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Determinants of spatial dynamics of dairy production: a review

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Abstract

This paper reviews studies analyzing the determinants of spatial dynamic dairy production. The review distinguishes three dimensions that may contribute to spatial dynamics: farm level determinants related to factor endowment, technology, and production costs; developments and differences at the dairy sector level; and spatial differences in public policy. Spatial dynamics is influenced by both, structural change and regional production change. Still, research analyzing both issues in context is still scare. We argue that research focusing on the co-evolution of farm structure and regional production could help to better encompass regional production change dynamics.

Keywords: dairy production, dairy sector, spatial dynamics, differentiation, heterogeneity
JEL-classification: Q12, Q13, R12

1 Introduction

Since 1984, the dairy production sector in Europe is regulated by a milk quota system aiming at controlling milk production and price while limiting public expenditure. As part of the milk quota regime no transfers of quota can take place across national borders and within some member states across regional borders. The 2003 Mid-Term Review has granted an extension of the milk quota system until 2015 but is then planned to be abolished. A more market oriented system would potentially induce a reorganization of the dairy production sector in Europe, above all in countries where quotas transfer were the most controlled by institutions.

Sustainable development in rural areas, decent farmer income and agricultural production competitiveness are central objectives of the European policy. Spatial and structural change can affect all of them. Spatial shifts of the production toward the most competitive places and enlargement of the most competitive farms are usually found to decrease production costs and then to increase competitiveness of agricultural production (MCDONALD ET AL., 2007). However, this phenomenon can also deteriorate rural livelihood. Spatial productions shifts do not necessary induce an equal redistribution of agricultural activities across regional territories according to their comparative advantages (DANIEL, 2003; BEN ARFA ET AL., 2009a). It causes problems of pollution and nuisance where production is highly concentrated, above all in the case of livestock production (BOEHLJE, 1999) and elsewhere, it can render sector- and industry-specific infrastructure obsolete, alter the local economic viability it alters the utilization of sector (ROE ET AL., 2002) and lead to biodiversity loss where pasture disappears (DUMONT ET AL., 2007). The issue is then to assess if the quota removal is likely to concentrate even more dairy production on a fewer number of farms and a fewer number of locations and if Least Favored Areas would lose dairy production. Eventually, estimating how these changes would affect competitiveness of European dairy production is an important research question.

We propose here to identify the current state of knowledge on the key determinants that govern spatial dynamics within a delimited heterogeneous territory. We discuss both, structural change and regional production dynamics, since local production dynamics result from changes in farm numbers (and usually referred to by "structural change") or changes in production per farm. At the light of economic and geographic theories, we review studies describing dairy spatial development and empirical analysis investigating their determinants. We organise our review according to three broad categories of determinants: those revealing comparative advantages of dairy farms, those linked to the spatial organisation of the dairy industry and those related to policy.

2 Spatial Heterogeneity and comparative advantages of dairy farms

Ricardo's theory of comparative advantage explains how it can be beneficial for two parties (countries, regions or individuals) to specialize production and exchange goods if one has lower opportunity costs of producing some good than the other. There would be a comparative advantage for one party if the efficiency gain obtained by allocating its resources to dairy production rather than to alternative activities is higher than the gain that would be obtained by the other party. Comparative advantage can arise from different indicators relevant for dairy production: spatial differences in demand for input factors and factor mobility over time, spatial heterogeneity in technology availability and use and dairy production costs where these reflect not only local input prices but also farms resources endowment, technology and farmers' efficiency. Main corresponding determinants analyzed in the dairy production literature are summarized in table 1.

The classical and neoclassical theories suppose that goods are more mobile than production factors so that trade in goods substitutes trade in factors (LASSUDRIE-DUCHÊNE AND ÜNAL-KESENCI, 2001). According to these theories, the spatial heterogeneity in factor endowment is then a driving factor of spatial heterogeneity in production. Factors could be heterogeneous in quality, in quantity available and in price with higher local prices resulting from a higher demand in relation to factor availability.

2.1 *Spatial differences in local demand (and price) for factors used in dairy production and factors mobility over time*

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2.1.1 *Land*

Among all the production factors, natural assets are undoubtedly the most tightened to the localisation. Since cattle can be fed from on farm products and raised outdoor, natural assets relevant for dairy production are linked to land availability according to soil quality, topography and climate.

Regarding *soil quality*, two aspects are important for dairy production: soil fertility that would define together with climate which kinds of crops can be grown, which yields can be expected and then how many animal can be fed from these resources; and load-bearing capacity of soils as this defines the number of animals that could graze on pasture without damaging their structure. Although soil fertility is an advantage for most crops, pasture production is one of the less demanding cropping activities in terms of soil quality. ISIK (2004, p. 160) observes that "the higher the suitable land in agriculture in a county, the lower the dairy cow inventories, the per-farm dairy inventories".

Slopes limit mechanisation possibilities and then intensification of crop and forage production. They are common in mountainous areas and are often associated with difficult transport condition as winding roads, adverse weather conditions and low soil fertility. They are not incompatible with dairy production since 4% of the European dairy production comes from systems based on mountain pastures (CEAS CONSULTANTS ET AL., 2000). Alternatives agricultural uses of these lands are limited, concerning mainly other grazing livestock productions. This could be an advantage to maintain this activity in mountainous areas. However, slopes do not seem favourable to production increase. In the SOREGAROLI ET AL. (2005) study on Italian farms, farm production increase is more likely in plane areas. ALLIANCE ENVIRONNEMENT (2008) stresses that in Spain production has shifted from more marginal locations such as the uplands to more productive lowland and coastal areas.

Table 1: Impacts of indicators of comparative advantages of dairy farm on regional dynamics

		Production level			Production change		
		Reg.	Farm size	Farm nb	Reg.	Farm size	Farm nb
Land	-Land fertility	-[11]	-[11]		/[11]		
	-Slope, altitude			/[4]		/[19]; -[17]	+[19]; /[17],
	-High Temp., low precipitation, Low var.	+[11]	+[11]	+[4]	+[11,13,9]	/[19]	/[19]; +[12]
	-Average price of land	-[2]		+[4]	+[9]; -[2,12]	-[19] /[18] +[18]	-[18,19] +[18]
	-Price of land over time	-[2]			-[2]		
	Urban pressure	/[11]	/[11]	/[4]	/[11]	-[19]	+[19]
Labor	Average farm wage	/[15]			-[9,15]		
	Unemployment rate	+[11]; -[15]	+[11]	/[4]	+[11]; /[15]	-[19]; /[8]	+[19,8]
	Farmers'age					/[19]; -[17]	/[19]; +[17]
	Income per Capita	-[15]			/[15]		
	Off farm-occupation				-[13]		
Tech-nology	Advanced technology					+[17]	/[17]
	Average milk yield					+[8,19]; /[18]	+[8]; /[18,19]
	Farm size, econ. of size	+[1]				+[6,19]; /[8]	/[8,19]
	Proportion of large farms	+[11]	+[11]		+[11,13]		
	Specialisation					+[17]	/[17]
	Capital cost/ha, sunk cost	-[11]	-[11]		/[11]	-[6]	-[12]
Produc-tion costs	Regional Feed cost	-[11]	-[11]		-[11]		
	Feed cost over time	-[1,2]			-[2]		
	Average production cost	-[5]					

Notes: - , + and / indicate resp. a positive, negative and unclear effect of the indicator on spatial dynamics; the number in superscript correspond to the reference detailed in appendix 1.
Source: Own compilation.

Weather stress decreases animal performance such as survival, growth, reproduction and milk production. Coping with adverse climate conditions often require to choose breeds adapted to local climate or to provide appropriate housing during a more or less long period of the year. Climate also constrains cropping possibilities and then the feeding system. In oceanic areas for instance, grazing is possible almost all year round and in mountainous areas, maize silage cannot be grown (CHATELLIER ET AL. 2008). In empirical studies, regarding the US dairy production, ISIK (2004) and OSEI ET AL (1996) find that counties with higher mean temperature and lower precipitation are favorable to dairy cow production.

PETERSON (2002) links milk production increase to a lower accumulation of cooler temperature. Milk production has indeed shifted from traditional production areas in the East coast to the West of the US, one of its advantages being the favorable climate that permits large scale operations with lower housing costs (BLAYNAY AND NORMILE, 2004).

The *value of land* is directly linked to agricultural land quality and to the pressure from alternative use for land. In the EBERLE ET AL. (2004) survey, US dairy farmers ranked land availability and above all land price as the most important criteria to locate and expand their production. Dairy production is more frequent on cheaper lands (OSEI AND LAKSHMINARAYAN, 1996; ISIK, 2002; BEN ARFA ET AL, 2009b). ZIMMERMANN AND HECKELEI (2010) confirm this negative impact of land rent value on EU farm number and farm enlargement. This means that dairy farming use less efficiently 'attractive' land than other activities. MILLIGAN (1978) and ADELAJA ET AL (1998), estimate that the raising price of land linked to highly populated area, induce a decrease of herd size and milk production over time. LASSEN ET AL. (2008) provides a similar example for Eastern Germany but linking the increasing land prices to increasing opportunity costs arising from better profitability of arable farming.

Land used for dairy production *can be converted* into other agricultural and non agricultural uses. However permanent grasslands have often few agricultural alternatives since they are usually grown on low fertile lands with reduced mechanization possibilities. Moreover, in the EU, a recent regulation imposes Member State to maintain the share of permanent grassland in their utilizable agricultural area. The conversion of agricultural land from grazing livestock enterprise to other agricultural activities is thus limited. In Germany, a high share in permanent grassland (>40%) appears favourable to an increase of regional dairy quota in the time period 1999-2007 (LASSEN ET AL., 2008).

According to CHAKIR AND MADIGNÉ (2006) former arable lands in France that are not abandoned are mainly converted into individual housings and roads. As population housing needs expand, farmers and non farmers compete for lands. Consequently, agricultural land for the location of dairy barns, to grow cereal and forage crops can lack or become too expensive. The number of building permits issued per capita can account for the urban pressure on agriculture. It exhibits a negative effect on local dairy inventories in ISIK (2004) and population seems to be deterrent for the development of the US livestock and dairy industries in LOPEZ ET AL. (1988) and RUTT (2007). OSEI AND LAKSHMINARAYAN (1996) and FOLTZ (2004) find the population density to be deterrent on dairy farm numbers but ZIMMERMANN AND HECKELEI (2010) observe a positive correlation with EU number of dairy farms and a negative one with farm enlargement. Effects of populations are ambivalent since they both constitute a potential market and a source of additional pressure for land use and favor more stringent livestock nuisance regulation. Job opportunities can also be higher if the population density is important creating more incentive for farmers to leave the sector (GOETZ AND DEBERTIN 2001 cited in RÖDER AND KILIAN, 2009). However, population increase seems more deterrent than beneficial for dairy production.

2.1.2 Labor

Labour quality, quantity and labour price are heterogeneous in space too. Labour is first needed to run a farm. Permanent or temporary employees could also be hired to work on the farm. In Western Europe, CHATELLIER AND JACQUERIE (2004) estimate that hired labour accounts for 14% of total farm labour.

Availability and *average wage* of labour is considered as a factor of intermediate importance for the US dairy farmers surveyed by ELBERLE ET AL. (2004), and surprisingly, larger farms consider this point as less important than smaller farms do. Average farm wage rate is used as a proxy of local labour cost and is found to be negatively correlated with the American state dairy inventory (HERATH ET AL. 2005) and dairy production change (RUTT 2007). This means that the presence of cheap labour favours local production. Nonetheless this effect becomes not as clear in empirical studies such as ISIK (2002) and ROE ET AL. (2002).

Unemployment rate can be not only an indicator of available persons to hire but also as alternative occupation possibilities for farm managers. In ISIK'S empirical study (2004), high local dairy inventory and local production enlargement are more likely in American counties characterized by a high unemployment rate. FOLTZ ET AL. (2005) and ZIMMERMANN AND HECKELEI (2010) also find that unemployment slows down structural adjustments of dairy farms. However, HERATH ET AL. (2005) and ROE ET AL. (2002) do not obtain significant relationships. GLAUBEN ET AL. (2006) even get a negative impact of unemployment on the farm number change in Western Germany.

Median income or per capita income can be considered as expected nonfarm income for farmers. It does not appear significant in local production change in ISIK (2004) while lower income per capita is linked to higher average milk production for RUTT (2007). Attractiveness of nonfarm jobs is probably more dependent on real opportunities for farmers and their employees to obtain higher income off farms. Dairy farming requires specific skills for the manager such as good technicality to monitor cow reproduction and cow feeding, managerial skills or good accountancy and financial knowledge. Specialization changes are more likely to happen between different kinds of livestock farming such as between beef and dairy (ZIMMERMANN AND HECKELEI, 2010), because of close overlapping knowledge of these two fields regarding animal breeding and feeding. The occupational conversion is more or less easy according to farmers age and farmers previous experience. According to farm location, mobility to change the specialization vary (ZIMMERMANN AND HECKELEI, 2010).

The *older farmers* get, the more difficult it would be for them to find another job (BREUSTEDT AND GLAUBEN, 2007). Labour is more mobile during the establishing stage, when farmers evaluate the opportunities in dairy farming compared to other occupational alternatives (BOEHLJE, 1992) or at the end of their career when farmers decide about retirement. In between, the continuation of the family farm is often not an issue (CHAVAS, 2001). GLAUBEN ET AL. (2006) report that counties with a higher proportion of farmer older than 45 years, experience higher decline of farm numbers in Germany. SOREGAROLI ET AL. (2005) and ZIMMERMANN AND HECKELEI (2010) also find that dairy farmer's age is positively correlated with farm exit and farm decline in size in Italy and the EU and negatively correlated to farm enlargement.

Part time farming raises labour mobility since information and transaction costs to find an off-farm job are decreased. However, in some studies such as in GLAUBEN ET AL. (2006), part time farming limits net farm loss in Germany. Off-farm employment indeed generates additional income that can compensate for losses generated on-farm and consequently contribute to the persistence of smaller and less productive farms. Regions with high rates of part time farmers are nonetheless less likely to increase their total production (PETERSON, 2002), probably because of a lower involvement in their farming activity.

2.1.3 Building and machinery

Costs for building and machinery are not necessary spatially differentiated even though materials and qualified entrepreneurs are not evenly available across countries. However, once built, buildings and machinery could be difficult to be moved out and could be considered as sunk cost. Those specific capital investments are "sunk" when the unit value of investment is greater than the unit value of disinvestment. A milking parlor would be of no use for other production activities and the barn would probably need to be reconditioned to suit other production needs whereas commercial vehicles could easily be sold and used by another firm in a completely different industry. According to CHAVAS (2001) sunk investment provides disincentive to exit an activity, interacts with uncertainty to provide a disincentive to invest and creates barriers to entry. For CHAVAS AND MAGAND (1988), sunk costs of capital measured as a function of change in herd size provide some incentives for US dairy farms to grow slowly.

2.2 Spatial heterogeneity of technology

Technology represents the relationship between inputs and outputs. The neoclassical theory assumes that technologies are the same across regions and countries. However, a wide range of technologies can coexist to produce milk. When some factors are rare or expansive in some places or in some farms, or that climate or availability of locally produced feedstuffs are critical, a different technology can be used. CHATELLIER AND PFIMLIN (2007) emphasize that, in Europe, places such as Galicia where land is scarce and expensive, cattle feeding relies on purchased products whereas regions such as Ireland, which benefit from favorable weather conditions have a feeding system based on grazing. A more detailed typology of the different dairy production system in EU is proposed by CEAS CONSULTANTS ET AL. (2000). Within a production region or a country, farms with the smaller production cost per milk produced appear to be those with *high milk yield* (WIECK AND HECKELEI, 2007), more intensive feeding system (grassland share is positively correlated to dairy marginal production cost in WIECK AND HECKELEI, 2007), and using advanced technology (recent investment is negatively correlated with marginal production costs in WIECK AND HECKELEI, 2007). Higher milk yield per cow has a positive effect on change in farm number and production per farm (FOLTZ, 2004; STOKES, 2006).

Technologies can also be spatially differentiated because technology diffusion and adoption are not uniform across space. RODGERS (1988) cited in BOEHLJE (1992), considers that technological change often results in a decrease in farm numbers. A new technology that is costless to adopt will increase output and decrease farm revenue assuming output demand is price inelastic. Conversely, for a technology costly to adopt, marginal farmers who do not have the managerial skills and who do not have appropriate advices or the investment capacity to cost effectively adopt these technologies will be penalized. ABDALLA ET AL. (1996) also explain American location shifts by the move of production to areas more amenable to changed methods than traditional ones. *Advanced technologies* such as the use of open stable, the unification of feeding and the introduction of modern milking systems are positively correlated to per farm dairy production (SOREGAROLI ET AL., 2005). However, advanced technology adoption is also linked to farm size (EL OSTA AND MOREHART, 1999), farm specialisation, and the production intensification process.

Larger farm sizes could beneficiate from *economies of scale* that are characterized by reductions in unit cost as the size of a facility increases which means increasing return to scale. Cost savings can stem from a reduction in fixed costs and marketing costs, possibilities to hire more skilled labor, and to invest in advanced technologies. In agriculture, constant return to scale are often assumed since technologies can be adapted to farm size, implying that the lower bound envelope of the minimum average cost across technologies is rather flat (CHAVAS, 2001). Nonetheless, economies of scale significantly explain lower production cost and marginal production costs in most dairy production studies (Wieck and HECKELEI, 2007; TAUER AND MISHRA, 2006; MOSHEIM AND LOVELL, 2009). The CEAS CONSULTANTS ET AL. (2000) report that production is concentrating on fewer, larger farms for virtually all dairy farms irrespective of system or biogeographical region. Regions with a higher proportion of large dairy farms are found more likely to have larger milk production and to increase their production levels per county and per farm in the USA (ISIK, 2004), to limit the decrease of farm number in Germany (GLAUBEN ET AL., 2006) and to benefit from quota mobility in Germany (LASSEN ET AL.,2008).

Economies of scope reflect the reduced costs associated with producing multiple outputs. For instance, in integrated crop livestock production system crops can provide feed for animals and animals can produce fertilizer for the crops. As mentioned in CHATELLIER AND JACQUERIE (2004), mixed production dairy farms represent around 30% of the EU dairy farms and are mostly localized in Germany, North and Center of France, Austria, Belgium, and the Mediterranean area. However, there is a tendency for commercial farms to be increasingly specialized. The degree of specialization can be seen as an indicator of better technical and management performance since all manager efforts can be concentrated on dairy production optimization. According to CEAS CONSULTANTS ET AL. (2000) dairying in the EU is becoming more intensive and more specialized. WIECK AND HECKELEI (2007) estimate that the more specialized dairy farms are, the lower are their marginal production costs. Economies of scope do not emerge as significant to explain US local hog average production and production change (ROE ET AL., 2002). ROE ET AL. measure however specialization within the hog industry and not within a broad ranges of agricultural activities. The percentage of revenue from dairy favours farm expansion in Italy (SOREGAROLI ET AL., 2005).

2.3 Spatial heterogeneity of dairy production costs

Production costs and marginal production costs are a measure of current farm competitiveness. Production costs reflect not only local input prices but also farms resource endowment, technology, and farmers' efficiency. These *production costs* are spatially differentiated across countries and within countries (CHATELLIER AND PFIMLIN, 2007; EUROPEAN COMMISSION, 2007). According to the EUROPEAN COMMISSION (2007), production costs are for instance higher in France and Germany than in Spain or in the United Kingdom. Taking into account only average feed costs per livestock unit in a county, high feed costs appear to be a deterrent to US dairy livestock inventory increase per farm, per county livestock inventory (ISIK, 2004) and a deterrent of US dairy farm location (OSEI AND LAKSHMINARAYAN, 1996). Total production costs are negatively correlated to the probability of US production location in Osei and Lakshminarayan (1996). BUTAULT ET AL. (1990) find that EU MS characterized by lower dairy production costs have also an agricultural production more specialized in dairy products. In reviewing the literature, no evidence has been found regarding the impact of total production cost on regional production change.

Marginal production costs correspond to the cost of producing one more unit of a good and give indications about the potential of local production change.

These costs can be computed on the short run allowing only variation in intermediary inputs or in the medium and long run when variations of capital goods are included (land, labour etc.). In the short run, when capital factors are supposed to be fixed, marginal productivity is supposed to decrease with increasing production since productivity gain becomes more and more expensive. These costs have been estimated in numerous empirical studies (WIECK AND HECKELEI, 2007; CATHAGNE ET AL., 2006; MORO ET AL., 2005 etc.). Although they vary according to the studies due to differences in the variables and the years taken into account, all these studies emphasize strong differences between European regions. Effects of marginal costs on production location and on production change have not been tested empirically.

According to micro-economic theory, at equilibrium, production equals marginal cost. Consequently, variations over time of production costs are likely to affect local production, slowing down or accelerating the spatial reallocation process. Increasing feed costs have been found responsible for decreasing dairy production in the US (ADELAJA ET AL., 1988). Variation in input costs over time can also affect differently regional and farm production since they are not based on the same technology. In the empirical study of RAHELIZATOVO AND GILLESPIE (1999) and of ADELAJA ET AL. (1991) on dairy farms, larger farms stronger reduce their production than smaller farms in response to feed price increases. In this case, feed costs may have more importance for large scale units who rely less on on-farm feed production.

3 Spatial heterogeneity of the dairy sector

3.1 Positive externalities and agglomeration economies

Studies of the effects of spillovers and external economies on production location choices date back to ALFRED MARSHALL (1920). They imply that the performance of one dairy operation improves with higher concentration of dairy operations in a given region. "The presence of other operations facilitates a local, industry-specific infrastructure of service individuals and information, which enhances the performance of each operation through lower transactions costs and improved diffusion of financial, production, and marketing information" (EBERTS AND MCMILLEN, cited in ROE ET AL., 2002). High concentrations of dairy operations attract specialized industries such as technical support services, insemination companies, veterinary services, or milk collection companies. Opportunities to buy inputs and services at lower costs by means of cooperatives are often given to farmers in such places. Milk collection cost, which is a key determinant of spatial dynamics according to DANIEL (2002), is also decreasing with production density. EBERLE ET AL. (2004) notice that farmers consider extension service, university research, assistance in obtaining permits, support from dairy or farm organizations, and the presence of dairy cooperative as rather important in their choice to expand or locate a dairy enterprise. The proximity of farms also affects how well knowledge travels among them to facilitate innovation and to improve efficiency (one economic system is said more efficient than another if it can provide more goods and services without using more resources). NIVIEVSKYI (2009) demonstrates for instance that improvement in farm efficiency in Ukraine was spatially correlated. CAPT AND SCHMIDT (2000) and BUTAULT ET AL. (1990) underline that the dairy production competitiveness of the northern European countries can be better explain by the knowledge and the technicality they have accumulated over time rather than on natural advantages.

Agglomeration economies in dairy production can result from two developments: processes of concentration in the industry itself and the existence of general infrastructure in close proximity. The measurement of agglomeration economies in dairy production resulting from dairy production concentration is usually done by entropy measures of spatial concentration using the distribution of local production weights via Theil or Gini indexes. A production sector is concentrated if a large part of the production is achieved in a limited number of localities (AIGINGER ET AL., 1999 cited in BEN ARFA ET AL., 2009a). BEN ARFA ET AL., (2009a) estimate that "départemental[1]" dairy production in France is concentrated even if the concentration rate is much lower than for hog and poultry production. DANIEL ET AL. (2003) emphasize that concentration of milk production has even increased between 1990 and 2004 within the delimited production areas (larger than nuts II regions) of the EU-15. The calculation of entropy of spatial concentration does not account for the spatial pattern of production across regions and cannot give hints about cluster dynamics. To do so, spatial weight matrices that attribute higher weights to the closest production areas can be used to test the statistical significance of spatial auto-correlation (via Moran's or Geary indexes). Regarding average production level, the dairy sector appears to be spatially autocorrelated in France (BEN ARFA ET AL., 2009a) and in the EU (DANIEL, 2003). Spatial lag production variables can also be directly integrated into regression models. In ISIK (2004), average dairy productions in neighbouring counties have a positive effect on average local production (table 2). In the pig sector, evidence of positive effects is also found in the US (ROE ET AL., 2002) and in Denmark (LARUE ET AL., 2009).

Initial concentration of dairy production can have repercussions on subsequent dynamics. The initial number of farms is positively correlated with farm number exit (GLAUBEN ET AL., 2006) and farm enlargement (FOLTZ, 2004). Regarding total regional production dynamics, effects are less clear. ROE ET AL. (2002) esti-

[1] The size of a "département" is similar to those of a US county.

mate that the initial regional production level does not have significant impact on hog inventory changes. PETERSON (2002) obtains a negative effect of initial US county milk production level that could be explained by the shift of US dairy production toward the western part of the nation. In Europe, ALLIANCE ENVIRONNEMENT (2008) reports that in the UK, dairy production has consistently moved to Wales, Scotland and Northern Ireland which were not historically the most productive area. In Italy, on the other side, the milk production tends to be even more concentrated along the Po Valley, and more particularly in Lombardia (ALLIANCE ENVIRONNEMENT, 2008). In a regional analysis of the German quota in- and outflows in the time period 1999-2007, LASSEN ET AL. (2008) note that regions with already existing high milk production per hectare (>2400 kg milk/hectare) benefit from quota mobility and gain considerable over time. Impact of neighboring dynamics is estimated to be not significant in Roe et al. (2002), positive in PETERSON (2002) and negative in ISIK (2004). Although Isik analyses US county dairy cow inventory and Peterson US county milk production, it is difficult to justify such difference. It is possible though that two kinds of dynamics coexist in the US and appear more or less important according to the years and variables studied: a reorganization of milk production within the traditional production area into patches and into a fewer number of farms because of a more competitive environment, and, a global positive dynamics for 'newly producing regions'.

As mentioned by ROE ET AL. (2002), "agglomeration economies can also arise from a more general infrastructure that facilitates all livestock production". ISIK (2004) emphasizes that local US dairy production and production increases are more important in counties where non dairy cattle inventory is high. Although pig inventory does not appear significant in Isik's study, in BEN ARFA ET AL. (2009a) presentation of production clusters in France, Brittany exhibits not only a high concentration of dairy production but also of pig and poultry production. To account for the global agricultural sector, ROE ET AL. (2002) calculate county's total livestock receipts less hog receipts. This indicator has a weak positive influence on average hog inventory and in some cases a negative impact on hog inventory change. In a similar way, agricultural gross share of economies is used in HERATH ET AL. (2004) empirical study to proxy agglomeration economies from the whole agricultural sector. Significant positive effects on change in US state dairy inventory is revealed. It is rather difficult to draw a general relationship between the dairy production and the other agricultural sectors. The different agricultural sectors can indeed be both competing and beneficiating from each other.

Table 2: Impacts of indicators of spatial organisation of the dairy sector on regional dynamics

		Production level			Production change		
		Reg.	Farm size	Farm nb	Reg.	Farm size	Farm nb
Positive externalities	-Regional production				-[13]		
	-Farm number						
	-Neighbouring values	+[11,15]	+[11]	+[4]	-[11] +[13] /[15]		
	-Cattle inventory	+[11]	+[11] /[15]	-[4]	+[11] -[13,15]		
	-Importance of the agricultural sector				+[9]		
Distance and transportation costs	-distance to market						
	-commercial feed industry			+[4]	-[13]		
	- short dist and high capacity of dairy processing industries	+[15]		+[4]	+[13] -[15]		
	Local population	/[11]	/[11]		/[11] +[13]	-[8]	-[8,12]
Spatial milk price differentiation	Average milk price	+[11]	+[11]	+[4]	+[11,13]	-[19] +[8] /[15]	/[19] +[8,12]
	Milk price over time	+[2,5]			+[2]	/[19] +[3]	+[19]
	Variability of milk price	-[11]	-[11]			-[19], [11], [8]	/[19] -[8]
	profitability	/[5];-[7]					

Notes: -,, + and / indicate resp. a positive, negative and unclear effect of the indicator on spatial dynamics; the number in superscript correspond to the reference detailed in appendix 1
Source: Own compilation

3.2 Distances and transportation costs

"Transportation, whether provided by commercial agencies or by the farmer himself, is a vital necessity to the economic functioning of agriculture" (1940 Yearbook of Agriculture cited in COYLE AND BALLENGER, 2001) In Europe and most developed countries, farms have no longer any subsistence goals and needs but rather the objective to export their production to relevant markets and to buy inputs. Classic location theory helps explaining how transport costs work in isolation. According to the Launhardt-Weber model, assuming that production costs are independent from location, that input and market locations are fixed and that the firm bears the transportation cost, the location problem consists in transport cost minimization (BECKMANN AND THISSE, 2000). Transport costs encompass the freight rate, the distance to cover and the required time of the journey. Freight rate for agricultural goods are relatively high compared to industrial products (DANIEL, 2007) because they are usually bulky, heavy, and more or less perishable. This is particularly true for fresh milk which contains a high amount of water and is highly perishable: it can be conserved only few days and requires refrigerated tankers. Quality of the infrastructure is important too since it affects both, the distance to cover and the average speed of the transport. Differences in transport infrastructure are not only sizeable between rich and poor countries (LIMÃO AND VENABLES, 2001) but also within each country: farms located close to a main transport axis in plane areas are generally advantaged compared to farms in remote countryside or mountainous areas. However, within the US, transportation infrastructure for hauling milk and supplies is not ranked as a major criterion to locate or expand dairy operation (EBERLE ET AL., 2004). To explain regional production dynamics, impacts of dairy farm inputs locations, of processing plants locations, and consumer market locations are investigated.

Regarding dairy farm inputs, in traditional production systems, most of the feed stuffs are produced on-farm. In PETERSON (2002), local hay production favors US local milk production increase while the quantity of silage produced locally appear more determinant in RUTT'S estimation (2007). Increasing farm specialization, animal production intensification, increasing commercial feeds availability, uncertainty regarding forage yield or scarcity of lands can induce a greater increase of the importance of off-farm inputs. BEN ARFA ET AL. (2009b) consider the number of feed processing plants as a measure of the availability of protein-rich feed. Significance is found in 2005 but not in 1995, underlining that dairy farms rely probably more and more on off-farm feeds. The percentage of dollars spent on commercially mixed feed relative to total dollars spent on livestock feed deters US county milk production increase (PETERSON, 2002) but this can also reveal higher total feed costs.

The presence of a market for milk and milk co-products was considered much more important than the availability of feed stuffs by farmers surveyed in the EBERLE ET AL. survey (2004). However, the size and volume of local dairy processors in area was ranked as intermediate. Access to processing plants is captured in the ROE ET AL. (2002) hog study by the distance to the nearest county holding a slaughtering facility and by its total slaughtering capacity, and by the total number and slaughtering capacity of facilities within 500 miles. Although some of these variables are significantly correlated with production levels, impacts on change in hog inventory are not straightforward. Access to processing facilities constrains undoubtedly more the dairy sector than the hog one. The number of milk processing plants within 600 miles is indeed significant to explain average milk production (RUTT, 2007) and the number of processing plants within 300 miles favors production change in PETERSON (2002). Whole milk equivalent used in manufactured dairy products at the US state level has positive influence on dairy inventory change (HERATH ET AL., 2005). In France, the number of dairy processing plants is linked to the number of dairy farms by 'département' (BEN ARFA ET AL., 2009b).

As mentioned by CAPT AND SCHMITT (2000), as agricultural production specializes in the production of raw products for industry, the influence of the distance to the next cities becomes less important. However, in the case of dairy production, raw milk still requires rather short transportation between the producer and the consumer. The population size can then be associated to a potential market. Thanks to an indicator taking into account interregional distances weighted by population, DANIEL (2003) draws from a regional analysis at European level that dairy production location depends on market distance. However, county population is not found significant by ISIK (2004). This can be explained by the fact that county market may not be the relevant market scale. As mentioned by Isik (2004), population is also not only a potential market but also a potential constraint for the production system. ROE ET AL. (2002) and RÖDER AND KILIAN (2009) underline that the relationship between population and local production vary according to regions, probably because a minimum population density is necessary to have the necessary infrastructure and is synonymous of consumer market, while high densely populated areas put too much pressure on production.

3.3 Imperfect competition and spatial price differentiation

Under imperfect competition, local output prices can be differentiated. Significant average milk price differences exist between the US regions: dairy prices tend to be higher in the south-eastern states and lower in the western states (HERATH, 2005). In the EU, some member states such as the UK (236 €) obtained lower milk price in 2006-2007 (BIZET, 2009) than some others such as Italy (310 €). There are also important differences between the different regions of a country. In France, farmers located in mountainous areas benefit generally from higher prices than in plane areas (312 € in mountainous areas versus 293 € in 2006). Not only average price differs according to regions but also their variability. In EU countries, Ireland suffered from the highest milk price drop in Europe in 2009 (-56%) after having beneficiated from the highest price increase in 2007/2008 (+74%). In comparison states such as Italy (+24% and -19%) have undergone less price variability (BIZET, 2009).

Different theories can explain this price differentiation. First, when *transport costs* are prohibitive, the Hotelling model (1929) explains how firms that produce homogeneous goods have interest to be spatially dispersed in order to propose higher prices to consumers or lower prices to suppliers (for instance when farmers have only one plant to sell their milk to). Second, the *share of the added value* among suppliers, dairy farmers, processing industries, and consumer varies according to regions. This share depends on the intensity of the demand and of the supply competition (LASSUDIRE-DUCHÊNE AND UNAL-KESENCI, 2001). According to COLMAN (2002, cited in the IPTS REPORT, 2007 p9), low price observed in the UK could be "due to the market power of the retail sector, which has squeezed producer margins, particularly for drinking milk". *The level of market integration* influences also milk price (IPTS, 2007). In Germany, farmers from Schleswig-Holstein that sell their milk to big world-market oriented cooperatives (200 € in 2009, source: BIZET, 2009) obtain lower average price than those from Bavaria (258 € in 2009). Similarly, Ireland who has faced high price variability exports 80% of its production. Eventually, p*roduct differentiation* is also a way to decrease the competition between firms. Higher prices received by farmers in the Jura or the Alps in France lies for instance in the added values of their cheese (PERROT ET AL., 2008). Although DEPALMA ET AL. (1985) state that product differentiation is a substitute for spatial differentiation, lots of differentiated agricultural products are linked to a specific production area. Protected Designation of Origin, Protected Geographical Indication and Traditional Speciality Guaranteed are labels that guarantee product origin. These labels limit then both spatial shift of the production and price homogenization.

3.3.1 Milk price across regions

According to EBERLE ET AL. (2004), local milk prices, ability to ship to higher price milk markets and costs to market milk are of first importance in farmer's decision to locate and to enlarge their dairy operation. Although in the US, OSEI AND LAKSHMINARAYAN (1996) emphasize that positive changes in US dairy farm numbers are more likely in regions where base year local price is high, at the EU level, ZIMMERMANN AND HECKELEI (2010) do not confirm this finding. Similarly, results obtained for US regional production are not converging: for ISIK (2002), higher county prices have a positive effect on US local dairy inventory and on per farm production but also on local production dynamics but for RUTT (2007) a negative impact on local dairy production. When dairy prices are added to the measurement of production costs or regional specialization, the correlation between specialization and production are much smaller (BUTAULT ET AL., 1990) and even negative for DANIEL (2003). Average local milk price could motivate farmers to locate and to increase their production, but a dynamic regional production, producing surplus of milk, can also suffer from competition that pull prices down (FUJITA AND THISSE, 2004).

3.3.2 Milk price over time

The neoclassical theory states that, at equilibrium, marginal production cost should equal output price. Assuming that production costs are concave and differ according to farmers, higher output prices enable farmers with higher production costs to stay in business and encourage production increase. A drop of the milk price accelerates farm structural change and to a lesser extent spatial reorganisation with, higher prices provided to the wealthier farms mean higher financial capacities to take over the least efficient ones. Empirical studies such as the ones of STOKES ET AL. (2006), FOLTZ (2004) BEN ARFA ET AL. (2007) and ZIMMERMANN AND HECKELEI (2010) demonstrate that lower prices over time raise the rate of dairy farm exit and demotivate farm enlargement. The same observation is made at the regional level by several studies such as ADELAJA AT AL. (1988; 1991) and WEERSINK AND TAUER (1990). Adjustment to price can however take place over several years. WEERSINK AND TAUER (1990) estimate that full adjustment of milk cow to long run optimum will occur in approximately five years and MILIGAN (1978) observe higher positive correlation with profit margin realised two years ago than with current profits.

3.3.3 Milk price variability

Price variability is a source of uncertainty that can inhibit production, above all if farmers are risk averse (HARDAKER ET AL., 2001). In empirical studies, the month-to-month variance of milk prices (FOLTZ, 2004; STOKES, 2006; ZIMMERMANN AND HECKELEI, 2010) decreases the number of farms that stay in business and prevents farm expansion. In ISIK (2004), between years county milk receipt variability is also negatively correlated to average local production level and appears to be a deterrent of local production expansion.

4 Spatial heterogeneity of public policy

4.1 Spatial heterogeneity in the implementation of market tools

By restricting national and sometimes regional milk production, and controlling EU importations, the quota system artificially increases price. This leads to the formation of a quota rent that corresponds to the difference between the price of the product received by farmers and the marginal cost evaluated at the quota level (RÉQUILLART ET AL., 2008). Without quota restriction, under microeconomic theory, the optimal quantity of milk produced is achieved when marginal cost equals milk price. In the RÉQUILLART ET AL. study (2008), this rent varies from zero where quota is not binding (UK, Sweden, Hungary and Czech Republic) to 0.13 in the Netherlands. As explained in the previous section, higher prices are responsible for higher production levels and more stable farm structures. Consequently, disparities of quota rents (and then of milk price) induced by the quota scheme implementation could have favoured heterogeneous development of milk production across the EU.

Since 1992 CAP reforms, member states obtained more flexibility to control quota transfer between farms and regions. Nowadays, rules for quota transfer vary considerably from one member state to another. Transfer of quota without land is not allowed in countries such as France. In the cases of such transfers are allowed, member states could add rules aimed at “successfully restructuring milk production or improving environment” (ALLIANCE ENVIRONNEMENT, 2008, p24) and reallocate quotas through administrative mechanisms in order to control their mobility between regions. Heterogeneity of quota mobility rules can be responsible for heterogeneous regional development of dairy production. In its deliverable report, ALLIANCE ENVIRONNEMENT (2008) compares two countries with opposite positions in the application of the quota system: the UK with a market oriented system and no geographic restriction and France where quota reallocations without land are administered. Although the difference in the percentage of reduction in the number of milk producers is not so different over the period 1984-2007 (76% in France versus 66% in the UK), the difference in the largest regional production outflow (18% in France versus 60% in the UK) and production gain (3% in France versus 18% in the UK) are much more important in the UK and the difference would be even greater in absolute terms. Although HUETTEL AND JONGENEEL (2008) noticed some difference in structural change according to EU member states, impacts of the quota scheme on structural production is less obvious.

In the USA, programs aiming at supporting milk price or reducing impact of milk price variability exist too with for instance the federal milk marketing order, federal milk price support program or state pricing programs (BLAYNEY AND NORMILE, 2004). FOLTZ (2004) test whether the price floor policy of New England that truncates the price distribution on farm structural changes lower dairy farm response to price signals. He finds that price support programs are a way to keep farm in business and to favor their expansion. In their report BLAYNEY AND NORMILE (2004) state that dairy policy had globally a modest impact but that their effect varies regionally and may lower the returns of some Western dairies.

4.2 Spatial heterogeneity of direct payments

In order to reduce distortion effects of national agricultural policy on world markets, most the OCDE countries are progressively converting their price support into direct payments. These direct payments can be heterogeneous across space since they are sometimes based on historical references or are tightened to production conditions and location characteristics. In France, some coupled payments directly aim at supporting livestock production based on grassland. In Europe, special payments are given to compensate for natural handicaps where production conditions are difficult because of altitude and slopes, of restricted water supplies or periodic flooding and more generally in regions with poor soils and low agricultural incomes. As mentioned by RÖDER AND KILIAN (2009) in their review, several studies indicate a stabilizing effect of direct payments on structural change but in some studies their effects are very small. DANIEL (2003) and BEN ARFA ET AL. (2009a) highlight that marginal areas become specialised in supported products since other agricultural products are locally declining. It is the case for instance in the French Massif Central, in Ireland and in the UK: beef and milk production have not significantly increased (at least between 1983 and 1995) but specialisations of these areas are more important. This can mean either that CAP support enables to maintain agricultural activities in the less competitive areas or that favour higher input costs and land costs can indeed increase because of land based subsidies.

4.3 Spatial heterogeneity in regulations stringency

To set minimum standard in terms of environment protection, animal welfare, and animal and plant health, regulations are created. These regulations can create regional disparities if they are unven across space. SNEERINGER AND HOGLE (2008), OSEI AND LAKSHMINARAYAN (1996), ROE ET AL. (2002), ISIK (2004), and HERATH ET AL. (2005) point out differences in regulation stringencies across US states. In Europe, the CAP cross compliance and Good Agricultural and Environmental Condition measures do impose mimimum conditions but leave considerable implementation leverage for every member state. Pollution havens can occur when one region has a less stringent environmental or welfare regulation than another region, leading “dirty” industries to grow in more pollution-friendly locations (SNEERINGER AND HOGLE, 2008). Most of the American studies have found indeed that environmental regulation stringency are a deterrent to farm location, to per farm production, to local dairy inventory ,and to local dairy inventory growth (OSEI AND LAKSHMINARAYAN, 1996; ISIK 2004; HERATH *ET AL.*, 2005; SNEERINGER AND HOGLE, 2008). No European studies exist to our knowledge regarding the effect of regulation on local dairy production dynamics.

In addition, although regulations are the same everywhere, it can be more or less costly to comply with them. KUIK (2006) and BEZLEPKINA ET AL. (2008) emphasize the different costs across Europe to comply with the nitrate directive. LARUE ET AL. (2008) appreciate the difficulty to comply with the manure regulation through the ratio between the local demand for spreading manure and the available land to spread manure. This indicator was negatively correlated to local hog production and its dispersion effect increases with time. LASSEN ET AL. (2008) provides the example of the German manure regulation with among others, specific upper limits for nitrate that already now restrict farm growth of animal farms in some regions in Niedersachsen.

In some studies, pressure on dairy production development is approximated by the population characteristics. Attitude of local population toward livestock operation can influence local production by allowing more or less easily the installation or enlargement of production operations and by tolerating and valuing more or less livestock farming. Potential incompatibilities exist indeed due to traffic, air, and water externalities that may emerge and may cause conflicts between residential populations and dairy production. Communities that absorb many people who are unfamiliar and unsympathetic to externalities generated by the sector, can express more resistance to the establishment or existence of large-scale operations (ROE ET AL., 2002). HERATH ET AL. (2005) explain indeed the positive effect of a greater share of rural population on dairy inventory by less resistance to livestock operations in states with a greater percentage of the population tied to agriculture. ISIK (2004) includes the poverty level of each county under the hypothesis that poorer counties will favour livestock operations and finds that it has a positive impact on change in dairy inventory (table 3).

Table3: Impacts of indicators of public policy on regional dynamics

	Production level			Production change		
	Reg.	Farm size	Farm nb	Reg.	Farm size	Farm nb
Regulated price, quotas	+[15]			-[15]		/[10]
Direct payments			/[4]			
Stringency index of environmental regulation	-[11] +[15]	-[11]		-[11,9,16]		-[12]
Vulnerable area			-[4]			
Level of poverty	/[11]	/[11]		+[11]		

Notes: -, + and / indicate resp. a positive, negative and unclear effect of the indicator on spatial dynamics; the number in superscript correspond to the reference detailed in appendix 1.
Source: Own compilation

5 Conclusion

The broad range of papers reviewed enables us to discuss the key determinants that govern spatial dynamics in dairy production. Analyzing comparative advantage of the different regions appears crucial to explain production location and production change. Among production factors (land, labor, machinery and buildings, and variable inputs) land characteristics appeared to be the most important. Dairy production and farm enlargement are usually more important where land is cheaper. However, it seems that current positive development of this activity is more likely on plane areas and on better soil qualities: intensification is easier and provides probably sufficient output per land unit to compete with other agricultural production orientations. However, the reduced possibilities to convert permanent grassland to other agricultural use will probably limit the withdrawal of grazing livestock enterprise from marginal lands. To characterize labor markets and dairy farm labor mobility, farm wage rate, unemployment rate, per capita average income, farmer's age, and part time farming represent the most studied criteria and appear significant in most of the studies. This argues for a consideration of the local economic environment beyond farming when analyzing and simulating dairy production evolution. Sunk costs linked to investments in buildings and equipments constrain spatial dynamics and time as a factor necessary to adjust herd sizes and farm labors advocate for a dynamic representation of production change. Technology plays an important role too since on the one hand, technological progress reduces traditional constraints of farms rendering production possible almost everywhere. On the other hand, technological progress leads to higher specialization and higher reliance on suppliers and purchasers, strengthening thus the importance of the local dairy industry in individual farm development. Production increases seem to occur nowadays in farms and region having rather intensive production systems with advanced technology. Regarding aggregated production costs, although most simulation studies are based on the assumption that costs are minimized and utility or profit maximized, we regret that their effects have not been tested empirically. Comparing availability and price of inputs across regions provide hints about technology choice rather than about the role of farm competitiveness.

Dairy production and dairy farm density are spatially correlated which supports the idea of agglomeration economies: dairy production benefits from shared infrastructures, technical services, and specific industries. External economies stemming from others activities such as non dairy cattle seems to have a positive influence, however, results are always difficult to interpret since these activities are also competing with dairy production. Contradictory results among US dairy production studies make it difficult to conclude whether dynamics are spatially correlated. We can imagine that spatially positively correlated dynamics could be found in rather new producing areas whereas traditional ones face negative dynamics due to a greater competitive environment. Further investigations are necessary though.

Transport cost is often seen as a dispersion force that counter balances the search for increasing returns. Although the presence in the vicinity of input industry is significant to explain average local production and production change for some production systems (according to the technology used), the location and the capacity of dairy processing industry appear more determinant. Transport of raw milk is indeed the most problematic. To properly capture the impact of a local market is difficult since population both represents potential consumers of dairy products and may constrain production systems due to nuisance factors and land prices). Neither inputs industries nor processing industries are really spatially fixed. Possibilities of co-evolution of these industries have then to be considered.

Distances between the different consumption and production areas can also enable firms to face lower competitive pressure and to propose lower prices to local dairy producers or higher prices to local consumers. This spatial differentiation can also result from differentiated products that are linked to a location by geographical indication. However, introducing relevant transport costs and possibilities of product differentiation could take into account price differentiation resulting from imperfect competition.

Eventually, by the mean of market supports, farm subsidies, and regulations, public policy modifies the production environment of farmers and dairy processors. Distribution of output prices, production costs and farmer income, and, average costs to enter or leave the professions are relevant factors that can be affected by policy. This can create spatial heterogeneity when the policy itself varies across space or when the policy targets production characteristics that are spatially heterogeneous. The quota system has especially strong implications on average price, price variability, and spatial dynamics. High differences in quota rents across EU regions let forebode an important spatial reorganization.

This review has let some questions unanswered though. First of all, local and macroeconomic factors appear to influence both structural change and regional production change. However, the interaction between structural change and regional production change remains unclear. Structural change and technology adoption are linked. Structural change could then progressively improve regional competitiveness and favors regional production increase. Regional development of dairy infrastructure and dairy industry could in turn foster dairy farm production. Technological changes modify also progressively the relationships between farm development and local characteristics, shrinking historical regional advantages. We advocate then that some research focusing on the co-evolution of farm structure and regional production could help to better encompass regional production change dynamics.

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Appendix 1: Empirical Analysis analyzing determinants of dairy production dynamics

	Reference	Method	Data	Dependant variables
1	Adelaja, 1991	Supply function according to farm size group, endogenous variables	1971-1985 northeastern US farms	Log (Regional dairy production per farm type)
2	Adelaja, 1998	Dairy cow demand function, panel data	1964 to 1992 for all counties of New jersey, New York and Pennsylvania	Ln (dairy cow inventory)
3	Ben Arfa 2007	Markov chain	Dairy French farm 1988-2003	Number of farm in each class
4	Ben Arfa, 2009	Linear regression + spatial autocorr	French 'departement' (similar to US county) 1995 and 2005	number of dairy farms per 'département'
5	Butault, 1990	Correlations	FADN data forEuropean Member state	rank of Agricultural specialization in each product
6	Chavas, 1988	Markov chain	Dairy farm in 4 US regions	Nb of farm in each size class
7	Daniel 2003	Linear regression	EU regions	Regional concentration index per product
8	Foltz J.D. 2004.	Farmer investment model under price volatility and sunk costs	Connecticut dairy farms over the period 1996-2001	-Nb of cows per farm -Nb of farms
9	Herath, 2005	Linear regression + panel effect	US state over 1975-2000	Change in livestock inventory divided by total national inventory
10	Huttel 2008	Markov chain	West Germany : n b of dairy farms 1971-2005, East germiany : from 1991-2005 , NL:1972-2006	Nb of farm in each size class

	Reference	Method	Data	Dependant variables
11	Isik, 2004	Linear regression + spatial autocorr	US County 1992 and 1997	-ln (Dairy cow Inventories) -ln (per farm DI) -ln (absolute changes in the DI) - relative changes in the DI
12	Osei, 1996	Logit model	US County 1987 and 1992	Change in dairy farm number
13	Peterson, 2002	Linear regression + spatial autocorr	US Counties 1995 and 2000	Ln (Milk Production 2000) -ln (MP 95)
14	Rahelizatovo, 1999	Markov chain	4 class size of dairy farms , Louisiana, 1981-1995	Nb of farm in each size class
15	Rutt, 2007	Probit model + spatial autocorr.	counties in 45 US states in 1997 and 2002	quantities of milk marketed in the months of May in 1997, in 2002 and production change between 1997 and 2002
16	Sneeringer, 2008	Trend Comparison	California counties over the period 1980-2008	Trend in milk cow before and after regulation
17	Soregaroli, 2005	Markov chain model	330 Italian farms +evolution of quota from 95 to 2003	increase milk quota from 2001 to 2003 ; exit of the dairy market from 2001 to 2003
18	Stokes J.D. 2006	Markov chain model	Pennsylvania dairy farm numbers from 1980 to 2003 according to their size categories	Farm number in each size class
19	Zimmermann, 2010	Markov chain model	EU15 dairy farms over the period 1995-2005	Farm number in each size class

Source: Own compilation.