may imply that few producers are willing to hold animals ineligible for payments. In this case, model parameters indicate that the payments and payment quotas have a major influence on marginal production decisions, while the effect of market prices is muted.

For the most part, other equations determining livestock and meat sector supply and demand follow the structure used in the global FAPRI modeling system. Where data permit, the model estimates different categories of slaughter (e.g., cow, calf, and other cattle slaughter; sow and other hog slaughter) separately. Model equations reflect investment behavior. For example, cattle slaughter may actually decline in the short run in response to a price increase, as producers hold back heifers to add to the breeding herd. Meat demand is handled conventionally, with the demand for each meat a function of its price, the prices of other meats, and income levels. Assumed demand elasticities are relatively low (own-price elasticities typically range from –0.2 to –0.3). The current version of the model uses producer prices to drive both supply and demand. One possible enhancement would be to shift to retail prices for demand equations.

3.3 Dairy sector
Given the current structure of EU dairy policy, milk production in most member states is largely determined by milk quotas. The model reflects this fact, allowing output and input prices to have only a modest effect on milk supplies. In Italy, the influence of the quota level on milk production is assumed to be weaker than in the other modeled countries. Milk production per cow is assumed to increase in line with historical trends, with some variation depending on prices and quota levels. As a result, for a given level of quota, milk cow numbers tend to fall over time in most countries. Model equations are not intended to handle large deviations from current dairy policies. In order to examine a large change in dairy price or quota policy, it would be necessary to modify the current model equations.

The EU GOLD model handles milk allocation in a way that ensures that both milk fat and protein balances are preserved. Milk production determines fat and protein production, given assumed technical parameters that are allowed to change over time. Fat and protein are allocated to various uses depending on relative product values (e.g., more protein will be allocated to cheese, all else equal, when cheese prices increase relative to milk powder prices).
Assumed technical coefficients convert the component allocations into estimates of cheese, butter, skim milk powder, and whole milk powder production.

Fluid milk prices are modeled as a function of product prices, with weights depending on production levels. Given a set of product prices, then, the amount of milk allocated to the drinking milk market is determined where the fluid milk price intersects the demand curve. The model assumes that the fat content of drinking milk is declining over time in most countries.

### 3.4 Trade and prices

In the EU GOLD model, the net export supply for each country is simply the difference between domestic supply and demand (Equation 7). Likewise, the net export supply for the European Union as a whole is equal to the sum of the net export supplies for the member states, which in turn is also equal to the difference between domestic EU supply and demand.

The problem is that EU net export supply at a given set of domestic market prices may not be consistent with the likely demand for EU exports at those prices. In the model, a net export demand function is specified for each commodity. These functions generally consider three different types of factors that can affect the demand for EU exports.

1. **European Commission’s desire to export surpluses.** The Commission may wish to encourage exports with the use of export subsidies in order to support market prices and avoid accumulation of intervention stocks. In the model, the Commission’s demand to export products is a function of exportable supplies and the relationship between domestic and world prices. When world market prices increase relative to domestic prices, per-unit export restitutions decline, which is assumed to lead to greater exports, all else equal.

2. **World Trade Organization (WTO) restrictions.** The Uruguay Round agreement limits quantities that can be exported with subsidies and requires that minimum access commitments be met for imports. The model does not permit net EU exports to exceed the amounts suggested by the agreement unless EU market prices fall to world market levels.

3. **Commercial export opportunities.** The European Union already exports a number of products without the use of export subsidies (e.g., pork and certain cheeses). Model equations make the demand for EU exports more elastic when EU prices fall to levels that allow unsubsidized exports, i.e., when domestic EU prices fall to levels prevailing for like products in world markets. In many cases, EU products may not be perfect substitutes for the products exported by other countries, so it is not assumed in the model that the demand for EU exports ever becomes perfectly elastic at the prevailing world price.

Equilibrium prices are those that bring EU export supply and export demand into balance. The model solves for French market prices, but prices in all other EU countries are linked to those French prices. The price linkage equations also consider relative self-sufficiency ratios in France and in the country in question. Thus, if the self-sufficiency ratio falls in a given country, that country’s price will rise relative to the French price. If the model were shocked by reducing supply in one country, the result would be higher prices across the European Union, with the sharpest price increase in the country experiencing the supply shock.

When operated in stand-alone fashion, the EU GOLD model uses reduced-form equations to estimate the response of world prices to changes in EU net exports. This allows the model to mimic the behavior of a global modeling system that recognizes that the European Union is a “large” trading bloc that can affect world market prices.
3.5 Using the EU GOLD model to evaluate Agenda 2000

Although the EU GOLD model is still under development and is undergoing constant revision, the model is operational and was used to evaluate the Agenda 2000 reforms to the CAP agreed in Berlin in March 1999 (Westhoff and Young, 1999). Compared to a baseline that maintained previous policies in place, the Agenda 2000 scenario found that the reforms would have important implications for EU commodity markets.

The analysis suggests that Agenda 2000 is unlikely to reduce market prices for most commodities by the same proportion as the mandated reductions in support prices. In some markets (e.g., beef), the reforms are likely to reduce or eliminate structural surpluses by reducing supply and increasing demand. This allows markets to reach a new equilibrium at prices in excess of the new lower support prices. In other markets (e.g., wheat), it appears possible that EU exports may be able to compete on world markets without the use of export subsidies. In this case, world markets can support EU prices above the new lower support prices. The analysis demonstrates the importance of having a model that permits domestic market prices to be determined by the interaction of market forces and policy.

4 Concluding comments

The EU GOLD model is a work in progress. Future work to improve the model may include:

- Resolving problems with data consistency. Price and quantity data are obtained from a variety of sources that do not always agree with one another.
- Improving parameters of the existing model. More model parameters could be estimated and all model parameters should be reviewed.
- Expanding commodity coverage. The current model does not include a number of commodities important to EU agriculture, including sugar, wine, olive oil, and rye.
- Expanding country coverage. Perhaps in conjunction with European partners, the model could break out some or all of the other 11 members of the European Union as well as candidates for accession.
- Developing sectoral indicators. Estimates of farm income and CAP expenditures could be developed, using approaches similar to those used in FAPRI’s system to estimate U.S. net farm income and government outlays on U.S. farm programs.

Future priorities in FAPRI’s EU modeling work will be established based on discussions with current and potential users of FAPRI analysis.

References


Abstract

Over the recent past the Common Agricultural Policy (CAP) underwent substantial revisions and many of these changes have been analyzed quantitatively. This paper reports on one of these modeling exercises that evolved from scholarly exercises based on an GE-approach, with emphasis on empirical estimation and microfoundations, to a more flexible simulation and accounting system (CAPMAT) that is based on detail, coverage, and timeliness in reporting on policy changes. The model has as main feature that it can address the policy impact on both market developments, farmers’ incomes and the agricultural budget, but otherwise pragmatism has prevailed in the design of an up-to-date model. A brief outline of the construction process and the achievements is given, followed by an exploration of the scope of the model on two accounts. First we deal with how to set exogenous variables, in particular world market prices. Commonly followed procedures provide little guidance how to choose world market prices, while it may render inconclusive policy recommendations. Second, we consider the content of the datasets, where it appears that data on crop and livestock specific input use are all but absent and subsequently imputed from hypothetical coefficients. Statistical exercises on farm-level surveys can replace such constructs and at the same time endow the model with a richer farm typology.

Keywords: CAP Modelling, CAPMAT, General Equilibrium Models, World Market Prices, FADN

1 Introduction

Agricultural policy has been since long a fruitful area for modeling exercises, since government involvement has always been pervasive which leaves much scope for policy advice and also because abundant information on quantities, prices and agronomic variables allows to model the specific features of agriculture. The Common Agricultural Policy (CAP) is no exception and it has been widely reviewed almost ever since its inception. Many different modeling approaches are now reported on (see Bauer and Henrichsmeyer, 1989, EAAE, 2000), ranging from linear programs, commodity and econometric models, general equilibrium models both in calibrated and (almost) fully estimated versions. Models also became more complex, as the number of member states enlarged substantially, commodity regimes became more complex as agriculture became more diverse and the CAP had to accommodate these changes. Policies changed too, from the rather uniform policies based on unconditional price support that are being replaced by a broader range of more market-oriented policies, with intervention policies as a safety net providing minimal price protection, and a shift toward less decoupled means of support.

1 The author acknowledges stimulating comments by Michiel Keyzer on earlier versions of the paper. Work on CAPMAT is conducted within the FEA project which is a joint venture between the Centre for World Food Studies (Amsterdam), and the Netherlands Bureau of Economic Policy Analysis (CPB) and the Agricultural Economics Research Institute (LEI), both in The Hague.
In 1985 a team of researchers, gathered through the ECAM project, started the construction of a detailed model for the CAP. Its primary characteristics are a strong focus on microeconomic foundations, construction of SAMs for the nine member states covered, econometrically estimated behavioral components for allocation, feed use, investments, human consumption, and occupational migration. Specific features are the maintenance of balances for land and feed, and an explicit treatment of roughage as feed intake. The model analyzed the MacSharry reform, the Blair House and GATT agreements, and reflected on long-term developments of the CAP, see Folmer et al. (1994, 1995). Although a robust modeling tool was designed, it appeared hard to maintain and difficult to keep pace with the enlargements of the EU. So, procedures to keep the model up-to-date had to evolve also, which marked the start of a successor project, called FEA (Future of European Agriculture). A new tool was developed for the member states of the EU (CAPMAT), with increased coverage in terms of activities, and steps were taken to increase transparency and portability of the tool (e.g. by replacing parts written in Fortran by Gams code).

This tool has been used for scenario analysis, mostly assessing aspects of Agenda 2000. It meets the policy maker’s need for detail and timeliness of results, but at the expense of rigor in the response by farmers to policy changes. In the paper we will describe the construction process and some of the simulation studies that have been performed. Since this paper figures in an assessment of modeling approaches, two aspects will be covered in some detail. First, we discuss the role of the exogenous variables. Outcomes appear to be robust with respect to most assumptions on exogenous variables (like yields developments and GDP growth), but the choice which world prices to use appears to be fairly intricate. This investigation is relevant as the proposed opening up of the European agriculture to world markets hinges upon the expectation that unsubsidized exports of the major CAP commodities (cereals, beef) eventually become feasible. Various options will be reviewed leading to different outcomes, which leaves the issue on EU’s export competitiveness inconclusive. Second, the construction of CAPMAT’s database is based on linking various datasets that require considerable processing for internal consistency. Many of these data are not primary data but have been constructed using mechanical devices and benchmark coefficients. We will explore what are the options to use primary data in the first place and how to replace the constructed data by econometric estimates.

The outline of the paper is as follows. In section 2 we report on the construction and experience with CAPMAT, in section 3 we consider various options how to link CAPMAT to the outside world, in section 4 we discuss data consistency and scope for using farm-level surveys, and section 5 concludes.

2 The CAPMAT experience

Construction

For the explanation of CAPMAT it is convenient to distinguish between the historical and the simulation period. Over the historical period a full set of data is available from which, after consolidation, the model relations are imputed; this model structure thus obtained is used in the simulation period to assess the impact of new policies.

Model construction departs from linking three major databases that are made consistent and define the model structure for 25 agricultural commodities and 49 agricultural activities. First, we construct the commodity balances (most of them refer to primary commodities, e.g. wheat or coarse grains, but oilseeds is split into oil and meals). The Supply Utilization Accounts (SUAs) of the FAO are used that provide information (and full balances) on processed commodities as well. All these products (flours, bran, molasses, whey, etc.) are transformed to the relevant commodity in CAPMAT’s classification. In most cases this means
transformation back to the raw product. Second, we take from the SPEL database the net revenues per unit, activities and yields for the agricultural activities and compute the input and output matrices that establish the link between activities and items of the commodity balances. Third, the FEOGA is used to identify all subsidies, premiums, direct transfers and costs of the CAP. These are then attributed to the commodities and activities (or treated as exogenously budget items, e.g. as in case of the guidance funds). This allows constructing farmers’ incomes from the gross revenues minus current inputs, adding net subsidies and directing transfers under the CAP.

The model is driven by various price assumptions. For the strong CAP commodities we use the intervention price as domestic price, for non-CAP commodities the tariff-ridden world price prevails. Intensive livestock sectors are priced by markup over costs. This allows showing the impact of lower feed prices. Furthermore, set-aside polices are incorporated, as are quotas for milk and sugar, references areas, and stabilizers that constrain budgetary outlays.

Summarizing, the exercise delivers a consolidated and internally consistent set of accounts based on historical data that generates the agricultural budget, farmers’ incomes and market developments. The advantages are a detailed, up-to-date coverage of countries and policies, and relatively simple maintenance; yet beyond agriculture it only yields environmental indicators based on fixed coefficients whereas income from non-agricultural activities is completely neglected. The scale of operation is national and farm-level analysis would only be possible ex post, using given distribution rules. The main purpose is to provide a medium-term framework for CAP reform.

The data consolidation process generates a set of accounts, but with no mechanism in place to reflect the impact of a policy change. The approach chosen here to fill this defect is to separate the computation of the response of new policies from the generation of the accounts. That means that a separate response model is needed that generates a baseline for activity levels, feed use, consumption and agricultural employment, and under an alternative scenario updates for these variables. This information is minimally needed to feed the accounting system. An interface can be used to accommodate differences in classification. Since ECAM currently performs the role of response model the interface is straightforward, apart from the country coverage. As main advantage we see that maintenance and update of the datasets and consolidation of the accounting system is much less time consuming than the whole model, since it can be done via transparent procedures on existing databases that are refreshed annually. Yet as the response model ages, its reactions become obsolete and less accurate, and it can only be used as a temporary measure.

Achievements
CAPMAT has been used for the early preparations of Agenda 2000, by studying options how to extend and deepen the 1992 reform (CWFS, 1996), in a study commissioned by DG-Economic and Financial Affairs. The Agenda 2000 package was studied in various stages of its inception. Analysis of the March 1998 proposal appeared in a study by DG-Agriculture, together with several other assessments. Main results are that farmers’ income decline due to partial compensation of the price falls, that after a small initial rise the budget stabilizes in nominal terms, and that the export position of the EU remains vulnerable since it can hardly expand to world markets (CEC, 1998a). Similar results were reported to the Dutch Parliament (SOW-VU, CPB, LEI, 1998), and various sensitivity analyses with declining hectare and headage premiums under various world market assumptions were reported to Dutch policy makers. The Agenda 2000 decisions mark a further shift from price support to direct

2 Space precludes formal representation of the accounts, available upon request.
payments which appear to have substantial implications for the net contributions of member states to the central budget, see Bettendorf and Merbis (1998).

The final Agenda 2000 decisions of March 1999 are just a weakened and postponed version of the proposal launched one year earlier, see Keyzer and Merbis (2000). It was shown that the EU cannot export its main agricultural products (cereals, dairy, beef) without subsidies, and that the subsidized exports are going to be limited by the GATT commitments (this is confirmed in Tangermann, 1999, based on the evidence available up to date). The Agenda 2000 decisions are aimed to reduce the gap between world and intervention prices. For wheat the gap can be closed if world market prices are not too depressed.

The model was refined to deal with the sugar regime in some detail, and used to analyze the scope of a sugar reform. Reform of this vertically integrated sector has to take into account the mutual dependency between industry and producers, which leads to problems how to coordinate the prices. In practice the EU settles this indeterminacy by issuing pricing rules both for the processed product (the white sugar intervention price) and the primary producer (minimum price for sugar beet). The study explores the depth of a price fall before sugar beet vanishes from the cropping pattern and the industry goes bankrupt (see Keyzer et al. (2000).

3 The role of world market prices in assessing scenario outcomes

CAPMAT is a model for the EU-15 and takes the rest of the world as given. This implies that assumptions must be made on the evolution of world market prices. How this is done could have major consequences for the final judgement of scenario outcomes, especially in scenarios that assume further decline in support prices. It must be realized that at this point strong abstractions are made that are usually sidestepped. The EU-15 is considered to be an integrated, frictionless market, and homogenous products are exported to one destination at a given ‘world price’. It is ignored that many transactions take place, along many trading channels to various destinations, that prices differ due to quality differences, transportation costs, informational asymmetries, or bargaining power. Policies play a role too, as the EU can use targeted export subsidies, e.g. to maintain its market share. This means that the model aggregates over destinations, time, and commodities.

In practice we simply compute the EU-relevant export price for strong CAP commodities as the difference between the average yearly intervention price and the export refunds per unit. For the future price evolution, information from other sources is needed, and here an essential choice must be made. Let us restrict ourselves to the case of soft wheat for which the intervention price is given in Figure 1. The Agenda 2000 package decides to decrease nominal wheat prices by 15%, which will then be frozen nominally afterwards. The crucial question is then when or if the EU-specific export price for wheat will reach this level, for which three options are available.

First, adopt the long-term development of world prices. Over the very long term, i.e. 1900-1986, the relative prices of nonfuel commodities decline by about 0.6 per cent a year and by 1.0 per cent after 1945, see Grilli and Yang (1988). For wheat we adopt a long-term decline of one percent. Unsubsidized wheat exports then remain unfeasible: the EU-export

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3 The EU export price in 2000 is then computed as the difference between the intervention price in 1999/00 and the average unit export refunds over 1999. Currently the EU through it open market tenders for wheat pays export refunds of 34 €/t. The unweighted average over 1999 is 33.88 €/t, and over January and February 2000 it is 33.86 €/t, see also Figure 2.
price of wheat remains firmly under the intervention price, see Figure 1. If the EU decides to
stock pile the surpluses, these could easily accumulate by some 10 mln t per year.

**Figure 1 Price gap between intervention price and EU-export price**

![Price gap chart](chart)

Note: EU-inflation is assumed to be 1.5% a year

Second, adopt outcomes from models that generate world prices endogenously. This is usually
the approach taken in CAPMAT. Since the outlooks in world models may differ substantially,
additional judgement remains needed. It is anyhow advisable not to accept these outcomes at
face value, since the record of structural models to project world market prices is poor
(Deaton and Miller, 1995). These models depend heavily on stylized assumptions such as
assumed GDP growth rates, and expert judgement continues to play a significant role. Some
recent forecasts show that the variety is large. If we assume an annual increase of 1.5 per cent
up in real terms, the gap between the EU export price and the real intervention price closes in
2006 only. The conclusion is that even under rather optimistic price forecasts the cereals
regime will produce rising exportable surpluses in the near future.

Third, incorporate the volatility observed in world markets. The previous approaches
are derived from highly stylized models and deliver typically growth rates over a certain
period. This hardly resembles the behavior of world markets that are characterized by periods
of extreme volatility, e.g. due to sudden and unforeseen shifts in demand (oil crises, Asia
crisis), or supply shocks due to weather or diseases, see Winters and Sapsford (1990). A
typical example is the Trigo Pan world wheat price, for which every 4-7 year substantial
peaks occur. Any such price series can be interpreted as a stochastic process \( \{ p_t \} \), to be
explained from its own past. If we apply its statistical properties for the year 2000 to the EU
export price, it is likely that in the coming period again a peak will occur that will move world

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4 Other policies could be pursued, of course, such as an increase of the set-aside rate (now at 10 percent), which
is a further retreat from market orientation, and a further lowering of intervention prices which can only be
achieved at the cereals’ regime review (planned for 2002).

5 The World Bank lets the real price go up by 3.1 per cent (World Bank, 2000, p. 65), and then shifts to a long
term decline of 1.2 per cent after 2005. Using the same price deflator, the FAPRI model predicts an increase
by a mere .2 per cent per year (FAPRI, 2000), the OECD (OECD, 1999, p. 100) by .5 per cent, and USDA
(USDA, 2000, p. 119) expects a decline, but no rates are given.
prices above the intervention price. 6 To fix ideas, let us assume that after 2002 the gap between world price and intervention price is 15 ε/t, then there is a probability of 40% that the EU-export price exceeds the intervention price in a particular year. Unsubsidized wheat exports are feasible in the years this is occurring.

The role of the dollar vis-à-vis the euro
Since early 1999 the euro has depreciated by some 20 per cent against the dollar, and one is easily led to believe that this should greatly help the CAP with its nominally fixed intervention prices to reduce the gap with US-dollar quoted world prices. This recent development, if continued over a longer period, would invalidate any concern about non-exportable surpluses. However, in case of wheat there is as yet no substantial evidence that the weak euro is of great help. As the dollar strengthened, the gap between external and internal prices indeed shrank, but the EU still pays some 35 euro for each ton of exported wheat, which is the average since January 1999, see Figure 2. Furthermore, we note that peaks and troughs of the two time series coincide. The figure lends some credibility to the procedure of using projected world market prices as a proxy for the future evolution of CAPMAT’s export price of wheat.

Figure 2: Open market tenders compared to difference intervention and world price (the “price gap”).

Note: World price is weekly Chicago price quotation for wheat, from Jan 7th, 1999, to Feb 24th, 2000. The intervention price equals 119.2 ε/t. Open market tenders are taken from AgraFocus and were suspended from June to mid September 1999.

Conclusion
A fundamental weakness of Agenda 2000: is that under low world market prices the policy regime becomes costly and eventually untenable. Even if one dismisses such a price evolution as overly pessimistic, certain periods of glut will occur and this points to the vulnerability of the CAP. The EU could benefit from price volatility, but this goes at the expense of the rest of

6 Among the many proposals in the literature to estimate commodity prices in this way we follow the suggestion of (Deaton and Miller, 1995) to use an autoregressive model of order 1. This is slightly modified here as pt – μ = a(pt-1 – μ) + bt + εt, with bt denoting a linear time trend and εt white noise. When applied to the real Trigo Pan price (see FAO Food Outlook for data) over the period 1960-1999 the estimated coefficients (with standard errors in brackets) are μ = .316 (29), a = -.64 (.13), b = -.463 (1.25), with standard error of the equation SE=39. This implies that the stochastic process {pt} has a standard error of SE/√(1-a²) = 51.4.
the world that has to bear the cost of adjustments and that would benefit from better price transmission of EU prices. The CAP then bears costs in political terms. The Commission envisaged much more optimistic world price levels when it designed Agenda 2000 (this was before the Asia crisis), and expected export competitiveness much earlier. Now the policy objective of internal price stabilization, which is still deemed important for farmers’ incomes, prevents that export demand comes to rescue the CAP. The lack of price transmission is thus the basic fault in the cereals regime.

4 Consolidation of datasets

The CAPMAT database is a consolidated dataset, merging SUAs, SPEL and FEOGA data, generating commodity balances and net revenues of agricultural activities to which the items of the agricultural budget have been allocated as subsidies, taxes, transfers and costs. Since CAPMAT aims to represent income and budgetary consequences of market developments, internal consistency of datasets is an important requirement. This is achieved in the process of consolidating the datasets. The findings are that the items of FEOGA only lead to slight problems of interpretation of their meaning; with respect to output levels there are only some problems of consistency, but dealing with inputs is more complicated. Since the allocation of inputs determines net revenues per unit (being the difference between gross revenues and current costs per unit), driving the crop and livestock allocation, this issue is at the core of the modeling approach. Especially data on crop and livestock specific inputs are weak: there exists scant information on crop specific fertilizer use, let alone feed utilization per animal type. The solution in SPEL is to derive some set of hypothetical input use coefficients in a particular year for a particular country from national standard gross margins and make these coefficients time dependent by regressing them on yield developments. A further calibration is then needed to assure consistency with national totals for all years (Eurostat, 1995).

This approach has the virtue that, after pricing, the aggregation of all activities makes input use consistent with the Economic Accounts of Agriculture (EAA). Yet it does not solve the data consolidation issue between inputs at the farm and the market, that is, between requirement and availability. In CAPMAT an input matrix is constructed so that input use over all agricultural activities equals corresponding demand in the commodity balance. In concrete terms, this means that total cereals required by all animals must match the feed demand in the cereals balance, and similarly for all other inputs. This could be downplayed as a mere data issue but it is a complicated one since the feed categories in the commodity balances also contain processed products (brans, etc.) and the feed intakes in the activity lists are broad aggregates only (seven types of feed are distinguished in SPEL, against over 400 primary commodities in the SUAs). Both sources (SUAs, SPEL) construct their input data largely by imputation or construction, and differences are bound to be large. The sheer size of the input matrices prevents extensive monitoring, and robust consolidation rules must be applied while preserving consistency with the EAA. Clearly, the data consolidation process exhibits fundamental weaknesses in this part of the datasets, which raises the question whether an alternative approach is feasible.

A major source of data with EU-wide coverage is left untapped: the Food Accountancy Data Network (FADN). This is an annual, large sample of farm data for all member states, with the purpose of designing monetary accounts of individual farms. It yields per farm data on acreage, livestock numbers, yields, and cost of fertilizer and purchased feed as major inputs. The data in FADN therefore do not allow to derive input use per activity directly, but the richness of the sample yields considerable variety over farming practices that can be used to estimate input use relations. From the responses of (parameterized) individual farm models an aggregate input cost can be generated, using national fertilizer or feed prices, and from the
confrontation with observations on costs in a suitable criterion estimates for the input use relation can be derived. This presents an alternative way to find input coefficients per crop and livestock activity at national level. One could go further by defining farm types and perform the estimation at a more disaggregated level. This allows then endowing the model with a farm typology richer than the national farm.

Preliminary exercises suggest that a programming approach to estimate feed utilization coefficients is feasible and promising. Consistency with the EAA can be preserved here too, by imposing consistency constraints at the aggregate level in the program. Currently a simple specification for the feeding technology is used, but suggestions for functional forms can also be drawn from data exploration techniques using non-parametric analysis, and specialized tools to visualize the dataset are helpful in this respect, see Keyzer and Sonneveld (1997). The application of statistical techniques (parametric and non-parametric) on the full range of FADN is anyhow recommended as it may reveal its major weaknesses and white spots and suggest which items must be added to the survey. Even in its present state it seems possible to recover the complete set of inputs for agricultural activities, and this approach could also broaden the policy analysis to farm level.

5 Conclusions and on-going work

The basic objectives of CAPMAT are the flexibility in design, a complete coverage of agricultural activities, commodities, member states and policy rules, and timeliness in reporting scenario outcomes when new proposals are announced. In practice this approach of consolidating datasets, designing an accounting system and using ECAM as response model has fulfilled its aims. It allowed focusing on maintenance efforts and reporting on policy issues for which recent and recognizable representation of the CAP and EU agriculture is deemed essential. Its model structure is still very much geared toward the CAP of today, which focuses on price stabilization by means of institutional prices and intervention stocks, and border protection.

Most of the conclusions reached are fairly robust with respect to the specification of exogenous variables. The major outcome is that in spite of the price reductions in Agenda 2000 (and earlier reforms), the EU cannot expand to world markets due to the limitations posed by the GATT commitments. This result, however, depends very much on world price forecasts. Typically for a medium-term scenario analysis, structural developments are considered, e.g. by adopting the long-term price decline, maybe preceded by short-term price movements toward that trend if commodity markets are severely depressed. Under sufficient volatility of the world market price, e.g. as observed over the past 40 years, there arises considerable scope for relief from the most pressing GATT commitments.

Apart from international tensions, domestic policy concerns figure high on the agenda as new objectives for the CAP are entering the scene. The European Model of Agriculture has been introduced (CEC, 1998b), stressing the multifunctionality of agriculture and the role of non-use values. For the time being, the transformation of the CAP to the European Model of Agriculture has a long way to go, and so do models to handle these issues. The FEA project team is envisaging these changes and is engaged in removing two limitations of the current approach. First, the response model (ECAM) is getting obsolete and will not be updated in its present form. It is being replaced by a recursively dynamic AGE-model taken from the AGE library in Ginsburgh and Keyzer (1997). The sample models presented there will be integrated with the accounting part of CAPMAT, endowed with CAP rules and after calibration it yields a stand-alone model serving as platform for the various extensions ahead. Second, CAPMAT consists of member state models based on the concept of the national farm, drawn from databases that show various weaknesses in the consolidation process. These could be
remedied by using data from the FADN to replace some of the synthetically constructed input coefficients. This is not straightforward, if only because of the limited access to the database. The quality of the survey has not been probed in a full-range evaluation, using semi- or non-parametric techniques. The database has known weaknesses, in particular input quantities per hectare/head, that can currently only be solved via estimation techniques, but are better solved by expanding the questionnaire. Solving these obstacles is one of challenges ahead, both for modelers and policy makers.

References


A Modelling Tool for Policy Makers: MFSS99

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Abstract
In response to demand by policy makers a new modelling tool for EU policy makers has been designed for future use by EU officials, the “MFSS99”. This paper presents the basic structure and some details on this static partial equilibrium model. Its design reflects a compromise between transparency and userfriendliness on the one hand and relevance on the other. Markets clear with exogenous international prices or exogenous EU trade volumes, requiring and permitting the tapping of information arising from trade models. Both the supply side and the demand side rest on elasticity sets which are calibrated to conform to microeconomic theory and assumptions on technology in the food sector. The model may handle the main CAP intruments such as border measures including WTO constraints, set aside, quotas and premia of different kind. Technical infrastructure has been developed to permit a user friendly operation of the model.

Keywords: CAP Modelling, Partial Equilibrium, Userfriendliness, Calibrated Elasticities

1 Background
To provide decision support for the recent Agenda 2000 project, a number of well known quantitative impact analyses have been performed (European Commission 1998 and 2000). One of the major contributions to these impact analyses came from the Medium-term Forecasting and Simulation System (SPEL/EU-MFSS), developed and operated for many years by Weber (Weber 1995). Because this system is both the starting point and the yardstick for the exercise to be described later, a very short discussion of this precursor will be useful. Common to all modules of the SPEL system developed in the past is the activity-based accounting approach. The agricultural sector is described in detail by an activity matrix with yield and input coefficients and linkage by product flows. The system covers the agricultural sector in the definitions of the Economic Accounts for Agriculture (EAA) and includes complete market and farm balances. This extensive database (Wolf 1995) was an abundant source of information tapped by the MFSS, but due to important changes in the EAA methodology and increased scarcity of public funding the continued maintenance and revision of this database is by no means certain. Uncertainty regarding a continuous provision of internally consistent input and output coefficients was one of the constraints to be reflected in any future modelling work at the EU level.

The Medium-term Forecast and Simulation System was a fairly complex partial equilibrium model. The core component on the supply side gave levels of production activities as a function of changes in the (autoregressively) expected value-added per unit of the production activities. Feed demand could be derived from these activity levels using requirement functions relying on nutrition science because the level of disaggregation was sufficiently high. Human consumption was modelled based on a calibrated set of elasticities.
However a high degree of differentiation together with explicit modelling of expectation formation and dynamic elements from the animal population implies already a quite complex structure. On top of this, the CAP was enriched, every other year, with qualitatively new policy instruments, which had to be integrated in the model, typically under very tight time constraints, which were dictated to a large degree by the political agenda of CAP amendments and reforms. Over the years, the MFSS had thus become increasingly cumbersome and difficult to handle. Furthermore, because the model was mainly written in Fortran, it was essentially handled by only a couple of people, finally becoming essentially a one man tool, as only a limited number of officials at Eurostat or other EU authorities had reasonable chances to directly look at its technical details. This caused additional delay and friction in the communication between model builder and operators on the one hand and ultimate users on the other.

Quite in contrast to this experience, let me quote from a 1999 press release (FAPRI 1999) some remarks of the Irish minister of agriculture made during a visit at the University of Missouri: "Joe Walsh in a visit to the University of Missouri campus told about using personal computers, loaded with models of the Irish economy, during meetings in Berlin with European trading partners. Representatives from EU countries were setting agricultural production quotas for each nation. "Ireland was the only country that really had a scientific basis to their negotiating stance," Walsh said. "We had in our negotiating rooms our PC's and we had our economic models. "Every time a policy option was put out at the negotiating table, we were able to feed that policy option into the computer system and come up with results. No other country in the European Union was doing that." It could be added "and neither the Commission representatives". Additional examples of policy information systems, which are developed for easy use and immediate results, are presented on this seminar (see Helming, Veenendaal, Peeters and Malitius, Mack, Moresino in this volume).

There is clearly a demand for speedy policy information systems by EU authorities. In this situation, Eurostat and DG Agri launched a new effort to trigger the development of a user friendly policy information system for the CAP. As a first step, the development of a simplified modelling tool for day to day use at Eurostat and the Commission was envisaged, for distinction from the former MFSS under the heading "MFSS99". The next section summarises the objectives and requirements for this project. Section 3 will lay down the basic structure of MFSS99. Section 4 addresses some critical issues in the application. Section 5 presents the technical infrastructure and section 6 concludes.

## 2 Objectives and requirements

From the background above follow quite naturally the objectives as well as a number of requirements for future modelling efforts:

- **User friendliness**: involving ease and speed of operation
- **Transparency**: for continued operation, maintenance, checking and discussion of model structures or modules by EU officials
- **Detailed coverage of products and CAP policies**
- **Economy in information requirements**
- **Results for the major variables of political interest**: agricultural income, market balances and trade, burden on consumers and budgetary impacts.

These objectives involve a number of evident trade-offs, requiring a compromise between them. Environmental impacts, for example, have not been mentioned even among the desired outputs because an appropriate modelling of environmental issues clearly requires further regional break down beyond the member state level. Budgetary impacts are not yet integrated
into the system although a number of basic variables for them emerge from the system. Past experience has shown that the consolidation of EAGGF data with the SPEL basic data system is a challenging task, which has been postponed for the time being.

3 Basic structure

3.1 Overview

MFSS99 is a comparative static modelling tool with behavioural functions driven by a set of synthetic elasticities. These behavioural functions derive from some variants of profit and utility maximisation to permit calibration to standard microeconomic conditions. It is well known that profit maximisation and utility maximisation will not hold in general for aggregate agents but these conditions should provide a useful framework even if valid only as an approximation.

Behavioural functions are completed with a number of accounting identities to form a set of market balances for agricultural products as covered by the EAA. Market clearing occurs essentially in one of two ways. For a number of products with a limited volume of trade in the past such as potatoes, or more importantly pigs and poultry, we assume that trade volume may be determined exogenously and market clearing determines endogenous prices. For major agricultural commodities such as cereals, oilseeds and beef, exogenous information on world market prices or more precisely EU trade prices is fed into the model, yielding trade or public intervention as endogenous variables.

Within this simple framework, most CAP instruments can be incorporated quite easily.

3.2 Supply side

Modelling of the supply side is considerably simplified both from a theoretical as well as from a practical point of view if yields are assumed exogenous. There is empirical evidence to the contrary (Jensen 1996; Guyomard, Baudry, Carpentier, 1996), but it appears that variations in intensity add little to the total supply response. The basic decision problem for agricultural producers is therefore:

\[
\max_{A_c, X} \left\{ \sum_c R_c A_c + \sum_a R_a A_a - \sum_n P_n X_n - \sum_f P_f X_f : \right. \\
\left. \sum_c A_c = \overline{A}, \quad \text{activity revenues} \right. \\
\left. \sum_a \kappa_a A_a = 0, \quad \text{land balance} \right. \\
T_1(A_c, A_a, X_n, Z) = 0, \quad \text{calves balances} \right. \\
T_2(A_a, X_f) = 0 \right\} \quad (1)
\]

where \( R_c \) and \( R_a \) are activity revenues of crop and animal activities respectively, calculated on the basis of the fixed yield assumption. Crop activity levels \( A_c \) have to comply with an exogenously given land constraint (2. line). Use (\( \kappa_a < 0 \)) or production (\( \kappa_a > 0 \)) of female and male calves by activities \( A_a \) in the cattle sector have to be consistent with a given net trade, assumed zero for simplicity in the 3. line of (1).

These physical constraints are relying on rather hard information such that their incorporation is expected to greatly increase the internal consistency of a simulation. For other inputs, say fertiliser per activity, the information from the current SPEL base model is less certain because it relies on little statistical information beyond the sectoral aggregates. Furthermore, it might be questioned whether fertiliser and some other (general) inputs are truly allocatable at all. It was decided therefore to treat all other technological constraints only in implicit form. These constraints stem from the operating capacity linking the activity levels and the use of non feed inputs \( X_n \) to activity levels (\( T_1 \)) and from a feed technology (\( T_2 \))
relating animal production and feed inputs $X_f$. Problem (1) may be decomposed in this case as follows:

$$\max_{A,X} \left\{ \sum_c R_c A_c + \sum_a R_a A_a - \sum_n P_n X_n - C(P_f, A_a) \right\} :$$

$$\begin{align*}
\Sigma_c A_c &= \bar{A}, \\
\Sigma_a R_a A_a &= 0 \\
T_f(A_c, A_a, X_n, Z) &= 0
\end{align*}$$

where $\pi(.)$ is an overall profit function with activity revenues taking over the role of prices.

Due to the structure imposed above, i.e. the feed technology being independent of crop activities and non feed inputs, feed demand may be obtained from the overall profit function or from the cost function $C(P_f, A_a)$ which results from the minimisation of feed costs subject to given animal activities and the feed technology above. An increasing feed demand will nonetheless cause crop production to follow for those products where market clearing is assumed to occur on the EU level (potatoes) or even at the member state level (roughage) with a corresponding endogenous price $P_f$.

Thinking of activity elasticities and price elasticities as deriving from problem (2) suggests to calibrate these elasticities to the implied microeconomic conditions. For this purpose we use a maximum entropy approach similar to the one on the demand side, as described in some detail elsewhere (Witzke, Britz 1998). Starting values and derived support values have been obtained by converting the gross margin elasticities from the former MFSS to revenue elasticities, which is possible given the fixed yield assumption. However these elasticities require further testing, updating and potentially econometric estimation, a task postponed to the future. For feed demand we chose to derive these from the cost function part in (2), expecting a larger number of estimations becoming available from the literature or own estimations for subsystems rather than for the complete supply side. An initial set of elasticities has been derived from the former MFSS. However because these rely on a number of assumptions underlying the feed allocation within the SPEL base system, it is highly desirable to obtain updated empirical evidence on feed demand for MFSS99.

The calibrated set of elasticities is used as parameters in double log functions. This has the disadvantage of losing microeconomic consistency when deviating from the point of approximation during simulations. The alternative would be to use a globally convex profit function such as the symmetric normalised quadratic (Diewert, Ostensoe 1988). However simplicity and the advantage of complete control over the elasticities used where given preponderance at the moment.

### 3.3 Demand side

Final demand is also specified based on a double log function with elasticities derived from an updated review of the recent literature. As mentioned above, an effort has been made to impose standard microeconomic consistency including full concavity (see Witzke, Britz 1998) but estimation is again deferred to the future. Given a consistent set of behavioural functions, consumer welfare changes may be calculated from the model.

Processing is modelled explicitly only for a number of products. For oilseeds and sugar beet it is assumed that derived products are produced with given output coefficients in fixed proportions such that profit maximisation of the processing industry for oilseeds require:

$$P_c \phi_c + P_o \phi_o = P_s + C_s(S, P_c)$$

where marginal revenues of a ton of processed oilseeds stem from fixed yields of cake ($\phi_c$) and oil ($\phi_o$) together with their prices ($P_c, P_o$) and marginal costs derive from the price of
seeds \( (P_s) \) and marginal cost in terms of other inputs such as energy \( (P_e) \). Solving for seeds \( S \) gives processing as a function of net revenues which is implemented in double log form with an assumed processing elasticity. This function determines a unique solution for EU processing and therefore for imports of seeds as opposed to imports of cake and oil.

For milk products, we may safely assume that there is no significant trade in raw milk. Consequently it may be assumed that milk is processed according to a constant returns technology with fixed processing costs (see also Bouamra, Requillard 1999) and constraints on milk fat and protein.

\[
\max_X \left\{ \sum_i (P_i X_i - c_i) - P_m X_m : \sum_j X_{ij} \gamma_{ij} = X_m \gamma_{mj} \right\}
\]

where \( X_i \) are processed products (in MFSS99 only skimmed milk powder, butter and other milk products) of raw milk \( X_m \). Milk fat and protein contents of milk products have been determined ex post, together with processing cost per unit processed, by a maximum entropy approach. More information on these parameters (and their relationship to underlying input prices) would improve this specification and might be obtained in collaboration with specialists on the milk market.

For the large number of products without explicit representation of processing, it has been assumed that the difference between producer and consumer prices is constant (fixed margin). Given that political interest mainly is focussed on agriculture it was decided to close the model at this point, but to close it rather simply.

3.4 Market clearing, price transmission and policy

Market balances are completed with remaining items (losses, consumption on farm, industrial use, private stock changes) either included as exogenous variables or linked to production. As mentioned above, markets clear either with exogenous international prices or with exogenous EU trade volumes. The latter category includes products with fixed member state trade and market clearing on the member state level (e.g. grass and other roughage), products with market clearing on the EU level (e.g. pork), and an intermediate case (e.g. calves). In this case markets clear on the member state level, but member state net imports are not completely fixed but rise somewhat, if member state prices rise more than an EU average price. Product association to these categories may be changed in a flexible way.

International prices are linked to EU prices using a price transmission equation based on the law of one price. Without border measures, these international prices would directly apply to EU markets. Price policy instruments are tariffs or, until tarification is complete, administered prices with associated flexible levies or export subsidies. Export quantities are constrained by WTO restrictions, possibly requiring public intervention up to maximal intervention quantities. Price changes in member states are assumed to equal those on the EU level in relative terms while the fixed margin assumption provides the linkage to consumer prices in most cases.

Apart from the above border measures the model incorporates quotas and set-aside obligations. In order to permit operation of the model with a single set of elasticities, we introduced shadow revenues distinct from ordinary revenues for activities with levels set by a quota or in another exogenous way. Because a serious modelling of set aside again requires regional differentiation, the impact of the obligatory set aside rate on total set aside (including voluntary set aside and uncompensated fallow) is described rather simple by an elasticity smaller one.

Premia may be incorporated quite easily in the activity revenues and potentially scaled to national envelopes, as in the recent Agenda 2000 package. Due to the fixed yield assumption, there is no difference in the effects of premia per ton of product or per activity. A
detailed analysis of different degrees of decoupling is thus beyond the scope of MFSS99. However, given that unification of premia across products and activities is the major decoupling device, this limitation does not preclude reasonable analysis of important issues on the structure of support.

Because there is no information on farm structure in the model, a number of important aspects of the CAP cannot be incorporated directly into this type of model. This applies for example to farm level upper limits on premia, which provide a serious challenge to CAP policy information systems.

4 Critical issues in application

The first application of MFSS99 required by policy makers is an Agenda 2000 simulation against a reference run, mainly to test its simulation behaviour and compare it with results of other systems operating on the EU level (MFSS, CAPMAT, FAPRI see EU Commission 2000). This simulation is currently scrutinised and discussed with Commission experts.

However even at this stage of the work some points are easily seen to be critical. The first of these is the demand for exogenous information on trade variables (prices or volumes). MFSS99 shares this demand with the former MFSS and a number of other models. It implies that the system is not designed for a "stand alone" application but requires some information typically provided by trade models such as WATSIM or FAPRI. As the divergence between these projections can be clarified only after some detailed scrutiny (Heckelei et al. 1998), it will be useful to tap the information from a single trade model, in this case for evident reason from WATSIM (von Lampe in this volume). A complete policy information system for the CAP only emerges in the combined application.

The second critical point is the demand for information below the member state level. This applies to the modelling of set aside, to the incorporation of farm structure information and to the impacts of "cross compliance" requirements on which future premiums may be conditioned in the future. For a number of issues requiring regional information, the MFSS99 may rely on the CAPRI system¹ (Heckelei, Britz in this volume). For structural information, however, there is currently no modelling system available at the EU level suggesting itself for a close linkage to MFSS99. The European FADN, a number of national models and possibly international typical farm networks are potential sources of structural information, but consolidation of this information appears to be a formidable task.

5 Technical infrastructure

The technical infrastructure of the former MFSS has been thoroughly revised even though a few very efficient utilities remain in use. Most importantly, the majority of data preparation, model simulation and evaluation steps are written in Gams instead of Fortran, increasing the chances for communication and critical discussion with experts at Eurostat and DG Agri. Furthermore, the use of Gams instead of Fortran does not only aid in transparency, but also in the application of efficient model solvers.

However, even though the number of Gams users has become quite large by now, it is not very likely that these technical skills are available at the level of policy makers or their high level staff. To make the MFSS99 a tool as useful for these DG Agri officials as the Irish model was for Joe Walsh from Ireland, the system incorporates a user surface which should enable any knowledgeable expert in the CAP to perform reasonable simulations on his own, after some minimal introduction.

¹ Furthermore it has to be acknowledged that the development of MFSS99 benefited a lot from discussions and programming assistance of Wolfgang Britz.
The first step in the operation of the model is the establishment of the database. For this purpose a Gams program reads the entire SPEL base model data and aggregates them to the condensed list of (still 50) goods and (now 31) activities. This step requires updating as soon as more recent statistical information is becoming available. Depending on the future of the SPEL base system, future updating might require some modifications.

The second step is the calibration of elasticities, which has to be repeated from time to time, but not for each simulation. As is the case with the first step, this has to be done by technical experts. The third step is the establishment of a reference run. At the moment, simple linear trend projections are used together with some security procedure (a nonlinear transformation of variables) forcing the projections to stay within “reasonable” bounds around the base year values. More sophisticated procedures for the detection of outliers (Judge et al. 1988, pp 892-7) may be implemented in the future but no mechanical procedure can be expected to entirely remove the need for plausibility checks by market experts.

The next step is to run the model. Users are guided through different menus to enter or change political variables conveniently (see the example below), to enter new world market prices and subsequently to run the model. It is expected that this step will be repeated frequently. Therefore it received a considerable amount of attention to optimise its user friendliness. Experience with previous modelling efforts and discussion with potential Eurostat users have led to the format below.

**Figure 1: Screen to enter political variables in MFSS99**

After the simulation, the user is guided to an output viewer permitting to view, arrange and export all output variables as desired, based on a utility called DAOUT which is well known by many users of the SPEL data by now. Alternatively, the user may rely on a set of pre-structured tables, offering political users a condensed view at the variables likely to be of greatest interest without requiring any familiarity with any SPEL typical utilities.
6 Concluding remarks

Previous sections have offered insight into the motivation, internal structure and technical implementation of a recent major modelling effort at the EU level, the development of the MFSS99. However, as the saying goes, 'the proof of the pudding is in the eating', which in this case is the Agenda 2000 simulation. Reliability and plausibility of the results, a necessary condition for the success of the system, are currently being investigated in detail.

Almost equally important, however, is the question whether the system will be accepted and continuously used in the administration. Past experience in Germany and other countries has revealed a considerable vulnerability even of modestly complex modelling systems to personal fluctuation. However, the quotations in the introductory paragraph and examples from other countries have shown that such implementation in distance to the model developers is possible. It remains to be seen whether the next major application of the system, probably in the course of the current WTO round, will be performed by the developers alone or with major contributions from EU officials.

After a success of the initial implementation, there are ample opportunities for improvements. Most evident is perhaps the need to improve the empirical basis for the elasticities driving the model. Equally important is the need to streamline the basic data treatment because this will determine the future of this model, which is still in its infancy.

References

Abstract

This paper presents the methodological concept and results of an explorative application of the CAPRI (Common Agricultural Policy Regional Impact) modelling system. CAPRI's objective is the EU-wide analysis of aggregate and regional impacts of the CAP. In order to achieve this ambitious objective the database and modelling system needs to be designed appropriately. The production and policy related part of the database is differentiated at NUTS-2 level and consistent to the national accounts. The modelling system combines regional programming models based on Positive Mathematical Programming with a multi-commodity market model. Results of a reference run and an Agenda 2000 scenario for the cereals and oilseeds sector as well as the beef and dairy sector are presented. They illustrate the functioning of the overall system and the type of information which can be generated.

Keywords: CAP, Regional Analysis, Positive Mathematical Programming, Agenda 2000, Multi-Commodity Market Model

1 Introduction

The main objective of the project CAPRI (Common Agricultural Policy Regional Impact) was the development of an EU-wide economic modelling system able to analyse the regional impacts of the Common Agricultural Policy (CAP). The project was co-financed by EU under the FAIR program in the years 1997-1999.

In order to achieve its ambitious objective, the project relied on the functionality of a European research network. Each of the five main partners was responsible for a specific cluster of Member States. They established research relationships with national sub-partners for data collection and interpretation of results. This paper introduces the concept and implementation of the CAPRI database (section 2) and modelling system (section 3). Selected results of an explorative application to a reference run and an Agenda 2000 scenario are presented to illustrate the type of information which can be generated with the modelling system (section 4). A short outlook concludes (section 5).

2 CAPRI Database

A major part of the CAPRI project was devoted to sample data and compile the regionalised CAPRI database. The involvement of different teams, the necessity to create a EU-wide database for different countries, and the necessity to make the database consistent with national accounts, created a high level of complexity. The database was designed to be used for different purposes, e.g., policy analysis, regional planning, and research. It was important to ensure that the database is comprehensive and covers all relevant aspects of the agricultural sector.

The database was developed in a collaborative effort between the five main partners, each responsible for a specific region. The data was collected from various sources, including national statistical agencies, research institutions, and private companies. The data was then processed and standardized to ensure consistency across different regions and countries.

Selected results of an explorative application to a reference run and an Agenda 2000 scenario are presented to illustrate the type of information which can be generated with the modelling system (section 4). A short outlook concludes (section 5).

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1 The research teams involved are institutes in the field of agricultural economics from the Universities of Bonn, Valencia, Galway, Bologna, and Montpellier (plus Research Station Tänikon (Switzerland) and NILF, Oslo).

2 This paper gives only a very limited account of the research performed within the CAPRI-project. The CAPRI web site (http://www.agp.uni-bonn.de/agpo/rsrch/capri/capri_e.htm) provides further information.
comparable information base, and the requirements of the economic modelling system demand a well defined database. The CAPRI database obeys the following principles:

- **Regional differentiation** of the European Union to 200 regional units (mostly according to NUTS II definition)
- **Production activity based break-down of agricultural production and input use**
- **Consistency** between sectoral and regional aggregates, i.e. data match official Eurostat statistics including the Economic Accounts of Agriculture (EAA)
- **Comprehensiveness:** complete coverage of product generation and input use according to the EAA, inclusion of activity levels, yields, input coefficients, prices, farm & market balances, economic performance, political instruments and environmental indicators

Currently, the database is complete for the years 1990-1995 for all regions. The key concept of the CAPRI database is termed Activity Based Accounting System (ABAS, WOLF 1995) breaking down the agricultural production process for a each period to individual production and use activities, both in physical and valued terms. CAPRI differentiates between 60 outputs and 35 inputs, covering the whole agricultural sector according to EAA definitions, and about 50 crop and animal production activities.

The output and input coefficients are defined consistently to sectoral output generation and input use (see figure 1). *Use activities* which define so called "farm balances" for each output and input describe the fate of the outputs and input "generation". Output produced may be sold, added to stocks, fed, used as seed etc. Inputs may be bought, taken out of stocks or stem from intra-sectoral transactions, for example young animals may be produced by another production activity. In order to link the physical sphere with the EAA, national *unit value prices* are used. They are residually defined by definitorial equations underlying the methodology of the EAA.

**Figure 1: Activity Based Accounting System (ABAS)**

<table>
<thead>
<tr>
<th>Physical Component</th>
<th>Price Component</th>
<th>Valued Component (Economic Accounts of Agricultural - EAA in gross and net concept)</th>
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<td><strong>O-coefficients</strong></td>
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<td>Output Prices</td>
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<td><strong>Income indicators</strong></td>
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<td>Sectoral income indicators</td>
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<td>Income (EAA)</td>
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</tbody>
</table>

At national level, the project could to a greater extent rely on the SPEL-EU database (WOLF 1995) from Eurostat, which integrates different databases, technological information and expert knowledge, and covers longer time series for all EU Member States. The REGIO domain of Eurostat represents the uniform regional data source which suffers, however, from incompleteness and a partially insufficient level of differentiation. Completely missing is information on CAP measures at regional level. Consequently, many statistical sources at national and even regional level had to be found, accessed, analysed, and compiled to achieve a uniform and complete database. The two key factor of success for this enormous task were (1) the establishment of a network of researchers from all Member States and (2) the clear methodological concept.
The database also comprises a set of environmental indicators. Useful indicators at this stage of the CAPRI information system are defined by (1) a direct link to the agricultural production system, (2) meaningful interpretation at CAPRI’s current regional level of differentiation, i.e. the NUTS II level, and (3) being operational with respect to data availability. These definitions exclude indicators which describe states of environmental problems at local level or with respect to ecological systems defined by specific regional boundaries (e.g. water catching, landscape). CAPRI, however, offers the unique chance to apply appropriate indicators in a consistent and uniform manner across Europe relating to the regional agricultural production system. Based on these considerations the project implemented nutrient balances and gas emissions relevant for global climatic change for all regions in the system.

3 Modelling system

3.1 Overall concept

From a methodological point of view, the main challenge was the development of a modelling system which could combine deep regionalisation with complete coverage of the EU-agricultural sector. This set-up was necessary in order to simultaneously analyse the effect of commodity market and policy developments on agriculture in the individual regions as well as the feedback from the regions to EU and world markets.

Since market and activity specific policy instruments require a rather disaggregated model in terms of products, a simultaneous system which would optimise producer and consumer surplus for 200 regions and some 50 products was computationally infeasible. Consequently, the model system was conceptually split-up into a supply and a market component. The supply module consists of individual programming models for about 200 NUTS II regions. The market module follows the tradition of multi-commodity models. Based on aggregated supply quantities from the regional models, the market model returns market clearing prices. An iterative process between the supply and market component ultimately achieves a comparative static equilibrium.

3.2 Supply module

The supply module consists of independent regional programming models, well-suited for a high degree of activity differentiation and the direct representation of relevant farm policy measures (e.g. premiums, set-aside obligations) and ensure simulation results consistent with general resource constraints. The objective functions maximise the aggregated gross value added including CAP premiums minus a quadratic cost function based on Positive Mathematical Programming (PMP).

The choice of the optimal production mix is restricted by a relative small number of constraints: availability of arable and permanent grass land, selling quotas for milk and sugarbeets, set-aside obligations, base area related premium reductions, and upper bounds for voluntary set-aside according to CAP regulations. Feed costs are minimised endogenously by determining the optimal mix of a limited number of aggregated marketable (e.g. "cereals") and non-tradable feedingstuffs (e.g. "hay") subject to requirement constraints, ensuring a technologically plausible mix. Nutrient requirements of crops can be covered either by mineral or organic fertilisers, the latter restricted to the amount produced by the regional herds. Constraints ensure that a crop specific percentage of the nutrient need is covered by mineral fertiliser.

"Positive Mathematical Programming" (PMP) - known since the late eighties but formally introduced to the community of agricultural economists by HOWITT (1995) - allows
to perfectly calibrate a programming model to observed data - in our case regarding activity levels and regional feed use. The basic idea of PMP is to introduce a non-linear objective function based on information contained in dual values of calibration constraints forcing the solution of the programming model to the observed allocation. Compared to linear models (LP), the introduction of a non-linear objective function allows solutions with more variables than binding constraints and results in a smoother, more realistic response behaviour of the model to changes in exogenous parameters. This advantage and the calibration property lead to a wide spread use of PMP in recent modelling exercises.

The conditions for perfect calibration are clearly defined and adopted by all PMP applications, but they allow for an infinite number of different parameter specifications, all perfectly calibrating the model to observed activity levels, but implying distinct differences with respect to the response in simulations (see: HECKELEI 1997 for a discussion). The non-linear parameters for the animal production activities in CAPRI are based on exogenous elasticities.

Since elasticities were not available for the differentiated set of crop production activities, the team explored the possibility to estimate multi-output quadratic cost functions based on a cross-sectional sample building upon an approach proposed by PARIS & HOWITT 1998. Their article showed the potential of applying Maximum Entropy estimation techniques in this context, but suffered from two important disadvantages: First, the method was just applied to a single observation, implying that the data did not contain any information on second derivatives of the cost function. Second, the employed reparameterisation of the cost function based on the Cholesky decomposition to impose correct curvature resulted in a somewhat arbitrary parameter specification.

The application in CAPRI could overcome both deficiencies by basing the estimation on cross sectional vectors of marginal costs and using the Cholesky decomposition of the matrix of second derivatives directly as constraints during estimation. In order to exploit the information contained in the sample, parameter restrictions across regions are introduced, based on the assumption that relative changes of marginal cost are equal across regions for same crop rotations and cropping conditions. In other words, the observed differences in marginal costs between regions are explained by regional differences in rotations and cropping conditions (measured as average revenue per ha).

Figure 2: Percentage deviations of crop activity levels for different "model" specifications from observed levels in "1994" for France

The resulting regional models were validated by an ex-post validation exercise: the newly developed methodology ("ME") and a standard PMP approach using one observation
The models were then solved under the policy and market conditions for the three year average "1994". Figure 2 shows absolute percentage deviations of model results from observed activity levels for single and aggregated production activities. The overall absolute percentage deviation of the ME approach is just 3% and far better than the standard approach. As a reference, an "intelligent no-change" forecast taking into account the effect of the obligatory set-aside regime is also presented. The regional forecasting accuracy of the ME-approach was also superior to the standard PMP application but generally less accurate (For details see HECKELEI & BRITZ 1999).

Note, that the employment of the PMP-methodology is indispensable with respect to the overall layout of the CAPRI modelling system. It provides an empirically validated supply response and, at the same time, allows to keep a "lean" layout of the regional programming model and the solution of the overall system computationally feasible. Furthermore, it avoids the use of weakly justified constraints often employed to guarantee a "plausible" simulation behaviour of programming models.

3.3 Market module

Methodological solutions for the market module are generally based on a the standard concept of multi-commodity models (BRITZ 1998), known since the days of SWOPSIM. Double log equations for supply and demand clear regional and international markets, driven by regional producer and consumer prices which are linked via price transmission functions to a uniform world market price. The parameters of the behavioural demand equations are not estimated, but instead calibrated under theoretical restrictions based on elasticity estimates taken from literature (WITZKE & BRITZ 1998).

The non-spatial net-trade model is regionalised at EU Member State level, Switzerland, Norway, and "Rest-of-the-World" (ROW). Data, behavioural parameters and exogenous shifts for ROW stem to a large extent from WATSIM, a world wide modelling system for trade in agricultural products (VON LAMPE 1998). Supply for all other regions is fixed to the results of the regional supply models. Price transmission functions cover tariffs, including flexible levies depending on internal price floors, as well as marketing and processing costs.

Processing of oilseeds is modelled explicitly assuming fixed extraction rates for cakes and oils from crushing. In the case of processed milk products (skimmed milk powder, butter and other), constraints equilibrate fat and protein content of processed quantities of raw milk and with the processed products. The price of raw milk and processed milk products is derived from uniform fat and protein prices weighted with their contents plus fixed per unit processing costs.

4 Application

The CAPRI modelling system was tested in late 1999 in an Agenda 2000 scenario (simulation run) compared to a continuation of the status quo policy for the European agricultural sector (reference run) for the year 2005. The subsequent description of scenario definition and selected model results is restricted to "cereals and oilseeds" and the "beef and dairy" sector, as the main target sectors of Agenda 2000.

4.1 Cereals and Oilseeds Sector

The political instruments of both scenarios for cereals and oilseeds are presented in the following table. Note that premiums in table 1 represent averages weighted by observed (base
year) and projected (reference and Agenda scenario) regional activity levels so that the resulting values are partly endogenous. Furthermore, differences between base year and reference scenario are also caused by (1) the third step of the 92 CAP reform which was not fully implemented in the base year and (2) a set of already decided changes such as the adjustment of historical yields for some regions.

Table 1: Political variables for Cereals and Oilseeds

<table>
<thead>
<tr>
<th></th>
<th>Base year 1994</th>
<th>Reference 2005</th>
<th>Agenda 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(% change to base year)</td>
<td>(% change to reference)</td>
<td></td>
</tr>
<tr>
<td>Cereals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intervention price</td>
<td>143.5</td>
<td>123.0 (-14%)</td>
<td>104.6 (-15%)</td>
</tr>
<tr>
<td>Average premium per ha</td>
<td>211.6</td>
<td>274.4 (30%)</td>
<td>319.9 (17%)</td>
</tr>
<tr>
<td>Oilseeds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average premium per ha</td>
<td>449.8</td>
<td>443.9 (-1%)</td>
<td>275.3 (-38%)</td>
</tr>
<tr>
<td>Set aside</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set aside rate (in %)</td>
<td>14.0</td>
<td>17.5</td>
<td>10.0</td>
</tr>
<tr>
<td>Average premium per ha</td>
<td>289.0</td>
<td>315.0 (9%)</td>
<td>303.4 (-4%)</td>
</tr>
</tbody>
</table>

Additionally, the following assumptions apply to the scenario definitions:
- + 1.33 % yield increase per year for cereals (EU average, regionalised at national level)
- + 1.45 % yield increase per year for oilseeds (EU average, regionalised at national level)
  (inputs adjusted accordingly with input saving technical progress of 0.5 % per year
- All oilseeds are cultivated under the main scheme (i.e. receive premiums)
- Small producer share is kept constant at base year levels

Table 2: Activity levels, Grandes Cultures (in 1000 hectares)

<table>
<thead>
<tr>
<th></th>
<th>Base year 1994</th>
<th>Reference 2005</th>
<th>Agenda 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(% change to base year)</td>
<td>(% change to reference)</td>
<td></td>
</tr>
<tr>
<td>Cereals (excl. rice)</td>
<td>35012</td>
<td>32663</td>
<td>33796</td>
</tr>
<tr>
<td>Wheat</td>
<td>16018</td>
<td>14990</td>
<td>15230</td>
</tr>
<tr>
<td>Barley</td>
<td>11072</td>
<td>10352</td>
<td>10916</td>
</tr>
<tr>
<td>Other cereals</td>
<td>7922</td>
<td>7321</td>
<td>7650</td>
</tr>
<tr>
<td>Pulses</td>
<td>1680</td>
<td>1676</td>
<td>1699</td>
</tr>
<tr>
<td>Oilseeds</td>
<td>5273</td>
<td>5141</td>
<td>4848</td>
</tr>
<tr>
<td>Rapeoseed</td>
<td>2258</td>
<td>2359</td>
<td>2165</td>
</tr>
<tr>
<td>Sunflower seed</td>
<td>2740</td>
<td>2512</td>
<td>2415</td>
</tr>
<tr>
<td>Soya beans</td>
<td>274</td>
<td>270</td>
<td>269</td>
</tr>
<tr>
<td>Non Food on set aside</td>
<td>618</td>
<td>935</td>
<td>777</td>
</tr>
<tr>
<td>Set aside</td>
<td>4131</td>
<td>5468</td>
<td>4063</td>
</tr>
</tbody>
</table>

At first we want to have a short look at aggregated EU-results. Table 2 presents activity levels for Grandes Cultures. The main developments from the base year to the reference scenario include a decrease of the cereal area by 6.7% to 32.7 million ha, mainly due to the increased set-aside rate. However, with technical progress driving up yields, the production is estimated to increase by 9.3% to about 192 million tons. Table 3 allows a differentiated look at market effects for wheat and barley. As domestic demand are nearly unchanged, net exports and/or intervention sales expand. Intervention prices for both cereals exceed simulated world market prices, as in many studies.
Comparing Agenda 2000 results to the reference run, reduced set aside rates increase cereal production by 3.5% to 195.8 million tons. Lower prices cause slightly extended domestic use, but do not affect EU's status as a cereal net exporter. In opposite to the reference scenario, world market prices for wheat are simulated to lay above intervention price level, allowing wheat exports without subsidies and WTO restrictions. Consequently, net exports rise considerably (Table 3). However, the simulated difference between world market and intervention price is rather small. With respect to barley, the intervention price is still above world market price implying continuing problems since exports would require subsidies and are limited by WTO restrictions.

Production of oilseeds is simulated to expand as well in the reference compared to the base year despite a slight area reduction. In the Agenda 2000 scenario oilseed premiums decrease quite drastically to the level of cereal premiums. The loss of profitability results in an estimated 6% reduction in oilseeds areas compared to reference run results (Table 2). Compared to the drastic premium cut, the simulation response of the model may at first look small. However, the following aspects should be taken into account:

- The Blair House agreement is no longer in effect. Consequently, the drop of the effective set-aside rate for oilseeds is larger than for cereals in many regions.
- Effective oilseeds premiums in the reference run are reduced in several Member States due to a simulated EU wide 8% overshoot of base areas, so that a simple comparison between declared oilseed premiums before and after Agenda 2000 is misleading.
- Sunflower seeds are much more resistant to droughts, so that a substitution with cereals in southern regions is restricted by availability of irrigation.

The aggregated results are already influenced by the model's capability to represent policy implementation at regional level which eliminates part of the aggregation error of aggregated models. Now we want have a closer look at some regional aspects of the policy impacts. Figure 2 shows the effect of Agenda 2000 on regional cereal activity levels. Compared to the reference run cereal area increases in most regions of Spain, Italy, Austria, east England, and the Scandinavian countries. It remains rather constant in the main cereal producing regions of France and Germany.

One reason for the differences are increased reference yields implying higher area premiums for cereals in some Spanish and Italian regions due to a special agreement in Agenda 2000. Premiums in Spain increase by about 27%, in Italy by about 20% and in the rest of Europe by 16%. Another reason is the lower price reduction for maize and durum wheat. Whereas the intervention price for cereals falls by 15% (from Reference to Agenda) the price for durum wheat falls by 13.7% and for maize by only 2.6%. Both crops (especially durum wheat) are primarily grown in southern Europe.

### Table 3: Balance sheet cereals (in 1000 tons)

<table>
<thead>
<tr>
<th></th>
<th>Base year 1994</th>
<th>Reference 2005</th>
<th>Agenda 2005</th>
<th>Reference to Base year</th>
<th>Agenda to Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wheat</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic supply</td>
<td>81659</td>
<td>90325</td>
<td>91134</td>
<td>10.6%</td>
<td>0.9%</td>
</tr>
<tr>
<td>Domestic demand</td>
<td>67232</td>
<td>66676</td>
<td>66149</td>
<td>-0.8%</td>
<td>-0.8%</td>
</tr>
<tr>
<td>Feed use</td>
<td>30041</td>
<td>29499</td>
<td>28948</td>
<td>-1.8%</td>
<td>-1.9%</td>
</tr>
<tr>
<td>Intervention</td>
<td>7799</td>
<td>8348</td>
<td>0</td>
<td>7.0%</td>
<td>-100.0%</td>
</tr>
<tr>
<td><strong>Barley</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic supply</td>
<td>42468</td>
<td>46150</td>
<td>47752</td>
<td>8.7%</td>
<td>3.5%</td>
</tr>
<tr>
<td>Domestic demand</td>
<td>29250</td>
<td>29719</td>
<td>30129</td>
<td>1.6%</td>
<td>1.4%</td>
</tr>
<tr>
<td>Feed use</td>
<td>29026</td>
<td>29497</td>
<td>29906</td>
<td>1.6%</td>
<td>1.4%</td>
</tr>
<tr>
<td>Intervention</td>
<td>4469</td>
<td>6430</td>
<td>7624</td>
<td>43.9%</td>
<td>18.6%</td>
</tr>
</tbody>
</table>
Figure 2: Impacts of Agenda 2000 on cereal production

Due to the premium effect of adjusted historic yields the reduction of set aside in Mediterranean regions is generally in line with the changes of the official set aside rate. In the highly productive cereal regions of northern France and Germany, however, obligatory set aside reduction is partially compensated by increased voluntary set aside, because the undercompensation of the overall price cut in Agenda 2000 (only about 50% based on historic yields) diminishes gross value added considerably. This effective under-compensation in 2005 is even stronger in regions with high technical progress in cereal production, namely French and German regions.

4.2 Beef and Dairy Sector

As the main political instruments of both scenarios are widely discussed, the following table 4 just present average changes of the quantitative measures in the sector at EU level.

Table 4: Political variables for the Cattle sector

<table>
<thead>
<tr>
<th></th>
<th>Base year 1994</th>
<th>Reference 2005 (% change to base year)</th>
<th>Agenda 2005 (% change to reference)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrative prices</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beef</td>
<td>4285</td>
<td>3475 (-19%)</td>
<td>2780 (-20%)</td>
</tr>
<tr>
<td>Butter</td>
<td>3202</td>
<td>2954 (-8%)</td>
<td>2511 (-15%)</td>
</tr>
<tr>
<td>Milk powder</td>
<td>2377</td>
<td>2055 (-14%)</td>
<td>1747 (-15%)</td>
</tr>
<tr>
<td>Premiums</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk cows</td>
<td>0</td>
<td>0</td>
<td>157</td>
</tr>
<tr>
<td>Suckler cows</td>
<td>133</td>
<td>164 (23%)</td>
<td>284 (73%)</td>
</tr>
<tr>
<td>Male adult cattle</td>
<td>105</td>
<td>136 (30%)</td>
<td>324 (138%)</td>
</tr>
<tr>
<td>Milk quota</td>
<td>113879</td>
<td>115577</td>
<td>120335</td>
</tr>
</tbody>
</table>

The following assumptions also apply:
- Milk yields increase due to technical progress (specific trend for each Member State)
- Long term trend to increased final weights continues to offset reduced availability of calves: + 10 % for male adult cattle and heifers fattening are assumed until 2005
- Adjustments of feed requirements according to yield development (milk, final weight) but 0.5 % increase in feed efficiency per year
Figure 3: Development of herd sizes in EU in reference run

Under both scenarios (reference run and Agenda 2000), the production of milk is clearly quota driven. Whereas production slightly increases following the quota expansion, the increase of average milk yields per cow leads to a distinct reduction of the dairy cow herd in Europe, affecting other cattle activities due to reduced output of calves as well as decreased demand for young cows.

Figure 3 shows the results from the reference run: the dairy cow herd is more or less exogenously determined by the slight quota increase (+1.5 %) combined with an average increase of milk yields by about 14 %. The reduced availability of calves keeps their prices relatively stable despite a drop of the beef price by 28 %. However, part of the price drop is compensated increasing premiums for male adult cattle. The stable calf prices favour suckler cows (herd size increases by 3.5 %). Reduced availability of calves decreases fattening of heifers (-17 %) and calves (-10 %).

The prices for final products relating to the cattle sector (beef, veal, milk and milk products) are mainly policy driven by the development of administrative prices. Effects on demand inside of the EU are rather low for these saturated markets. However, the outcome of the simulations runs depends on the endogenous prices for young animals. For further analysis of the cattle sector, two improvements are envisaged: a split-up of calves into male and female ones and endogenous final weights for fattening processes.

Table 5: Animal production in Europe, Physical production (1000 tons)

<table>
<thead>
<tr>
<th>Animal Type</th>
<th>Base year 1994</th>
<th>Reference 2005</th>
<th>Agenda 2005</th>
<th>Reference to Base year</th>
<th>Agenda to Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beef</td>
<td>24268</td>
<td>24955</td>
<td>24753</td>
<td>2.8%</td>
<td>-0.8%</td>
</tr>
<tr>
<td>Veal</td>
<td>7694</td>
<td>7558</td>
<td>7471</td>
<td>-1.8%</td>
<td>-1.2%</td>
</tr>
<tr>
<td>Sheep- and goatmeat</td>
<td>849</td>
<td>775</td>
<td>824</td>
<td>-8.7%</td>
<td>6.3%</td>
</tr>
<tr>
<td>Pigmeat</td>
<td>1284</td>
<td>1217</td>
<td>1220</td>
<td>-5.3%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Poultry</td>
<td>16573</td>
<td>17397</td>
<td>17282</td>
<td>5.0%</td>
<td>-0.7%</td>
</tr>
<tr>
<td>Eggs</td>
<td>7757</td>
<td>7268</td>
<td>7246</td>
<td>-6.3%</td>
<td>-0.3%</td>
</tr>
<tr>
<td>Milk (unprocessed)</td>
<td>4893</td>
<td>5583</td>
<td>5579</td>
<td>14.1%</td>
<td>-0.1%</td>
</tr>
<tr>
<td>Cow milk</td>
<td>129475</td>
<td>130436</td>
<td>135698</td>
<td>0.7%</td>
<td>4.0%</td>
</tr>
<tr>
<td>Sheep and goats milk</td>
<td>119741</td>
<td>121347</td>
<td>126497</td>
<td>1.3%</td>
<td>4.2%</td>
</tr>
<tr>
<td>Cow milk</td>
<td>9734</td>
<td>9089</td>
<td>9201</td>
<td>-6.6%</td>
<td>1.2%</td>
</tr>
</tbody>
</table>

Tables 5 summarise the results for the two scenarios. Changes inside the cattle sector in Agenda 2000 mainly result from a milk quota increase driving up the dairy cow herd (+4.6 %) and a larger suckler cow herd (+2.8 %) due to the premium raise. The higher availability of calves compared to the reference run favours the fattening activities. For other meat products, reactions mostly depend on the feed back from the market. The somewhat astonishing substitution between poultry and pig meat in the reference run is based on tariff reductions for poultry meat which leads to an exogenous price shift. Here, further insight in the application
of trade policies in the meat markets is clearly necessary. It should be mentioned that tariff impacts on meat markets are generally a sensible and complicated field as instruments relate to specific cuts and qualities whereas the model deals with the combined effect on the raw product price. Presented results clearly reflect the current weighting scheme and must be carefully discussed and eventually re-designed by market experts. Additionally, pig and poultry markets are strongly influenced by assumed market developments in rest-of-the-world as well. Overall, the results show that the system is operational, but underlines the necessity for co-operation with market experts in order to better define trade policy measurements.

5 Conclusions
The CAPRI project has been successful in developing a regionalised agricultural information system for the EU. It is now in the position to establish an enduring usefulness for EU- and national policy makers to address the manifold expressed interest during the development phase. In order to insure a survival of the system, a regular update of the database, partial methodological improvements as well as a systematic validation of the model are necessary. It is quite clear that this can only be achieved (1) in the network approach which ensures the in-depth knowledge of regional aspects of agricultural production and the access to national data sources and (2) in a close dialogue with policy makers to efficiently use the system for policy design and evaluation.

References
The impact of South-East Asian food demand on global markets – An application of WATSIM

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Abstract
This paper analyses the impact of macroeconomic variables on food demand in South-East Asia and hence on international markets. Changes on regional and global markets due to different income and urbanisation situations in the ASEAN region are simulated both for the medium term and the long term. In addition, lower income growth in China is evaluated as well. The simulations were done making use of the non-spatial partial equilibrium model WATSIM. This model, which is highly differentiated in terms of regional and commodity representation, focuses on two main areas of interest, namely long-term market developments and impacts of sectoral and macroeconomic shift factors, and medium-term developments and the impacts of policy changes.

The model results show that both variables, income and urbanisation, have significant impacts on regional markets. While on most Asian markets higher income results in increasing domestic demand, higher urbanisation results in lower food demand for coarse grains and vegetable oils. Impacts on international markets, however, are particularly significant if larger regions are affected by the shock. Lower income growth in both the ASEAN region and China would significantly reduce food demand on world markets, and hence price prospects. These price changes in turn would worsen the export situations for regions that heavily rely on subsidised exports and are affected by limits on these subsidies due to the Uruguay Round Agreement on Agriculture, such as the European Union.

Keywords: Agricultural Trade Model, International Trade, Income, Urbanisation, Food Demand, Asia, WATSIM

1 Introduction
Growth in the demand for agricultural commodities in the South-East Asian region has been identified as an important issue in terms of future world market developments. After the economic crisis following 1996, when growth rates of real per capita income decreased significantly in a number of countries and in some cases became even negative (The World Bank, 1998), growth of demand for high-value food commodities, particularly for meat, has slowed down considerably, resulting in lower growth in import demand from that region (USDA 1999). Many Analysts expected additional pressure on global markets due to the reduced demand also for subsequent years, yielding lower international prices. These in turn would increase the problems of exporting commodities from highly protected markets like the European Union (EU) grain markets, given the budgetary limits and the commitments on subsidised exports agreed in the context of the Uruguay Round Agreement on Agriculture (IATRC 1994).

The importance of Asian food demand for global markets and hence for the EU is therefore more or less undisputed, and many projections of international trade point out this uncertainty. Little is known, however, about the magnitude of the impact of Asian developments, i.e. the sensitivity of market prospects to the relevant driving forces of Asian
Martin von Lampe

This paper focuses on the quantitative relationships between macroeconomic variables determining Asian food demand and global market prices. Simulations were done using the World Agricultural Trade Simulation (WATSIM) modelling system, a partial equilibrium model developed at the University of Bonn. While the model also includes the markets for oilseed products, eggs, milk and milk products, this paper will only focus on the results for the grains, oilseeds and meat markets.

After a brief description of the modelling system with particular attention on the representation of macroeconomic shift factors\(^1\), section 3 will outline the scenario assumptions for the sensitivity analysis. Section 4 will present and discuss the simulation results, followed by some concluding remarks in section 5.

2 The WATSIM modelling system

The WATSIM modelling system focusses on several principal areas of interest, namely long-term developments on regional and international markets and the impacts of sectoral and macroeconomic shift factors, medium-term developments and the impacts of policy changes, and, though not yet realized in the system, the analysis of short-term market shocks.

In general the model represents a standard partial equilibrium approach. Based on a comprehensive database, the model was specified for this study with 29 interdependent commodity markets in 15 regions. Each regional market is represented by several supply and demand functions in double-log form, describing the impact of price changes on market quantities. Regional markets are cleared via net trade positions meeting on the world markets. To bring global markets to a new equilibrium after changes in some of the variables (e.g. policies, or shift factors over time), world market prices, which are linked to the regional market and incentive prices via price transmission functions, are adjusted. Apart from political border measures, these functions also include a transport cost term depending on the regional net trade.

In order to make the model capable of different market adjustments and substitutions between commodities both on the supply and the demand side, the respective functions include not only own price elasticities, but also a full set of calibrated cross price elasticities. In this context, the proper representation of the livestock-feed relationships is of particular importance. The appropriate calibration of available parameters ensures that the regional feed markets are balanced in terms of total feed energy use.

2.1 Database System

The WATSIM Database System has been developed as a comprehensive and consistent sample of available data from different sources. It comprises time series from 1961 to 1997 on supply, demand and trade data for some 100 agricultural commodities, as well as on sectoral and macroeconomic data, on a single country level. The agricultural market part is mainly fed from the FAOSTAT database (FAO 1999), complemented by the USDA’s PS&D (USDA 1999). Macroeconomic data are taken from the UN World Population Prospects (UN 1999) and the World Development Indicators (The World Bank 1998).

Data from the various sources are brought together into a consistent data set. Aggregation both in terms of regions and in terms of commodities is realised in a flexible manner to allow for an easy adjustment to the modelling needs. The Database System not only serves to provide the base data for projections and simulations, however. It is also necessary to judge projections in the context of long-term developments, which is the more important the longer the time horizon of the projection is. In addition, it is well suited to analyse ex-post

\(^{1}\) For a more detailed presentation of the model see von Lampe (1999).
developments of agricultural supply, demand and trade patterns in different regions for a long period of time.

2.2 Policy representation

A subset of policy measures enter the price transmission functions. Ad valorem and specific tariffs, direct product-related payments and other subsidies, as well as administrated minimum market prices, are included here. In addition, given that average yields are assumed to be independent from prices, premium levels paid per hectare of harvested area or per livestock unit are transformed to price equivalents and included in the price transmission functions as well. Other measures directly influence supply and trade quantities. Production quotas set upper bounds to production quantities and are modelled by price-independent fixation of supply variables. Compulsory set-aside of land reduces harvested areas and is taken into account by adjusting the production areas for each affected commodity. Export restrictions limit the exports of certain commodities whenever subsidies are necessary, i.e. if the relation between domestic and foreign trade prices does not permit unsubsidised exports. If market prices are fixed, administrated stocks are modelled to buffer the excess supply, otherwise, market prices should decline until the domestic markets are cleared.

Most of the data on policy measures are taken from the OECD, supplemented by various other sources. For most developing countries, however, no policy data are included, implying the assumptions of full price transmission and unchanged policies in both the baseline projections and the simulations.

2.3 Representation of shift factors

The longer the time horizon of model simulations, the more important changes in the socio-economic and natural environment become relative to policy decisions. But even in shorter terms macroeconomic shocks are of significant importance, as, for example, the Asian crisis has shown. In order to make the WATSIM model capable to represent and simulate these developments, a set of exogenous shift factors are explicitly included. These key variables are considered to be the main quantifiable driving forces for supply and demand on agricultural markets. Projections on the shift factors are taken from other sources, e.g. the United Nations or the International Monetary Fund, whenever available.

2.3.1 Supply side

Land availability for crop production is strongly limited and partly even decreasing in most regions of the industrialised world, but also in several developing countries in Asia, under the pressure of land needs for other purposes (e.g. urbanisation, industrialisation and infrastructure). For most regions, however, an increase in the cropping index is expected: On average, a given land will be harvested more often within one year, a development much more important with respect to the increase of agricultural production than the cultivation of new land. Projections on both total land availability and cropping indices are based on time series analysis, explicitly taking into account the impact of urbanisation.

An important factor with respect to both cropping indices and crop yields, namely the share of irrigated land, is explicitly considered to formulate crop production developments. Projections on irrigation are based on time series analysis and checked against information from the literature. The functional relationships between the share of irrigated land and both cropping indices and average crop yields are assumed to be linear and are derived from various literature sources.

The changes both in feed regimes and feed efficiency is crucial to determine the future needs of the livestock sectors. On the one hand, a further improvement in feed efficiency can be expected throughout the world due to breeding and technological developments. In many
regions, particularly in the developing world, however, the development towards a more market-oriented, larger-scale production of animal products will also lead to higher shares of marketable products in the feed regimes and thus increase energy inputs from marketable feeding stuffs per unit of animal product. Feed requirement parameters were estimated as feed energy intake per kg of animal product and were projected via time series analysis and expert judgement.

Technical progress, particularly due to modern breeding and biotechnological research, holds a tremendous potential impact on productivity. This aspect is difficult to quantify and is captured mainly by trend estimation and supplemented by expert judgement.

2.3.2 Demand side

By modelling human consumption as per capita demand, the consideration of population growth, projected by the UN, becomes straightforward.

Further growth in income, approximated as real gross domestic product per capita, is believed to be one of the most important driving sources for the development of consumption growth on agricultural markets, particularly in the developing countries. Generally, similar to other partial equilibrium models, demand shifts are related to income changes via income elasticities. Given the rapid changes in per capita incomes particularly in developing countries, these parameters cannot be assumed to be constant over time, however. To capture the impact of income growth on income elasticities, a semi-logarithmic functional relationship between these tow parameters was estimated by a cross-section estimation using the available data on the 15 model regions. Given that income elasticities not only depend on per capita income, but differ across regions also due to cultural and other reasons, only the slope coefficient of this estimation was used, describing the change of income elasticities due to a one percent change in real per capita income, whereas the resulting error term of the estimation was used to describe regional specificities, i.e. the income elasticities found in literature were taken for true in the estimation year. By using a semi-logarithmic relationship between per capita income and income elasticities, food demand in the model is expressed as a quadratic double-logarithmic function of income. By modelling the income-demand relationship in this way, changes in the response to income growth over time due to higher income levels are explicitly accounted for. Income projections were derived from the World Economic Outlook (IMF) and other sources.

Independent of income growth, urbanisation has proved to have significant impacts on consumption patterns: Wheat, sugar and particularly livestock products are consumed more in urban areas than in rural ones even for equal per capita income, while rice, coarse grains, starchy products and pulses are consumed less. The functional relationship between the share of urban population and consumption quantities at a given level of per capita income is derived from surveys on Asian consumption patterns (Huang and Bouis 1996, Huang and David 1993). As the projections on total population, urbanisation figures were taken from the World Population Assessment.

3 Scenario assumptions

To analyse the impact of different shocks in macroeconomic variables on South-East Asian food demand and hence on agricultural markets, a set of sensitivity scenarios was set upon a baseline projection. For the latter, basic macroeconomic assumptions include the projections published by UN (total population, urbanisation), IMF (real GDP growth), and The World Bank (global inflation rates) as well as data used by FAPRI (real GDP growth in the longer run). Trend-based projections include those for land availability and irrigation of agricultural land and were cross-checked with available literature such as Alexandratos (1995). Policy
assumptions were made in accordance to the results of the 1993 Uruguay Round Agreement on Agriculture, the 1999 EU Agenda 2000 and the 1996 US Fair Act. With respect to agricultural policies in developing countries, the implicit assumption of constant policies was made given the lack of appropriate data.

Five sensitivity simulations were done and compared with the baseline in order to estimate the impact of two important variables influencing food demand in Asia, i.e. the development of real per capita income, and the growth in the urban population share. Firstly, the growth rates of real per capita income in the Association of South-East Asian Nations (ASEAN) were either increased or decreased by one percentage point annually throughout the simulation period. These simulations were complemented by a third one including lower income growth both in the ASEAN region and in China. Finally, the increase in urbanisation shares in the ASEAN region was either increased or decreased by 50 percent of the growth assumed in the baseline assumption. Both the baseline projection and the scenario simulations were done for two target years: To analyse medium-term developments, the equilibrium situation for 2005 was calculated. Additionally, the year 2020 was taken into account to show long-term trends and impacts.

4 Simulation results

Due to limited space, the baseline will not be discussed in detail. Only some major results are pointed out here. The baseline results suggest a continuation of decreasing real world market prices for crop products, though with lower rates compared to the past decades, and about constant real prices for meat. These comparatively strong prices result from rapidly growing demand in many developing regions, which is partly met by increasing agricultural imports from industrialised countries, particularly from the US. Strong prices, together with the reduction of support prices due to the Agenda 2000 reform package in the European Union, are expected to reduce the need for subsidised wheat exports well below the limits set by the Uruguay Round Agreement on Agriculture, while exports of coarse grains will continue to rely on subsidies.

The developments of both per capita income and urbanisation have significant impact on the consumption of agricultural commodities in the affected regions. The strongest impact can be seen in the meat demand: By 2005 and 2020, the higher income scenario results in an increase of total meat demand in the affected ASEAN region by +6% and more than +12%, respectively. The increase of oil demand shows similar magnitudes at +5% and +10%, while grain demand (including feed demand) is affected only by +0.8% and +1.0%, respectively. Since domestic supply shows only little reaction to changes in per capita income, most of the demand changes result in changes in the region’s net trade position, with higher meat and grain imports, and lower exports of oilseeds and oils.

Basically, the lower income scenario shows the opposite effect. Two factors cause differences in the magnitude of changes, however: On the one hand, given the quadratic double-log functional relationship between income and per capita demand, changes in the per capita income results in different average income elasticities depending on the direction of the changes, i.e., the income response to lower per capita income is stronger than to higher income. On the other hand, changes in the net trade position cause changes in the average foreign trade price, and hence in domestic prices, even under constant world market condition.

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2 Note that no non-market impacts of income changes on agricultural production, e.g. due to improvements of infrastructure or better capital availability, are taken into account in the calculations.

3 Additionally, of course, the fact has to be kept in mind that relative declines ceteris paribus are generally smaller than the corresponding relative increase, e.g. the opposite of a 10% decline is an 11.1% increase, rather than a 10% increase.
Larger import quantities will generally increase import prices, since more, possibly further distant exporters have to be found, trading capacities have to be extended, and so forth. Larger exports, on the other hand, will generally decrease export prices for similar reasons. The magnitude of these price effects depends on the tradability of the specific commodity (e.g., meat is more expensive to trade than grains) and the baseline trade position (e.g., to change from a net exporter to a net importer will cause a stronger price change than to increase an already large import quantity).

The results of the two urbanisation scenarios emphasise that changes in consumption patterns due to this factor are different from those resulting from income changes. While higher urban shares of the ASEAN population would lead to higher demand for meat (+1.2% and +2.6% in 2005 and 2020, respectively), demand for rice and coarse grains would be lower than under baseline conditions despite larger feed use resulting from slightly higher livestock production. Similarly, oil consumption is reduced in the high-urbanisation scenario. Again, most of the demand changes lead to changes in the net trade position, with higher meat imports and lower imports of the food grains wheat and rice in the high urbanisation scenario compared to the baseline.

While relative changes are therefore significant in the affected region itself, the impact is comparatively limited on international markets. In the high-income scenario, international commodity prices are increased by between 0.3% and 0.9% in 2005, as compared to the baseline results (Table 1). Expressed as changes in the average annual price developments, the impact of higher income in the ASEAN region is between +0.03% p.a. and +0.08% p.a. In 2020, the impact on international prices is between 0.9% and 2.2% (Table 2), which translates into similar annual changes. Given the uncertainties associated with model results, the impact on international markets can therefore be judged as small. The impact of changes in the urbanisation share of the ASEAN region is even smaller. None of the four simulated changes is sufficient to significantly change the export subsidy situation in the EU.

This however does not mean that changes in the macroeconomic environment in Asia is irrelevant for international food markets, as the additional scenario shows which assumes lower income growth rates in both the ASEAN region and in China. In this scenario, the impacts on world market prices are about seven times stronger than in the low income in ASEAN scenario, and particularly significant in the pigmeat market. The reasons for this are threefold: Firstly, of course, the Chinese market is much more important due to its mere size. The Chinese population has about 2.5 times the size of the ASEAN population, although this relation reduces over time due to different population growth rates.

Secondly, consumption patterns of the two regions differ considerably. With some 34 kg, per capita meat consumption in China was more than twice as high as per capita consumption in the ASEAN region in the mid-1990s. For pigmeat alone, Chinese per capita consumption is four times the consumption in the ASEAN region.

Thirdly, income elasticities in China are generally higher than in the ASEAN region, particularly due to the lower per capita income in China. Income changes have therefore a larger impact on the demand of high-value commodities even in relative terms.

Price drops under these income conditions in China and the ASEAN region are therefore much more significant than in the aforementioned scenarios, and may have severe consequences for the EU export subsidy situation. Particularly in the case of coarse grains, these pessimistic income prospects would have to lead to policy responses reducing supply on the EU markets. If set-aside rates were left unchanged (EU set-aside rates were assumed with

Note that this scenario assumes that changes in Chinese domestic demand are partly be met by changes in the foreign trade, which cannot be taken for granted given the prevalent foreign trade policies of the Chinese government.
10% in all scenarios), this would mean higher intervention purchases in the medium term, and a prolongation of intervention activities in the longer run.

5 Conclusions and outlook

This paper has focused on the impact that macroeconomic shifts have on the demand for agricultural commodities in South-East Asia, and hence on global markets. Simulations were done using the World Agricultural Trade Simulation (WATSIM) modelling system, a comparative static, non-spatial partial equilibrium model for agricultural markets, which is fairly detailed in terms of commodity representation and regional differentiation. Besides a detailed representation of agricultural policies, the model explicitly takes into account changes in macroeconomic variables including population growth, urbanisation, growth of per capita income, total land availability and irrigation of agricultural land. By making income elasticities depending on real per capita income, changes in the income response due to increasing wealth are also accounted for.

The simulations done show that domestic demand in the affected regions react significantly on changes in both income and urbanisation shares. While the income response for most commodities is still positive, food demand for coarse grains and rice, and for vegetable oils decreases with rising urbanisation shares.

The impact of macroeconomic changes solely in the ASEAN region on international markets are relatively limited. Inferior income conditions in larger areas, as simulated by lower income growth in both the ASEAN region and China, may significantly reduce price prospects on global markets. Given the size of the Chinese market, the different consumption patterns and the generally higher income elasticities in China, this country has a significantly larger influence on market developments than the ASEAN region. Lower incomes in these regions may also worsen the situation for export subsidising regions like the EU both in the medium and the longer term.

Modelling macroeconomic changes and their impact on global markets is one of the aims of WATSIM. Policy analyses is another major area of work with this model. In order to make the system more capable of representing the different trade related policy issues that are becoming more differentiated, the necessity of representing gross trade, i.e. imports and exports rather than net exports only, has led to the next steps in the model development. In addition to the abovementioned Non-Spatial Database (NSDB), the new Spatial Database also comprises trade flows between the model regions and is mainly fed by the Comtrade database and calibrated to consistency with the NSDB trade data. The equilibrium model is being redesigned to capture changes in gross trade quantities making use of the Armington approach. Both the SDB and the gross trade representation in the WATSIM modelling system will significantly improve the value of ex-post data and ex-ante projections.

References


Appendix

Table 1: Impact of macroeconomic shifts on agricultural world market prices, 2005

<table>
<thead>
<tr>
<th>Product</th>
<th>Scenario</th>
<th>Higher income ASEAN</th>
<th>Lower income ASEAN</th>
<th>Lower income ASEAN &amp; China</th>
<th>Higher urbanisation ASEAN</th>
<th>Lower urbanisation ASEAN</th>
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</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>Higher income</td>
<td>+0.62%</td>
<td>-0.63%</td>
<td>-4.12%</td>
<td>+0.11%</td>
<td>-0.12%</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower income</td>
<td>+0.86%</td>
<td>-0.83%</td>
<td>-5.31%</td>
<td>-0.05%</td>
<td>+0.04%</td>
</tr>
<tr>
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<td>ASEAN</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower income</td>
<td>+0.78%</td>
<td>-0.63%</td>
<td>-4.35%</td>
<td>-0.36%</td>
<td>+0.35%</td>
</tr>
<tr>
<td></td>
<td>ASEAN &amp; China</td>
<td>+0.77%</td>
<td>-0.72%</td>
<td>-4.72%</td>
<td>-0.18%</td>
<td>+0.17%</td>
</tr>
<tr>
<td></td>
<td>Southeast Asia</td>
<td>+0.41%</td>
<td>-0.45%</td>
<td>-2.64%</td>
<td>-0.68%</td>
<td>+0.69%</td>
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<tr>
<td></td>
<td>Southeast Asia &amp; China</td>
<td>+0.01%</td>
<td>-0.07%</td>
<td>-0.04%</td>
<td>+0.14%</td>
<td>-0.14%</td>
</tr>
<tr>
<td>Soybeans</td>
<td>+0.83%</td>
<td>-0.81%</td>
<td>-4.00%</td>
<td>+0.07%</td>
<td>-0.07%</td>
<td>+0.07%</td>
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<tr>
<td>Sunflower Seed</td>
<td>+0.59%</td>
<td>-0.59%</td>
<td>-2.73%</td>
<td>-0.07%</td>
<td>+0.07%</td>
<td>+0.07%</td>
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<tr>
<td>Rape seed</td>
<td>+0.61%</td>
<td>-0.68%</td>
<td>-4.48%</td>
<td>-0.04%</td>
<td>+0.04%</td>
<td>+0.04%</td>
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<tr>
<td>Beef &amp; veal</td>
<td>+0.37%</td>
<td>-0.35%</td>
<td>-1.85%</td>
<td>+0.14%</td>
<td>-0.14%</td>
<td>+0.14%</td>
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<tr>
<td>Pigmeat</td>
<td>+0.61%</td>
<td>-0.64%</td>
<td>-6.41%</td>
<td>+0.01%</td>
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<tr>
<td>Sheep &amp; goat meat</td>
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<td>-3.29%</td>
<td>+0.14%</td>
<td>-0.14%</td>
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<tr>
<td>Poultry</td>
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<td>-0.83%</td>
<td>-3.68%</td>
<td>+0.08%</td>
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</table>

Source: WATSIM simulation results

Table 2: Impact of macroeconomic shifts on agricultural world market prices, 2020

<table>
<thead>
<tr>
<th>Product</th>
<th>Scenario</th>
<th>Higher income ASEAN</th>
<th>Lower income ASEAN</th>
<th>Lower income ASEAN &amp; China</th>
<th>Higher urbanisation ASEAN</th>
<th>Lower urbanisation ASEAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>Higher income</td>
<td>+1.76%</td>
<td>-1.71%</td>
<td>-8.85%</td>
<td>+0.38%</td>
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<td></td>
<td>ASEAN</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower income</td>
<td>+2.81%</td>
<td>-2.63%</td>
<td>-13.48%</td>
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<td></td>
<td>Lower income</td>
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<td>ASEAN &amp; China</td>
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<td>+0.28%</td>
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<tr>
<td></td>
<td>Southeast Asia</td>
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<td>-0.61%</td>
<td>-4.19%</td>
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<td>Soybeans</td>
<td>+2.04%</td>
<td>-2.02%</td>
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<td>Sunflower Seed</td>
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<td>-5.50%</td>
<td>-0.16%</td>
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<td>Beef &amp; veal</td>
<td>+0.88%</td>
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<td>Pigmeat</td>
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<td>-1.47%</td>
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<td>Sheep &amp; goat meat</td>
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<td>-7.89%</td>
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<tr>
<td>Poultry</td>
<td>+2.17%</td>
<td>-1.96%</td>
<td>-8.24%</td>
<td>+0.21%</td>
<td>-0.21%</td>
<td>-0.21%</td>
</tr>
</tbody>
</table>

Source: WATSIM simulation results
Modeling the GATT “Agreement on agriculture”. Assessing the Compatibility of EU “Agenda 2000” with GATT Commitments for Wheat

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Abstract
This paper presents an original approach to modeling GATT commitments, accommodating some of the most often raised policy modeling concerns related to assessing the implications of the “Agreement on agriculture”. In particular, CAMINÌA - the modeling framework presented: explicitly models “ad valorem” as well as “per unit” import tariffs and export subsidies; explicitly models, and endogenously determines, “variable levies” and “export restitutions”; accommodates for preferential trading; explicitly models minimum intervention price policies; allows for intra-industry trade when “minimum” tariff reduced import quotas (TRQs) exist; allows imports within the TRQs to occur only if profitable; allows for imports above the TRQs to occur at the above-quota tariff rate; explicitly models export competition commitments and allows non-subsidized exports to occur once one of the two relevant constraints becomes binding. The main results obtained by using CAMINÌA to assess the “compatibility” of “Agenda 2000” wheat policy reform with EU GATT commitments for wheat are briefly discussed.

Keywords: Spatial Modeling; Mathematical Programming; GATT Agreement on Agriculture; CAP; Agenda 2000; Wheat.

1 Introduction
Since the launch of the Uruguay Round in 1986 there has been a growing interest in quantifying the effects of the different trade liberalization scenarios emerging from the negotiation and the expected implications of the implementation of the agreement which has been reached in December 1993. However, the modeling of policies in place as well as of the commitments resulting from the GATT agreement has often been less than fully satisfactory. In most cases the structural characteristics per se of the models used - which often were originally designed to provide answers to other policy questions - do not allow for a proper explicit modeling of commitments and policy tools (Salvatici et al., 2000).

This paper presents an original approach to modeling GATT commitments which tries to accommodate some of the policy modeling concerns specifically relevant to assessing the implications of the GATT agreement and of the possible outcomes of the WTO agricultural negotiation which just started. In particular, CAMINÌA - the modeling framework presented - explicitly models “ad valorem” as well as “per unit” import tariffs and export subsidies;

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explicitly models and endogenously determines “variable levies” and “export restitutions”; accommodates for preferential trading, which includes, as a special case, the creation or the enlargements of free trade areas and customs unions; explicitly models minimum intervention price policies, representing them as the public sector entering the domestic market with an infinitely elastic demand at the minimum guaranteed price; allows for intra-industry trade when GATT “minimum” import tariff reduced quotas (TRQs) exist; allows imports within the TRQs to occur only if profitable; allows for imports above the “minimum” import quota to occur at the above-quota tariff rate; explicitly models export competition commitments and allows non-subsidized exports, if economically feasible, to occur once the constraint on the volume of subsidized exports or that on the export subsidy expenditure becomes binding.

The next section introduces the characteristics of CAMINÌA. Section two describes the simulation scenarios considered, the assumptions made and the modeling choices. Section three briefly discusses the results obtained by using CAMINÌA to assess the “compatibility” of the “Agenda 2000” wheat policy reform with EU GATT commitments for wheat.

2 The “CAMINÌA” model
CAMINÌA is a mathematical programming spatial partial equilibrium model (Takayama and Judge, 1971). The model solution is found by maximizing a “quasi-welfare” function (Samuelson, 1952) subject to a set of constraints. The model expands on Anania and McCalla (1991), Anania, Bohman and Carter (1992), and SOLAGRAL (1998). To allow for an assessment of the GATT “Agreement on agriculture”, the base model time reference is 1994, the year before the beginning of the implementation of the agreement.

Only one commodity is considered, wheat\(^2\), which is assumed to be a homogeneous product. All values are expressed in US dollars and exchange rates are exogenous to the model. All quantities are expressed in metric tons. With the exception of the distortions which are explicitly considered in the model, perfect competition conditions are assumed to hold both in domestic and international markets. Domestic production and consumption are explicitly modeled; demand and supply functions are assumed to be linear (or to be well approximated by a linear function in their portion which is relevant for the model simulations) and are obtained from observed produced and consumed quantities\(^3\), producer and consumer prices\(^4\), and supply and demand elasticities at the equilibrium in the base year in each country or region. Producer prices are farm gate prices; consumer prices are intended to be net of consumer subsidies, if any. In each country the per unit transportation and handling cost for moving wheat from the farm gate to domestic consumers is assumed to be the same as the cost for moving wheat to be exported from the farm gate to the border, or for moving imported wheat from the border to domestic consumers. International transportation and handling costs represent the costs of moving the wheat from border to border\(^5\). Domestic and international per unit transportation and handling costs are assumed to be constant, i.e. not to change either with the volume exchanged or over time.

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2 This includes both soft and durum wheat, as well as wheat flour.
3 The data source for production and utilization in 1994 is the FAO “Food Balance Sheet” database for “wheat & products”. Although the term “consumption” is often used here interchangeably for “utilizations”, the latter would be more appropriate, “consumption” including food, feed, seed and other uses as well as wastes.
4 The source for production prices for most countries has been IWC (1995). Information produced by FAO and OECD has been used as well. Most consumer prices have been determined based on prices of bread as listed in IWC (1995).
5 These have been obtained based on information provided in IWC (1995).
Stock changes are incorporated in the model through country specific stock release functions. In each country/region stock changes are assumed to be a linear function of producer price. These functions have been obtained from stock releases in 1994 as given by FAO, observed producer prices in the same year and stock release elasticities. Domestic markets in 19 countries and regions (all major importing and exporting countries and regional aggregations of remaining countries) are modeled. Compensatory payments in the EU are assumed to be fully “decoupled”. The “compulsory set aside” percentage is implicitly defined in the model as the “rotational” equivalent, assuming a 15% set aside percentage being equivalent to the maximum allowed non-rotational percentage (17.5%). Support granted by deficiency payments in the US is assumed to be fully “decoupled”. Minimum guaranteed market prices in the US and EU are given by the “loan rate” ($2.45/bu.) and the “intervention price” (115.49 Ecu/t), respectively; minimum guaranteed farm gate prices are lower by the per unit domestic handling and transportation costs incurred by farmers to deliver the wheat to the intervention.

EU variable “export restitutions” are endogenously determined as the export subsidies which make EU exports competitive on the different markets, based on the EU reference threshold export price, which is exogenous to the model. In the 1994 base scenario, where EU export subsidies are not subject to any constraint, restitutions make producer price in the EU equal to the farm gate reference export threshold price ($162/t), and EU production in excess of domestic consumption, net of the change in stocks, exported. The per unit export subsidy in Canada is given by the average subsidy provided under the Western Train Transportation Act. US per unit EEP export subsidies by country/region of destination are based on average bonuses paid in 93/94; subsidies are assumed to be paid in cash and subsidized exports are assumed to be unconstrained. Finally, per unit export subsidies used by Turkey and South Africa are those applied in 1994, as listed by the WTO.

For countries that subsidized wheat exports in 1994 which are not individually considered in the model (Hungary, for example), rather than modeling the export subsidy by forcefully extending its use to all countries of the region, the choice has been not to take the subsidy into account. EU market protection in 1994 has been modeled through a “variable levy”. The levies are endogenously determined as the difference between the exogenous import “threshold price” (172.74 Ecu/t) and the (potential) c.i.f. export prices at the EU border for each of the other countries. The protection granted to its domestic market by Japan through JFA, a state trading enterprise, is represented by a constraint on its imports (a quota) equal to the observed volume of wheat imports in 1994. Trading between US and Canada is assumed to be tariff free due to the NAFTA. For the same reason Canada and US exports to the Central America region, which includes Mexico, are subject to a preferential import tariff (10.5%, rather than 67%). Existing bilateral agreements in 1994 involving commitments in

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6 A negative release implying an increase in stocks.
7 The 19 countries or regions considered are: the European Union (15 members); the United States; Canada; Argentina; Australia; China; Japan; South Africa; the countries of the former Soviet Union, apart from Estonia; Turkey; the other Mediterranean countries; the other European countries; Mexico and the other Central American and Caribbean countries; the other South American countries; the other African countries; the other countries of the Near East; the other countries of the Far East; the other countries of Oceania; the candidate countries most likely to become members of the EU in the near future (Cyprus, Estonia, Poland, the Czech Republic, Slovenia and Hungary). Although the time reference of the “Base» model is 1994, a European Union of 15 members has been assumed in order to facilitate comparisons with other scenarios.
8 This is given by 110% of the intervention price, which was equal to 115.49 ECU/t (117 ECUs minus the agrimonetary correction) times the “switch-over» coefficient (1.21), divided by the average ECU/$ exchangerate in 1994 (.8431), less domestic transportation and handling costs in the EU ($20/t).
wheat trading, as listed in IWC (1995), have been imposed as minimum constraints in bilateral trade flows.

Arbitraging - a country importing and exporting at the same time to take advantage of import tariffs and export subsidies differentiated by source of imports or destination of exports, respectively - is made impossible (Anania e McCalla, 1991) for all countries but South Africa (which was a net importer in 1994 while at the same time subsidizing exports) and the Central and Eastern European candidates to join the EU (which, as a region, were in 1994 a marginal exporter). 9

Calibration of the “Base 1994” model turned out to be quite satisfactory. The average percent difference, in absolute value, between the values observed and those produced by the model in the 19 countries/regions was, in fact, 2.6% for the quantities produced and 3.1% for those consumed.

3 The simulations
Simulations are produced with respect to three different time horizons: 2001, 2002 and 2005. In 2001 the implementation period of the GATT agreement by developed countries will be completed, and these will have to fulfill the export subsidy commitments as indicated in their schedules, i.e. without being able to use any “credit” accumulated in previous years, if any; in addition, in 2001 the first step of the implementation of the EU wheat policy changes introduced with “Agenda 2000” will take place. 2002 has been considered to assess the full implementation of the EU policy reform for wheat. Finally, the 2005 time horizon has been chosen to provide a medium term assessment of what one should expect from “Agenda 2000” as regards its capability to make reformed EU wheat policies “compatible” with current commitments deriving from the GATT agreement and with those which could possibly derive from the conclusion of the forthcoming WTO negotiations.

3.1 The “Base” 2001, 2002 and 2005 scenarios
The Base 2001, 2002 and 2005 scenarios are “reference” scenarios. They differ from the “Base 1994” as follows: the demand and supply functions have been modified to take into account expected changes in population, per capita incomes and yields; the model now includes the implementation of the 1994 GATT “Agreement on agriculture”, the FAIR (Federal Agricultural Improvement and Reform) Act of the United States, and the full implementation of the 1992 reform of wheat policies in the European Union.

The demand functions have been modified on the basis of expected population and per capita income, and on the income elasticities of utilizations. It has been assumed that per capita (food and feed) utilizations, ceteris paribus, do not change between 1994 and the three time horizons considered. Expected population has been obtained by applying to the population in each country in 1994 (World Bank, 1996) the percent annual growth rate between 1990 and 2000, as forecasted by the United Nations (Alexandratos, 1995; Table A.1). Per capita income has been assumed to change at the same annual rate as that observed between 1985 and 1995, as estimated by the World Bank (World Bank, 1997).

Supply functions have been modified on the basis of expected yields in 2001, 2002 and 2005. For each country/region these have been obtained by fitting a linear trend by OLS to observed yields between 1980 and 1994 (FAO). It has been assumed that, ceteris paribus, wheat area does not change.

GATT “domestic support” commitments are assumed not to be a constraint for any country/region. Tariff levels are based on country schedules. For many importing developing

9 Detailed information regarding the model structure and databases can be obtained from the author.
countries observed tariff rates in 1994 were lower than bound rates listed in their schedules. When this was the case, tariffs were assumed to be the same as in 1994. Tariffs applied by countries that are not members of WTO - China for example - have been assumed not to change. The preferential tariff imposed by “Central America” on its imports from USA and Canada has been reduced to 6% (from 10.5% in the “Base 1994” scenario), as a result of the implementation of NAFTA.

Relevant information for the European Union is based on the “schedules” for EU-15. The “tariffication” of the EU variable levy being subject to the additional constraint that the tariff inclusive import price cannot exceed 155% of the intervention price is assumed to leave the EU protecting its domestic market by using a variable levy, as it was before the implementation of the GATT agreement (Josling and Tangermann, 1995; Tangermann and Josling, 1994). However, the reference threshold price used to compute the variable levy is now lower ($219.1/t, equivalent to 155% of the new intervention price, compared to the $248/t threshold price in the “Base 1994” scenario) and the levy is constrained so as not to exceed the ceiling indicated in the EU “schedules” ($112.7/t, the equivalent of 95 ECU/t).

Japan’s protectionist policies are assumed not to change. Based on expected changes between 1994 and 2001, 2002 and 2005 in domestic production and utilizations due to changes in per capita income, population and yields, and assuming that protection to farmers in Japan is driven by the goal of maintaining the domestic price at a chosen level (assumed not to change), the constraint on the volume of imported wheat has been increased from 6.048 million tons in the “Base 1994” scenario to 6.350 in 2001, to 6.403 in 2002, and to 6.550 in 2005.

Reduced tariff “minimum” and “current” import quotas are explicitly modeled. As stated by the agreement, countries are not forced to fill the quotas; instead, they are assumed to allow imports at the reduced tariff rate indicated in their “schedules” up to the quota, as long as these imports are economically profitable. The model allows imports over “minimum” and “current” quotas to occur at the standard above-quota tariff rates.

GATT “export competition” commitments are explicitly modeled as well. Constraints are included for subsidized exports and export subsidy expenditures not to exceed the maximum values indicated in the “schedules”. If either one of the two constraints - that on the volume of subsidized exports, or that on the export subsidy expenditure - becomes binding, the model allows for non-subsidized exports to occur, if profitable.

The EU variable export restitution mechanism is assumed not to be modified as a result of the GATT agreement; however, it is subject to the commitments, and the reference price used to compute the restitutions is now lower ($155.5/t compared to $182/t) as a result of the lower intervention price.

It is assumed that the elimination of the (implicit) export subsidy under the Western Train Transportation Act implied the abolition of wheat export subsidization in Canada.

The implementation of the 1996 FAIR Act is represented in the model by (a) the elimination of the target price and the deficiency payments; (b) an increase of wheat acreage by 3.35%; and (c) by assuming the loan rate in 2001 being equal to its maximum possible level ($2.58/bu.). US direct payments are assumed to be fully “decoupled”.

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10 The source for the quotas is the WTO, that for the in-quota tariff rates is OECD (1995).
11 As forecasted by USDA (1997) for harvested wheat area between 93/94 and 00/01. The change derives from the increase of farmed land as a result of the elimination of set aside as a condition for access to the direct payments, and from the removal of distortions in land allocation decisions as a result of the decoupled nature of the support.
Export subsidy commitments for the US are those listed in the “schedules”, as foreseen in the Act for 2001.\textsuperscript{12} US per unit export subsidies are assumed to be automatically reduced if the constraint on the export subsidy expenditure is binding while that on subsidized exports is not. This reflects the goal of US in using export subsidies to maximize the volume of exports (within the given constraints).

EU wheat policies are modeled assuming that set aside “slippage” does not change, and that the percentage of land under the “simplified scheme” decreases from 30% to 20% of the total land where wheat is grown benefitting from compensatory payments.

To take into account the likely effects of changes in the set aside rate on both yields (the lower the set aside, the lower the yields) and voluntary set aside participation (the lower the mandatory set aside, the higher the voluntary set aside), it is assumed that the production effect of a change in cultivated land with respect to the base scenario is equal to only 80% of what should be expected ceteris paribus.

The intervention price is equal to $141.4 (the equivalent of 119.19 ECU/t; it was $166/t in the “Base 1994” model) as a result of the full implementation of the 1992 CAP reform.

### 3.2 The “Agenda 2000” 2001, 2002 and 2005 scenarios

The “Agenda 2000” scenario at 2001 differs from the “Base 2001” only in the modeling of EU wheat policy, reflecting the changes decided in March 1999.

Intervention price is now lower by 7.5% (110.25 ECU/t instead of 119.19; 130.8 $/t instead of 141.4). As a result, both the reference price for calculating the export restitutions (which is equal to 110% of the intervention price) and the reference threshold price for calculating the variable import tariffs (which is given by 155% of the intervention price) are now lower (the former decreases from 155.5 $/t to 143.9; the latter from 219.1 $/t to 202.7).

The “Agenda 2000” and the “Base” scenarios at 2002 and 2005 differ only for the modeling of EU wheat policy. The intervention price is now lower by an additional 7.5% with respect to the “Agenda 2000” scenario at 2001 (down to 101.31 ECU/t, or 120.2 $/t); the threshold reference price for calculating the restitutions is now 132.2 $/t and that used to compute the variable import tariffs 186.3 $/t.

### 4 Results

The main results of the simulations for the EU are shown in Table 1.

In 2001 pre-“Agenda 2000” policies are forecasted not be “compatible”\textsuperscript{13} with EU GATT export subsidy commitments. Regardless of the compulsory set aside rate, the GATT commitment on the maximum volume of subsidized wheat exports would always be binding for the European Union. When the percentage of compulsory set aside is equal to 5% or 0%, the domestic price drops to the intervention price\textsuperscript{14} and the quantity withdrawn from the market is equal to 0.5 and to 3.7 million tons, respectively. With a set aside set at 15% or at 10%, domestic price in the EU rises sufficiently to make it profitable for exporters to fill the EU reduced tariff “minimum access” GATT quota (equal to 350,000 tons).

The export subsidy commitments being binding implies that the subsidies allocated are less than those which are requested. This means that those who are granted the subsidies will enjoy a rent: e.g. they receive a higher “net price” than those who sell their wheat on the domestic market.

\textsuperscript{12} For the years before 2000 the allocation to export subsidies in the Act is lower than the maximum export subsidy expenditure allowed by GATT commitments.

\textsuperscript{13} EU policies are here defined “compatible” with the GATT commitments if these are not binding, that is if the market equilibrium which is attained with the constraints in place is the same as if they did not exist.

\textsuperscript{14} 102.4 EURO/t at the farm gate, equivalent to the 119.19 EURO/t intervention price.
In 2001 only the first of the two steps of the wheat policy reform decided in March 1999 will have been completed; institutional prices, therefore, will be lower than those in the "Base 2001" scenario by only 7.5%. When the percentage of the compulsory set aside is 15% or 10% such a reduction is, nevertheless, sufficient to render community policies “compatible” with GATT commitments. When the set aside percentage is 10% - that is the percentage decided as the “reference” compulsory set aside rate for the whole 2000-2006 period - EU

Table 1: European Union. Simulation results.

<table>
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<tr>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>15% SA</td>
<td>10% SA</td>
<td>5% SA</td>
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<tr>
<td>Production (Mill t)</td>
<td>85.7</td>
<td>89.3</td>
<td>90.6</td>
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<td>Consumption (Mill t)</td>
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<td>78.4</td>
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<td>-2.2</td>
<td>-1.9</td>
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<td>Exports (Mill t)</td>
<td>16.7</td>
<td>14.4</td>
<td>14.4</td>
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<tr>
<td>Imports (Mill t)</td>
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<td>0.350</td>
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<tr>
<td>Net Trade Position (Mill t)</td>
<td>16.7</td>
<td>14.1</td>
<td>14.1</td>
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<td>Subsidized Exports (Mill t)</td>
<td>16.7</td>
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<tr>
<td>Max Subsidized Exports (Mill t)</td>
<td>14.4</td>
<td>14.4</td>
<td>14.4</td>
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<tr>
<td>Export Subsid. Expend. (Mill $)</td>
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<td>1041.8</td>
<td>992.6</td>
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<tr>
<td>Max Exp. Subsid. Exp. (Mill $)</td>
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<td>1529.7</td>
<td>1529.7</td>
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<tr>
<td>Consumer Price (Euro/t)</td>
<td>153.4</td>
<td>130.6</td>
<td>123.9</td>
</tr>
<tr>
<td>Producer Price (Euro/t)</td>
<td>136.6</td>
<td>113.7</td>
<td>107.0</td>
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<tr>
<td>Intervention (Mill t)</td>
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<td>0.0</td>
<td>0.0</td>
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<tr>
<td>Intervention Price (Euro/t)</td>
<td>123.1</td>
<td>102.4</td>
<td>102.4</td>
</tr>
<tr>
<td>Ref. Price V.E.R. (Euro/t)</td>
<td>136.6</td>
<td>114.2</td>
<td>114.2</td>
</tr>
</tbody>
</table>

In 2002 only the first of the two steps of the wheat policy reform decided in March 1999 will have been completed; institutional prices, therefore, will be lower than those in the "Base 2002" scenario by only 7.5%. When the percentage of the compulsory set aside is 15% or 10% such a reduction is, nevertheless, sufficient to render community policies “compatible” with GATT commitments. When the set aside percentage is 10% - that is the percentage decided as the “reference” compulsory set aside rate for the whole 2000-2006 period - EU

Table 1 continued...

<table>
<thead>
<tr>
<th>Year</th>
<th>Base 2002</th>
<th>&quot;Agenda 2000&quot; - 2002</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15% SA</td>
<td>10% SA</td>
</tr>
<tr>
<td>Production (Mill t)</td>
<td>90.2</td>
<td>91.7</td>
</tr>
<tr>
<td>Consumption (Mill t)</td>
<td>78.1</td>
<td>79.1</td>
</tr>
<tr>
<td>Stock Changes (Mill t)</td>
<td>-2</td>
<td>-1.8</td>
</tr>
<tr>
<td>Exports (Mill t)</td>
<td>14.4</td>
<td>14.4</td>
</tr>
<tr>
<td>Imports (Mill t)</td>
<td>0.35</td>
<td>0.0</td>
</tr>
<tr>
<td>Net Trade Position (Mill t)</td>
<td>14.1</td>
<td>14.4</td>
</tr>
<tr>
<td>Subsidized Exports (Mill t)</td>
<td>14.4</td>
<td>14.4</td>
</tr>
<tr>
<td>Max Subsidized Exports (Mill t)</td>
<td>14.4</td>
<td>14.4</td>
</tr>
<tr>
<td>Export Subsid. Expend. (Mill $)</td>
<td>970.3</td>
<td>702.7</td>
</tr>
<tr>
<td>Max Exp. Subsid. Exp. (Mill $)</td>
<td>1529.7</td>
<td>1529.7</td>
</tr>
<tr>
<td>Consumer Price (Euro/t)</td>
<td>153.4</td>
<td>121.9</td>
</tr>
<tr>
<td>Producer Price (Euro/t)</td>
<td>136.6</td>
<td>105.1</td>
</tr>
<tr>
<td>Intervention (Mill t)</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Intervention Price (Euro/t)</td>
<td>102.4</td>
<td>102.4</td>
</tr>
<tr>
<td>Ref. Price V.E.R. (Euro/t)</td>
<td>136.6</td>
<td>114.2</td>
</tr>
</tbody>
</table>

1: farm gate price; this is lower than the consumer price by the per unit handling and transportation costs to the domestic market or to the intervention, both assumed to be equal to $20 per ton.
subsidized wheat exports are equal to 12.9 million tons (the maximum allowed under the GATT agreement being 14.438 million tons). In this case, the GATT commitment not being binding, domestic consumer price is equal to the reference price (121.3 EURO/t) utilized for calculating export restitutions, while the farm gate producer price, which is $20 lower, is equal to 104.5 EURO/t. If the set aside percentage were fixed at 5% or 0%, the constraint on the volume of subsidized exports would come into force and producer and consumer prices in the EU would decline. However, the price in the EU would remain above the intervention price.

If instead of the $/ECU exchange rate used in the “Base 1994” model (equal to 1.1861), the one pertaining to June, 1999 (1.04)\textsuperscript{15} is used, the wheat policies introduced with the “Agenda 2000” package become “compatible” with the GATT commitments on export subsidies for wheat even if the set aside rate is 0%. Subsidized exports are equal to 11.6 million tons and the farm gate producer price in the EU is equal to 110.3 EURO/t (as opposed to 95.1 EURO/t for the same simulation using the base 1994 $/ECU exchange rate).

In 2002, pre-“Agenda 2000” policies would again be “incompatible” with EU GATT constraints on subsidized wheat exports; this would be the case even if the set aside rate were set at the maximum agreed level. In this case too, with a set aside rate of 5% or 0% the domestic price would fall to the level of the intervention price; the quantities withdrawn from the market would equal 1.9 and 5 million tons, respectively.

The “Agenda 2000” scenario in the year 2002 reproduces the full implementation of the 1999 reform, i.e. a 15% reduction of the intervention price and, as a result, of the reference prices for calculating variable levies and export restitutions. EU wheat policies now become “compatible” with the GATT commitments even with a set aside rate of 5%. In the latter case the simulation foresees the European Union exporting 12.4 million tons and, the GATT commitments not being binding, a domestic price equal to the reference price used for calculating export restitutions (94.6 EURO/t at the farm gate). When the set aside rate is 0%, the GATT commitments become binding and the price drops, albeit slightly, below the reference price for calculating the export restitutions.

In this case once again, if a $/EURO exchange rate of 1.04, rather than 1.1861, is assumed, the new CAP is “compatible” with the GATT commitments even with a set aside rate of 0%. Moreover, the domestic price within the EU is higher than the reference price for the calculation of the export restitutions, and it becomes possible to export without subsidies the entire difference between EU wheat production and domestic utilizations; these exports would amount to slightly over 9 million tons.

The “incompatibility” of pre-“Agenda 2000” EU wheat policies with the EU GATT commitments would have become with time even more marked. The results of the simulation in 2005 show that only a set aside rate set at the maximum level would have avoided the systematic use of intervention; this would have involved 2.4 million tons with a set aside rate of 10%, 5.7 with a set aside rate of 5%, and 9 million tons if the mandatory set-aside were abolished.

While in 2002 the policies decided in March 1999 would be “compatible” with the GATT commitments with a set aside rate set at 5%, 10% or 15%, in 2005 there would only be

\textsuperscript{15} Between 1979 and 1999 the $/ECU exchange rate fluctuated between 0.72 in 1980 and 1.32 in 1985.
compatibility” if the set aside rate were set at 10% or 15%\(^{16}\). If compulsory set aside were removed, EU wheat subsidized exports would still be equal to the maximum allowed under the GATT agreement but, along with these, there would be 1.8 million tons of unsubsidized wheat exports. In fact, domestic price would fall to such an extent that EU exports would become competitive on the world market even without subsidies.

5 Conclusions

The model presented in this paper introduces an innovative modeling framework to assess the implications of the 1994 GATT “Agreement on agriculture” based on a detailed explicit modeling of the commitments as well as of relevant domestic and trade policies. The mathematical programming spatial partial equilibrium structure of CAMINÌA is powerful and very flexible; it can be easily curved to meet most policy analysts’ needs.

The main structural limitations of the proposed modeling framework are those typical of partial equilibrium models. As for all agricultural policy models, its effectiveness depends on its intrinsic qualities as much as on the quality of the data it is fed with; this is certainly an area in which tremendous improvements are needed and possible.

Doable improvements of the current version of the model include a more sophisticated modeling of production, utilization and stock changes; moving to a multi-product framework; releasing the perfect competition assumption to include the implications of international wheat trade being controlled by very few actors exerting market power; introducing a policy interaction mechanism endogenizing country policy reactions to changes in market equilibrium.

References


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\(^{16}\) Both OECD (OECD, 1999) and FAPRI (FAPRI, 1999; European Commission, 2000) have made available results from simulations undertaken on the effects of the “Berlin Agreement”. The results of the OECD estimates indicate that in 2004 the EU would be in a position to export wheat above the volume allowed by the GATT agreement without export subsidies; overall EU wheat exports would be equal to 18.6 million tons. The OECD estimates were obtained by using the AGLINK model and assuming, amongst other things, a set aside rate of 17.5%. The simulations performed by FAPRI in 1999 – which assume a EURO/$ exchange rate of 1.08 - forecast however that from 2003 (with a compulsory set aside rate of 10%) the EU would be in a position to export grain without subsidies even with pre-“Agenda 2000” policies; the March 1999 reform, even assuming a set aside rate of 5%, would make unsubsidized exports possible from as early as 2001. The simulations by FAPRI whose results are presented in European Commission (2000), based on the different models developed by FAPRI at Iowa State and at the University of Missouri, confirm that with the policy changes introduced with Agenda 2000 package the EU is expected to be able to export wheat without subsidies already in 2002. The FAPRI-Iowa model assumes a EURO/$ exchange rate of 1.25 and a 10% set aside rate; the FAPRI-Missouri model assumes a 1.08 exchange rate and a 5% set aside rate. Rayner et al. (1999) found a 90% probability of the EU export subsidy constraints becoming binding in 2000/01 with the pre-“Agenda 2000” policies, assuming a 15% set aside rate; on the other hand, with an ECU/$ exchange rate equal to 1.14, they estimate the probability of EU not needing subsidies to export wheat to be equal to 84%.


Chapter VII

The Role of Public Agencies and the Institutional Setting for Policy Modelling
Let me first of all thank you very much for your kind invitation to this important seminar. After the impressive presentations and discussions you have had during the last few days, I am afraid that my contribution can only be very modest. I would like to present to you our use of agricultural sector modelling in the Directorate General for Agriculture of the European Commission - in DG Agri as we say now -, present what we did in the past, what our needs are today and our hopes and ambitions for the future.

Due to the limited internal resources available for modelling, DG Agri relies mostly for its policy analysis on models developed by outside institutions. However, we have tried over the years to constitute teams and to develop skills that allow us to increase our participation in the agricultural modelling debate and to reduce the gap between the world of policy administration and the world of quantitative economics. We believe that this has been a worthwhile and successful effort for both sides: We now appreciate much better the insights offered by policy modelling, while modellers seem to be a little bit more sympathetic to the fact that economic theory cannot always be that easily translated into applied policy. Moreover, this better understanding has helped us to improve our political bosses’ awareness of the possibilities that exist to characterise agricultural policies and to analyse their impact by using quantitative tools. Today, we are sometimes even confronted with expectations and with requests for analysis from them which go beyond what we are able to deliver.

Inside the Commission, our activities in the field of sector modelling over the last 15 years have been developed in close cooperation with Eurostat, the Statistical Office of the European Union. Eurostat not only delivered the source data and prepared them for modelling needs, but also initiated and financed to a large extent the modelling work, with us as their major client.

In fact, when we made our first tentative steps as model users in the early eighties, the possibilities of modelling were still limited. Only a few quantitative tools were available and they were not very user friendly. The main tool for testing EU agricultural policy scenarios we had at our disposal was the SPEL model developed for Eurostat by our hosts here in Bonn. Over the years, the SPEL model would be developed further and improved. It was used – in our eyes quite successfully – as an analytical support in the context of the 1992 reform proposals and the Uruguay Round. In this latter context, we also worked with an international trade model – MISS – developed by INRA in Rennes.

In the context of the 1992 reforms, we also tried to assess the macroeconomic impacts of the agricultural reform proposals. This opened the way for close cooperation with colleagues in the Directorate General for Economic and Financial Affairs and allowed us to benefit also from their modelling activities. This cooperation has continued since then. We tested together the CAPMAT model developed by the University of Amsterdam and used this model also, in addition to the SPEL model, to assess the impact of the Agenda 2000 reform proposals and decisions. The assessment of the reform proposals was published last year and the assessment of the final decisions has been available on Internet since a few weeks.

Now that the main work on Agenda 2000 lies behind us, I think that it is time to review our needs and to explore new ways to pursue our modelling activities.
Let me first say a few words about what I believe will be our needs over the next decade. The CAP will certainly continue to be in a process of adjustment and reform. Adjustment pressures will come from both external and internal developments. On the external side, just think of expected world market developments, of the new Round of multilateral trade negotiations and of the process of enlargement. On the internal side, agricultural policy makers are confronted at the same time with increasingly severe budget constraints and with the call for better integration of environmental concerns, with the prospect of internal market imbalances and with the challenge of rural development and its articulation with agricultural policy.

Needless to say that for all these questions a lot of analysis will be required, be it in the form of ex-post diagnosis of developments or in the form of impact analyses of alternative policy scenarios and their evaluation with respect to political objectives.

We will have to carry out these analyses partly in-house and for this purpose we will need reliable and easily accessible data systems as well as some transparent and user-friendly modelling tools, in particular for ad hoc calculations during the political negotiation process. In addition to this, however, I believe that we will have to rely increasingly on services from external research institutes, supplying us with results from models they run and with scientifically based evaluations and interpretations. In this context, it would also be desirable from our point of view to analyse and compare contributions from different modelling approaches.

Looking at the many requests we currently get from policy makers, we will certainly need a new generation of sector models for the EU, be it for the agricultural sector as a whole or be it for specific sub-sectors as for example the dairy sector. We will also need tools to assess the impact of enlargement on the agricultural economies of the CEECs. We will need models to analyse the impacts on and the feedbacks from world markets and to assess the consequences of different outcome scenarios of the new WTO-Round. And last, but not least, we will increasingly need regionalised and/or farm sample models to get some insight into the regional dimension and the environmental aspects of agricultural adjustment.

Fortunately, if we look at the present and the near future, we have reasons to be much more optimistic than 15 or 10 years ago about the richness of the analytical work on agricultural policy and the tools developed in this context. A new phase in the activity developed by Eurostat has just started and we feel confident that, in line with the latest developments of modelling, the new tools will be more flexible, manageable and user friendly than some of their predecessors.

In addition – and this would appear to be a more recent development which we strongly encourage and support – the Community research programmes are increasingly used by research teams to develop and to test new modelling instruments. We try to follow closely what is going on in this field and we are prepared to cooperate as much as we can to make these projects successful. Let me briefly mention some of these efforts:

Regarding domestic policies, we are at the moment actively following the research teams at INRA France and Wageningen University which are developing a number of EU sectoral models for crops, livestock, dairy, sugar and wine in the framework of a FAIR research project supporting the economic analysis linked to the next WTO-Round. We offered them our assistance in terms of market data and understanding of market regulations through regular meetings, which also involved experts from our market units.

Another model we are closely following at the moment is CAPRI, also recently developed within a FAIR research project financed by the Commission. The model is for the moment in an experimental phase (the first complete run was presented at the end of 1999), and it is too early to say if and how it could be used for actual policy purposes. Nonetheless, colleagues from DG AGRI are keeping in close touch with the teams working on this project, and are willing to participate in the exploration of such a possibility.
The same applies to models dealing with international issues. Recently, we have devoted some financial and human resources to contribute to the development of a new Armington specification for the WATSIM model, developed by the University of Bonn, which should allow a first explicit representation of our WTO commitments on export competition and market access. This work is still progressing in the framework of a three year FAIR project, but first results are expected before the end of this year.

Another project financed by the EU Commission, is the concerted action to explore the potential of the GTAP framework in relation to some of the agricultural policy issues currently faced by the EU. The results of the first phase of this research were presented as one of the plenary papers during this conference, and the team of researchers, in close collaboration with colleagues in DG Agri, already agreed upon a set of four so called "minor applications" to be undertaken in the next months, which will be implementing specific scenarios for the EU enlargement, Agenda 2000, WTO, and environmental issues.

Currently, we are also carrying out some autonomous modelling effort inside DG Agri, for example in the framework of our medium term market outlook. Moreover, the ESIM model, after being developed in the framework of a FAIR project dedicated to the CEECs, is now also running in DG Agri, and this should enable us to improve our exchange with analysts and policy makers on some of the most important issues linked to the EU enlargement.

In the last two years we also trained internal resources to be able to run AGLINK. We hope that these skills will allow us in the near future to have a more active collaboration with colleagues in the OECD, so that the European module of AGLINK could be improved and updated to better reflect the actual agricultural policy implemented in the EU.

Again in the framework of our cooperation with the OECD, colleagues from our team developed a model for the European crop sector in the Policy Evaluation Matrix (PEM), which is a pilot project developed at the OECD with the participation of the US, Canada, the EU, Mexico, Japan, and recently Switzerland. The first PEM paper with the results and the documentation of the crop model was de-restricted by the OECD at the beginning of March, and we are currently working on the European module for dairy and on some experiments on environmental policy, which should conclude the pilot phase.

As far as the data side is concerned, we are currently undertaking a major overhaul of our Farm Accountancy Data Network. The main objectives of this ambitious modernisation project are to improve the quality of the data, to facilitate data processing and to make results much more rapidly and much more easily accessible through Internet. The new system is expected to become fully operational in 2002.

Finally, some staff from DG Agri worked on the EU contribution to the Agricultural Market Access Database, an interagency project undertaken by the EU Commission, AgriFood Canada, OECD, FAO, USDA, and UNCTAD to build up a complete and transparent database on commitments on tariffs and tariff rate quotas of the WTO member countries. As most of you certainly know, the AMAD database is currently in its testing phase, and the plan is to make it available as soon as possible as a "public good" to all researchers.

Although direct participation in all these projects has been extremely interesting and productive, it also taught us the lesson of how quickly we can run into the constraints imposed by the scarcity of our internal human resources. It is in fact more and more evident that to face the big analytical problems challenging the future of our agricultural policy, we need to continue along the line of outsourcing modelling activity, deepening at the same time the debate and the collaboration with the teams involved in this kind of research.

What does this mean in concrete terms for the future relationship between modellers and policy administrators? This is a difficult question, but I will try to answer it by giving you
a short list of the key issues we have in mind. We already know that not all our ambitions can be realised, but to present them can help clarify the direction where we would like to go.

Let me start by saying that, in the future, we would like you to trust us as a “semi-skilled” counterpart willing to cooperate to make your efforts successful, but also determined not to simply accept nicely packaged results without the possibility to evaluate how they have been produced.

This implies that we are going to request from you a big effort to make your models transparent and well documented, and to bring them closer to political needs. This means calibrating them on updated base years as well as using more recent parameter estimations and a more explicit representation of policy instruments.

But this also means that we are available for discussion as partners with our in-house expertise. Moreover, we will support your efforts wherever we can to obtain complete, consistent and updated databases at the European and the international level, since we know that one of the main constraints currently faced by modellers is the availability and the quality of data. I am sure that in this field, we have a common interest with you and a common goal with our colleagues in Eurostat.

Another heavy burden we would like to place on your shoulders is the exploration of what could be done to model “bottom-up” policies – that is, the rural development measures linked with the new second pillar of the CAP. We know that this is the ultimate challenge for models and modellers, which might somehow change the entire philosophy of their approach. But we need to start developing tools for assessing the impact of these policies and monitoring them after implementation. Thus, we think that some attempt in this direction could be really worthwhile especially if research teams are able to enhance collaboration among themselves, currently perhaps too scarce, to exploit possible synergies and avoid wasting resources.

Let me come to a final ambition, or should I say a dream: that of seeing emerge over time a European-wide network of modellers and models, working in close cooperation and with us in order to develop the best analytical tools. These could be offered to policy makers to help them better understand the developments of the past and the concepts needed for an agriculture policy in Europe adapted to the demands of the future.
Position of Eurostat

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General
1. As most present will know, Eurostat, the Statistical Office of the European Communities is a Directorate-General of the European Commission. We collect data from EU Member State statistical services, check them, stock them and make them available to policy makers and to the general public. Community agricultural statistics were developed early and are still one of the most comprehensive sets with two important units in Eurostat specialised in agricultural statistics (one on structural and economic data, the other on production statistics). However there are new needs we are struggling to tackle, and maintaining and improving the relevance and quality of our output is a constant endeavour.

Agricultural modelling at Eurostat
2. For nearly 20 years, Eurostat has been involved in modelling work, collaborating principally with our hosts here in the SPEL model, also well known to most of you. We have recently been reflecting on how this modelling work should best be carried forward and what is the most appropriate role for Eurostat. This has to take account of resource restrictions, the announced intention of the European Commission to concentrate its scarce staff on core functions while "externalising" (outsourcing) what can be equally well (or better) performed by outside expertise. So the present discussion is particularly timely for us.
3. Eurostat-F started work on modelling for two reasons. One was for checking consistency and quality. It was a particularly purposeful application of the idea that using one's data is the best way to get to know it and its characteristics, its strengths and its weaknesses. The other reason for starting this work was the consciousness that much of the agriculture statistics at the European level was not as up-to-date as it should be. There is however much inertia in the agricultural system and so good possibilities of "nowcasting" without getting involved in scenario assumptions. This idea lay behind the early focus on what was called the SFSS, the short term forecasting system.
4. Gradually the potential for the SPEL tool for outlook work and for exploring the consequences of alternative policy futures was realised. The MFSS (medium term forecasting system) allowed farmers' reactions to be taken into account. This work has proved valuable for policy makers. It is a way of getting extra value out of the data available. A single sophisticated in-house model is not a completely satisfactory approach however. It requires expertise not naturally available in Eurostat. Experience has shown that it is difficult to ensure the continuing presence of staff adequately qualified to develop and maintain appropriate models (as opposed to following and stimulating modelling work and managing its application to European level topics). The scenarios, the alternative policy futures, do not themselves come from Eurostat, they are proposed by policy makers. By turning to appropriate outside organisations with their own modelling activity, a sharing of overheads, a capitalising on existing experience, and a mobilisation of extra resources should be possible. Furthermore a structure which allows a variety of independent modelling activities should lead to more robust and more widely accepted general conclusions.
A fresh approach

5. Eurostat-F has thus begun thinking of a certain redirection of its activities in this area, and an approach better matching current requirements. This has lead to our project AgrIS. It involves restructuring our work on agricultural modelling to focus Eurostat's work more sharply on those aspects where Eurostat has an advantage in efficiency (in particular through its contacts with those responsible for the official agricultural statistics in Member States) and where there are the greatest advantages in improving data. What exactly is AgrIS then?

What is the aim of AgrIS?

6. Eurostat's agricultural statistics are stored in several separate databases and provided to the users through NewCRONOS. There is however a close relationship between all the different agricultural data delivered to Eurostat. The aim of the Agricultural Information System (AgrIS) is to bring together all this data into one harmonised framework. When all the data are gathered and stored, AgrIS will be able to serve as a tool for checking the consistency of the agricultural statistics in Eurostat. For this purpose, AgrIS will incorporate not only NewCRONOS data, but also data from other sources (FADN and FAO). The AgrIS will also allow the present situation in the agricultural sectors of the EU as a whole and the Member States (and increasingly the Candidate Countries) to be monitored and evaluated. Lastly, the AgrIS can be a bridge between people responsible for data gathering and people responsible for modelling. In this manner AgrIS is on the one hand, a tool for ex-post analyses of sectoral developments and on the other hand, provides a solid basis on which to make short term and medium term forecasts.

What does AgrIS look like?

7. The AgrIS database brings together the agricultural data available in the different domains of NewCRONOS. For the moment there are three domains of interest for AgrIS:
- the COSA domain: containing information on the Economic Accounts for Agriculture (EAA), the unit values and agricultural labour input statistics
- the ZPAI domain: containing quantitative information on crops and animals
- the PRAG domain: containing agricultural price statistics.

In constructing AgrIS around these NewCRONOS data, three major problems have been encountered.

8. Firstly, there is the problem of errors and missing data. The AgrIS database contains a built-in function to detect these errors and missing data. By using the best fit of different trend calculations, the AgrIS provides a set of estimates for the missing data. The AgrIS proposals for the missing data are provided to national experts, who can choose whether or not to accept them into their series. Where they are not accepted, national experts are free to provide Eurostat with a complete new set of consistent and plausible data.

9. The second problem concerns the complete lack of certain data at Eurostat. In this case, a solution can only be found through direct cooperation with national experts. They will have to provide Eurostat with some rough estimate based on either technical data or farm accountancy data (FADN).

10. Once the AgrIS database is complete with time series data for the various variables, there is then the third problem of inconsistency between the different data sources. Since the backbone of AgrIS is formed by the EAA, all data that are provided by other domains (prices, quantities) have to be brought into line. In order to achieve this, bilateral contacts with the

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1 Already New CRONOS contains some data on agriculture from Candidate Countries. Eurostat-F is engaged in establishing as soon as may be, the full set of data from these countries to meet the EU requirements.
Member States will be necessary. The AgrIS can, however, be a very useful tool to start this discussion with Member States.

AgrIS and modelling

11. The purpose of AgrIS however goes beyond its use as a tool for data quality. It aims to provide an authoritative, best possible set of data on agriculture as a common starting point for those doing agricultural modelling at the European level. Eurostat-F wants its service to be regarded as the first choice for all users of European statistics relating to agriculture. AgrIS, in the same way, aims to be the tool in which all agricultural statistics available at Eurostat and the European Commission as a whole are brought together in a harmonised and consistent way. For analysis of individual sectors (milk, wine, etc.) data sets are required which are comparable between countries. For overall policy analysis there are additional data requirements: statistics which are comparable between the Member States, complete, consistent and available under a uniform system regarding the terms and methods used. Using AgrIS as THE database for modelling activities ensures that all modelling results are based on the same basic data set. For this basic data set, Eurostat takes the responsibility to make the data comparable, reliable and consistent. This process is however, for a very important part, depending on good and close contacts with Member States and their full cooperation. The use of AgrIS, on which a large amount of preparatory work is already being done by Eurostat, for modelling activities will increase the comparability of the modelling results through Europe. This will serve the Directorate-General Agriculture and Member States in their decision taking. It should help create an informed public opinion on policy alternatives. It should allow economies to modellers who will be relieved of some, perhaps much of the heavy data spade-work which precedes the actual modelling phase. Finally a well documented and well developed AgrIS database will be a significant contribution to the transparency and user friendliness that model developers seek to provide.

Some speculative ideas on institutional relations for efficient work on modelling

12. Eurostat is interested in delivering data which are as useful as they possibly can be. To work on data consistency and completeness is natural, particularly given the relative wealth of data available in agricultural statistics. So Eurostat-F's work logically and efficiently extends to preparing its data in such a manner that it is useful for modellers. In this it will endeavour to be independent of any particular models' special requirements. This will follow naturally from a focus on fundamental data relationships. It is also sensible for Eurostat to avoid areas where a variety of specialised modelling knowledge is needed and particularly where the work done is not of wide benefit.

13. The question can be put however: are there some further general operations on the special data set produced by Eurostat for modellers, that can be usefully undertaken by one body but that have sufficient modelling-technical difficulty to make it unreasonable for Eurostat to try to do them?

14. It seems in any case likely that each modeller will wish to do some tailoring of the standard set of agricultural statistics for modellers (AgrIS) to make them suitable for his own specific uses. So are we thinking of a three stage rocket with i) a large first stage of data (structured, gaps filled, made consistent) prepared by Eurostat, ii) a second stage of technical adaptation common to all or most models, and iii) a final stage splitting up like cluster bombs with each "bomb" making the further adjustment needed by a specific model.

If the central stage is sufficiently large so that it offers useful economies by doing certain work once only on behalf of various separate modellers, practical questions arise which will have to be addressed by the "modelling community". Who should do this work?
How should it be organised? How can the modelling community finance it? What about access to the second stage output by those who have not contributed, in cash or in kind, to funding it?

15. This issue is mentioned here not only for logical completeness. Should this path be followed close links would need to be established between Eurostat-F and the structure constituting the second stage to ensure the efficient functioning of this unique interface between AgriS and modellers, including organisation of feedback on data quality and influence on the way the Eurostat work is organised and executed.
The OECD Experience

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Why is the OECD involved?

The OECD’s involvement in agricultural policy analysis reflects the growing international dimension of agricultural policies as well as the fact that agriculture is important in a number of priority areas for the OECD. Key areas for discussion and analysis by the OECD include economic growth, structural adjustment, trade, investment, sustainable development and new technologies. With the exception of economic growth and investment issues, the other priority areas are all highly relevant to discussions, evaluation, design and reform of agricultural policy.

Equally important is that agricultural policies have increasingly taken on an international dimension over the last few decades. High levels of support resulted in trade frictions between OECD countries in the 1980s. Domestic policies, though their market distorting effects, are at the heart of the problem. This was acknowledged by OECD trade ministers, when they mandated the OECD in 1982 to study the impacts of domestic policies on agricultural trade. The well known PSE/CSE concept, in line with a partial equilibrium model for OECD agriculture, the MTM model, were developed to provide the analytical framework for this mandate.

Based on the analysis under the 1982 mandate, the OECD Council at ministerial level agreed in 1987 on a set of principles to reform agricultural policies. The OECD was again mandated to evaluate possibilities and monitor progress of gradual and concerted reform towards market orientated agricultural policies. This work within the OECD, and in particular the PSE/CSE concept, has contributed to the successful inclusion of the agriculture in the multilateral trade negotiations under the Uruguay Round. With the signature of the Marrakech agreement in 1994, agricultural trade became for the first time subject to a rules based system.

In 1998, OECD Ministers for Agriculture agreed on a number of shared goals for the agricultural sector. A market oriented sector, integrated in the multilateral trading system is still one of the principal objectives. But new issues have emerged, and the objectives for agriculture now also include food safety, rural development, sustainable resource use and global food security. All these ‘old’ and ‘new’ concerns have cross boundary implications and are further strengthening the growing international dimension of agricultural policies.

An overview of quantitative tools

**PSE/CSE**

Support to agriculture has been measured by the OECD since 1987 using the Producer and Consumer Subsidy Equivalents (PSE and CSE). In 1998, the names of the support measures were changed in Producer and Consumer Support Estimates (PSE and CSE) and two other measures were added, the General Services Support Estimate (GSSE) and the Total Support Estimate (TSE). The coverage, definitions, criteria of classification and methods of calculation of these four indicators of support associated with agricultural polices are published by the OECD\(^1\).

\(^1\) Agricultural Policies in OECD Countries: Monitoring and Evaluation. OECD, June 1999.
Currently, the OECD is developing another policy analysis framework - the Policy Evaluation Matrix (PEM). The aim is to quantify the impacts of changes in farm support in OECD countries on a range of indicators of policy effects: production, consumption, trade, commodity prices, and benefits and costs to various groups such as farm households, agricultural input suppliers, taxpayers, and consumers. The PSE is the starting point for such analysis. The PSE measures monetary transfers, from consumers and taxpayers to farmers, resulting from agricultural policy measures, classified according to the way the associated policies are implemented. The PEM approach combines this PSE information with an economic model to simulate the policy impacts. The economic model adopted for the work comes from an aggregate, partial equilibrium model of the farm sector developed by Gardner. The type of analysis undertaken using this framework has become known more generally as 'equilibrium displacement modelling' 2.

To support market access analysis for the next round of trade negotiations, the OECD is also coordinating an international effort to establish a comprehensive database of market access variables. The Agricultural Market Access Database (AMAD) is under development by the OECD Secretariat, the USDA/ERS, Agriculture and Agri-Food Canada, the EU Commission DGVI, UNCTAD and the FAO. It includes scheduled and notified TRQs, bound tariff rates of non-TRQ products, in-quota tariffs, over quota tariffs, applied tariffs, supply and utilisation data, conversion factors, exchange rates and actual trade levels. World unit prices are also part of the database and are entered to allow the calculation of the ad-valorum of specific tariffs. The database is currently at the beta testing phase and will shortly be available for public use on a dedicated web site.

Aglink is a dynamic economic model of major temperate-zone agricultural commodity markets. It currently consists of modules for the eight main agricultural producing and trading countries, or groups of countries, within the OECD, a complete agricultural sector module for China and Argentina, and a beef sector module for other MERCOSUR countries. The modules are all developed and maintained by the Secretariat in conjunction with country experts and, in some cases, assistance from other national administrations. The model is used in the OECD’s medium term outlook process to assess future market and trade developments and the impacts of changes in policies and policy settings.

The use of the AGLINK model

Applications

One of the main applications of the Aglink model is in the generation of medium term outlook projections. These projections cover production, consumption, stocks, trade and prices for major temperate zone agricultural commodities in OECD and a number of major non-OECD

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countries. While a considerable amount of expert judgement is being brought to bear on the final projections, the Aglink model is used to ensure maximum consistency in the results. The projections form the basis for an assessment of medium term developments in agricultural commodity markets, against the background of detailed assumptions of a macro economic and policy nature. The results of this activity including a methodological note on the process is published annually by the OECD in its Agricultural Outlook report.

The evaluation of market outcomes over the medium term allows an evaluation of the impact of policies, as the assessment itself reflects the assumed state of agricultural policies in OECD countries over the outlook period. But the baseline projections can also be used as a yardstick to evaluate the impact of policy changes. This has become an increasingly important element in the annual outlook activity. The most recent report, for instance, includes a complete evaluation of the market impacts of the Berlin Agreement, the effects of the elimination of export subsidies in cereal trade, the impacts of Loan Deficiency Payments in the United States on oilseed markets and an assessment of price pooling systems for milk.

In addition to the annual analysis of policy relevant scenarios against the baseline projections, the model is also used in analysis to support the next round of trade negotiations. In this context a forward looking evaluation is underway of export competition measures, including export subsidies, export credits and selected forms of food aid. In connection with the earlier mentioned AMAD database, analysis is in progress to appraise the market impacts of improved market access through various options for tariff reductions or changes in the TRQ system. Finally, the Secretariats of the FAO and the OECD are currently looking into the possibility of interaction between the FAO’s World Food Model and the OECD’s Aglink model to evaluate the impacts of further trade liberalisation of food security in developing countries.

**Procedures**

The projections presented and analysed in the OECD Agricultural Outlook are the result of a process bringing together information from Member countries and a number of other sources. The starting point of the outlook process is the reply by Member countries (and some non-Member economies) to an annual questionnaire circulated by the OECD Secretariat at mid-year. Through these questionnaires, the Secretariat obtains information from Member countries on future market developments and on the evolution of agricultural policies in OECD countries. This information is supplemented by that obtained from other sources, such as the FAO, the World Bank or the IMF, to establish a view of the main forces determining market developments in the non-OECD area. This part of the process is aimed at creating a first insight into possible market developments and at establishing the key assumptions which condition the Outlook.

As a next step, the OECD’s Aglink model is used to facilitate a consistent integration of this information and to derive an initial set of global market projections (baseline). The initial baseline results are compared with those obtained from the questionnaire replies and any emerging issues are discussed in bilateral exchanges with Member countries. On the basis of these discussions and of updated information, a second baseline is produced.

The information generated is used to prepare reports presenting outlook assessments for cereals, oilseeds, sugar and livestock products. These reports are discussed at the annual meetings of OECD Working Groups. These discussions focus on key issues emerging from the replies to the questionnaires and any adjustments which have to be made to Member country projections in order to derive a coherent global baseline. Subsequent to the meetings of the commodity Working Groups and final data revisions, a revised baseline is produced.

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and its sensitivity to major uncertainties is evaluated. These final projections form the basis for the OECD Agricultural Outlook publication.

**Synergies through cooperation**

As is evident from the description in the foregoing paragraphs, both the outlook and related policy analysis as well as the underlying model development and maintenance work is the result of close cooperation between the OECD and its Member countries. In terms of the outlook assessment, the inclusion of bilateral reviews with Member country experts and multilateral reviews in OECD meetings ensures that a considerable amount of Member country expertise is added to that available within the OECD Secretariat. This ensures the inclusion of insights in the final assessment which otherwise might not have been available. It allows the generation of a consensus outlook and thereby the acceptability of this outlook as a starting point for policy assessment.

Equally important is the collaboration in model development and maintenance. Most OECD Member countries have taken responsibility in maintaining the database underlying their respective country modules. An increasing number has taken full responsibility of the maintenance of their country module, including data, parameters and specification changes necessitated by policy changes or developments of a structural nature. These updates and maintenance changes are annually consolidated in the Aglink model by the OECD Secretariat, if needed after discussion with Member country experts. The OECD Secretariat thus remains responsible for the overall consistency and quality of the model. After consolidation, the entire model and its database is made available to Member countries for use in their own outlook and policy analysis work.

Through this process of cooperation, a model is being developed and maintained of a scale which would have been outside the resource scope of the OECD Secretariat and that of almost all of its Member countries. The Aglink model represents a joint resource input and a pool of expertise which is several times larger than that available in almost any of the cooperating agencies in the project. As a result of this institutionalised cooperative effort, a ‘low cost’ tool for market and policy evaluation is available to the OECD and its Member countries.