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Abstract

Conspicuous conservation is a newly emerged phenomenon of status driven environmentalism, where individuals undertake publicly visible conservation activities for the purpose of gaining social esteem. This paper studies the role of conspicuous conservation as an additional means of regulating environmental issues in an extended Uzawa-Lucas model with leisure choice, environmental externality and social status. Particular attention is paid to the long-term impact of conspicuous conservation on environmental quality, production culture, and the overall welfare along the balanced growth path (BGP) in a decentralized economy. Conspicuous conservation is found to aid pollution taxation and always increase environmental quality by providing additional incentives for pollution abatement. It however also increases the dirtiness of the aggregate technology, and encourages the use of the polluting factor. The overall welfare impact is positive when pollution control is absent or weak, but eventually turns negative as pollution taxation becomes increasingly stringent. The numerical example further suggests that strong status comparison is generally undesirable except at zero or extremely low pollution control.

Keywords: Conspicuous conservation, social status, pollution, economic growth
JEL classification: Q50, D62, D91, O41, O44

1 Introduction

While environmental issues have been a much studied topic in economic growth literatures, the majority of these studies have focused on the role of the public sector in dealing with environmental externalities. More recent examples include Acemoglu et al. (2012), and Economides and Philippopoulos (2008). At the same time, as behavioral research points to the importance of preference and demand driven actions in tackling environmental issues (see for example Kinzig et al., 2013; Beretti et al., 2013), empirical and theoretical studies on the mechanism and effect of such actions are needed.

A newly emerged phenomenon in the recent years, conspicuous conservation, falls into this category. Termed after Veblen's (1899) "conspicuous leisure" and "conspicuous consumption", the concept of conspicuous conservation is used to describe status driven, publicly visible environmental conservation actions. With this kind of "going green to be seen" (Griskevicius et al., 2010) behavior, the environmental degrading effect of status-seeking is turned around to serve the purpose of environmental protection.

There are different explanations concerning why this kind of pro-social, pro-environmental behavior exist in the first place. One of these explanations is the so-called "costly signaling theory" (Zahavi, 1975). According to this theory, individuals engage in behaviors that are costly to themselves in order to signal information about themselves that are considered desirable. In the evolutionary sense, individuals that undertake this kind of costly actions would be considered by potential reproductive partners as having high fitness due to their ability of bearing costs and disadvantages, which in turn supports higher reproductive success. Van Vugt et al. (2007) suggest in their competitive altruism hypothesis that altruism and pro-social behavior might qualify as such costly behavior and altruists advertise the quality of themselves and their access to resource by showing that they are willing and able to spend excessive amount of energy, time and money for unselfish purposes. Therefore, by publicly undertaking self-sacrificing actions, one can signal one's willingness and ability to incur costs for others' behalf (Bird and

Smith, 2005; Griskevicius et al., 2010). In any case, the costly signaling theory has gained much support from theoretical and empirical studies of both animal signaling and human behavioral ecology such as Gintis et al. (2001), Gurven et al. (2000), and Smith and Bird (2000), and has begun to be used also for explaining aspects of human psychology (see Griskevicius et al., 2007, 2010).

As yet a novel phenomenon, conspicuous conservation is believed by some to possess large potential for becoming an effective environmental conservation approach. In experimental settings, Griskevicius et al. (2010) show that activating status motive leads to higher willingness for purchasing environmentally friendly goods among participants. As for the magnitude of the effect, using vehicle purchase decision data, Sexton and Sexton (2013) have identified a mean willingness to pay between $430 and $4200 for the “green” signals. Even at the national level, similar positional concern is shown to kindle “‘races’ toward sustainable development” (Beretti et al., 2013), as demonstrated by nations’ effort in moving up their ranks in the Yale Environmental Sustainability Index.

While conspicuous conservation potentially offers an innovative approach to increase efforts of environmental protection, much doubt and criticism still exists. Sceptics question the effectiveness of such status driven conservation effort, and point to the threat of increased aggregate production and higher negative environmental impact as in “Jevons Paradox” (see Elliott, 2013).

Against this background, a thorough investigation of the conspicuous conservation phenomenon appears highly relevant and necessary. Especially, insights on whether and how conspicuous conservation influences the long-term environmental quality, production culture and overall welfare are needed. For these purposes, an economic growth model, which enables treatment of status-seeking conservation behavior and offers long-term perspectives on both the economic and ecological affairs of human society, appears helpful.

While status-seeking is already a much analyzed issue in growth literature, existing literature mainly focuses on the more conventional forms of status concern, such as in terms of conspicuous consumption (see for example Rauscher, 1997; Fisher and Hof, 2000; and Tournemaine and Tsoukis, 2008) or relative concerns for wealth (Cahuc and Postel-Vinay, 2005; Tournemaine and Tsoukis, 2008; Nguyen-Van and Pham, 2013). To our knowledge, there has not yet been any attempt in modeling status concern in terms of environmental protection behavior in the context of economic growth theories. By incorporating conspicuous conservation behavior in an economic growth model, the present paper thus aims at providing a better understanding of status-seeking conservation behavior and offers insights into its environmental, economic and welfare impact.

To study the impact of conspicuous conservation, we adopt a two-sector Uzawa (1965)-Lucas (1988) model with leisure choice, environmental externality and status-seeking green wealth, as represented by one’s holding of abatement capital relative to the average abatement capital in society. Prior studies using Uzawa-Lucas models with environmental externality have shown that such models can well support long-term growth with constant environmental quality (see Gradus and Smulders, 1993; Bovenberg and Smulders, 1995; and Hettich, 1998). Such two-sector models thus offer a good starting point for extension and can be used to study the long-term impact of the status-seeking behavior. In particular, the current paper modifies and extends the model of Hettich (1998) by incorporating quality leisure, environmental stock, abatement capital, and status comparison.

After setting up the model, we derive the equilibrium conditions and properties of balanced growth path (BGP). The analyses focus on the decentralized economy, while the social planer’s solution serves only as a benchmark. Conclusions on the environmental, economic and welfare impact of conspicuous conservation are drawn from the comparison of the decentralized BGPs with and without conspicuous conservation. The analyses yield a few main results. First, conspicuous conservation is found to always effectively raise abatement and environmental quality. Second, although the overall effect on the environment is positive, conspicuous conservation raises the dirtiness of technology and stimulates the use of the pollution generating production factor. Finally, with increasing strictness of pollution control, conspicuous conservation is first welfare enhancing but eventually leads to lower welfare.

The rest of the paper is organized as follows. Section 2 introduces the formal model, and Section 3 derives the equilibrium conditions. In Section 4, the existence and properties of the BGPs are established and the impact of conspicuous conservation is analyzed. A numerical example is further provided to illustrate the analytical results. After a discussion in Section 5, Section 6 concludes the paper.

2 The Model

We consider a closed economy with a constant population normalized to 1. The economy is assumed to be populated by identical, infinitely-lived agents uniformly distributed over the interval [0,1]. The identical agents are assumed to have perfect foresight and make decisions to maximize their life-time utility. We further assume competitive markets while discussing decentralized economies.

2.1 *Aggregate Technology and Environment*

The aggregate production technologies of the two-sector economy are given by[1]:

$$Y_t = AK_t^{\alpha}(u_t H_t)^{1-\alpha} \tag{1}$$

$$\dot{H}_t = Bv_t H_t = B(1 - u_t - l_t)H_t \tag{2}$$

where Y_t is the final output produced, K_t is the productive capital, u_t is the amount of time devoted to final output production and $u_t H_t$ the effective labor, $0 < \alpha < 1$ is the exogenous output elasticity of productive capital;[2] H_t is the amount of human

[1] We assume a zero depreciation rate for the productive, human and abatement capital in this paper. Using a positive depreciation rate would complicate the analyses, but will not alter the results.

[2] Lucas (1988) has assumed a positive externality of average stock of human capital on output production. We assume away this externality throughout our analyses.

capital accumulated at time t, B is the productivity parameter for the education sector, and v_t the times devoted to education. Given the total time endowment of 1 and denoting the amount of leisure times by l_t, the education time is also given by $(1 - u_t - l_t)$. The education sector thus has a linear technology. The final output production function exhibits constant return to scale with respect to productive capital and effective labor, has diminishing marginal product in the two factors, and further satisfies the Inada conditions. Productive capital used in final output production is assumed to generate pollution flows, which can be reduced by the use of abatement capital G_t. The net pollution flow is thus given by

$$P_t = K_t^x G_t^{-\beta} \tag{3}$$

where $x > 1$ and $0 < \beta \leq x - 1$ are the exogenous elasticities of pollution with respect to productive and abatement capital, respectively. The condition $\beta \leq x - 1$ rules out the notion of highly effective abatement so that simultaneous doubling of physical and abatement capital will lead to increased pollution[3].

The abatement capital evolves according to

$$\dot{G}_t = \mu Z_t^\gamma \tag{4}$$

where Z_t is the abatement investment, $\mu > 0$ is the productivity parameter, $\gamma > 0$ is the elasticity of abatement capital with respect to the abatement investment and specifies the speed of abatement capital accumulation. The effect of net pollution is that it reduces environmental quality, which evolves according to

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[3] This condition warrants the joint concavity of the maximized Hamiltonian with respect to physical and abatement capital that is needed for the Arrow Sufficiency Theorem (see Arrow and Kurz, 1970; Seierstad and Sydsaeter, 1977) in the optimal control theory, which ensures the sufficiency of the first order conditions to be used in the equilibrium analysis in Section 3. The quality leisure modification of Hettich's (1998) model serves the same purpose and warrants the concavity of the maximized Hamiltonian with respect to human capital.

$$\dot{E}_t = -\delta E_t - \theta P_t, \quad \text{with } E_{min} < E_t < E_{max} = 0, \tag{5}$$

where δ is the regeneration rate of the environment, θ is the depletion rate or rate of damage from pollution, E_{min} is the lowest possible (stable) environmental quality or the "disaster state", and E_{max} is the so-called "virgin state", which can only be achieved in the absence of industrial production. Given that E_t takes nonpositive values, the variable can be interpreted as the deviation from the virgin state. A higher E_t thus represents a lower deviation from E_{max} and a higher environmental quality.

2.2 *Household*

Households or individuals in the economy derive utility from consumption, quality leisure, environmental quality and social status. Social status is generated through the comparison of one's green wealth, which is the level of one's abatement capital holding. The visibility of the individual green wealth is established if we assume that the shares of abatement capital can only be purchased at specific banks and no online banking option is available. For green wealth to be status generating, abatement capital holding must further be costly to the individuals and involves some form of self-sacrifice. It is therefore important that investing in abatement capital should not be as profitable as investing in productive capital, and it must be clear to all individuals that the holding of abatement capital signifies some degree of economic disadvantages. This condition is however easily satisfied given the public good nature of pollution abatement.

The instantaneous utility function of the representative individual is given by

$$U_t(C_t, H_t, l_t, G_t, \bar{G}_t, E_t) = \ln C_t + \eta_l \ln(H_t l_t) + \eta_s \ln \frac{G_t}{\bar{G}_t} - \eta_E \frac{(-E_t)^{1+\psi}}{1+\psi} \tag{6}$$

where $\eta_l, \eta_s, \eta_E > 0$ are exogenous parameters measuring the importance of quality leisure, social status and environmental quality relative to consumption in the individual's utility, and $\psi > 0$ is the inverse of the intertemporal substitution elasticity of environmental quality. The amount of quality leisure[4] $H_t l_t$ depends on both the level of human capital and leisure time. The representative individual's social status is expressed via her green wealth relative to society's average ($\frac{G_t}{\bar{G}_t}$), and is determined by her own holding of abatement capital $G_t > 0$ and the average abatement capital in the economy $\bar{G}_t > 0$, which she takes as exogenous.[5]

Individuals are further asset owners in the economy. They receive productive capital income (both interest and dividend), wage, abatement capital rent, and face the following budget constraint:

$$\dot{K}_t = I_t = r_t K_t + w_t u_t H_t + q_t G_t + \pi_t - C_t - Z_t \tag{7}$$

where I_t is the investment into productive capital, and r_t, w_t, q_t, and π_t are the competitive interest rate, wage, abatement capital rent, and dividend, respectively.

2.3 *Firms*

Taking the competitive interest rate, wage, abatement capital rent, pollution tax, and lump sum transfer from the public sector as given, firms maximize their profits

$$\pi_t = Y_t - r_t K_t - w_t u_t H_t - q_t G_t - \tau_t P_t + L_t \tag{8}$$

[4] Examples of such quality time include seeing opera, reading a book, playing music, etc. Although modeling leisure in terms of quality time is mainly out of technical considerations (see Footnote 3), the specification can be considered sensible insofar if we consider the total time endowment as net of raw leisure time, or time spent for maintaining physical functions of human body (such as sleeping).

[5] We assume $G, \bar{G} > 0$ so that $\ln \frac{G_t}{\bar{G}_t}$ is always defined.

where τ_t is the pollution tax per unit of pollution and L_t the lump sum transfer.

2.4 *Public Sector*

The role of the public sector is minimal in our model. The public sector levies a pollution tax $\tau_t \geq 0$ and makes a revenue-neutral lump sum transfer L_t to the firms. The governmental budget is always balanced and $\tau_t P_t = L_t$ always holds.

3 Equilibrium

3.1 *Competitive Decentralized Equilibrium (CD)*

We start our analyses with the competitive decentralized equilibrium (CD), which is jointly determined by 1) profit maximization of the firms, 2) utility maximization of the individuals, 3) ex post symmetry in individual decisions, and 4) balanced governmental budget. For simplicity of notation, we will drop the time subscript in the rest of the paper whenever it does not cause confusion.

Taking the competitive interest rate, wage, abatement capital rent, pollution tax and lump-sum transfer as given, the representative firm maximizes its profit by choosing the optimal level of K, uH and G according to

$$\max_{\{K,u,H,G\geq 0\}} \pi = AK^{\alpha}(uH)^{1-\alpha} - rK - wuH - qG - \tau P + L \tag{9}$$

which leads to the following first order conditions:

$$r = \alpha\frac{Y}{K} - x\tau\frac{P}{K} = \alpha\frac{Y}{K} - \phi^{CD}\frac{Z}{K} \tag{10}$$

$$w = (1-\alpha)\frac{Y}{uH} \tag{11}$$

$$q = \beta\tau\frac{P}{G} = \phi^{CD}\frac{Z}{\gamma G} \tag{12}$$

where ϕ^{CD} is a variable given by $\phi^{CD} = x\tau\frac{P}{Z}$. Firms' profits will thus be

$$\pi = (x-\beta)\tau P. \tag{13}$$

Condition (10) shows that when the environmental externality is internalized by a positive pollution tax, the net marginal product and thus the competitive interest rate of productive capital will be reduced by its marginal environmental costs ($x\tau\frac{P}{K}$), expressed by the pollution tax payment. With positive pollution tax, firms will pay a lower share of their total revenue ($\frac{rK}{Y}$) for renting productive capital and instead spend some of their resources for renting abatement capital ($\frac{qG}{Y}$). Due to the increasing return to scale property ($x - \beta \geq 1$) of the net pollution function, however, the saved cost of productive capital ($x\tau P$) is larger than the additional cost of abatement ($\beta\tau P$) so that the net profit of firms actually increases, compared to the zero profit when pollution control is absent. Since the saved costs $x\tau P$ represent the environmental costs of productive capital, a natural interpretation of ϕ^{CD} is thus the environmental costs per unit of abatement investment.

From the distributional point of view, conditions (10)-(13) also reveal the distributional impact of pollution taxation. In particular, the owners of the productive capital are punished by the dirtiness of their assets and they bear a total loss of $x\tau P$. The owners of the abatement capital and the owners of the firms, on the other hand, are rewarded by a gain of $\beta\tau P$ and $(x - \beta)\tau P$, respectively. In our model, where the representative agent is the owner of all types of assets, such redistribution of course does not occur. However, the changes in interest rate and abatement capital rent caused by pollution taxation provide financial incentives for the asset owners to adjust their investment decisions.

Taking the competitive wage, interest rate, abatement capital rent and dividend payment as given, individuals maximize their lifetime utility

$$W = \int_0^\infty \left[\ln C + \eta_l \ln(Hl) + \eta_s \ln\frac{G}{\bar{G}} - \eta_E \frac{(-E)^{1+\psi}}{1+\psi}\right] e^{-\rho t} dt\,, \qquad \text{(P1)}$$

subject to:

$$\begin{cases} \dot{K} = rK + wuH + qG + \pi - C - Z \\ \dot{H} = B(1 - u - l)H \\ \dot{G} = \mu Z^\gamma \end{cases},$$

where ρ is the rate of time preference and the absence of the environmental constraint reflects the public good nature of environmental quality.

Applying optimal control theory, the solution to (P1) can be found by maximizing the following current value Hamiltonian:

$$H = \ln C + \eta_l \ln(Hl) + +\eta_S \ln\frac{G}{\bar{G}} - \eta_E \frac{(-E)^{1+\psi}}{1+\psi} + \lambda_1[rK + wuH + qG + \pi - C - Z\,] + \lambda_2[B(1-u-l)H] + \lambda_3 Z^{\gamma} \quad \text{(H1)}$$

where C, Z, u, l are the choice variables, K, H, G the state variables and λ_1 to λ_3 the co-state variables or shadow prices corresponding to the state variables. Maximizing (H1) leads to, inter alia, the following set of optimality conditions:

$$\frac{\dot{C}}{C} = \alpha\frac{Y}{K} - \phi^{CD}\frac{Z}{K} - \rho \quad (14)$$

$$\frac{\dot{K}}{K} = \frac{Y}{K} - \frac{C}{K} - \frac{Z}{K} \quad (15)$$

$$\frac{\dot{H}}{H} + \frac{\dot{l}}{l} = B - \rho \quad (16)$$

$$\frac{\dot{G}}{G} = \frac{\mu Z^{\gamma}}{G} \quad (17)$$

$$\frac{\dot{E}}{E} = -\delta - \theta\frac{P}{E} \quad (18)$$

$$\lambda_1 = \lambda_3(\mu\gamma Z^{\gamma-1}) \quad (19)$$

$$-\frac{\dot{\lambda_3}}{\lambda_3} = \frac{\frac{\eta_S}{G} + \lambda_1 q - \rho\lambda_3}{\lambda_3} = \eta_S\gamma\frac{C}{Z}\frac{\dot{G}}{G} + \phi^{CD}\frac{\dot{G}}{G} - \rho \quad (20)$$

Condition (14) reveals that with positive pollution tax, the growth rate of consumption will be corrected by abatement costs. Since one unit of unconsumed output can be either invested into productive or abatement capital, investment into the two types of capital is interchangeable and must generate the same real marginal return in terms of output or consumption at equilibrium. This is reflected by condition (19). The left hand side of (19) represents the value of one extra unit of investment into productive capital, which is equal to $\frac{\mathrm{dK}}{\mathrm{dI}}\lambda_1$ with $\frac{\mathrm{dK}}{\mathrm{dI}} = \frac{\mathrm{dK}}{\mathrm{d\dot{K}}}\frac{\mathrm{d\dot{K}}}{\mathrm{dI}} = 1$, while the right hand side is the value of one extra unit of investment into abatement capital and is equal to $\frac{\mathrm{dG}}{\mathrm{dZ}}\lambda_3$ with $\frac{\mathrm{dG}}{\mathrm{dZ}} = \frac{\mathrm{dG}}{\mathrm{d\dot{G}}}\frac{\mathrm{d\dot{G}}}{\mathrm{dZ}} = \mu\gamma Z^{\gamma-1}$.

According to condition (20), the marginal value of abatement capital in real terms (λ_3) depends both on its status return (marginal status utility $\frac{\eta_s}{G}$) and its financial return (marginal benefits in terms of consumption $\lambda_1 q$). The total return of abatement capital thus sums up the return from its both roles as status symbol and financial assets. With conspicuous conservation ($\eta_s > 0$), conditions (19) and (20) together suggest that the marginal financial returns of abatement capital will be lower than that of productive capital at equilibrium. Thus investing into abatement capital does indeed represent some economic disadvantages. Further, since the marginal financial return of abatement capital relative to its shadow price, $\frac{\lambda_1 q}{\lambda_3}$, can also be written as $\phi^{CD}\frac{\dot{G}}{G}$, an alternative interpretation of ϕ^{CD} is thus the relative marginal financial return of abatement capital adjusted by its growth rate.

3.2 *Social Planer's Solution (SP)*

To maximize the overall welfare, a benevolent social planer will choose exactly the same set of consumption, capital, leisure, education and abatement for all individuals since all individuals are identical and weighted equally. Thus in the social planer's solution (SP) $G = \bar{G}$ will hold at any instant of time. Consequently, the ratio $\frac{G}{\bar{G}}$ is always equal to one and the term $\eta_s \ln\frac{G}{\bar{G}}$ vanishes from the welfare function. In other words, individuals' relative standing and social status are of no importance to the social planer's optimization considerations, which is a standard result when relative status comparison is concerned (see e.g. Rauscher, 1997; Fisher and Hof, 2000). The planer's problem can then be written as

$$\max W = \int_0^\infty \left[\ln C + \eta_l \ln(Hl) - \eta_E \frac{(-E)^{1+\psi}}{1+\psi}\right] \mathrm{e}^{-\rho t}\mathrm{dt}\,, \tag{P2}$$

subject to

$$\begin{cases} \dot{K} = AK^{\alpha}(uH)^{1-\alpha} - C - Z \\ \dot{H} = B(1-u-l)H \\ \dot{G} = \mu Z^{\gamma} \\ \dot{E} = -\delta E - \theta P \end{cases}.$$

The following conditions must hold in the social planer's solution:

$$\frac{\dot{C}}{C} = \alpha\frac{Y}{K} - \phi^{SP}\frac{Z}{K} - \rho \tag{21}$$

$$\frac{\dot{K}}{K} = \frac{Y}{K} - \frac{C}{K} - \frac{Z}{K} \tag{22}$$

$$\frac{\dot{H}}{H} + \frac{\dot{l}}{l} = B - \rho \tag{23}$$

$$\frac{\dot{G}}{G} = \frac{\mu Z^{\gamma}}{G} \tag{24}$$

$$\frac{\dot{E}}{E} = -\delta - \theta\frac{P}{E} \tag{25}$$

$$\lambda_1 = \lambda_3(\mu\gamma Z^{\gamma-1}) \tag{26}$$

$$-\frac{\dot{\lambda_3}}{\lambda_3} = \phi^{SP}\frac{\dot{G}}{G} - \rho \tag{27}$$

$$-\frac{\dot{\lambda_4}}{\lambda_4} = \frac{\eta_E(-E)^{\psi}}{\lambda_4} - (\delta + \rho) \tag{28}$$

where λ_1 to λ_3 have the same interpretation as before, λ_4 is the shadow price of environmental quality, and ϕ^{SP} is a variable given by $\phi^{SP} = \frac{x\theta\lambda_4 P}{\lambda_1 Z}$.

Comparing the decentralized equilibrium with the social planer's solution, we see that while there is an additional condition (28) describing the change in the shadow price of environmental quality in the social planer's solution, in the absence of status concern ($\eta_s = 0$), conditions (14)-(20) are almost identical to conditions (21)-(27) except that in the decentralized solution ϕ^{CD} replaces ϕ^{SP}. This comparison thus reveals that without conspicuous conservation, any difference between the decentralized equilibrium and the social planer's solution will essentially be a result of the difference in the environmental costs per unit of abatement investment (i.e. ϕ^{CD} vs. ϕ^{SP}). While in the social planer's solution ϕ^{SP}

directly reflects the environmental costs of pollution, in the decentralized equilibrium ϕ^{CD} is linked to the pollution tax. If in the decentralized equilibrium the pollution tax correctly reflects the real environmental costs per unit of pollution, that is, if $\tau = \frac{\theta\lambda_4}{\lambda_1}$, then in the absence of status concern the environmental externality is fully internalized, and ϕ^{CD} will coincide with ϕ^{SP}.

If status concern is present, however, the difference between (20) and (27) indicates that the decentralized economy is further distorted by the additional source of externality arising from status comparison. Apparently, even if the pollution tax fully reflects the real costs of pollution, the decentralized equilibrium will departure from the social optimum. However, if we concern ourselves with more realistic settings of suboptimal pollution tax, whether and under what conditions this additional source of externality might be of long-term benefit is not a trivial question. The rest of the analyses aims at addressing this question.

4 Balanced Growth Path

We now look at the long-term equilibrium of the model. In particular, we are interested in the so-called balanced growth path (BGP), which is a long-term equilibrium where the time allocation and the environmental quality are constant, and all other variables grow at a constant (possibility zero) growth rate.

4.1 *Existence*

Following the definition of BGP, it can be easily established that any BGP in the social planer's solution must satisfy:

$$\frac{\dot{Y}}{Y} = \frac{\dot{K}}{K} = \frac{\dot{C}}{C} = \frac{\dot{H}}{H} = \frac{\dot{Z}}{Z} = B - \rho \tag{29}$$

$$\frac{\dot{l}}{l} = \frac{\dot{u}}{u} = 0, \quad \frac{l}{u} = \frac{\eta_l}{1-\alpha}\frac{C}{Y}, \; v = \frac{B-\rho}{B} \tag{30}$$

$$\frac{\dot{G}}{G} = \frac{\mu Z^{\gamma}}{G} = \gamma\frac{\dot{Z}}{Z} = \gamma(B-\rho) \tag{31}$$

$$\frac{\dot{P}}{P} = \frac{\dot{E}}{E} = 0, \quad P = \zeta \left(\frac{Z}{K}\right)^{-x}, \; E = -\frac{\theta}{\delta} P \tag{32}$$

$$\phi^{SP} = \frac{x\theta\lambda_4 P}{\lambda_1 Z} = \phi \tag{33}$$

while in the decentralized economy the following must hold besides (29)-(32):

$$\frac{\dot{\tau}}{\tau} = B - \rho \;\text{ if } \tau > 0 \tag{34}$$

$$\phi^{CD} = \frac{x\tau P}{Z} = x\zeta \frac{\tau}{K}\left(\frac{Z}{K}\right)^{-x-1} = \phi - \eta_s \gamma \frac{C}{Z} \tag{35}$$

where in the above conditions $B > \rho$ and $x = \beta\gamma$ are required for the existence of the BGP, and $\zeta = \left[\frac{\gamma(B-\rho)}{\mu}\right]^{\beta}$ and $\phi = 1 + \frac{\rho}{\gamma(B-\rho)}$ are two parameters. The equality of the variable ϕ^{SP} to the parameter ϕ in (33) means that ϕ^{SP} must assume the constant value ϕ along the BGP, while by (35) the value of ϕ^{CD} depends, among other things, on the degree of status concern and must satisfy $\phi^{CD} \leq \phi$.

Further, in the decentralized economy, if pollution taxation exists, condition (34) requires the pollution tax to grow at the same rate as output, consumption and productive capital along the BGP. If we define the pollution tax rate as

$$\hat{\tau} = \frac{\tau}{K} \tag{36}$$

the pollution tax rate must thus stay constant along the BGP. Conditions (35) and (32) together then suggest that the actual environmental quality along the BGP depends crucially on this constant pollution tax rate.

The above conditions reveal that, at least theoretically, a BGP is well-defined. Along such a path, per capita income and consumption grow steadily without depleting the environment. In order for the pollution flows not to grow without bound, the condition $x = \beta\gamma$ requires the resource use in pollution abatement to be sufficiently efficient in reducing gross pollution. Together with the inefficiency of abatement capital ($x \geq \beta + 1$) this implies $\gamma > 1$ so that abatement capital must have a higher than proportional accumulation rate. Thus, since abatement capital does not reduce pollution fast enough, to keep the pollution flows bounded, resources must be very efficiently converted into abatement capital so that abatement capital can grow disproportionally fast. In other words, the inefficiency of pollution reduction by abatement capital must be compensated by the high efficiency in abatement investment and abatement capital accumulation. It is worth noting that there must be some sort of knowledge or technology component in the abatement capital accumulation process in order for such high efficiency to occur.

To continue with the analysis it appears helpful to transform the variables from levels into ratios. Let us define $\widehat{\mathrm{Y}} = \frac{\mathrm{Y}}{\mathrm{K}}$, $\widehat{\mathrm{C}} = \frac{\mathrm{C}}{\mathrm{K}}$, $\widehat{\mathrm{Z}} = \frac{\mathrm{Z}}{\mathrm{K}}$ and $\widehat{\mathrm{K}} = \frac{\mathrm{K}}{\mathrm{uH}}$, where

$$\widehat{K} = A^{\frac{1}{1-\alpha}} \hat{Y}^{-\frac{1}{1-\alpha}} \tag{37}$$

obviously holds since $\hat{Y} = A\widehat{K}^{-(1-\alpha)}$. The four transformed variables represent output per unit of productive capital, consumption per unit of productive capital, abatement investment to productive capital ratio (henceforth: abatement investment ratio) and productive capital per effective labor unit, respectively. We also use g_i to denote the growth rate of a variable i, so that $g_C = \frac{\dot{C}}{C}$, $g_K = \frac{\dot{K}}{K}$ and so on.

Socially Optimal BGP

To derive the socially optimal BGP, we plug (21) and (22) into $g_C = B - \rho$ and $g_K = B - \rho$, respectively, which leads to

$$\hat{Y} = \frac{\phi}{\alpha} \hat{Z} + \frac{1}{\alpha} B, \tag{38}$$

$$\hat{C} = \frac{\phi - \alpha}{\alpha} \hat{Z} + \frac{1}{\alpha} \Omega, \tag{39}$$

where $\phi^{SP} = \phi$ is used and Ω is a parameter given by $\Omega = (1-\alpha)B + \alpha\rho$. Additionally, by the constancy of the environmental quality along the BGP, equation (40) can be derived from $g_E = 0$, $g_{\lambda_4} = 0$, $\phi = \frac{x\theta\lambda_4 P}{\lambda_1 Z}$ and $P = \zeta \hat{Z}^{-x}$:

$$\hat{C} = \Lambda \hat{Z}^{1+x+x\psi}, \tag{40}$$

where Λ is a parameter given by $\Lambda = \frac{\phi(\delta+\rho)}{x\theta\eta_E}\left(\frac{\delta}{\theta}\right)^{\psi}\zeta^{-(1+\psi)}$.

Since by (37)-(39), (30) and (32) all the key variables ($\hat{C}$, $\hat{Y}$, $\hat{K}$, E, $\frac{l}{u}$) can be expressed as functions of the abatement investment ratio $\hat{Z}$, solving for the socially optimal BGP is reduced to finding the optimal $\hat{Z}$. The two equation system (39) and (40) serves this purpose. While (39) describes the desired relation of the two variables out of economic considerations, (40) relates economic considerations to the ecological equilibrium. Using the two equation system, Proposition 1 follows.

Proposition 1: Existence of a Unique Optimal BGP

Given the parameter values $B > \rho$, $x = \beta\gamma$, $x \geq \beta + 1$ and a sufficiently low disaster state environmental quality E_{min}, there is a unique socially optimal BGP with the optimal abatement investment ratio, denoted by Γ, that satisfies $\Gamma \geq \Gamma_{cri}$, where $\Gamma_{cri} = \left[\frac{\theta}{\delta(-E_{min})}\right]^{\frac{1}{x}}$.

Proof: See Appendix B.

Decentralized BGP

Along the decentralized BGP the following hold:

$$\hat{Y} = \frac{\phi^{CD}}{\alpha}\hat{Z} + \frac{1}{\alpha}B \tag{41}$$

$$\hat{C} = \frac{\phi^{CD}-\alpha}{\alpha}\hat{Z} + \frac{1}{\alpha}\Omega \tag{42}$$

$$\eta_s\gamma\hat{C} = \phi - \phi^{CD}\ . \tag{43}$$

Similar to the derivation of the socially optimal BGP, solving for the decentralized BGP requires solving the two equation system (42) and (43). We start with the special case $\eta_s = 0$. Without status concern, (43) is reduced to

$$\phi^{CD} = x\zeta\hat{\tau}\hat{Z}^{-x-1} = \phi. \tag{44}$$

from which we have

$$\hat{Z}^* = \left(\frac{x\zeta}{\phi}\hat{\tau}\right)^{\frac{1}{1+x}} . \tag{45}$$

That is, in the absence of status concern the abatement investment ratio along the decentralized BGP only depends on the pollution tax rate $\hat{\tau}$. Recall from earlier discussion that in this case the decentralized equilibrium corresponds to the social planer's solution if the pollution tax rate is set optimally. Since in the absence of status concern the optimal pollution tax rate should lead to the optimal abatement investment ratio Γ, from (45) we can derive the optimal pollution tax rate as

$$\hat{\tau}^* = \frac{\phi}{x\zeta}\Gamma^{x+1} , \tag{46}$$

which is unique by the uniqueness of Γ. We thus have the following proposition:

Proposition 2: Existence of a Unique Optimal Pollution Tax Rate if $\boldsymbol{\eta_s = 0}$

Given $B > \rho$, $x = \beta\gamma$, $x \geq \beta + 1$, a sufficiently low E_{min} and the absence of status concern ($\eta_s = 0$), there is a unique socially optimal pollution tax rate $\hat{\tau}^* = \frac{\phi}{x\zeta}\Gamma^{x+1}$, with which the decentralized economy reaches the socially optimal BGP.

We now turn to the more general case and continue our analyses conditional on a given pollution tax rate $\hat{\tau}$. We further express the actual pollution tax rate in terms of $\hat{\tau}^*$ by introducing the parameter ϵ ($\epsilon \geq 0$) as the ratio of actual pollution tax rate to optimal pollution tax rate:

$$\hat{\tau} = \epsilon\, \hat{\tau}^* = \epsilon \frac{\phi}{x\zeta}\Gamma^{x+1} \tag{47}$$

Using $\hat{\tau}^*$ as a benchmark, ϵ depicts the strictness of the pollution control policy (henceforth: policy strictness). In particular, $\epsilon = 0$ indicates zero pollution control, while a higher ϵ represents a higher actual pollution tax rate and thus more stringent pollution control. Corresponding to the critical abatement investment ratio, we also define the critical level of policy strictness ϵ_{cri} as

$$\epsilon_{cri} = \left(\frac{\Gamma_{cri}}{\Gamma}\right)^{x+1}. \tag{48}$$

Using the policy strictness parameter ϵ, ϕ^{CD} can be rewritten as

$$\phi^{CD} = \epsilon\phi\Gamma^{x+1}\hat{Z}^{-x-1}\,. \tag{49}$$

Plugging (49) into (42) and (43) and eliminating $\hat{C}$, we have $\Psi(\hat{Z}) = 0$, where $\Psi(\hat{Z})$ is a function of $\hat{Z}$ as given by

$$\Psi(\hat{Z}) = \alpha(\phi + \eta_s\gamma)\hat{Z} - (\alpha + \eta_s\gamma)\epsilon\phi\Gamma^{x+1}\hat{Z}^{-x} - \eta_s\gamma\Omega. \tag{50}$$

Analyzing the properties of $\Psi(\hat{Z})$ leads to the following proposition:

Proposition 3: Multiple Decentralized BGPs

A BGP exists in the decentralized economy as long as $\eta_s \geq \eta_{s_{cri}}$ is satisfied, where

$$\eta_{s_{cri}} = max\left\{\frac{\alpha\phi(1-\epsilon\epsilon_{cri}^{-1})}{\gamma[\epsilon\epsilon_{cri}^{-1}\phi-\alpha+\Omega\Gamma_{cri}^{-1}]}, 0\right\} \tag{51}$$

Under the above condition, there is a unique BGP for any given policy strictness ϵ, while multiple BGPs can exist corresponding to different levels of ϵ. Further, the abatement investment ratio $\hat{Z}^*$ increases with increasing ϵ, that is, $\frac{d\hat{Z}^*}{d\epsilon} > 0$.

Proof: See Appendix B.

4.2 *Impact of Conspicuous Conservation*

We have so far established the existence of the BGP and its conditions for the decentralized economy. To study the impact of conspicuous conservation, we now compare the decentralized BGP with and without status concern. For clarity, the decentralized economy without conspicuous conservation ($\eta_s = 0$) is referred to as the benchmark economy. In order to be able to compare the absolute level of the key variables, we also assume the same initial human capital (H_0) at the beginning of the BGP for both the benchmark economy and the economy with conspicuous conservation. Since the growth rate of human capital along the BGP is independent of the status concern (see (29)), the human capital level of the two economies will always be equal.

Environment Quality

Since along the BGP condition (32) always hold, environmental quality is a monotonically increasing function of the equilibrium abatement investment ratio:

$$E^* = -\frac{\theta}{\delta}\zeta \hat{Z}^{*^{-x}} . \tag{52}$$

To assess the environmental impact of conspicuous conservation we only need to analyze how the equilibrium abatement investment ratio changes with status-seeking conservation effort. Implicit differentiation of $\Psi(\hat{Z})$ leads to

$$\frac{d\hat{Z}^*}{d\eta_s} = -\frac{\partial\Psi}{\partial\eta_s}/\left(\frac{\partial\Psi}{\partial\hat{Z}}\right) > 0, \quad \forall\, \eta_s \geq 0, \tag{53}$$

where

$$\frac{\partial\Psi}{\partial\hat{Z}} = \alpha(\phi + \eta_s\gamma) + x\eta_s\gamma\phi^{CD} > 0 \tag{54}$$

$$\frac{\partial\Psi}{\partial\eta_s} = \alpha\gamma\hat{Z} - \gamma\phi^{CD}\hat{Z} - \gamma\Omega = -\alpha\gamma\hat{C} < 0 . \tag{55}$$

Thus, we also have $\frac{dE^*}{d\eta_s} > 0$ so that environmental quality is also an increasing function of the degree of status concern and the following proposition holds:

Proposition 4: Environmental Impact

Assume $\eta_s \geq \eta_{s_{cri}}$ is satisfied, the environmental quality along the decentralized BGP is an increasing function of the degree of status concern, and conspicuous conservation always leads to higher environmental quality.

The result in Proposition 4 is hardly surprising. As we have discussed before, Equation (20) shows that the total return of abatement capital includes both its financial and status return. While the financial return is determined by pollution taxation, the status return depends crucially on the degree of the individuals' status concern. For any given policy strictness and thus a given level of financial return, whether more or less will be invested into abatement capital thus depends on how much individuals care about the status signal their holding of abatement capital generates. As individuals' status concern increases, the total return of abatement capital rises and the status conscious individuals will invest more into abatement capital, which in turn leads to a higher environmental quality.

A special case is when $\epsilon = 0$, that is, if pollution control is absent. In this case, firms will not rent any abatement capital so that the competitive rent for abatement capital will be zero. Investing into abatement capital thus does not provide any financial benefit, but is instead a sort of charity. Abatement capital holding in this case is solely rewarded by the status gain it generates. If individuals care enough about their social status (i.e. if $\eta_s \geq \eta_{s_{cri}}$), conspicuous conservation can lead to a sufficiently high abatement investment ratio that a decentralized BGP can exist even without pollution control. This highlights the role of conspicuous conservation as an alternative incentive source in regulating environmental issues.

Production, Leisure, and Consumption

By (41) and (49), output per unit of productive capital $\hat{Y}^*$ is a monotonically decreasing function of the equilibrium abatement investment ratio according to

$$\hat{Y}^* = \frac{1}{\alpha}\epsilon\phi\Gamma^{x+1}\hat{Z}^{*^{-x}} + \frac{1}{\alpha}B, \tag{56}$$

which together with (53) suggests $\frac{d\hat{Y}^*}{d\eta_s} < 0$, that is, output per unit of productive capital decreases with the degree of status concern. Since the consumption to output ratio $\frac{C^*}{Y^*}$ is both increasing in $\hat{Y}^*$ and decreasing in $\hat{Z}^*$ according to

$$\frac{C^*}{Y^*} = \frac{\hat{C}^*}{\hat{Y}^*} = 1 - \frac{\hat{Z}^*}{\hat{Y}^*} - \frac{g_K}{\hat{Y}^*}, \tag{57}$$

$\frac{d\left(\frac{C^*}{Y^*}\right)}{d\eta_s} < 0$ must hold and the ratio $\frac{C^*}{Y^*}$ decreases as status concern becomes stronger. Consequently, by condition (30), $\frac{d\left(\frac{l^*}{u^*}\right)}{d\eta_s} < 0$ and $\frac{du^*}{d\eta_s} > 0$ both hold and higher status concern leads to longer working time. Further, since by (37) productive capital per unit of effective labor $\widehat{K}^*$ decreases with $\widehat{Y}^*$ and thus increases with η_s, the productive to human capital ratio $\frac{K^*}{H^*} = u^*\widehat{K}^*$ will also increase, as status concern becomes stronger. Compared to the benchmark economy, conspicuous conservation thus leads to higher $\frac{K^*}{H^*}$, u^*, and lower $\frac{C^*}{Y^*}$. Starting from the same initial human capital level, the next proposition thus obviously holds:

Proposition 5: Impact on Production, Leisure and Consumption

Assume $\eta_s \geq \eta_{s_{cri}}$ is satisfied, starting from the same initial human capital H_0, conspicuous conservation leads to higher productive capital K, working time u (lower leisure l) and aggregate output Y. The dirtiness of technology, as measured by $\frac{K}{H}$, also increases. Due to the decrease in the consumption to output ratio $\frac{C}{Y}$, the impact on absolute consumption C, is ambiguous.

Thus, although conspicuous conservation leads to relatively more abatement investment (higher $\hat{Z}^*$), status comparison also paradoxically results in both a higher dirtiness of technology, as measured by the ratio $\frac{K}{H}$, and a higher absolute level of the polluting factor K. In the race of individuals to hold more abatement capital than others, the need for higher income increases. In order to keep up with the rest of the economy, individuals sacrifice their leisure time and invest more in the dirty productive capital to generate sufficient income for holding more abatement capital. A higher portion of their income will be spent for pollution abatement, leaving less for consumption, although the net impact on absolute consumption is ambiguous due to the increased income. These impacts will be further strengthened as the degree of status concern becomes higher. As social status becomes more important, more productive capital will be built up and longer working time will apply. Individuals will invest an increasing portion of their increased income in abatement to keep up with the status race.

Although the higher gross pollution caused by the increased use of the dirty factor is more than offset by the status driven conservation efforts and the resulting environmental quality is higher compared to the benchmark economy, the simultaneous increase of gross pollution and abatement as well as the reduced leisure time still hint on potential wastefulness. Thus, while its net environmental impact is positive, the side effect of increased technology dirtiness, production and gross pollution shows that the "Jevons Paradox" type of concerns are not completely unsubstantial.

Welfare

For the assessment of the welfare impact along the BGP, we only need to compare the instantaneous utility of the representative individual, since the growth rates for all utility components along the BGP are known constants. The ex-post instantaneous utility of the representative individual along the decentralized BGP for any given ϵ is given by

$$U^* = \ln C^* + \eta_l \ln(Hl^*) - \eta_E \frac{(-E^*)^{1+\psi}}{1+\psi}, \tag{58}$$

which can be further manipulated to yield

$$U^* = \left[\ln\left(\frac{C^*}{H^*}\right) + \eta_l \ln(l^*) - \eta_E \frac{(-E^*)^{1+\psi}}{1+\psi}\right] + (1+\eta_l)\ln H \tag{59}$$

where E^* is given by (52), and

$$\frac{C^*}{H^*} = \hat{C}^* * \hat{K}^* * u^* = \hat{C}^* * \hat{K}^* * \frac{\rho}{B}\left(1 + \frac{l^*}{u^*}\right)^{-1} \tag{60}$$

$$l^* = \frac{\rho}{B}\left(1 + \left(\frac{l^*}{u^*}\right)^{-1}\right)^{-1}. \tag{61}$$

Notice that the terms in the square bracket in (59) are all constants along the BGP, while the term outside of the bracket increases with time as the level of human capital increases. The welfare comparison thus reduces to the comparison of the constant terms of the instantaneous utility functions for the two economies. More precisely, the welfare impact of conspicuous conservation will depend on the direction and magnitude of its impact on the ratios $\hat{C}^*$, $\hat{K}^*$, $\frac{l^*}{u^*}$ and $\hat{Z}^*$ along the

BGP. Since U^* is a function of the policy strictness ϵ, the impact of conspicuous conservation also depends on ϵ. For analytical tractability, we restrict the analysis to the range of η_E that is reasonably large according to Assumption 1.

Assumption 1

Environmental concern is sufficiently important so that when environmental quality is at its lowest level in the decentralized economy with conspicuous conservation, increasing policy strictness increases the overall welfare, that is, $U_\epsilon(\epsilon = 0, \eta_s \geq \eta_{s_{cri}}, \eta_E) > 0$.

Assumption 1 requires that the environmental concern is at least large enough so that when environmental quality is too low, people would want to trade consumption and leisure for improved environmental quality. This is a plausible assumption, if we observe from reality that increased environmental consciousness and tighter conservation policies often accompany severe environmental degradation and disasters. Under assumption 1, the next proposition can be proved.

Proposition 6: Welfare Impact when $\epsilon \leq 1$

Given $\eta_s \geq \eta_{s_{cri}}$, $\epsilon \leq 1$ *and* η_E *satisfying Assumption 1, the overall welfare exhibits an inverted U-shape with respect to the policy strictness* ϵ, *with the welfare maximum achieved at* $\epsilon^* = 1$ *for the benchmark economy and at* $\hat{\epsilon} < 1$ *for the economy with conspicuous conservation. Compared to the benchmark economy, conspicuous conservation is first welfare increasing but eventually leads to lower welfare, as the policy strictness* ϵ *increases. The level of the policy strictness* $\tilde{\epsilon}$ *that equates the welfare of the benchmark economy with the status-seeking economy satisfies* $\epsilon_{cri} \leq \tilde{\epsilon} < 1$.

Proof: see Appendix B.

The above analysis reveals that the impact of conspicuous conservation on the overall welfare depends on the existing pollution control. If we concern ourselves with the empirically most relevant range of the policy strictness parameter, that is,

$\epsilon \leq 1$, Proposition 6 establishes that conspicuous conservation has positive welfare impact when pollution control is absent or weak, but negative impact once existing pollution control becomes sufficiently strong. The intuition behind this result is that by providing status incentive for abatement investment, conspicuous conservation encourages pollution abatement and increases environmental quality. Compared to the benchmark economy, however, there is generally an overuse of the resources (e.g. forgone consumption and leisure) for pollution abatement. Nevertheless, when environmental quality is low, the marginal benefit of increasing environmental quality is so high that it surpasses the costs of overusing economic resources. As environmental quality increases with increasing policy strictness, the effect of increasing abatement and environmental quality is outweighed by the overuse of economic resources for abatement and the overall welfare is lowered.

Summarizing the analysis so far, we see that conspicuous conservation is a desirable phenomenon as far as improving environmental quality is concerned, since it always encourages pollution abatement. However, the improvement of environmental quality is not undertaken at the most efficient way. At low levels of environmental quality, such inefficiency is tolerated since environmental protection would be the priority of society. As environmental quality improves, however, such inefficiency eventually becomes a burden to the society.

4.3 *Numerical Example*

To enable a better grasp of the analytical results, this section provides a numerical example of the model, where the environmental externality is modeled in terms of carbon emission (P) and atmospheric CO2 concentration (E). Beside the varying parameter ϵ, the derivation of the analytical results involves a total of 14 parameters (α, A, B, ρ, x, γ, μ, E_{max}, E_{min}, θ, δ, ψ, η_E and η_l). The parameter values are chosen as follows. The output elasticity of productive capital (α) is set to the commonly used value of $1/3$ (see e.g. Gradus and Smulders, 1993), approximating the observed value in the US economy. The productivity parameters for final output (A) and human capital (B) are set to 1 and 0.05, respectively, consistent with Gradus and Smulders (1993) and Benhabib and Perli (1994). To generate a 2% long-term growth rate in per capita income, the time preference rate ρ is set to 0.03. The pollution elasticity with respect to productive capital (x) is assumed to be 3. The pollution elasticity of abatement capital (β) is assumed to be 1.25 for the baseline scenario, whereas 1 and 1.5 are used for sensitivity analysis.[6] The parameter γ is then calculated as $\gamma = \frac{x}{\beta}$, and the abatement capital accumulation productivity μ is set to 0.5.

The environmental quality variable E is interpreted as the deviation of actual CO2 concentration from the pre-industrial CO2 concentration of 280 ppm (parts per million). E can thus also be seen as the excess level of atmospheric CO2 concentration. For the lower bound of environmental quality, we follow Acemoglu et al. (2012) and use a 6 degree (Celsius) increase in temperature as the absolute disaster state and apply the same approximation[7] to come to an atmospheric CO2 concentration of 1120 ppm, or $\mathrm{E_{min}} = -840$ ppm.

The pollution variable P depicts carbon emission and is measured in units of PgC (Petagram of carbon). Using the conversion ratio of 2.13 PgC for 1 ppm of atmospheric CO2 (Trenberth, 1981) and assuming a pollution absorption rate of 55% by ocean and land (IPCC, 2014), a depletion rate of $\theta = 0.2113$ is calculated. For the regeneration rate parameter δ, Greiner et al. (2009) use the inverse of the atmospheric lifetime of greenhouse gases as the environment's regeneration rate. While CO2 does not have a uniform lifetime, IPCC (2014) points to a lifetime range of (10, 200) years. While Greiner et al. (2009) use a regeneration rate of 0.01 for the entire carbon in the atmosphere, this rate should be significantly higher if

[6] Note that the varying values of β must satisfy the condition $\beta \leq x - 1$

[7] The approximation predicts a 3 degree (Celsius) temperature increase (compared to the preindustrial level) for any doubling of CO2 concentration.

the variable E only considers "excess carbon". We choose a regeneration rate of $\delta = 0.1$, while using the values of 0.05 and 0.15 for sensitivity analysis.

For the parameters ψ and η_E in consumer preference, we follow Gradus and Smulders (1993) and set $\psi = 1$ and $\eta_E = 0.01$ in the baseline scenario, while $\eta_E = 0.005$ and 0.05 are used in sensitivity analysis. The utility weight of quality leisure (η_l) is calibrated to be 2 so that working time u along the socially optimal BGP in the baseline scenario will be approximately 0.18. Assuming a daily time endowment of 14 hours[8], $u = 0.18$ is equivalent to 900 working hours per year, which is between the total working hours per year for an average American and that of an average French in working age (see Alesina et al., 2005).

With the parameter values given above, Table 1 gives the values of Γ, Γ_{cri}, $\hat{\tau}^*$, and ϵ_{cri} for the baseline and the sensitivity analyses. For both the baseline and all the sensitivity analyses, while only a very low pollution tax rate is needed to warrant the existence of a BGP in the benchmark economy ($\hat{\tau}_{cri} = \epsilon_{cri}\hat{\tau}^*$), to reach the social optimum, a substantial amount of resource will need to be invested into pollution abatement (Γ ranging from 0.16 to 0.34). Comparing the different scenarios, we also see that the optimal abatement investment ratio increases with the degree of environmental concern (η_E), but decreases with the regeneration rate (δ) and the pollution reduction efficiency of abatement capital (β).

In Table 2, the values of $\eta_{s_{cri}}$ are provided for varying levels of policy strictness ϵ. For all scenarios, to support a BGP a positive status concern is only needed when pollution control is absent or ϵ is extremely low. As pollution control becomes more stringent, $\eta_{s_{cri}}$ gradually decreases and eventually becomes zero.

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[8] Assuming 10 hour raw leisure time (e.g. sleeping, having meals etc.) needed for physical maintenance, the total time endowment will be 14 hours per day.

Compared to the baseline scenario, according to (51), $\eta_{s_{cri}}$ will increase, if ϵ_{cri} becomes higher, as is in the case with a lower η_{E}, δ or β.

Table 1: Optimal vs. Threshold Abatement and Pollution Taxation

	Base-line	Varying $\boldsymbol{\eta_E}$		Varying $\boldsymbol{\delta}$		Varying $\boldsymbol{\beta}$	
		0.005	**0.05**	**0.05**	**0.15**	**1**	**1.5**
$\boldsymbol{\Gamma}$	0.210	0.172	0.336	0.247	0.189	0.271	0.160
$\boldsymbol{\Gamma_{cri}}$	0.051	0.051	0.051	0.065	0.045	0.07	0.038
$\boldsymbol{\hat{\tau}^*}$	1.97 %	0.88%	12.99%	3.76%	1.29%	2.26%	1.68%
$\boldsymbol{\epsilon_{cri}}$	0.35%	0.79%	0.05%	0.47%	0.32%	0.37%	0.34%

Baseline: $\alpha = 1/3$, $A = 1$, $\mathrm{B} = 0.05$, $\rho = 0.03$, $\theta = 0.2113$, $\delta = 0.1$, $\mathrm{x} = 3$, $\gamma = 2.4$ $(\beta = 1.25)$, $\psi = 0.1$, $\eta_{\mathrm{E}} = 0.01$, $\eta_{\mathrm{l}} = 2$, $\mathrm{E_{max}} = 0$, $\mathrm{E_{min}} = -840$

Table 2: Threshold Status Concern $\boldsymbol{\eta_{s_{cri}}}$ at Varying Level of $\boldsymbol{\epsilon}$

	Base-line	Varying $\boldsymbol{\eta_E}$		Varying $\boldsymbol{\delta}$		Varying $\boldsymbol{\beta}$	
		0.005	**0.05**	**0.05**	**0.15**	**1**	**1.5**
$\boldsymbol{\epsilon = 0}$	0.44	0.44	0.44	0.67	0.36	0.53	0.37
$\boldsymbol{\epsilon = 0.1\%}$	0.17	0.27	0	0.26	0.13	0.17	0.16
$\boldsymbol{\epsilon = 0.2\%}$	0.07	0.18	0	0.12	0.05	0.07	0.06
$\boldsymbol{\epsilon = 0.3\%}$	0.02	0.12	0	0.06	0.005	0.02	0.01
$\boldsymbol{\epsilon = 0.4\%}$	0	0.08	0	0.02	0	0	0
$\boldsymbol{\epsilon = 0.5\%}$	0	0.05	0	0	0	0	0

Baseline: $\alpha = 1/3$, $A = 1$, $\mathrm{B} = 0.05$, $\rho = 0.03$, $\theta = 0.2113$, $\delta = 0.1$, $\mathrm{x} = 3$, $\gamma = 2.4$ $(\beta = 1.25)$, $\psi = 0.1$, $\eta_{\mathrm{E}} = 0.01$, $\eta_{\mathrm{l}} = 2$, $\mathrm{E_{max}} = 0$, $\mathrm{E_{min}} = -840$

The environmental impact of conspicuous conservation is illustrated by Figure 1, where a higher environmental quality corresponds to a lower atmospheric CO2 concentration. For better visibility, Figure 1 only shows the lower part (CO2 concentration between 280 and 500 ppm) of the entire figure. Compared to the benchmark economy, conspicuous conservation unambiguously leads to a higher environmental quality along the BGP independent of existing pollution control. And the stronger the status concern, the better the environmental quality will be, although the differences are negligible between the different status scenarios.

Figure 1: Environmental Impact

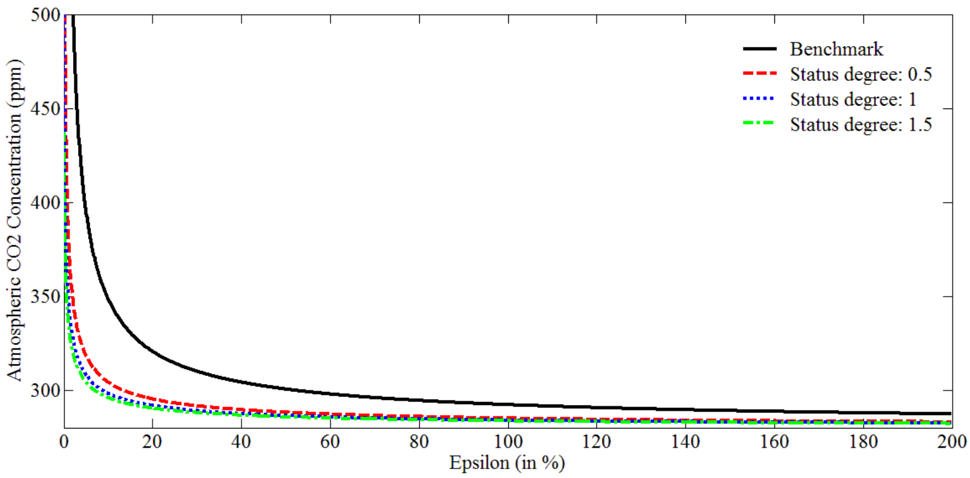
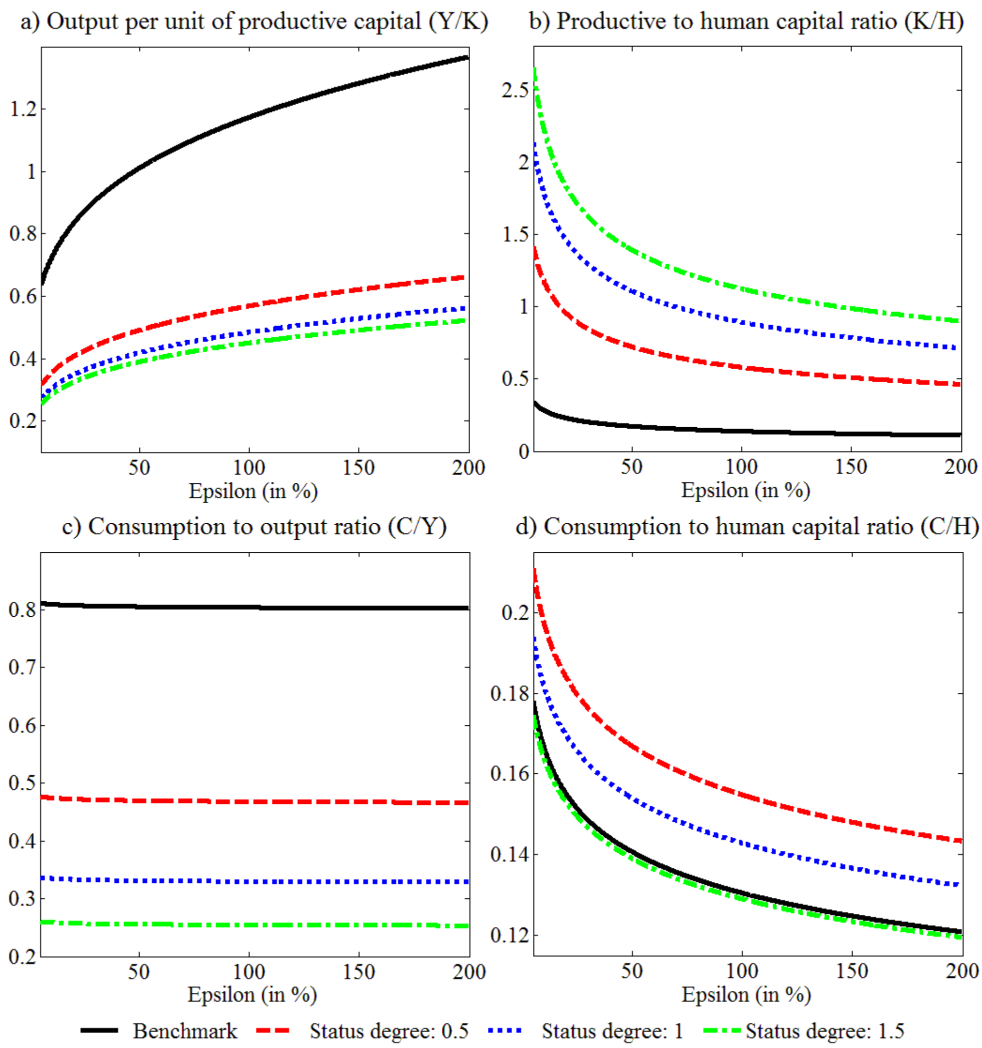


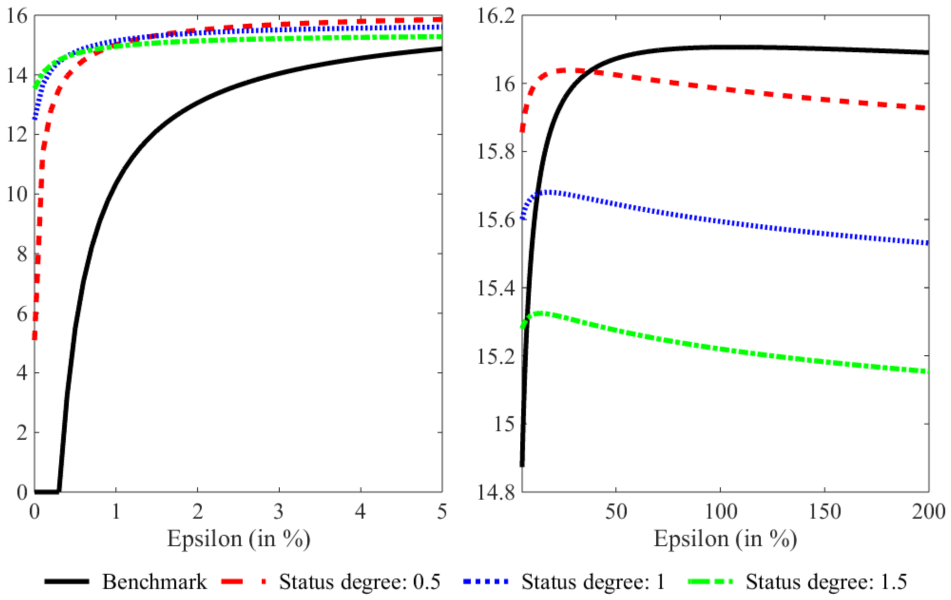
Figure 2 presents the impact of conspicuous conservation on the key economic variables. In Panel a), the lower output per unit of productive capital $\frac{Y}{K}$ shows that conspicuous conservation greatly reduces the productivity of the polluting factor K at equilibrium, and the reduction is greater with stronger status concern. The dirtiness of production technology $\frac{K}{H}$, on the other hand, becomes much higher as shown in Panel b). While in the benchmark economy $\frac{K}{H}$ is lower than 0.5 for most policy strictness levels, with conspicuous conservation the ratio is much larger than 0.5 and could reach 1.5 ($\eta_s = 0.5$) at low level of pollution control. The effect is amplified as the degree of status concern increases. Panel c) shows a large decrease in consumption ratio $\frac{C}{Y}$ with conspicuous conservation. While over 80% of the final output is consumed in the benchmark economy, depending on the strength of status concern, conspicuous conservation leads to a consumption ratio of less than 50%, 40% and 30%, respectively. Finally, the ambiguous effect on absolute consumption is revealed in Panel d) (since the human capital level H is always identical between the two economies), where conspicuous conservation first increases but eventually decreases consumption level as status concern becomes stronger.

Figure 2: Impact on Key Economic Variables



In Figure 3, the welfare impact of conspicuous conservation is illustrated. In all scenarios, the welfare is calculated according to equation (59), where the term $(1 + \eta_l) \ln H$ is set to an arbitrary positive number 20 in all scenarios. For better visibility, the left panel of Figure 3 shows the different welfare curves at extremely low policy strictness ($\epsilon \leq 5\%$), while in the right panel welfare curves are shown for $\epsilon > 5\%$. The impact on the overall welfare, as obvious in Figure 3, depends on the policy strictness ϵ. While conspicuous conservation leads to higher welfare at low policy strictness, it becomes welfare reducing once existing pollution control becomes sufficiently stringent. The turning point of the welfare impact is reached at a policy strictness level of ca. 40% with $\eta_s = 0.5$, and it becomes lower as η_s increases. Thus, even though conspicuous conservation improves welfare when pollution control is absent or very weak, this welfare-increasing effect could be offset rather fast as pollution control becomes more stringent. This is particularly true if the degree of status concern is high. Further, once the pollution control is beyond the extremely low level (e.g. if $\epsilon > 5\%$), the welfare with conspicuous conservation decreases with increasing degree of status concern. Based on Figure 3, it seems that as long as the pollution control is not completely absent or extremely low, high degree of status comparison is not generally helpful. However, if existing pollution control is rather weak, moderate degree of conspicuous conservation could enhance welfare and should be encouraged.

Figure 3: Welfare Impact



5 Discussion

In order for the economic output to exhibit continuous growth without depleting the environment, it is important that sufficient resources will be spent on pollution abatement, which in a decentralized economy in turn requires sufficient incentives be provided for the agents to conduct abatement. Given the utility function in our model, there could be a few different motivations for environmental conservation: pure altruism (the component E), status effect (the component $\frac{G}{\bar{G}}$), and financial incentives (through its impact on the component C). In the decentralized economy, as a consequence of the public good nature of environmental quality, the pure altruistic motive cannot find its expression in actions. Thus only the latter two sources of incentives are potentially feasible without a benevolent social planer.

In this paper, we have especially explored the role of status comparison as an alternative incentive source beside financial incentives. From the BGP analysis, we see that, theoretically, for the existence of BGP and for inducing sufficient pollution abatement, one of the two incentives will suffice. We have further shown that conspicuous conservation has some undesirable side effects such as increasing the dirtiness of technology and encouraging the use of the polluting factor. Compared to conspicuous conservation, pollution taxation thus has the clear advantage of internalizing environmental externality without additional distortion. Nevertheless, when optimal taxation is unfeasible, conspicuous conservation could prove powerful in helping to provide the environmental public goods. This is particularly true in the case of insufficient financial incentives such as in the lack of governance in general (e.g. the case of global environmental issues) or in the presence of blockage by certain interest groups. As we see in the equilibrium analysis, while without status concern investment into abatement capital must generate the same marginal financial return as productive capital, with conspicuous conservation there could be a gap between the marginal financial returns of the two. The additional incentives through status comparison can thus compensate the insufficient financial incentives. The gap in the financial incentives of productive and abatement capital could further be larger if a stronger status concern is present.

Further, in light of norm evolution, as individuals strive to increase their social ranking, the general perception of acceptable behavior could change over time, leading to a positive feedback effect on environmental protection. The mechanism of conspicuous conservation can be more clearly illustrated if we decompose the status component of the unity function further:

$$\eta_s \ln \frac{G}{\bar{G}} = \eta_s \ln(G) - \eta_s \ln(\bar{G}), \tag{62}$$

where $\eta_s \ln(G)$ is a warm glow component, and $\eta_s \ln(\bar{G})$ is the social influence component in the status-seeking green behavior. On one hand, through the warm glow component, conspicuous conservation translates the preference for a public environmental good into the preference for a private environmental conservation activity, and thus offers a possibility to avoid (at least partially) the public good issue in environmental good provisioning. Since warm glow puts a psychological value to environmental conservation itself, conspicuous conservation potentially also enjoys a higher permanence compared to pollution taxation. On the other hand, through the social influence component, conspicuous conservation offers another channel to alleviate the free-rider problem associated with environmental public good by providing a channel for individuals to influence others' behavior.

Taking together, conspicuous conservation should thus be valued as a means to promote environmental protection, although cautions are needed for the suitability of its application. Despite its undesirable side effects, conspicuous conservation should be especially encouraged when pollution control is weak. Its potential positive feedback effects further strengthens its effectiveness.

As a final remark, we want to point out that while conspicuous conservation offers a completely different reason for environmental protection, having environmental conservation as a status channel ultimately still reveals the society's environmental awareness and consciousness. As Ridgeway and Walker (1995, p.281) point out, social status involves "actors' implicit valuations of themselves and one another according to some shared standard of value". The existence of conspicuous conservation therefore also reflects a shared value in society concerning environmental sustainability.

6 Conclusion

In this paper, we have studied the long-term impact of conspicuous conservation by adopting a two-sector Uzawa-Lucas model with leisure choice, environmental externality and status-seeking green wealth, as represented by one’s holding of abatement capital relative to the average abatement capital in society. The impact of conspicuous conservation on the BGP is analyzed by comparing the BGP with and without conspicuous conservation. It is found that conspicuous conservation always increase pollution abatement and environmental quality, but not necessarily takes the most efficient route to achieve this goal. The impact on the overall welfare is nevertheless positive at low level of environmental quality, but becomes negative as environmental quality improves. The numerical example further suggests that moderate status concerns would be generally more desirable than strong ones unless the pollution control is completely absent or extremely low.

Despite its undesirable side effects, conspicuous conservation should still be considered a valuable means in regulating environmental issues. We suggest that the conspicuous conservation behavior be encouraged when there is a lack of environmental governance or when there are strong interest group activities against other more efficient environmental instruments such as pollution taxation. We further suggest taking the potential positive dynamic feedback effects into account when evaluating the desirability of conspicuous conservation.

While our model has enabled a better understanding of the conspicuous conservation phenomenon, status-seeking environmental protection behavior deserves further studies and investigations. In particular, future studies focusing on the impact of conspicuous conservation in the transitional dynamics, small open economy settings, and heterogeneous agent frameworks are needed. Additional insights from the empirical studies are also highly necessary and beneficial for understanding the phenomenon more in depth.

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Appendix A: The Intermediate Value Theorem (IVT)

The Intermediate Value Theorem (IVT) given below is used repeatedly in the analysis:

Theorem 3.1 (Fuente 2000, p. 219)

Let $f: R \longrightarrow R$ be a continuous function on the interval I. Given two points in I, x' and x'', with images y' and y'', for each number y between y' and y'' there exists some point x in I, lying between x' and x'', such that $f(x) = y$.

Appendix B: Proofs of the Propositions

Proof of Proposition 1

The existence of a BGP requires $E^* = -\frac{\theta}{\delta}P^* = -\frac{\theta}{\delta}\zeta\Gamma^{-x} > E_{min}$, so that $\Gamma \geq \left[\frac{\theta}{\delta(-E_{min})}\right]^{\frac{1}{x}}$ is derived. Eliminating $\hat{C}$ in (39) and (40), we have $\Psi^{SP}(\hat{Z}) = 0$, where

$$\Psi^{SP}(\hat{Z}) = \alpha\Lambda\hat{Z}^{1+x+x\psi} - (\phi - \alpha)\hat{Z} - \Omega \, . \tag{A1}$$

Since $\Psi^{SP}(\hat{Z})$ is a continuous function of $\hat{Z}$ on the domain $(0, \infty)$ and since $\lim_{\hat{Z}\to 0} \Psi^{SP}(\hat{Z}) = -\Omega < 0$ and $\lim_{\hat{Z}\to\infty} \Psi^{SP}(\hat{Z}) = \infty$ hold, the existence of solutions to $\Psi^{SP}(\hat{Z}) = 0$ follows from the IVT. The uniqueness of the solution is further established by noting that the solution can only exist on the monotonically increasing branch of the function $\Psi^{SP}(\hat{Z})$.

Proof of Proposition 3

For any given ϵ, the existence of solution to the equation $\Psi(\hat{Z}) = 0$ with $\Psi(\hat{Z})$ given by (50) is easily established by the IVT, since the continuous function $\Psi(\hat{Z})$ satisfies $\lim_{\hat{Z}\to 0} \Psi(\hat{Z}) = -\infty$ and $\lim_{\hat{Z}\to\infty} \Psi(\hat{Z}) = \infty$. The solution is further unique for a given ϵ, since by

$$\frac{\partial\Psi(\hat{Z})}{\partial\hat{Z}} = \alpha(\phi + \eta_s\gamma) + x(\alpha + \eta_s\gamma)\phi^{CD} > 0, \tag{A2}$$

the function $\Psi(\hat{Z})$ is monotonically increasing in $\hat{Z}$.

The existence of BGP further requires $\hat{Z}^* \geq \Gamma_{cri}$. By $\Psi(\hat{Z}) = 0$ and the monotonicity of $\Psi(\hat{Z})$, we thus have $\Psi(\Gamma_{cri}) \leq 0$, from which we can derive

$$\eta_s \geq \frac{\alpha\phi(1-\epsilon\epsilon_{cri}^{-1})}{\gamma[\epsilon\epsilon_{cri}^{-1}\phi-\alpha+\Omega\Gamma_{cri}^{-1}]} \tag{A3}$$

the right hand side of which will be negative if $\epsilon \geq \epsilon_{cri}$. Thus for any given ϵ, the existence of BGP requires $\eta_s \geq \eta_{s_{cri}}$ with $\eta_{s_{cri}}$ given by (51). Further, as long as $\eta_s \geq \eta_{s_{cri}}$ holds, for different ϵ's, implicit differentiation leads to

$$\frac{d\hat{Z}^*}{d\epsilon} = -\frac{\partial\Psi}{\partial\epsilon}\Big/\left(\frac{\partial\Psi}{\partial\hat{Z}}\right) > 0, \tag{A4}$$

where $\frac{\partial\Psi}{\partial\hat{Z}} > 0$ holds by (A2) and

$$\frac{\partial\Psi}{\partial\epsilon} = -(\eta_s\gamma + \alpha)\phi\Gamma^{x+1}\hat{Z}^{-x} < 0\ . \tag{A5}$$

Proof of Proposition 6

Since direct differentiation of U with respect to η_s is rather difficult, we take an alternative route for the analysis. Differentiating U with respect to ϵ, we have

$$U_\epsilon = \frac{d\hat{Z}}{d\epsilon}\frac{1}{\hat{C}\,\hat{Y}}\frac{1}{\alpha+\eta_s\gamma}D, \tag{A6}$$

where

$$D = D1 + D2 + D3 \tag{A7}$$

$$D_1 = -\frac{\rho(\gamma-1)}{\gamma}\frac{1+\eta_l}{1+\frac{l}{u}} \quad \text{(A8)}$$

$$D_2 = -\frac{\alpha}{1-\alpha}(\phi + \eta_s\gamma)\hat{C} \quad \text{(A9)}$$

$$D_3 = \eta_E x(\alpha + \eta_s\gamma)\left(\frac{\theta}{\delta}\zeta\right)^{1+\psi}\hat{Z}^{-(1+x+x\psi)}\hat{C}\hat{Y} \quad \text{(A10)}$$

and $\frac{d\hat{Z}}{d\epsilon} > 0$ by Proposition 3. Since the terms on the right hand side of (A6) are all always positive except for D, the sign of U_ϵ depends on whether D is positive, zero or negative. Differentiating D with respect to ϵ and η_s, respectively, we have

$$\frac{dD}{d\epsilon} = \frac{dD_1}{d\epsilon} + \frac{dD_2}{d\epsilon} + \frac{dD_3}{d\epsilon} < 0, \quad \text{(A11)}$$

$$\frac{dD}{d\eta_s} = \frac{dD_1}{d\eta_s} + \frac{dD_2}{d\eta_s} + \frac{dD_3}{d\eta_s} < \left[-D\left(\frac{1}{\hat{Y}}\frac{1}{\alpha}x\phi_s\right)\right]\frac{d\hat{Z}}{d\eta_s} < 0, \text{ if} > 0\ . \quad \text{(A12)}$$

where

$$\frac{dD_1}{d\epsilon} = \left[D_1\frac{\frac{l}{u}}{1+\frac{l}{u}}\frac{1}{\hat{C}\hat{Y}}\frac{\rho}{\alpha+\eta_s\gamma}\frac{\gamma-1}{\gamma}\right]\frac{d\hat{Z}}{d\epsilon} < 0 \quad \text{(A13)}$$

$$\frac{dD_2}{d\epsilon} = \left[\frac{D_2}{\hat{C}}\frac{\phi-\alpha}{\alpha+\eta_s\gamma}\right]\frac{d\hat{Z}}{d\epsilon} < 0 \quad \text{(A14)}$$

$$\frac{dD_3}{d\epsilon} = D_3\left[-\frac{1+x+x\psi}{\hat{Z}}\frac{d\hat{Z}}{d\epsilon} + \frac{1}{\hat{C}}\frac{\phi-\alpha}{\alpha+\eta_s\gamma} + \frac{1}{\hat{Y}}\frac{\phi+\eta_s\gamma}{\alpha+\eta_s\gamma}\right]\frac{d\hat{Z}}{d\epsilon} < \left[-D_3\frac{x(1+\psi)-1}{\hat{Z}}\right]\frac{d\hat{Z}}{d\epsilon} < 0 \quad \text{(A15)}$$

$$\frac{dD_1}{d\eta_s} = \left[D_1\frac{\frac{l}{u}}{1+\frac{l}{u}}\left(\frac{1}{\hat{C}}\left(\frac{1}{\alpha}x\phi_s + 1\right) - \frac{1}{\hat{Y}}\frac{1}{\alpha}x\phi_s\right)\right]\frac{d\hat{Z}}{d\eta_s} < \left[-D_1\left(\frac{1}{\hat{Y}}\frac{1}{\alpha}x\phi_s\right)\right]\frac{d\hat{Z}}{d\eta_s} \quad \text{(A16)}$$

$$\frac{dD_2}{d\eta_s} = \left[D_2\left(\frac{1}{\hat{C}}\frac{\phi-\alpha}{\alpha+\eta_s\gamma}\right)\frac{1}{\alpha}x\phi_s\right]\frac{d\hat{Z}}{d\eta_s} < \left[-D_2\left(\frac{1}{\hat{Y}}\frac{1}{\alpha}x\phi_s\right)\right]\frac{d\hat{Z}}{d\eta_s} \quad \text{(A17)}$$

$$\frac{dD_3}{d\eta_s} = D_3\left[-\frac{1+x+x\psi}{\hat{Z}}\frac{d\hat{Z}}{d\epsilon} + \frac{1}{\hat{C}}\frac{\phi-\alpha}{\alpha+\eta_s\gamma} + \frac{1}{\hat{Y}}\frac{\phi+\eta_s\gamma}{\alpha+\eta_s\gamma}\right]\frac{d\hat{Z}}{d\eta_s} < -D_3\left[\left(\frac{1}{\hat{Y}}\frac{1}{\alpha}x\phi_s\right)\right]\frac{d\hat{Z}}{d\eta_s} \quad \text{(A18)}$$

and $\frac{d\hat{Z}}{d\eta_s} > 0$ holds by Proposition 4.

Denote the welfare of the benchmark economy and the economy with conspicuous conservation by U^{BM} and U^{CC}, respectively. By Proposition 2, $U_\epsilon^{BM}(\epsilon = 1) = 0$ so that $D^{BM}(\epsilon = 1) = 0$. By (A11), $U_\epsilon^{BM}(\epsilon_{cri} \leq \epsilon < 1) > 0$ and

$U_{\epsilon}^{\mathrm{BM}}(\epsilon > 1) < 0$ hold so that as ϵ increases $\mathrm{U}_{\epsilon}^{\mathrm{BM}}$ will first be positive but eventually becomes zero and then negative. Similarly, since under Assumption 1 $D^{\mathrm{CC}}(\epsilon = 0) > 0$ hold, by (A11) U^{CC} will also first increase and then decrease with ϵ. Thus both in the benchmark economy and the economy with conspicuous conservation, the welfare function will be an inverse U-shaped function of ϵ. Further, since by (A12) $\mathrm{D}^{\mathrm{CC}} = 0$ is reached at a lower ϵ, the welfare maximum in the economy with conspicuous conservation is reached at some ϵ lower than 1.

Assume now $\epsilon \leq 1$. From the above analysis and the following two conditions

$$U^{CC}(\epsilon) > U^{BM}(\epsilon) \text{ for any } \epsilon < \epsilon_{cri} \tag{A19}$$

$$U^{CC}(1) < U^{BM}(1) \tag{A20}$$

there are therefore three possible positions for U^{CC} that can be described by

1) $\hat{\epsilon} < \epsilon_{cri},\ U^{CC}(\hat{\epsilon}) > U^{BM}(\hat{\epsilon})$
2) $\epsilon_{cri} \leq \hat{\epsilon} < 1,\ U^{CC}(\hat{\epsilon}) \geq U^{BM}(\hat{\epsilon})$
3) $\epsilon_{cri} \leq \hat{\epsilon} < 1,\ U^{CC}(\hat{\epsilon}) < U^{BM}(\hat{\epsilon})$.

Since we further have

$$\frac{dU_{\epsilon}}{d\eta_s} < -U_{\epsilon}\frac{d\hat{Z}}{d\eta_s}\frac{x}{\hat{Z}}\frac{\eta_s\gamma\Omega\hat{Z}^{-1}}{\alpha(\phi+\eta_s\gamma)+(\alpha+\eta_s\gamma)x\phi_s} < 0, \text{ if } U_{\epsilon} > 0, \tag{A21}$$

for each of the three possibilities, by the IVT $U^{CC}(\epsilon)$ will have a unique intersection with $U^{\mathrm{BM}}(\epsilon)$ at $\tilde{\epsilon} \in [\epsilon_{cri}, 1)$ so that

$$\begin{cases} U^{CC}(\epsilon) \geq U^{BM}(\epsilon), & \text{if } \epsilon \leq \tilde{\epsilon} \\ U^{CC}(\epsilon) < U^{BM}(\epsilon), & \text{if } \tilde{\epsilon} < \epsilon \leq 1 \end{cases}.$$

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