Regulating the Environmental Consequences of Preferences for Social Status Within an Evolutionary Framework

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Abstract

Taking as given that we are consuming too much and that overconsumption leads to environmental degradation, the present paper examines the regulator's choices between informative advertisement and consumption taxation. We model overconsumption by considering individuals that care about social status apart from the intrinsic utility, derived from direct consumption. We assume that there also exist individuals that care only about their own private consumption and we examine the evolution of preferences through time by allowing individuals to alter their behavior as a result of a learning process, akin to a replicator dynamics type. We consider the regulator's choice of consumption taxation and informative advertisement both in an arbitrary and an optimal control context. In the arbitrary overconsumption control context we find that the regulator could decrease, or even

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eliminate, the share of status seekers in the population. In the context of optimal overconsumption control, we show that the highest welfare is attained when status seekers are completely eliminated, while the lowest in the case that the entire population consists of status seekers.

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1 Introduction

Over the past few decades a number of influential studies have sounded sound warnings regarding overexploitation of natural resources, fast population growth and environmental degradation (see for example Meadows et.al. (1972) and Elrich and Elrich (1976)). Although the continuously increasing consumption has been met by increased use of raw material, confounding most of the catastrophic predictions of these studies, it is undisputable it placed huge pressure on specific resources and most importantly environmental services. During the twentieth century, as reported in Arrow et al. (2004), world population grew by a factor of 4, industrial output increased by a factor of 40, energy use has increased by a factor of 16, annual fish harvesting by a multiple of 35 and carbon and sulfur dioxide emissions by a factor of 10.

Furthermore, Arrow et al. (2004) provide evidence, admittedly not conclusive, supporting the view that consumption's share of output is likely to be higher than that which is prescribed by the maximize present value criterion. Increased consumption in the poorest parts of the world has a positive impact by improving living conditions. On the other hand, overconsumption in the developed world is far less justifiable. An answer to the question, "are we consuming too much?" could be that we are indeed consuming too much when consumption becomes an end to itself, that is, when consumption is driven by social preferences, such as the attainment of social status. As a growing body of literature shows, apart from our desire for individually consumed goods, our choices are driven by the quest for social status.

The present paper considers preferences that incorporate social status, that is, individuals' concerns about relative position (relative consumption) that lead to excess consumption. However, not every individual's choices are driven by social status; there exist individuals that care only about their own private consumption. Since the share of each group in the total population determines the extent of overconsumption, we examine the evolution of preferences through time by allowing individuals to alter their behavior as a result of a learning process, akin to a replicator dynamics type. Given that overconsumption leads to environmental degradation, the main goal of the paper is to examine the effectiveness of environmental policy.

More precisely, we assume that there are two groups of agents: those that their preference has two components: a private utility component (depending on private consumption) and a social utility component (depending on the average consumption of the entire population) and those that their preference depend only on their own private consumption. Both types of agents are influenced by a common externality, degradation of environmental quality, caused by consumption. We assume that agents can change type and that their incentive to change type depends on the difference between own and average payoff. Furthermore, we assume that status seeking agents have an additional incentive to change type when they receive information about the detrimental effect of pollution and overconsumption as a pollution driver. This informative advertisement is provided by the government in an attempt to decrease the pollution externality, along with a tax on consumption. We consider the regulator's choice of these two policy instruments in the following two contexts: (i) using taxation and informative advertising to attain a *desired* proportion of status seekers as a steady state outcome by controlling the replicator dynamics equation (*arbitrary overconsumption control*), and (ii) using taxation and informative advertising to maximize a welfare objective (*optimal overconsumption control*). In the context of arbitrary overconsumption control we show that the regulator could decrease, or even eliminate, the share of status seekers in the population by appropriately choosing the tax rate and informative advertisement. However, the welfare properties of the arbitrary policy far from being clear. In the context of optimal overconsumption control, we show that a steady state exists and we obtain some insights about optimal regulation by studying the steady states through numerical simulations. The results of the simulations show that the highest welfare is attained in the case that there are no status seekers, while the lowest in the case that the entire population consists of status seekers.

The paper relates to the recent literature on the role of information provision to induce more environmentally friendly behavior. The role of information provision as a policy instrument to supplement environmental taxation has been examined in a static framework in Petrakis et.al. (2005) and in a dynamic framework in Sartzetakis et.al. (2012). The information provided by the government, through advertisements, shifts consumers towards less polluting alternatives, reducing the rate of the tax and improving welfare. More recently Hong and Zhao (2014) examine the role of information provided by environmental groups in inducing International Environmental Agreements. More closely related to the present paper is Kallbekken (2010), considering appeals to social norms as a policy instrument to address consumption externalities. They find that when the existing norm helps to shift consumption towards the socially optimal level of consumption, taxation welfare dominates appeals to social norms as a policy tool, while when the norm shifts behavior away from what is socially optimal the opposite is true.

Our paper is based on the theoretical and empirical literature supporting the Veblenian claim that individuals exhibit preferences for social status, by linking individual preferences to average consumption. From this quite large literature, credit should be given to the seminal contributions of Veblen (1899) and Duesenberry (1949). A very good presentation of the main ideas from sociology and their economic applications is given in Weiss and Fershtman's (1998) survey of social status and economic performance. The role of preferences for social status has been studied, relative to their effect on the allocation of resources by Fersthman and Weiss (1993), on savings and the accumulation of human capital by Cole et al. (1992), and relatively to their effect on endogenous growth models by Corneo and Jeanne (1996) and Rauscher (1996). Bernheim (1994) examines a model of social interaction while Bisin and Verdier (1998) study the formation of preferences for 'social status' as the result of intergenerational transmission of cultural traits

The rest of the paper is organized as follows. The next Section lays out the basic assumption on which our model is built. Section 3 presents the optimal choices of the representative agents and Section 4 the replicator dynamics. Section 5 examines the policy options and Section 6 concludes the paper.

2 The model

We assume that the total population consists of two types of agents. Type 2 agents' utility depends only on private consumption while type 1 agents' utility is influenced also by the average consumption of the total population. For type 2 agents consumption is used as a devise to signal wealth and improve social status. Acting in this manner type 2 agents consume too much having a negative effect on environmental quality E, and thus we call them non-environmentally friendly agents. We assume that the total population of agents is n, constant in time (without loss of generality), and $n_1(t)$, $n_2(t)$ is the population of type 1 and type 2 agents respectively at time t. We also define $x(t) = \frac{n_1(t)}{n}$ the fraction of type 1 agents and thus, $1 - x(t)$ is the fraction of agents at type 2. Our working assumption is that an agent may change type as an account of "learning" or as an account of external control, imposed by a central planner.

Both types of agents are influenced by a common externality, this is the degradation of environmental quality. Let $P(t)$ be the pollution stock at time t. Assuming homogeneity in space, we assume that pollution depends on the total consumption, in the sense that consumption activities and the implied production to provide the consumption goods generate emission that increase pollution. To simplify things we assume that emissions generated per unit time due to consumption and related production process are proportional to total consumption. Assuming further a natural cleaning process of the environment at the rate λ, pollution accumulation can be described as:

$$\varepsilon \frac{dP}{dt} = -\lambda P(t) + \theta C_{tot}, \tag{1}$$

where C_{tot} is the total consumption from the population of agents and the parameters $\lambda, \theta > 0$ are constants related to the rate of natural decay of the pollution stock and the effect of total consumption on the total pollution stock. Parameter ε is a small positive number, that basically describes the speed of the pollution accumulation process. The smaller ε the faster is the relaxation of the pollution stock to its steady state value. At the limit $\varepsilon \to 0$, the pollution stock relaxes instantaneously to its steady state $P = \theta C_{tot}/\lambda$.

We now consider the utility function of the two types of agents. The utility function of agents of type 1 is of the form $u_1(C_1, \bar{C}; P)$, i.e. depends on consumption C_1, average consumption $\bar{C}$ and the total pollution stock P. The utility function u_1 is increasing in C_1, $\frac{\partial u_1}{\partial C_1} > 0$, and decreasing in P, $\frac{\partial u_1}{\partial P} < 0$. Furthermore, following Bisin and Verdier (1998), we assume that if the average consumption $\bar{C}$ increases, type 1 agent's utility decreases, $\frac{\partial u_1}{\partial \bar{C}} < 0$, and that the marginal utility of average consumption is increasing in C_1, $\frac{\partial^2 u_1}{\partial C_1 \partial \bar{C}} > 0$. These assumptions imply that the optimal choice of C_1 is increasing in $\bar{C}$, thus modelling a catching up with the Joneses effect. Finally, we assume that marginal utility of private consumption is more sensitive to C_1 than to $\bar{C}$. In summary, type 1 agent's behavior has the following characteristics,

$$\frac{\partial u_1}{\partial C_1} > 0, \ \frac{\partial u_1}{\partial P} < 0, \ \frac{\partial u_1}{\partial \bar{C}} < 0, \ \frac{\partial^2 u_1}{\partial C_1 \partial \bar{C}} > 0, \ \left| \frac{\partial^2 u_1}{\partial C_1 \partial \bar{C}} \right| < \left| \frac{\partial^2 u_1}{\partial C_1 \partial C_1} \right|. \quad (2)$$

An example of such a type of utility functions can be the one provided by Bisin-Verdier, which is of the general form $u_1(C_1, \bar{C}) = u(C_1) + v(C_1 - \bar{C})$, where v is strictly increasing when $C_1 - \bar{C} < S$ and constant otherwise, where S is a critical value. The utility function u is a standard utility function. Without loss of generality we may assume $v(0) = 0$ so that $u_1(C_1, C_1) = u(C_1)$.

The utility function of type 2 agents is of the form $u_2(C_2; P)$, i.e., depends only on the agent's private consumption C_2 and the total pollution stock P. Agents of type 2 are not influenced by their peers' decisions. The function u_2 is increasing in C_2 and decreasing in P.

3 Optimal choices for the representative agent

Let us now consider the utility optimization problem for each type of representative agent, that will be used to determine their demand. The representative agent of type 1 at time t solves the maximization problem,

$$\max_{(m, C_1)} u_1(C_1; \bar{C}(t), P(t)) + m, \quad \text{subject to}$$
$$\bar{p} C_1 + m \leq Y_1,$$

where m is a numeraire good, Y_1 is the income of the representative agent of type 1, $\bar{p} = p + \tau$, where p is the price of the consumption good and τ is a tax imposed on the consumption good by a central planner in an attempt to regulate pollution. By a standard Lagrange multipliers approach, this becomes equivalent to solving,

$$\max_{C_1} u_1(C_1; \bar{C}, P) + (Y_1 - (p + \tau) C_1),$$

where $\bar{C}$ and P are externally given and treated as (time dependent) parameters. Define as,

$$D_1(t) := C_1^*(t) = \arg\max_{C_1} \left(u_1(C_1, \bar{C}(t); P(t)) + (Y_1 - (p + \tau) C_1) \right),$$

the solution of the above maximization problem. This is the demand function for the consumption good of type 1 agents, which depends on the average consumption $\bar{C}(t)$ and the total pollution stock $P(t)$ at time t. Assuming that interior solutions exist for this problem, we may implicitly determine the demand of type 1 agents in terms of the algebraic equation,

$$\frac{\partial u_1(C_1, \bar{C}; P)}{\partial C_1} - (p + \tau) = 0, \tag{3}$$

$$C_1^*(t) = c_1^* \left(\bar{C}; P, p, \tau \right). \tag{4}$$

This algebraic equation is assumed to hold for any t. Furthermore, define as,

$$\begin{aligned} U_1(t) &:= u_1(C_1^*(t), \bar{C}(t); P(t)) + (Y_1 - (p + \tau)C_1^*(t)) \\ &= u_1^* \left(\bar{C}, P, p, \tau \right), \end{aligned} \tag{5}$$

the indirect utility of the representative agent of type 1.

Similarly, at time t, the representative agent of type 2, solves the maximization problem

$$\begin{aligned} &\max_{(m, C_2)} u_2(C_2; P(t)) + m, \quad \text{subject to} \\ &(p + \tau)C_2 + m \leq Y_2, \end{aligned}$$

where m is the numeraire good, Y_2 the income of type 2 agent and the other parameters are defined as above. The above constrained maximization problem becomes equivalent to,

$$\max_{C_2} u_2(C_2; P(t)) + (Y_2 - (p + \tau)C_2).$$

In a similar to type 1 agents' case, we define as,

$$D_2(t) := C_2^*(t) = \arg\max \left(u_2(C_2; P(t)) + (Y_2 - (p + \tau)C_2) \right),$$

the solution of the above maximization problem. This is the demand function for the consumption good of type 2 agents, which depends on the total pollution stock $P(t)$ at time t. The demand of type 2 agents is given by the implicit, algebraic equation,

$$\begin{aligned}\frac{\partial u_2(C_2;P)}{\partial C_2} - (p+\tau) = 0,\\ C_2^*(t) = c_2^*\left(P,p,\tau\right).\end{aligned} \tag{6}$$

This algebraic equation is assumed to hold for any t.

Furthermore, define as

$$\begin{aligned}U_2(t) &:= u_2(C_2^*(t);P(t)) + (Y_2 - (p+\tau)C_2^*(t)),\\ &= u_2^*\left(P,p,\tau\right)\end{aligned} \tag{7}$$

the indirect utility of the representative agent of type 2.

The total consumption at time t is then equal to $C_{tot}(t) = n_1(t)D_1(t) + n_2(t)D_2(t)$, and the average consumption becomes

$$\bar{C}(t) = x(t)C_1^*(t) + (1-x(t))C_2^*(t). \tag{8}$$

Since C_1^* and C_2^* depend on $\bar{C}(t)$ and $P(t)$, which in turn depend on $\bar{C}(t)$, it is evident that (8) is to be considered as an implicit equation determining the average consumption $\bar{C}(t)$ as a function of the price p, the tax rate τ, the fraction of type 1 agents x, and time.

4 Replicator dynamics

We now allow agents to alter their behavior as a result of a learning process, akin to a replicator dynamics type. We assume that at each time period, each agent of either type learns the average payoff of the total population, $\bar{U}\left(t\right) := x(t)U_1(t) + (1-x(t))U_2(t)$, and compares her own payoff, that is, her indirect utility $U_i(t)$, $i = 1,2$, to $\bar{U}\left(t\right)$. We assume that the incentive of each agent to change type depends on the difference between his own and the average payoff. For example, the incentive for agent 1 to change type is proportional to the difference $U_1(t) - \bar{U}(t) = (1-x(t))(U_1(t) - U_2(t))$. The greater the difference between the two types of agents' payoffs, the higher is the agent's incentive to change her type. In this context, agents' behavior is chosen by imitation, and the type of behavior leading to a higher payoff is imitated in a manner that is proportional to the payoff difference (see

Xepapadeas (2005) and Schlag (1998, 1999)).

Furthermore we assume that the government in an attempt to decrease the pollution externality, apart from taxing consumption, provides informative advertising regarding the detrimental effect of pollution and overconsumption as a pollution driver. The flow of informative advertising at time t is $\alpha(t)$. We assume that this information provides an additional incentive to type 1 agents to change behavior. Information is effective only if there exists a positive number of environmentally aware agents, so that type 1 agents can associate the information to existing consuming behavior. According to the above discussion we assume that the rate of growth of the share of type 1 agents in the total population is given by,

$$\begin{aligned}\frac{dx(t)/dt}{x(t)} &= \beta\left(U_1(t) - \bar{U}(t)\right) - (1 - x(t))\,\phi(\alpha(t)) \\ &= \beta x(t)(1 - x(t))(U_1(t) - U_2(t) - \phi(\alpha(t))), \qquad (9)\end{aligned}$$

where $\phi(\alpha)$ represents the incentive that informational advertisement provides to type 1 agents to change their behavior, with $\phi(0) = 0$, $\phi' > 0$, $\phi'' \geq 0$. If the share of type 2 in the population, which is $(1 - x(t))$, is not zero, then a positive flow of information will reduce the share of type 1 in the total population. This means that if some non status seekers exist then a flow of informative advertising will turn some status seekers into non status seekers. If everybody is a status seeker then informative advertising will have no impact.

As it was mentioned above, we assume a simple proportional effect of the utility difference, where β is a positive parameter. The utility gap incentive $U_1(t) - \bar{U}(t)$ indicates that if the indirect utility of type 1 is less than the average utility the share of type 1 population will be reduced.

Note that (9) is deceptively simple, since the term $U_1(t) - U_2(t)$ depends on $x(t)$, through the dependence of $\bar{C}(t)$ on $x(t)$ via (8). Using the definitions of $U_1(t)$, $U_2(t)$, and $\bar{C}(t)$, from (5), (7) and (8) respectively, and setting, without loss of generality, $\beta = 1$, the replicator dynamics equation is,

$$\dot{x} = x(1 - x)\left[U_1(x, P, p, \tau) - U_2(x, P, p, \tau) - \phi(\alpha)\right], \qquad (10)$$

where the stock of pollution is defined in (1).

5 Regulation

Consider now a regulator who is concerned with the environmental aspect of overconsumption. The regulator's policy instruments are the emissions tax $\tau(t)$ and the flow of informational advertising $\alpha(t)$. Regarding policy schemes we consider the case where the regulator has two options:

1. To use taxation and informative advertising to attain a *desired* proportion of status seekers as a steady state outcome by controlling the replicator dynamics equation. E.g. $\lim_{t\to\infty} x(t) = 0$, that is none is a status seeker, or $\lim_{t\to\infty} x(t) = x^* \in (0,1)$, which implies that a polymorphic population of status seekers and non-status seekers is attained in the long run. We will call this approach *arbitrary overconsumption control.*

2. To use taxation and informative advertising to maximize a welfare objective. In this case the regulator chooses the optimal paths for taxes $\tau(t)$, and the flow of informational advertising $\alpha(t)$ in order to maximize discounted welfare subject to replicator dynamics constraint and the steady state proportion of status seekers is the outcome of the optimization process. We will call this approach *optimal overconsumption control.*

The replicator dynamics equation which is the basis for arbitrary or optimal control of overconsumption is given by (10). In order to attain tractable results, we consider the case where the pollution dynamics are relatively faster than the status dynamics. By taking the limit as $\varepsilon \to 0$ in (1), which implies instantaneous relaxation to the steady state, the pollution path is given by[1]

$$P(t) = \frac{\theta}{\lambda} C_{tot}(t) \text{ with } C_{tot} = n\bar{C}. \tag{11}$$

Thus, we can write,

$$P(t) = \gamma \bar{C}(t) \ , \ \gamma = \frac{\theta}{\lambda} n \tag{12}$$

Furthermore we assume the following specific functional form for each of

[1] This assumption does affect the results regarding the structure and the efficiency of the policies, arbitrary or optimal, chosen by the regulator.

the two type of agents' utility,

$$u_1(C_1, \bar{C}, P) = C_1 - \frac{1}{2}C_1^2 + b(C_1 - \bar{C}) - \frac{1}{2}b(C_1 - \bar{C})^2 - \frac{1}{2}d_1 P^2, \qquad (13)$$

$$u_2(C_2, P) = C_2 - \frac{1}{2}C_2^2 - \frac{1}{2}d_2 P^2, \qquad (14)$$

where $b > 0$ is a parameter indicating the relative influence of status seeking in type 1 agent's utility and $d_i > 0$ indicates each type of agents' perception of pollution damage. Note that for $\frac{\partial u_2}{\partial C_2} > 0$, we need $C_2 < 1$ and for $\frac{\partial u_1}{\partial C_1} > 0$, we need $C_1 < 1 + \frac{b}{1+b}\bar{C}$. The above specification satisfies the Bisin-Verdier conditions provided in (2) since, $\frac{\partial u_i}{\partial P} = -d_i P < 0$, $\frac{\partial u_1}{\partial \bar{C}} = -b + b(C_1 - \bar{C}) < 0$, which implies (given $b > 0$) that $C_1 - \bar{C} < 1$, $\frac{\partial^2 u_1}{\partial C_1 \partial \bar{C}} = b > 0$, and $\left|\frac{\partial^2 u_1}{\partial C_1 \partial \bar{C}}\right| < \left|\frac{\partial^2 u_1}{\partial C_1 \partial C_1}\right|$ since $b < 1 + b$.

Using the above preferences' specification we derive the optimal consumption choice for each type of agents,

$$D_2(t) := C_2^*(t) = 1 - \bar{p} = \widehat{p}, \qquad (15)$$

$$D_1(t) := C_1^*(t) = \frac{1 + b - \bar{p} + b\bar{C}}{1 + b}. \qquad (16)$$

The average consumption is,

$$\bar{C} = \widehat{p} + \frac{bx}{1 + b - bx}. \qquad (17)$$

Substituting $\bar{C}$ from above into (16) yields,

$$D_1(t) := C_1^*(t) = \widehat{p} + A_1(x), \qquad (18)$$

where $A_1(x) = \frac{b}{1+b-bx}$.

Substituting (18), (15), (12) and (17) into (13) and (14), yields the indirect utility functions of the two types of agents.

$$U_1 = \frac{1}{2}(1 - \delta_1)\widehat{p}^2 - 2\delta_1 x A_1(x)\widehat{p} + B_1(x) - \delta_1 x^2 A_1(x)^2 + Y, \qquad (19)$$

$$U_2 = \frac{1}{2}(1 - \delta_2)\widehat{p}^2 - 2\delta_2 x A_1(x)\widehat{p} - \delta_2 x^2 A_1(x)^2 + Y, \qquad (20)$$

where $B_1(x) = A_1(x)\left\{-\frac{A_1(x)}{2} + b(1-x)\left(1 - (1-x)\frac{A_1(x)}{2}\right)\right\}$ and $\delta_i = (1/2)\gamma^2 d_i$, $i = 1, 2$. Note that we assume the same income Y for both type of agents, so that our outcome does not depend on income distribution.

5.1 Arbitrary overconsumption control

When the regulator exercises arbitrary control, the objective is to choose policy instruments τ and α, to steer the replicator dynamics equation (10) to a desired steady state.

The replicator dynamics equation (10) has two steady states at the boundaries $x_0^* = 0$, $x_1^* = 1$, and possibly interior steady states if for the given choice of τ, α there exist

$$x_j^* \in (0,1) : (U_1(x^*, \tau) - U_2(x^*, \tau) - \phi(\alpha) = 0$$

The local stability properties of a steady state depend on the sign of the derivative

$$\left.\frac{d\dot{x}}{dx}\right|_{x=x_i^*, i=0,1,j} \begin{array}{ll} < 0 & \text{Local stability} \\ > 0 & \text{Local instability} \end{array}$$

When τ and α are used as controls the controlled replicator dynamics equation becomes. Substituting (19) and (20) into (10) the controlled replicator dynamics equation becomes,

$$\dot{x} = S(x)\left[\delta\widehat{p}^2 + 2\delta x A_1(x)\widehat{p} + B_2(x) - \alpha\right], \tag{21}$$

where, $\delta = \delta_2 - \delta_1 > 0$, since type 2 agents are assumed environmentally aware, $S(x) = x(1-x)$, $\alpha = \phi(a)$ and

$$A_1(x) := \frac{b}{1+b-bx}, \tag{22}$$

$$B_1(x) := A_1(x)\left\{-\frac{A_1(x)}{2} + b(1-x)\left(1 - \frac{A_1(x)}{2}(1-x)\right)\right\},$$

$$B_2(x) := B_1(x) + \delta x^2 A_1(x)^2. \tag{23}$$

The replicator dynamics always has two fixed points, the $x = 0$ and the $x = 1$ solutions. The $x = 0$ corresponds to the whole population being agents of type 2 while $x = 1$ corresponds to the whole population being agents of type 1. There is the possibility of more fixed points x, defined by the solution of the algebraic equation,

$$A(x) := \delta\widehat{p}^2 + 2\delta x A_1(x)\widehat{p} + B_2(x) - \alpha = 0. \tag{24}$$

Thus the regulator may be able, by choosing τ and α, to steer the system to a steady-state monomorphic population $x = 0$ or $x = 1$, or to a steady-state polymorphic population x^* which is determined by (24). To obtain a clear picture of the possible outcomes we run numerical simulations.

Assuming the following parametrization

$$p + \tau = 0.5, \alpha = 0.5, b = 3; \gamma = 1; d_1 = 0.5.0; d_2 = 0.6, I = 100 \tag{25}$$

the regulator can attain a stable polymorphic steady state at $x^* = 0.492$. This means that if the cost of the consumption good, including the tax, is 0.5 and the flow of informative advertisement is fixed at $\alpha = 0.5$, then at the steady state 49.2% of the population will be status seekers. This shown in figure (1).

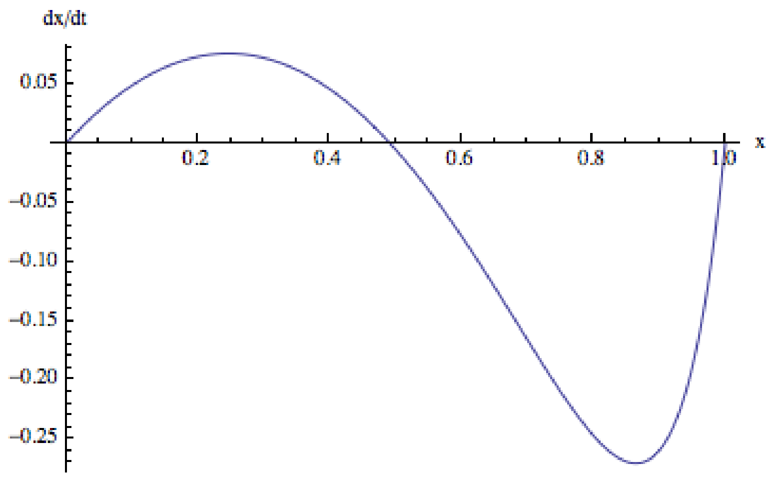

Figure 1: Stable polymorphic steady state

The polymorphic steady state is stable, as indicated by the negative slope, of the phase diagram at the steady state $x^* = 0.492$. This suggest that the monomorphic steady states are unstable.[2] Therefore for the given parametrization and arbitrary controls, irrespective of the initial proportion of status seekers their long run equilibrium proportion in the population will be 49.2%.

[2] This is indicated by the positive slope of the phase diagram at the steady states $x = 0, x = 1$.

If the weight b associated the relative influence of status seeking in type 1 agent's utility is reduced to $b = 1.75$, with all other parameters the same, then the share of the status seekers in the population is reduced to 9.24%.

An increase of informative advertisement to $\alpha = 2$, with everything else kept at the initial levels (25), will produce at the steady state a monomorphic population without any status seekers. This steady state is stable, while the steady state where everybody is a status seeker ($x = 1$) is unstable. This is shown in figure (2).

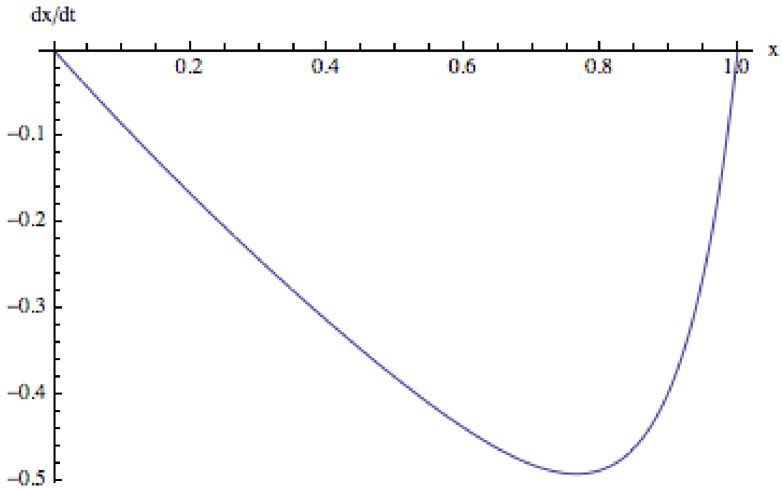

Figure 2: Monomorphic steady state without any status seekers

Furthermore an increase in tax to $p + \tau = 0.8$, while keeping the level of informative advertisement at the relatively lower level of $\alpha = 1$ and everything else at the initial levels (25), will produce a steady state of status seekers of 12.8%.

Thus an increase in the tax rate or informative advertisement will reduce, or even eliminate the share of status seekers in the population. Although this type of regulation can control for overconsumption and the associated environmental externality, the welfare properties of the arbitrary policy are far from being clear. This is because the reduction in status seekers and in pollution will tend to increase welfare, but on the other hand the cost of taxation, in terms of consumer surplus, and the cost of providing informative advertisement will tend to reduce welfare. A balance between welfare gains and loses from regulation can be achieved by a regulator following optimal policies.

5.2 Optimal overconsumption control

The regulator, in this case, chooses paths for $\tau(t)$ and $\alpha(t)$ that will optimize discounted social welfare. The instantaneous social welfare can be expressed as,

$$W(t) = x(t)\,U_1\left(\bar{C}, P, p, \tau\right) + (1 - x(t))\,U_2(P, p, \tau) - c(a(t)), \qquad (26)$$

where $c(a(t))$ is the cost of information provision a at time t and $P(t)$ and $x(t)$ are given by (12) and (10) respectively.

The problem to be solved is,

$$\max_{\tau(t),\alpha(t)} \int_0^\infty e^{-\rho t} W(t) dt$$
subject to
$$\dot{x} = x(1-x)\left[U_1(x, P, p, \tau) - U_2(x, P, p, \tau) - \phi(\alpha)\right]$$
$$P(t) = \gamma \bar{C}(t).$$

Using the our specification for the utility function, he optimal control problem is,

$$\max_{\tau(t),\alpha(t)} \int_0^\infty \mathrm{e}^{-\rho t} \left(x(t)U_1 + (1 - x(t)U_2) - \frac{1}{2}ea^2 \right) dt$$
subject to
$$\dot{x} = S(x)\left[\delta\widehat{p}^2 + 2\delta x A_1(x)\widehat{p} + B_2(x) - \alpha\right],$$

where $\frac{1}{2}ea^2$ denotes the cost of providing informative advertisement $\alpha(t)$, and $A_1(x)$, $B_2(x)$ are defined in (22),(23). The current value Hamiltonian of the above problem is,

$$\mathcal{H} = F_1(x,q)\widehat{p}^2 + F_2(x,q)\widehat{p} + F_3(x,q)a - -\frac{1}{2}ea^2 + F_4(x,q),$$

where,

$$\begin{aligned}
F_1(x,q) &:= E_1(x) + 2\delta q S(x),\\
F_2(x,q) &:= E_2(x) + 2\delta q x S(x) A_1(x),\\
F_3(x,q) &:= -qS(x),\\
F_4(x,q) &:= E_3(x) + qS(x)B_2(x).
\end{aligned}$$

$$\begin{aligned}
E_1(x) &= 2\delta x - 2\delta_2 + 1,\\
E_2(x) &= 2xA_1(x)(\delta x - \delta_2),\\
E_3(x) &= xB_1(x) + x^2 A_1(x)^2(\delta x - \delta_2) + I.
\end{aligned}$$

The maximum principle implies the following controls in a feedback form

$$\hat{p}_{max} = -\frac{F_2(x,q)}{F_1(x,q)}, \tag{27}$$

$$\alpha_{max} = \frac{1}{e} F_3(x,q). \tag{28}$$

Then the maximized Hamiltonian is defined as:

$$H^*(x,q) = F_4(x,q) - \frac{F_2(x,q)^2}{2F_1(x,q)} + \frac{1}{2e} F_3(x,q)^2 \tag{29}$$

To obtain a tractable approximation of the maximized Hamiltonian (29) we expand it around $\delta = 0$ to obtain the first order contribution to the Hamiltonian[3], H_0^*. Setting $\bar{q} = S(x)q$ and recalling that $S(x) = x(1-x)$, the maximized Hamiltonian takes the form:

$$\begin{aligned}
H_0^*(x,\bar{q}) = {} & \frac{1}{2e}\bar{q}^2 + A_1(x)^2(f_0 + f_1 x + f_2 x^2)\bar{q} \\
& + \frac{1}{2b^2 e(2\delta_2 - 1)} A_1(x)^2 (s_0 + s_1 x + s_2 x^2 + s_3 x^3),
\end{aligned} \tag{30}$$

[3]The approximate Hamiltonian is:

$$\begin{aligned}
H^*(x,\bar{q}) &= H_0^*(x,\bar{q}) + \delta H_1^*(x,\bar{q})\\
&= \frac{1}{2e}\bar{q}^2 + B_2(x)\bar{q} + \left\{ E_3(x) - \frac{E_2(x)^2}{2E_1(x)} \right\} + \delta \frac{E_2(x)(E_2(x) - 2xA_1(x)E_1(x))}{E_1(x)^2}\bar{q}
\end{aligned}$$

where,

$$f_0 = 1 + b,$$
$$f_1 = -2(1 + b)$$
$$f_2 = b + 2\delta,$$

and,

$$s_0 = 2Ie * (b + 1)^2(2\delta_2 - 1),$$
$$s_1 = -b * e * (2\delta_2 - 1)(b + 1)(4I - b),$$
$$s_2 = 2b^2e(1 + b - \delta_2(1 - 2I + 2b) - I),$$
$$s_3 = b^3e(2\delta_2 - 1).$$

Using (30) the Hamiltonian system becomes:

$$\dot{q} = \rho q - \frac{\partial H_0^*}{\partial x}, \tag{31}$$
$$\dot{x} = \frac{\partial H_0^*}{\partial q} \tag{32}$$

where the costate variable q can be interpreted as the shadow value of having a 1% change in the proportion of status seekers in the population. If $q < 0$ having an increase in the status seekers is a cost in terms of welfare. Solution of the system (31),(32) with an initial conditions for the proportion of status seekers $x(0) = x_0$ and the transversality condition at infinity $\lim_{t\to\infty} \mathrm{e}^{-\rho t} q(t)\, x(t) = 0$, will provide the optimal paths for $x^*(t)$ and $q^*(t)$. Substitution of $(x^*(t), q^*(t))$ into (27),(28), will provide the optimal control either in feedback or open loop form. These control will constitute the optimal regulation for controlling overconsumption and the resulting environmental externality.

A steady state for the proportion of status seekers and its shadow value is a point (q^*, x^*) such that

$$0 = -\frac{1}{e}S'(x)^2 - \left\{B_2(x)S'(x) + B_2'(x)S(x)\right\} q - V'(x) + \rho q, \tag{33}$$
$$0 = \frac{1}{e}S(x)^2 q + B_2(x)S(x), \tag{34}$$
$$V(x) := \frac{1}{2b^2e(2\delta_2 - 1)} A_1(x)^2(s_0 + s_1x + s_2x^2 + s_3x^3).$$

Monomorphic steady states for the proportion of status seekers x emerge at the boundaries $x = 0$, $x = 1$, since $S(x) = x(1-x)$, while a polymorphic steady state may emerge at the interior, i.e., $x^* \in (0,1)$.

The stability properties of a steady state are determined by the Jacobian determinant evaluated at the steady state:

$$J = \begin{pmatrix} \frac{\partial \dot{q}}{\partial q} & \frac{\partial \dot{q}}{\partial x} \\ \frac{\partial \dot{x}}{\partial q} & \frac{\partial \dot{x}}{\partial x} \end{pmatrix}$$

We can obtain some insights about optimal regulation by studying the steady states through numerical simulations.

Using the same parametrization as in (25), with $e = 1$ and $\rho = 0.03$, the optimal steady state is $x^* = 0.436989$, $q^* = -2.67587$, with corresponding steady-state optimal controls $(p+\tau)^* = 0.33$, $\alpha^* = 0.66$ and welfare $W^* = 3328.99$. The shadow value of x is negative indicating that an increase in the share of status seekers at the optimal steady state creates welfare cost. Note that with arbitrary control a steady state of $x^* = 0.492$ was attained with $p + \tau = 0.5$, $\alpha = 0.5$. The optimal steady state is a saddle point, as expected, with the phase diagram presented in figure (3).

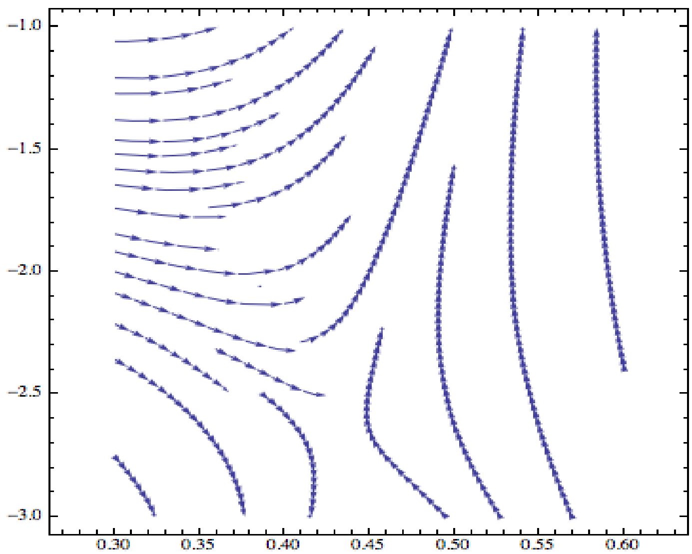

Figure 3: Phase diagram of the optimal polymorphic steady state

The stable manifold has a negative slope at the steady state. In terms of regulation, this means that for an initial proportion of status seekers around 43.7%, the regulator should choose initial value for the shadow value $q(0)$ so that the system starts on the stable manifold. Given this choice of $(x(0), q(0))$ the initial values of the controls are fully determined through (27), (28), so that the resulting paths of the optimal controls will attain the optimal path of status seekers $x^*(t)$, with $\lim_{t\to\infty} x^*(t) = 0.436989$.

To examine the sensitivity of solution to the cost of advertisement we increased e to 10. The resulting optimal steady state was $x^* = 0.623616$, $q^* = -587308$, $(p+\tau)^* = 0.03$, $\alpha^* = 0.13$, $W^* = 3311.79$. Thus an increase in the cost of advertisement will increase the share of status seekers and reduce welfare. It is interesting that the tax rate is not increased but is reduced. This suggest that taxes and informative advertisement might not always be substitutes.

A reduction of b to $b = 0.2$, with all other parameters kept at there initial value, reduces as expected, the share of status seekers at the optimal steady state to $x^* = 0.183$, and increase welfare to $W^* = 3333.37$. This steady state has the saddle point property.

For the monomorphic steady states we need to notice that the following conditions hold:

No status seekers, $x^* = 0$.
$(x^*, q^*) = (0, q_0)$ with $q_0 = \frac{-b^2}{(b^2-2rb-2r)}$ finite

$$\alpha_{max}(x,q) \simeq 0, \;\; \hat{p}_{max}(x,q) \simeq -\frac{F_2(0,q)}{F_1(0,q)} = -\frac{E_2(0)}{E_1(0)} = 0$$

The eigenvalues at the steady state are :

$$\lambda_1^{(0)} = \frac{b^2}{2b+2}, \;\; \lambda_2^{(0)} = \frac{-b^2+2rb+2r}{2b+2} \tag{35}$$

This means that we have a saddle point for large b and small ρ, or unstable for small b. The steady state welfare is, $W_0^* = \frac{1}{r}I$.

Using $e = 1$, $\rho = 0.03$, $b = 3$ we obtain $x_0^* = 0$, $q_0^* = -1.0274$, $(p+\tau)^* = 0$, $\alpha^* = 0$, $W_0^* = 3333.33$. The steady state is a saddle point saddle point. In order to compare the steady state welfare with the corresponding polymorphic steady state recall that, $x^* = 0.436989$, $q^* = -2.67587$, $W^* = 3328.99$. Thus on welfare grounds it seems preferable to attain the monomorphic steady state.[4]

[4] The way that regulation should be designed depends however on the structure of the

Everybody is a status seeker, $x^* = 1$.

Using $e = 1$, $\rho = 0.03$, $b = 3$ we obtain $x^* = 1$, $q^* = 19.2073$, $(p+\tau)^* = 7$, $\alpha^* = 0$, $W_1^* = 2833.33$. The monomorphic steady state is a saddle point, but is clearly inferior on welfare grounds to the polymorphic and the monomorphic $x^* = 0$ steady states.

It should be noted that when b is reduced to $b = 0.2$ both monomorphic steady states are unstable. In this case the polymorphic steady state shown in figure (4) is globally stable in $[0, 1]$ and the design of optimal regulation is straightforward.

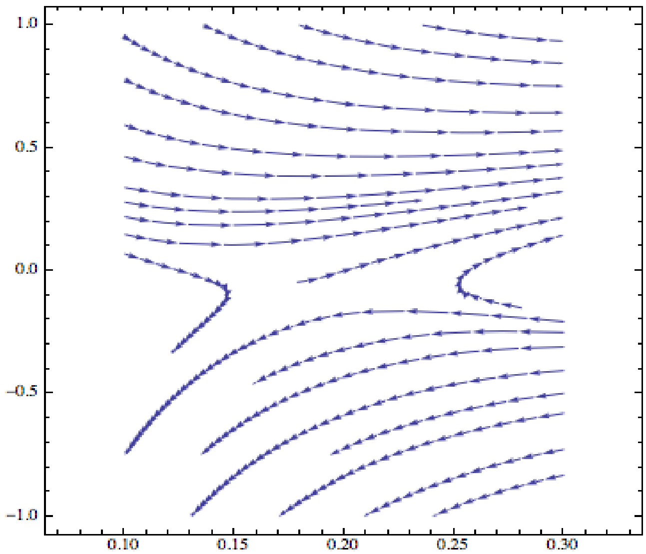

Figure 4: Phase diagram of the optimal monomorphic steady state

The results of the above simulations, using the same parameter values, show that the highest welfare is attained in the case that there are no status seekers, while the lowest in the case that the entire population consists of status seekers. The polymorphic steady state with 43, 7% status seekers yields welfare that is below the case that status seekers are eliminated and above the case that there are only status seekers.

stable manifolds associated with the two steady states, which requires further research.

6 Conclusions

We develop a model incorporating preferences for social status and we assume that there are two groups of individuals, those that overconsume in their effort to establish their social status and those that care only about the intrinsic value of their consumption and thus are more environmentally friendly. We examine the evolution of preferences through time by allowing individuals to alter their behavior as a result of a learning process that is influenced by informative advertisement provided by the government. We consider the regulator's choice of informative advertisement and environmental taxation within two different contexts: (i) *arbitrary overconsumption control*, and (ii) *optimal overconsumption control*. In the context of *a*arbitrary overconsumption control we show that the regulator could decrease, or even eliminate, the share of status seekers in the population by appropriately choosing the tax rate and informative advertisement. However, the welfare properties of the arbitrary policy far from being clear. In the context of optimal overconsumption control, we show that a steady state exists and we obtain some insights about optimal regulation by studying the steady states through numerical simulations. The results of the simulations show that the highest welfare is attained in the case that there are no status seekers, while the lowest in the case that the entire population consists of status seekers.

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