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Abstract

Continuously increasing consumption of material goods drives current resource and environmental crises, including climate change and loss of biodiversity. Technology offers solutions the development and the adoption of which though is not at the speed required to address the crises. Therefore, demand side responses have to be triggered and the most common economic suggestion is to use price signals. Increases in fuel prices during the last decade in both Europe and North America though, have not yielded the expected reductions in the fuel economy. Furthermore, ambitious increases in fuel prices have resulted in considerable opposition, especially by low-income people. The present paper offers an explanation for the reduced effectiveness of environmental taxation by focusing on relatively high-income individuals whose consumption of highly polluting material goods is driven by motivations to improve their social status. Furthermore, the paper shows that complementing the tax with information provision aiming at moderating status seeking overconsumption improves social welfare. Convincing people, through information campaigns and/or advertisement that

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consuming highly polluting material goods does not improve their social status could have a substantial effect which perfectly complements taxation, improving actually its effectiveness.

JEL codes: Q53, Q58, D62, D82

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1 Introduction

A number of influential studies in the seventies have sounded loud warnings regarding overexploitation of natural resources and environmental degradation.[1] Although the continuously increasing consumption of resources that followed did not yield the predicted devastating shortages in raw material, it indisputably placed huge pressure on specific resources and environmental services. During the twentieth century, as reported in Arrow et al. (2004), world population grew by a factor of four, industrial output increased by a factor of forty, energy use has increased by a factor of sixteen, annual fish harvesting by a multiple of thirty five and carbon and sulfur dioxide emissions by a factor of ten. There is mounting evidence showing that increased global consumption of material goods contributes significantly to environmental crises, including climate change and loss of biodiversity.

Tackling these problems cannot be delegated solely to technological innovation, especially given the urgency of the situation, and thus, it is particularly important to examine consumers' contribution, both policy induced and voluntary. The vast literature on environmental policy examines the effectiveness of market-based instruments, standard setting and more recently environmental awareness raising campaigns. With very few exceptions, the literature does not consider the effect that social influences on individuals' consumption could have on environmental policy. In this paper we incorporate in consumer's objective function (well being) her response to other individuals' level of consumption. In particular, we consider the case in which consumers increase their level of consumption in response to an increase in average consumption, so as to attain a higher social status. We allow the social component in consumer's well being to vary among individuals and we further assume that each one can change the social aspect of her behavior by adopting that of a more "successful" individual, through a replicator dynamic process. Thus, total consumption and thus pollution depends on each individual's level of consumption and the share of differently behaving individuals in the population. Within this framework we examine the effectiveness of environmental policy. We show that environmental taxation creates perverse effects by increasing the share of the highly consuming group of individuals, limiting thus its effectiveness. This lead us to

[1] Meadows et al. (1972) and Elrich and Elrich (1976).

examine the use of information provision aiming at reducing the importance of the social component in consumer's well being as a complementary policy instrument. We show that a combination of these two policy instruments maximizes social welfare.

Motivation

To coin any increase in consumption as overconsumption is simplistic since consumption levels differ widely among different parts of the world and groups of people, depending on wealth, income and preferences. Furthermore, the type and magnitude of consumption's environmental impact differs substantially among different types of goods. In particular we are interested in relatively affluent consumers whose income allows purchases that go beyond the satisfaction of their basic needs to what it has been defined in the literature as positional (Frank, 1985), or status goods (Bisin and Verdier, 1998). This literature recognizes that the value some individuals derive from the consumption of certain goods depends strongly on how their own consumption compares with other peoples' level of consumption.[2] That is, their consumption decisions are heavily motivated by consumption's expected effect on their social environment. These consumers are not confined only to rich countries anymore but are also located in developing and in transition countries and according to various studies account for a large and increasing share of global population and consumption.[3] In the

[2]The literature on status-seeking consumption originates with Veblen's work on conspicuous consumption (Veblen, 1994) and Duesenberry's 'relative income hypothesis' (Duesenberry, 1949). According to Harsanyi (1980) ".. apart from economic payoffs, social status (social rank) seems to be the most important incentive and motivating force of social behavior." 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.

[3]The new consumers emerged in significant numbers in the early eighties, and their major increase occurred largely during the nineties. Myers and Kent (2002) report 1.1 billion of "new consumers" in 17 developing and three transition countries on top of the 850 million long-established consumers in rich countries. A widely cited Coldman Sachs (2008) study estimates that this group of consumers (income bracket equivalent to US$6,000-$30,000 in PPT terms) increases by 70 million people each year a trent that if it continues will result in over 2 billion of new consumers by 2030. For more recent information on the growing importance of middle income new consumers see Kharas (2017) and WEF (2020).

present paper we are concerned about the old and new affluent consumers' excessive consumption of material goods for the purpose of improving their social status.[4]

Although the disproportionate impact of the global population's wealthiest part on environment is well documented,[5] we do not claim that affluence or status seeking necessarily lead to unsustainable consumption: High incomes are likely to allow people to purchase higher quality, more durable material goods with an overall lower environmental impact. Furthermore, people may choose to channel their increased income on less polluting material goods (from a cleaner car to a piece of fine arts) or nonmaterial services (education, cultural services), or even donations to environmental groups. Also, we do not claim that lower income people ignore social status, but we focus on status seeking practices that have significant environmental effect.[6] However, we recognize that a large and continuously growing part of global population possesses the means and seeks social recognition through visible material consumption in the same time that we observe the slow adoption of more environmentally friendly preferences in developed countries and the small effect that this change has had on pollution reduction.

In attempting to improve their relative position in society, status seekers increase their own consumption which raises the average level of consumption, lowering thus the relative position of similar thinking agents. Thus, the existence of status desire implies that each individual's action has negative external effects on the levels of other agents' utility, adding an additional externality to the environmental one. This leads to continuously increasing consumption, or to what has been termed as a "positional treadmill" or consumption "rat race" (Frank 1985).

The basket of status or positional goods includes those supporting diets

[4] The importance of conspicuous consumption has also been shown empirically by, for example, relating such consumption to excessive spending on weddings and other events in developing countries (Banerjee and Duflo 2008), the wealth gap between blacks and whites in the United States (Charles et al., 2009) and to personal bankruptcy decisions (Agarwal et al., 2016). More recently Bursztyn et al. (2018) provide field-experimental evidence of the existence of status goods using a sample of upper-middle-class bank customers in Indonesia, one of the home-countries of what we called above "new consumers".

[5] For example, Oxfam (2020) reports that, in 2015, the world's wealthiest 10% were responsible for around half of global carbon dioxide emissions, while the top 1% were responsible for 15% of emissions, nearly twice as much as the world's poorest 50%, who were responsible for just 7%.

[6] See the discussion in Brekke (1998) as to whether status seeking is primarily to be found in rich societies.

of highly processed foods and meat; big housing; high fuel consuming vehicles; personal computers and other consumer electronics produced under the strategy of planned or programmed obsolescence; fashionable apparel and accessories such as jewelry.[7,8] Intertemporally, status seeking is also related to high turnover of the consumer's stock of goods in this basket. A strong indication of the importance of purchasing goods even purely for their positional impact, is the fact that the market for fake designer products is worth tens of billions of dollars globally: consumers are willing to purchase goods that they know are of low quality just to imitate higher status. Although we recognize the gradual development of green consumerism, the evidence indicates that the great majority of new consumers adopt the old, environmentally harmful, overconsuming behavior of which the social component is a major driver. Thus, at least for the immediate future, the main environmental pressure is expected to come from individuals eager to make their new income visible by purchasing environmentally harmful material goods.

Contribution

In the present paper we incorporate social status into our model by assuming that individuals' well being has two components: a private and a social, each weighing differently across consumers. For simplicity we assume that there are only two groups of consumers: those that assign a positive weight on the social component of utility and those that care only about their own private utility. We assume that both groups possess the same level of income. Furthermore, we group consumption goods and services in two broadly defined baskets: The first comprises of material goods that provide intrinsic private utility up to a certain level but their abundance is considered by the first group of consumers to signal higher social status. The second basket includes goods that provide self-centered utility and are necessary to support a basic standard of living, non-material educational, health care, entertainment and other services that increase the standard of

[7]For example, Charles et al. (2009) based on a survey they conducted, considered the following categories as status goods: apparel (including accessories such as jewelry), personal care, and vehicles. They also recognize the importance of housing, but they exclude it from their study for reasons of racial differential treatment in the housing market.

[8]A number of studies broadly specify the sectors of housing, food and beverages, mobility and tourism as the primary sources of environmental pressure coming from consumption (for example, with reference to the EU see JRC/IPTS, 2006; EEA, 2010 and EEA, 2013).

living and goods that generate lower environmental damage, like electric cars.[9] Goods in the latter basket have lower environmental impact relative to the former and for simplicity we will assume that only goods that can be used to project status generate pollution. Both groups of consumers purchase goods from both baskets, with the status seeking group consuming higher quantities of the first, more polluting, basket.

Degradation of environmental quality, generated by pollution, affects both types of agents. However, given that each consumer acts individually, we assume following the literature, that each takes the pollution level as given. Thus, although their utility is decreasing in pollution, their consumption is not responsive to pollution. This assumption simplifies the analysis considerably while it does not affect the results, since individual responses, without "warm glow" effects or other type of altruistic motives, do not affect greatly total pollution driven mainly by to the external effects of private consumption.

Given the interdependency of individual consumers' choices through average consumption, we consider the choice of seeking status through increased consumption as a choice of strategy. We further allow individual consumers to change their strategy through time as a result of a learning process akin to a replicator dynamics. Since the share of each group of agents in the total population determines the extent of overconsumption, we examine the evolution of consumers' choice of strategy. Each agent's choice of assigning a positive or zero weight on the social component of her utility is a strategic choice and separate from her preferences, which remain stable even if the agent changes her choice of seeking to improve her social status through material consumption. We assume that the agent's decision to change social strategy depends on the difference between her own and the average payoff. Furthermore, we assume that status seeking agents have an additional incentive to change strategy when they receive information about the detrimental effects of 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.

[9] As noted above, some of the goods included in this basket could be used to attain social status within groups that place high value on environmental protection. We reiterate that the data do not support that such groups are numerous enough yet to have an important global effect. Future research could examine the case in which status provision shifts from the environmentally harmful to friendly goods.

As expected, we confirm that status seekers consume higher quantities of the goods that signal status. However, the well being of the consumers that care about status could be lower for a wide range of parameter values. In the absence of any type of environmental regulation, in the steady state either all consumers will be status seekers or there will be a polymorphic steady state in which both types of consumers co-exist. Employing particular functions for consumers' well being we are able to define analytically the steady states and perform comparative analysis for the most important parameters. Furthermore, given that status seekers overconsumption exacerbates the environmental problems, we discuss the effectiveness of two environmental policy instruments: environmental taxation and information provision aiming at reducing the importance of the social component of consumers' well being. We find that the effectiveness of environmental taxation can be compromised under certain conditions leading to an increase in the well being of status seekers relative to the other group, yielding an increase in their share. A public information campaign that effectively convinces status seekers to change their social strategy could be an important policy instrument to complement taxation. The problem of defining the optimal choice of policy instruments is highly non linear and deriving analytical solution is not possible. Resorting to a numerical simulation we are able to show that indeed a combination of the two policy instruments yields an improvement in social welfare.

Literature review

Our work is based on the literature on conspicuous consumption, briefly reviewed in footnote 2. More recently, Dasgupta et al. (2016) examine the effectiveness of environmental policies when socially embedded preferences are taken into account. They consider the case that consumption is competitive, as in our paper, when is used for conformity and they also examine the case of socially directed preferences, i.e. taking into account altruistic behavior. To the best of our knowledge this is the only paper that directly examines the interaction of environmental and social externalities. Although this work is very closely related to ours, the research questions are different. While they are concerned with defining optimal taxes in a broad range of socially embedded preferences in a static framework with identical agents, we focus on status seeking behavior by a segment of the population and we examine the effect of environmental policies on the evolution of the share of status seekers through time. There are a few other papers that examine the effect of social norms on the pollution. Nyborg et al. (2006) model green consumers by including moral motivations which create interdependencies between the demand of different individuals. Chander P. and S. Muthukrishnan (2015) show that collective action by green consumers,who derive benefits from consuming environmentally cleaner products, can reduce pollution and improve social welfare in the same manner as pollution taxes or subsidies for reducing pollution can.

The paper also relates to the 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, 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 et al. (2010), which considers 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 the socially optimal the opposite is true.

The rest of the paper is organized as follows. The next Section lays out the general framework of our analysis. Section 3 presents the optimal choices of the representative agents and Section 4 the replicator dynamics. Section 5 presents a particular specification of the model which allows the derivation of analytical solutions, first in the absence of policy intervention and subsequently for selective, exogenously determined, policy intervention, allowing us to discuss the effectiveness of policy instruments. Section 6 defines the optimal choice of policy instruments and Section 7 concludes the paper.

2 The model

For the purposes of our analysis we group all goods and services into two bundles: one containing less-polluting goods and services which we denote by m[10] and another bundle comprising of highly polluting goods whose consumption indicates status, denoted by C[11]. For simplicity we treat the two bundles as composite goods. We further normalize their impact on pollution, by assuming that the composite good m generates zero pollution.

We assume a group of individuals of size n, whose consumption decisions are interdependent. We model this interdependency by assuming that agents' well being depends not only on their personal enjoyment from consuming m and C, but also on the group's average consumption of C. Furthermore, their well being is affected by the damages pollution inflicts on them. Although preferences regarding the consumption of m and C as well as environmental preferences and the choice of strategy regarding status seeking could vary among consumers, for simplicity we assume that there are only two types of consumers. Given the focus of the paper, we separate the two types according to the choice of their strategy: Type 2 agents, hereafter called green agents, consume C only for the sake of their own satisfaction, enjoyment, or personal meaning. Type 1 agents, hereafter called status seekers, apart from personal satisfaction from consuming C they are motivated by the desire to earn social recognition (status). We will formalize this by assuming that status agents' utility depends not only on their own consumption but also on the average consumption of C. Acting in this manner, status seekers consume beyond their personal needs, generating relatively more pollution.

Our working assumption is that agents can change their strategy through a "learning process" which comprises of comparing the utility they derive from their current strategy to that derived by the alternative strategy; if the alternative strategy offers higher payoff, they will switch strategy. Furthermore, we assume that agents may also change strategy as a result of policies implemented by the government.

[10] This bundle includes goods covering basic needs and other low polluting goods and services.

[11] This bundle includes products purchased for their symbolic and social value rather than only for their "intrinsic utility", that is, goods associated with choice of life-style rather than covering basic needs.

We assume that the total population of agents n remains constant over time, and we denote by $n_1(t)$ and $n_2(t)$ the population of type 1 and type 2 agents at time t respectively. 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 of type 2. We normalize assuming $n = 1$, which implies $x(t) = n_1(t)$.

We denote by $P(t)$ the pollution level at time t. For simplicity, we assume flow pollutants which are proportional to total consumption of C at each time period, $TC = n_1 C_1 + n_2 C_2$, which under the normalization $n = 1$, is equal to average consumption $\bar{C} = xC_1 + (1 - x)C_2$.[12] Thus, the pollution path is, $P(t) = \bar{C}(t)$, assuming for simplicity that emissions per unit of output is unity. Pollution inflicts damages on individuals assumed non-decreasing and convex in P,

$$D(t) = \gamma P^2(t). \tag{1}$$

The well being of consumers consists of the utility, the personal enjoyment, they derive from the consumption of C and m, the disutility they experience due to environmental damage D and, in the case of status seeking agents, the enjoyment they derive from social status, which is assumed to depend on the difference between own and average consumption of C. We will use the following formulation of such type of well being functions,[13]

$$w_i = u_i(m_i, C_i; P) + v_i(C_i - \bar{C}), \tag{2}$$

where $i = 1, 2$ indicates the type of consumer and v is strictly increasing when $C_i - \bar{C} < S$ and constant otherwise, where S is a critical value of consumption. The utility function u is a standard utility function, increasing in both m, $\frac{\partial u_i}{\partial m_i} > 0$ and C, $\frac{\partial u_i}{\partial C_i} > 0$, and decreasing in P, $\frac{\partial u_i}{\partial P} < 0$. Without loss of generality we may assume $v(0) = 0$. Given the definition of green consumers, $v_2 = 0$, for any C_2. Furthermore, for the status seeking consumers, we assume that if the average consumption $\bar{C}$ increases, their well being decreases, $\frac{\partial w_1}{\partial \bar{C}} < 0$, and that the marginal well being of average con-

[12]It should be noted that the assumption of flow pollutants affects the results regarding the structure and the efficiency of the policies chosen by the regulator. However, it simplifies considerably the analysis relative to the case of stock pollutants which should be examined in future research.

[13]Similar kind of functions have been used for exapmle by Bisin and Verdier (1998), without environmental damages, and Dasgupta et al. (2016), with environmental damages.

sumption is increasing in C_1, $\frac{\partial^2 w_1}{\partial \bar{C} \partial C_1} > 0$. 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 consumption is more sensitive to C_1 than to $\bar{C}$, that is, $\left|\frac{\partial^2 u_1}{\partial C_1 \partial \bar{C}}\right| < \left|\frac{\partial^2 u_1}{\partial C_1 \partial C_1}\right|$.

3 Optimal choices for the representative agent

In order to focus our attention on the polluting composite good C, we assume that the utility function of both types of consumers is quasilinear in m. Neutralizing income effects is a reasonable assumption given that we focus on a consumers' group with specific income and we do not examine changes in income. For simplicity, we assume that both types of agents have the same income. We also assume that all goods are produced in perfectly competitive markets under constant returns to scale. Thus, before-tax prices are equal to the constant marginal and average cost of production. To simplify further, we normalize setting the price of m equal to 1, so that p denotes the relative price. Recalling the assumption of zero pollution from m, there is no need for corrective taxation on m and thus, m's after tax price is unity.

Given these assumptions, the constrained maximization problem of type 1 representative agent's well being at time t is,

$$\max_{(m_1, C_1)} w_1 = u_1(C_1; P) + \mu_1 m_1 + v_1(C_1 - \bar{C}),$$
$$\text{subject to: } \bar{p} C_1 + m_1 \leq Y,$$

where μ_1 indicates type 1's agent's constant marginal utility of m; Y presents the sum of agent's income, y, plus any lump-sum redistribution of the tax revenues, s, that is, $Y = y + s$; $\bar{p}$ is the after tax price of C, that is, $\bar{p} = p + \tau$, where p is the price and τ is a per unit tax imposed on C by the government in an attempt to regulate pollution and overconsumption due to status seeking.[14] Given that we set m as the numeraire good, μ_i is equal to the marginal utility of income. The intention is to allow differences between the two types of agents' marginal rate of substitution $MRS_{C,m}$, so as to examine both effects of environmental taxation on C's consumption: the

[14]The different nature of the two externalities require different treatment: the environmental externality a per unit tax while the overconsumption externality an ad valorem tax (see Dasgoupta et al., 2016). Since the emphasis of the present paper is on the evolution of status seeking behavior, we assume only one type of tax is levied.

usual direct reduction and the indirect effect through changing the share of status seeking agents by affecting the relative well being at the equilibrium.

We further assume that both types of consumers take $\bar{C}$, and thus P, as given when they make their choices. The individual agent realizes the minimal effect her consumption has on aggregate/average consumption and thus on P and ignores it. Assuming that status seekers take $\bar{C}$ as given when choosing C_1, implies that they do not choose strategically in order to manipulate $\bar{C}$. Assuming that both status and green agents take P as given, implies that each agent, regardless of her type, ignores the damage her own consumption inflicts on her, which is a reasonable assumption given that the own effect is very small relative to the externality created.

The first order conditions of the Lagrange function corresponding to the above problem yield,

$$u_{C_1} + v_{C_1} = \lambda_1 \bar{p}$$
$$\mu_1 = \lambda_1$$

where $u_{C_1} = \frac{\partial u_1}{\partial C_1}$, $v_{C_1} = \frac{\partial v_1}{\partial C_1}$ and λ_1 denotes the Lagrange multiplier. Solving the above yields type 1 agent's demand for C, as a function of the exogenous parameters $\bar{p}$, $\bar{C}$ and P at each time period t. Assuming that interior solutions exist for this problem, we may implicitly determine status agent's demand as,

$$C_1^*(t) = c_1^*\left(\bar{C}(t), \bar{p}(t); \mathbf{z}_1\right). \tag{3}$$

where, $\mathbf{z}_1$ denotes the vector of preference parameters including μ_1.

The representative green agent solves a similar to the above maximization problem, with the only difference that $v_2(.) = 0$. In a similar manner as above, green agent's demand for C is,

$$C_2^*(t) = c_2^*\left(\bar{C}(t), \bar{p}(t); \mathbf{z}_2\right). \tag{4}$$

Both (3) and (4) are assumed to hold at any time period t.

Notice that C_i^* depends on the equilibrium average consumption,

$$\bar{C}^*(t) = x(t)C_1^*(t) + (1 - x(t))C_2^*(t). \tag{5}$$

Therefore, it is evident that the system of equations (3), (4) and (5) can be solved for the consumption of status and green agents and the average consumption $\bar{C}(t)$ as functions of the price p, the tax rate τ, the fraction of status agents x and time t. That is, we can define, $C_i^*(t) = c_i^*(\bar{p}(t), x(t))$ and $\bar{C}^*(t) = \bar{c}^*(\bar{p}(t), x(t))$. Substituting these expressions into each type of agent's well being, given in (2), we obtain,

$$W_i(t) := f_i^*(\bar{p}(t), x(t), Y; \mathbf{z}_i), \tag{6}$$

the indirect well being at time t of type $i = 1, 2$ agent.

4 Replicator dynamics

We now allow agents to alter their strategy regarding status seeking as a result of a learning process, akin to a replicator dynamics defined in evolutionary biology (Taylor and Jonker, 1978 and Schuster and Sigmund, 1983) and used in evolutionary game theory. The replicator dynamics based on imitation, asserts that a strategy's share in the population is increasing linearly with the net payoff that this strategy yields relative to the alternative strategy (see Xepapadeas (2005) and Schlag (1998, 1999)). In terms of our framework, agents choose whether to adopt a status seeking strategy or not based on the relative utility they derive at equilibrium. More precisely, we assume that the incentive of each agent to change strategy depends on the difference between her own and the average well being defined as, $\overline{W}(t) := x(t)W_1(t) + (1 - x(t))W_2(t)$. We assume that at each time period each agent of either type learns the average payoff. She then compares her own payoff, that is, her indirect well being $W_i(t)$, $i = 1, 2$, to $\overline{W}(t)$. For the status agent, for example, the incentive to change strategy is proportional to the difference $W_1(t) - \overline{W}(t)$. The greater the difference between her own and the average payoff is, the larger is the incentive to retain her strategy and for green agent to change her strategy, thus increasing the share of status agents in the population. In the opposite case, if the indirect well being of status agents is less than the average utility their share in the population will be reduced. Accordingly, the replicator equation is,

$$\dot{x}(t) = dx(t)/dt = x(t)\,\beta\left(W_1(t) - \overline{W}(t)\right),$$

where β is a positive parameter.

Furthermore, we assume that the government in an attempt to decrease pollution damages could employ two policy instruments: an environmental tax τ, already incorporated into the price, and informative advertising θ, which is financed by the government in order to communicate the message that overconsumption is a major pollution driver providing thus incentives to move away from the status strategy. As consumers tend on the one hand to observe others' behavior and mimic the "privately successful" one, while on the other hand ignore the effect of their overconsumption on the environment, public advertisement has the important role to reveal to consumers information regarding the contribution of overconsumption, resulting from status seeking, to environmental damages. It is reasonable to assume that status seekers will respond to the information that their overconsumption exacerbates the environmental crisis since they too suffer from environmental damages. Information is effective only if there exists a positive number of green agents, so that status agents can associate the information to existing consumption behavior. The higher is the share of green agents, the more effective is informative advertisement.

According to the above discussion we assume that informative advertisement decreases the utility status agents derive from using C to attain status. That is we assume that $\frac{\partial v_i(C_i-\bar{C})}{\partial \theta}<0$, and thus, $\frac{\partial W_1(t)}{\partial \theta}<0$. Given that $W_1(t)-\overline{W}\left(t\right)=(1-x(t))\left(W_1(t)-W_2\left(t\right)\right)$, $\dot{x}(t)$ is written as,

$$\dot{x}(t)=x(t)(1-x(t))\left[\beta\left(W_1(\theta\left(t\right),t)-W_2\left(t\right)\right)\right]. \tag{7}$$

If the share of green agents in the population is not zero, $x\left(t\right)<1$, then a positive flow of information could reduce the share of status agents in the population, where $\frac{\partial v_i(C_i-\bar{C})}{\partial \theta}$ represents the incentive that informative advertisement provides to status agents to change their strategy. If everybody is a status seeker then informative advertising will have no impact.

Note that (7) is deceptively simple, since the term $W_1(t)-W_2\left(t\right)$ depends on $x(t)$, as shown in (6). Substituting (6), for $i=1,2$, into (7) and setting, without loss of generality, $\beta=1$, the replicator dynamics equation is,

$$\dot{x}=x(1-x)\left[f_1^*\left(\bar{p}(t),x(t),Y,\theta(t);\mathbf{z}_1\right)-f_2^*\left(\bar{p}(t),x(t),Y;\mathbf{z}_2\right)\right]. \tag{8}$$

Thus, the replicator dynamics equation is a function of the policy instruments τ and θ and the price p. As mentioned above, we do not model production explicitly and we assume that the price p is exogenously given, determined in competitive markets.

From (8) is evident that if each strategy's payoff is independent of its share, the evolutionary outcome will be a population completely dominated by one of the two strategies depending on the relative payoff. When individual payoffs depend on the share of each strategy, as (6) indicates, we could have polymorphic evolutionary stable strategy equilibrium. That is, the replicator dynamics equation (8) has two steady states at the boundaries $x_0^* = 0$ and $x_1^* = 1$, and possibly interior steady states $0 < x_i^* < 1$ such that $x_i^* = \arg\{f_1^*(\bar{p}(t), x(t), Y, \theta(t); \mathbf{z}_1) - f_2^*(\bar{p}(t), x(t), Y; \mathbf{z}_2) = 0\}$. In order to derive analytical results, we introduce specific functional forms for each type of agents' well being. In the following Section we characterize analytically the possible steady states in the absence of policy intervention and discuss the effectiveness of the two policy instruments τ and θ.

5 Analytical solution with particular utility functions

We assume the following specific functional form for each of the two types of agents' well being,

$$w_1 = a_1 C_1 - \frac{1}{2}C_1^2 + b\left[(C_1 - \bar{C}) - \frac{1}{2}(C_1 - \bar{C})^2\right] + \mu_1 m_1 - \frac{1}{2}d_1\gamma P^2, \quad (9)$$

$$w_2 = a_2 C_2 - \frac{1}{2}C_2^2 + \mu_2 m_2 - \frac{1}{2}d_2\gamma P^2, \quad (10)$$

where, a_i, $i = 1, 2$ indicates the maximum intrinsic utility each type of agent receives from consuming C, with $a_1 \geq a_2$; $b > 0$ is a parameter indicating the relative importance of status in type 1 agent's well being, μ_i indicates the constant marginal utility of m, and $d_i > 0$ indicates each type of agent's perception of pollution damage, with $d_2 \geq d_1$. In this Section we assume that the two types of agents have different preferences, that is, $a_1 > a_2$, $\mu_1 < \mu_2$ and $d_1 < d_2$. These reflect the assumption that status agents, apart from using C to signal status, they derive higher utility from C relative to green agents and downplay environmental damages. These assumptions are made to assist us in discussing the effectiveness of policy instruments and they are dropped in order to perform welfare analysis in the next Section.

The above specification satisfies the conditions set following (2). It should be noted that the condition $\frac{\partial w_1}{\partial \bar{C}} = -b + b(C_1 - \bar{C}) < 0$, implies (given $b > 0$) that $C_1 - \bar{C} < 1$ or $C_1 - C_2 < \frac{1}{1-x}$.

Using the above specification of individuals' well being we derive the optimal consumption choice for each type of agents, the average consumption and the difference between the two types of agents' consumption,

$$C_2^* = a_2 - \mu_2 \bar{p}, \tag{11}$$

$$C_1^* = a_1 - \mu_1 \bar{p} + \frac{b - b(1-x)(\Delta a - \Delta\mu\bar{p})}{1 + b(1-x)} = a_2 - \mu_2 \bar{p} + B, \tag{12}$$

$$\bar{C}^* = a_2 - \mu_2 \bar{p} + xB, \tag{13}$$

$$\Delta C^* = C_1^* - C_2^* = B. \tag{14}$$

where, $B = A_1 + A_2 = \frac{b + \Delta a - \Delta\mu\bar{p}}{1+b(1-x)}$ with $A_1 = \frac{b}{1+b-bx}$, $A_2 = \frac{\Delta a - \Delta\mu\bar{p}}{1+b(1-x)}$, $\Delta a = a_1 - a_2 \geqslant 0$ and $\Delta\mu = \mu_1 - \mu_2 \leqslant 0$. Consumption of status agents consists of two parts: one that provides intrinsic utility and another that increases well being by improving social status which is positive assuming $b > 0$ and $0 < \Delta a - \Delta\mu\bar{p} < \frac{1}{1-x}$.[15] Consumption of both types of agents is decreasing as the after tax price increases, that is, an increase in the tax will decrease average/aggregate consumption. However, an increase in the tax will increase the difference between the two types of agent's consumption:[16] an increase in the tax reduces the consumption of green agents relatively more and thus, it affects the replicator dynamic process. Furthermore, the difference in consumption ΔC^* is increasing in b and in x, with $\frac{\partial B}{\partial x} > \frac{\partial B}{\partial b}$, for $x < 1$.[17,18]

Substituting (11), (12), (13) and (14) into (9) and (10) we derive the difference between the two types of agents' well being at equilibrium W_i. For presentation purposes we divide the difference of agents' indirect well being into three components: the difference between the two groups' intrinsic indirect well being, $\Delta W_{\text{intrinsic}}$, the well being status seekers derive from using the consumption of C as status indicator, ΔW_{status}, and the difference in

[15] The latter holds since it is a necessary and sufficient condition for $\frac{\partial w_1}{\partial \bar{C}} < 0$

[16] $\frac{\partial B}{\partial \bar{p}} = -\frac{-\Delta\mu}{1+b(1-x)} > 0$, given that we assumed $\Delta\mu < 0$.

[17] We derive, $\frac{\partial B}{\partial b} = \frac{1-(\Delta a - \Delta\mu\bar{p})(1-x)}{(1+b(1-x))^2} > 0$, given that $B < \frac{1}{1-x}$, and $\frac{\partial B}{\partial x} = \frac{b[b+(\Delta a - \Delta\mu\bar{p})]}{(1+b(1-x))^2} > 0$.

[18] Note that ΔC^* gets its highest value for $x = 1$, $\Delta C^*_{\max}(x=1) = b + (\Delta a - \Delta\mu\bar{p})$, and its lowest for $x = 0$, $\Delta C^*_{\min}(x=0) = [b + (\Delta a - \Delta\mu\bar{p})]/(1+b)$

the perception of environmental damages ΔW_{env}. The difference in agents' well being is,[19]

$$\Delta W = \underbrace{\Delta a C_1^* + \Delta\mu m_1^* - \frac{B^2}{2}}_{\Delta W_{\text{intrinsic}}} + \underbrace{b\,(1-x)\left(1 - \frac{(1-x)\,B}{2}\right)B}_{\Delta W_{\text{status}}} - \underbrace{\frac{1}{2}\Delta d\gamma\left(\bar{C}^*\right)^2}_{\Delta W_{\text{env}}}, \tag{15}$$

where, $\Delta W = W_1 - W_2$ and $\Delta d = d_1 - d_2$. If we focus on the social element of consumers' well being, assuming $\Delta a = \Delta\mu = \Delta d = 0$, (15) becomes, $\Delta W = -\frac{B^2}{2} + b\,(1-x)\left(1 - \frac{(1-x)B}{2}\right)B$, with $B = A_1$. Therefore, for $b > 0$, the difference between the two types of agents' well being could be either positive or negative, $\Delta W \gtreqless 0$ if $x^{\min} \lesseqgtr \frac{1+b-\sqrt{1+b}}{b}$, which for $0 < b < 1$ is in the range $\frac{1}{2} < x^{\min} < 2 - \sqrt{2}$. That is, for any given b, there is a limit in the status agents' share in the population above which their well being at the equilibrium is smaller relative to that of green agents. The competitive nature of status seeking imposes a limit on the share of status seekers beyond which status seeking becomes less appealing. Assuming all agents have the same preferences, this limit depends only on the importance of social status in agents' well being. Under homogeneous preferences the after tax price has no effect on ΔW.

We now examine the case of heterogeneous preferences. As expected, $W_{\text{status}} > 0$, since the term in parenthesis is positive as we have already assumed $B < \frac{1}{1-x}$. An increase in the after tax price increases ΔW_{status}, that is, $\frac{\partial W_{\text{status}}}{\partial \bar{p}} > 0$.[20] An increase in the tax will increase the spread between the status agent's and the average consumption, $C_1^* - \bar{C}^*$,[21] and therefore the satisfaction she enjoys from her increased social status.

Under the assumption that green agents have a higher preference for m relative to status agents, that is $\Delta\mu < 0$, the difference between status and green agent's intrinsic utility is negative, $\Delta W_{\text{intrinsic}} < 0$, except for relatively large differences Δa. If $\Delta a = 0$ status agents consume more C relative to green agents both because of their higher $MRS_{C,m}$ and of their strive to improve their status. Since the benefits from improving their status

[19] The Appendix provides the basic steps of the calculations.

[20] Note that, $\frac{\partial W_{\text{status}}}{\partial \bar{p}} = \frac{\partial W_{\text{status}}}{\partial B}\frac{\partial B}{\partial \bar{p}}$ with $\frac{\partial W_{\text{status}}}{\partial B} = b\,(1-x)\,[1-(1-x)B] > 0$ and $\frac{\partial B}{\partial \bar{p}} > 0$.

[21] From (12) and (13) we have $C_1^* - \bar{C}^* = (1-x)\,B$.

are counted in W_{status}, green agents' intrinsic utility is clearly higher. The effect of the after tax price $\bar{p}$ on $\Delta W_{\text{intrinsic}}$ depends on the relative size of the differences Δa and $\Delta\mu$. For $\Delta a = 0$ and $\Delta\mu < 0$, an increase in the tax reduces the gap between green and status agents' indirect intrinsic well being. The intuition is as follows: The tax addresses both the environmental and the rat race externality. With respect to the intrinsic utility, the effect of the tax is to decrease status agents' consumption of C aligning thus their relative consumption of C and m to their intrinsic preferences and for this reason it reduces at a lower rate their intrinsic utility relative to the green agents' utility.

From the last component in (15), it is evident that the sign of Δd determines the sign of ΔW_{env}. It seems reasonable to assume that green agents would be more sensitive to environmental damages $d_2 > d_1$. This is a very common representation of the differences among consumers' environmental awareness in the literature.[22] Under this assumption, $\Delta d < 0$ and thus, the environmental component in (15) is positive. This implies that the range of parameters for which $\Delta W < 0$, becomes smaller the larger is Δd. As it will be explained in what follows, within the mimicking framework employed in the present paper, this effect leads to some counterintuitive results. An increase in the tax reduces the size of ΔW_{env} since it reduces the average consumption.

The above discussion is summarized in the following Proposition.

Proposition 1. *Status seeking agents always consume more of C than green agents at the equilibrium, $C_1^* > C_2^*$. However, their well being at the equilibrium could be lower, $\Delta W < 0$, as their share in the population x increases, assuming the importance of status is significant (high b) and the difference between the two types of agents' intrinsic preferences are small. If the two groups of agents have also different $MRS_{C,m}$, with $MRS_{C,m}^1 > MRS_{C,m}^2$, then green consumers well being becomes higher for even smaller x. In such case, an increase in the after tax price makes the status strategy relatively more attractive.*

As expected, the effect of an environmental tax τ on ΔW depends on the difference between the two types of agents' intrinsic preferences. If both types of agents have the same intrinsic preferences, that is, $\Delta a = \Delta\mu =$

[22] See for example Constantatos et al (2021).

$\Delta d = 0$, the environmental tax has no effect on ΔW since it does not affect the difference between the two types of agents' consumption at the equilibrium. In such case, the tax will have the primary effect of decreasing both type of agents' consumption of C, but will not have any multiplier effects by affecting ΔW. For $\Delta a = 0$ and $\Delta \mu < 0$, that is when green agents relative evaluation of m is higher than that of the status agents, the environmental tax –in addition to the primary effect of decreasing aggregate consumption of C– will make the status strategy relatively more attractive. We turn now to examine the evolution of strategies described by the replicator dynamics equation (8).

5.1 Steady state in the absence of policy interventions

Before determining the optimally chosen values of the two policy instruments, environmental tax τ and informative advertisement θ, we define the steady state in the absence of policy intervention and we also examine combinations of policy instruments that can steer the economy to a desired, exogenously determined, steady state.

The replicator dynamics equation (8) has two steady states at the boundaries $x_0^* = 0$ and $x_1^* = 1$, and possibly interior steady states if, in the absence of policy intervention, or for a given choice of τ and θ, there exist,

$$x_i^* \in (0,1) : W_1(p, x^*, \tau, \theta; \mathbf{z}_1) - W_2(p, x^*, \tau; \mathbf{z}_2) = 0.$$

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

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

We examine first the case with no policy intervention, that is, we set $\tau = \theta = 0$. With respect to preferences we focus on the difference in $MRS_{C,m}$, that is, we assume $\Delta a = \Delta d = 0$ and $\Delta \mu < 0$. Under these assumptions, (15) becomes,

$$\Delta W = \Delta \mu m_1^* - \frac{B^2}{2} + b(1-x)\left(1 - \frac{(1-x)B}{2}\right)B. \tag{16}$$

Given that $\Delta \mu < 0$, it is clear that green agents' indirect well being could be higher even when the share of status agents is smaller relative to the case that $\Delta\mu = 0$. That is, if the relative evaluation of status goods in green agents' preferences is lower relative to status agents, then it is more likely that green consumers attain higher well being at the equilibrium.

From the replicator dynamics equation (8) and (16) it is clear that apart from the two trivial fixed points, $x_0^* = 0$ and $x_1^* = 1$, $\dot{x}$ may have additional interior fixed points x^*, defined by the solution of (16). Given that (16) is quadratic in x, there are two possible interior fixed points $x^*(\Delta\mu, b, p)$,[23] of which only one is admissible, that is, $x^* < 1$. For admissible values of the parameters yielding an interior x^*, an increase in the price increases x^*. That is, a price increase apart from reducing both types of agents 'consumption of C, it has an indirect effect on total consumption by increasing the share of the overconsuming segment of the population.

For $\Delta\mu = 0$, according to Proposition 1 and the preceding discussion, the higher is the importance of status in type 1 agents' well being, that is the higher b is, the larger x^* will be. When $b = 0$, that is, when both types of agents are the same, naturally $x = 1/2$. As the difference in the social part of the well being increases, keeping individual preferences the same, status agents' share in the population increases up to $x^* = \frac{1+b-\sqrt{1+b}}{b}$, with $\lim_{b\to\infty} x^* = 1$. For $\Delta\mu < 0$, the price affects x^*. For given price, as $\Delta\mu$ increases, naturally x^* decreases. For given value of $\Delta\mu$, as the price increases, x^* increases. For values of $\Delta\mu$, b, and p for which $\Delta W|_{\tau=\theta=0} \gtreqless 0$, for $x \lesseqgtr x^*$, only the polymorphic steady state is stable, since the slope of $\dot{x}$ will be negative at x^*.

The following Proposition summarizes the above discussion.

Proposition 2. *In the absence of policy intervention, $\tau = \theta = 0$, if consumers differ only in their attitude towards using material consumption to attain social status, the share of status agents is $x^* > 1/2$ and increasing in the importance placed on status, $\frac{\partial x^*(0,b,p)}{\partial b} > 0$. In this case, a tax cannot affect the share of status agents in equilibrium. If consumers' preferences differ in the relative evaluation of goods and assuming $MRS^1_{C,m} < MRS^2_{C,m}$, the share of status agents in the steady state is decreasing in the preferences' difference for given price, $\frac{\partial x^*(\Delta\mu,b,p)}{\partial\mu} < 0$ and is increasing in the price for*

[23] The roots of are $x^*(\Delta\mu, b, p) = \frac{\Phi\pm\sqrt{\Psi}}{\Omega}$, where $\Omega = b\left(b^2 - \Delta\mu^2 p^2 + 2b\Delta\mu m_2^*\right)$, $\Phi = b(1+b)\left[b + \Delta\mu\left(2m_2^* - p\right)\right]$ and $\Psi = b(1+b)(b-\Delta\mu p)^2\left[b + \Delta\mu\left(m_1^* + m_2^*\right)\right]$. Only the negative root can give values less than unity under certain restrictions regarding the size of $\Delta\mu$ relative to the rest of the parameters.

given difference in preferences, $\frac{\partial x^*(\Delta\mu,b,p)}{\partial p} > 0$.

We can briefly discuss now the effect of different environmental preferences between the two types of agents, which in the current framework implies different perceptions of environmental damages. Since the intuition of the results is straight forward we choose to avoid complicated analytical proofs, which though are available upon request. It is reasonable, although not necessarily always true, to associate status seeking behavior with dismissal of environmental damages, implying a relatively lower d, that is, we assume $\Delta d = d_1 - d_2 < 0$. In such case, the last term in (15) is positive and thus, the share of status seekers in the polymorphic steady state gets higher, for any values of $\Delta\mu$, b and p for which $x^*(\Delta\mu, \Delta d, b, p) < 1$, that is, $\frac{\partial x^*(\Delta\mu,\Delta d,b,p)}{\partial \Delta d} > 0$. Actually it can be shown that for high values of γ and $\Delta d < 0$, x_1^* is the only stable steady state. For $\Delta\mu = 0$, and given Δd and b, an increase in the price will decrease average/total consumption an thus, it will have a negative effect on x^*, that is, $\frac{\partial x^*(0,\Delta d,b,p)}{\partial p} < 0$, eroding the positive effect of Δd. The above discussion is summarized in the following Corollary.

Corollary 1. *In the absence of policy intervention,* $\tau = \theta = 0$*, an increase in the environmental sensitivity of green agents leads to the decrease in their share in the population. When agents' preferences differ in their environmental sensitivity only, an increase in the price will have a negative effect on* x^**.*

The intuition is straight forward: assuming that green agents' perception of environmental damages is higher, $d_2 > d_1$, reduces their well being at the equilibrium faster relatively to status agents at any level of pollution. That is, when status seeking is associated with caring less about environmental damages (lower d) yields a higher level of well being relative to the green agents, which renders green behavior less attractive, reducing thus their share in the population.

5.2 Steady state at selective, exogenously determined, policy interventions

When taxes τ and informative advertisement θ are used as controls, the controlled replicator dynamics equation, substituting (15) into (8) yields,

$$\dot{x} = x(1-x)\left[W_1(p, x^*, \tau, \theta; \mathbf{z}_1) - W_2(p, x^*, \tau; \mathbf{z}_2)\right], \qquad (17)$$

where, $\dot{\theta} = \phi(\theta)$.

As discussed above, the replicator dynamics always has two fixed points, the $x_0^* = 0$ and $x_1^* = 1$, solutions while there is the possibility of more fixed points x^*, defined by the solution of the algebraic equation,

$$W_1(p, x^*, \tau, \theta; \mathbf{z}_1) - W_2(p, x^*, \tau; \mathbf{z}_2) = 0. \qquad (18)$$

Thus, the regulator may be able, by choosing τ and θ, to steer the system to a steady-state monomorphic population $x_0^* = 0$ or $x_1^* = 1$, or to a steady-state polymorphic population x^*, determined by (18). Given that $\bar{p} = p + \tau$, it is evident from Proposition 2 first that, for $\Delta\mu = \Delta d = 0$, taxation will have no effect on ΔW and thus on x^*. Second, that, for $\Delta\mu < 0$ and $\Delta d = 0$, an increase in the tax will increase the share of status seeking agents in the population, that is $\frac{\partial x^*(\Delta\mu, b, p)}{\partial\tau} > 0$. However, we also know, from Corollary 1, that if $\Delta\mu = 0$ and for given $\Delta d < 0$, an increase in taxation will have the opposite effect of decreasing the share of status seekers. The overall effect of taxation on x^* will obviously depend on the relative size of the difference in agents' environmental and intrinsic consumption preferences, that is the size of $\Delta\mu$ and Δd. Denote by $x^*(\Delta\mu, \Delta d, b, p, \gamma)$ the solution of $\Delta W = 0$ as defined in (15). Then, $\frac{\partial x^*(0,0,b,p,\gamma)}{\partial\tau} = 0$, $\frac{\partial x^*(\Delta\mu,0,b,p,\gamma)}{\partial\tau} > 0$, $\frac{\partial x^*(0,\Delta d,b,p,\gamma)}{\partial\tau} < 0$, and thus, $\frac{\partial x^*(\Delta\mu,\Delta d,b,p,\gamma)}{\partial\tau} \lesseqgtr 0$. Taxation definitely decreases aggregate/average consumption of C. However, its effectiveness could be compromised when consumers' preferences differ, in which case the tax could promote status seeking behavior among agents. The above discussion is summarized in the following Proposition.

Proposition 3. *Taxing material consumption that is used by some individuals to signal social status, has two effects: the usual direct reduction of aggregate consumption and an indirect effect that could erode the direct effect. An increase in the tax could, under reasonable differences in preferences, decrease the share of green agents in the population.*

A tax on the composite good C will change the relative price, shifting consumption away from material goods used to improve status. Assuming $0 < x^* < 1$, an increase in the tax could have a positive effect on status seeker's relative well being in equilibrium. Thus, status seeking behavior will become more attractive and more agents will adopt the status strategy. Therefore, the overall effect of taxation is reduced: all individuals reduce their consumption of C, but a higher share of them overconsumes for social purposes.

The regulator has also the option of investing in the provision of information to directly influence the social component of status agents' demand for C. When social motivations of consumption are ignored, information provision usually targets individual's perception of environmental damages resulting from consumption, which in our model is denoted by parameter d_i, or consumers' evaluation of the dirty relative to clean alternative, which in our model is denoted by parameter μ_i.[24] However, as discussed in the introduction, even if an environmental awareness campaign is very successful and convinces all individuals to take into account the negative effect that their consumption has on them, only a small part of the problem will be addressed, since the main problem is due to the externalities created.[25] Furthermore, if information provision increases d's at different rate resulting in larger Δd, this will increase the share of status seekers in the population.

Instead of targeting consumer's intrinsic and environmental preferences, in this paper we assume that information provision policies target the social element in consumers' well being. That is, we assume that government's investment in information provision affects the parameter indicating the relative importance of status in type 1 agent's well being, that is, $b(\theta)$, with $\frac{\partial b(\theta)}{\partial \theta} < 0$. Public advertisement convinces individuals to change their strategy concerning social status. If status agents place less importance on social status, then both their excess consumption relative to green agents is reduced, since $\frac{\partial \Delta C^*}{\partial b} > 0$, and their share in the population decreases.

Proposition 4. *A public information provision campaign that is effective in reducing the importance of social status in individuals' well being, is successful in reducing both overconsumption due to status seeking and the share of status seeking agents in the population.*

It is clear that information provision targeting b is successful at reducing

[24] See for example Petrakis et al. (2005), Sartzetakis et al. (2012).

[25] Important effect could only be derived by promoting altrouistic behavior, creating "warm glow" effects.

overconsumption of status seekers. At the extreme, a completely successful campaign reducing substantially b, will eliminate the difference between the two types of agents. However, to correct the environmental externality created by green consumers we need a tax. In addition, information provision is costly, and thus, the optimal combination of the two instruments is not obvious. In the next Section we define the optimal combination of the two policy instruments.

6 Optimal choice of policy instruments

In deriving the regulator's optimal choice of policy instruments we use a simple mechanism through which information provision affects agents' choice of strategy. We assume first, that it is the level of currently provided information that affects the agents' choice and second that information provision θ at time t has a constant and equal to one effect on the parameter indicating the relative importance of status in type 1 agent's well being, that is, $b(\theta) = b - \theta$. We resort to these simplifying assumptions in order to derive numerical solution to the optimal policy choice problem. Obviously the process is far more complicated. For example, Sartzetakis et al. (2012) assume that agents' choice is affected by the stock of information accumulated at time t and use, instead of a linear, an S-shaped response function to information provision. The cost of providing information at time t, $c(\theta(t))$, with $c(0(t)) = 0$, is assumed convex, as suggested in the relevant literature.

Within this framework, the regulator chooses paths for $\tau(t)$ and $\theta(t)$ that will optimize discounted social welfare over an infinite time horizon subject to replicator dynamics. The instantaneous social welfare can be expressed as,

$$W(t) = x(t) f_1^*(\bar{p}(t), x(t), Y) + (1 - x(t)) f_2^*(\bar{p}(t), x(t), Y) - c(\theta(t)), \tag{19}$$

where $f_i^*(\bar{p}(t), x(t), Y)$, $i = 1, 2$ are defined in (6). Therefore, the regulator's optimal policy choice problem is,

$$\max_{\tau(t),\theta(t)} \int_0^\infty \mathrm{e}^{-\rho t} W(t) dt$$

subject to

$$\dot{x}(t) = x(t)(1-x(t)) \left[f_1^* \left(\bar{p}\left(t\right), x\left(t\right), Y \right) - f_2^* \left(\bar{p}\left(t\right), x\left(t\right), Y \right) - \phi\left(\theta\left(t\right)\right) \right]$$

$$x(0) = x_0$$

The current value Hamiltonian of the above problem is,

$$\mathcal{H}\left(x\left(t\right), \lambda\left(t\right), \tau\left(t\right), \theta\left(t\right)\right) = W\left(t\right) + \lambda\left(t\right) \dot{x}\left(t\right),$$

where, $\lambda\left(t\right)$ is the shadow value of the proportion of status seekers indicating the change in maximized welfare from a small change in $x\left(t\right)$. Pontryagin's maximum principle implies the following conditions:

$$\tau^*\left(t\right) = h^\tau\left(x\left(t\right), \lambda\left(t\right)\right) \ , \ \theta^*\left(t\right) = h^\theta\left(x\left(t\right), \lambda\left(t\right)\right). \tag{20}$$

which are obtained as the solution of:

$$\frac{\partial \mathcal{H}\left(x\left(t\right), \lambda\left(t\right), \tau\left(t\right), \theta\left(t\right)\right)}{\partial \tau} = 0 \ , \ \frac{\partial \mathcal{H}\left(x\left(t\right), \lambda\left(t\right), \tau\left(t\right), \theta\left(t\right)\right)}{\partial \theta} = 0,$$

assuming interior solutions, and the Hamiltonian system

$$\dot{x}\left(t\right) = \frac{\partial \mathcal{H}\left(x\left(t\right), \lambda\left(t\right), \tau^*\left(t\right), \theta^*\left(t\right)\right)}{\partial \lambda} \ , \ x\left(0\right) = x_0 \tag{21}$$

$$\dot{\lambda}((t) = \rho \lambda\left(t\right) - \frac{\partial \mathcal{H}\left(x\left(t\right), \lambda\left(t\right), \tau^*\left(t\right), \theta^*\left(t\right)\right)}{\partial x}. \tag{22}$$

The steady state of the Hamiltonian system is defined as

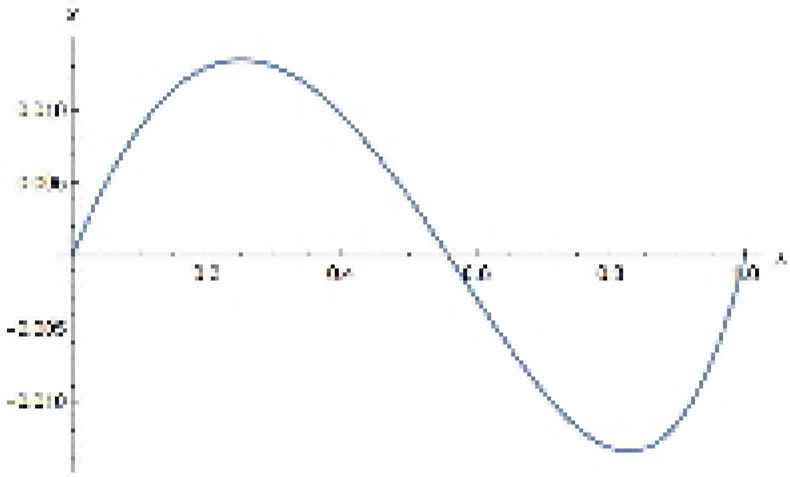
$$\left(x^*, \lambda^*\right) : \dot{x}\left(t\right) = 0, \ \dot{\lambda}((t) = 0.$$

The structure of (21) implies that the Hamiltonian system will have for x the steady state $x^* = 1$, $x^* = 0$ and potentially additional interior steady states $x^* \in (0,1)$. An optimal solution $(x^*(t), \lambda^*\left(t\right))$ of the Hamiltonian system, if it exists, will provide, after substitutions into (20), the optimal paths for the controls $\tau\left(t\right)$ and $\theta\left(t\right)$.

The Hamiltonian system (21)-(22) is highly nonlinear and, because of this, closed form solutions are not possible. In order to provide some insight into the choice of optimal controls we resort to the following numerical simulation. Since we are interested in exploring the impact of optimal policy relative to the case in which no policy is applied we consider steady states for type 1 consumers when $x(t)$ is evolving according to the replicator dynamics and no policy is applied, that is $\tau = 0$, $\theta = 0$ and then we compare them with steady states resulting from optimal policies determined by (21)-(22).

For the numerical analysis we use the following values for the parameters: $a = 1.5$; $\mu_1 = \mu_2 = 0.4$; $b = 0.6$; $d_1 = d_2 = 1$; $\gamma = 1$; $p = 2$ and $Y = 10$. In Section 5.1 we stated that setting ΔW, given in (16), equal to zero yields, the interior solutions $x^* \in (0, 1)$ of the static model in the absence of policy intervention. Assuming no difference in preferences between the two groups of consumers, that is, when $\Delta\mu = \Delta d = 0$, the admissible no-policy interior steady state is $x^* = \frac{1+b-\sqrt{1+b}}{b}$, which for $b = 0.6$ becomes $x^*_{NP} = 0.558482$. Figure 1, plotting the replicator dynamic equation in (8) as function of x, illustrates the result in Section 5.1 that for the specific parametrization only the polymorphic steady state is stable, since the slope of $\dot{x}$ is negative at x^*_{NP}, while the steady states at the boundaries $(0, 1)$ are unstable.

1



1.jpg

Figure 1: The no-policy steady states with $x^*_{NP} = 0.5585$

Next we consider a first order expansion of the Hamiltonian functions around the no-policy stable steady state $x^*_{NP} = 0.558482$. We consider this approximation as reasonable since it allows comparisons between the no-policy and the optimal policy outcomes. The results of the solution under this approximation are summarized in Table 1. The first two rows in Table 1 present the steady states for (x^*, λ^*) obtained from the maximization of the linearized Hamiltonian function.[26] Columns three and four report the optimal controls $\tau(x^*, \lambda^*)$, $\theta(x^*, \lambda^*)$ that correspond to each steady state. The last column presents the values of the steady state welfare, defined as $W^*_{SS} = \frac{1}{\rho} W(x^*, \tau(x^*, \lambda^*), \theta(x^*, \lambda^*))$. To facilitate comparison, the last row presents the value of the welfare W^*_{NP} at the steady state in the absence of policy intervention.

	x^*	λ^*	$\tau(x^*, \lambda^*)$	$\theta(x^*, \lambda^*)$	W^*
	0	-3.710	1.421	0.379	392.8
Optimal policy	0.036	-3.551	$1,566$	0.323	394.822
No policy	0.558	–	0	0	377.947

Table 1. Numerical results at the steady states and the no-policy case

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

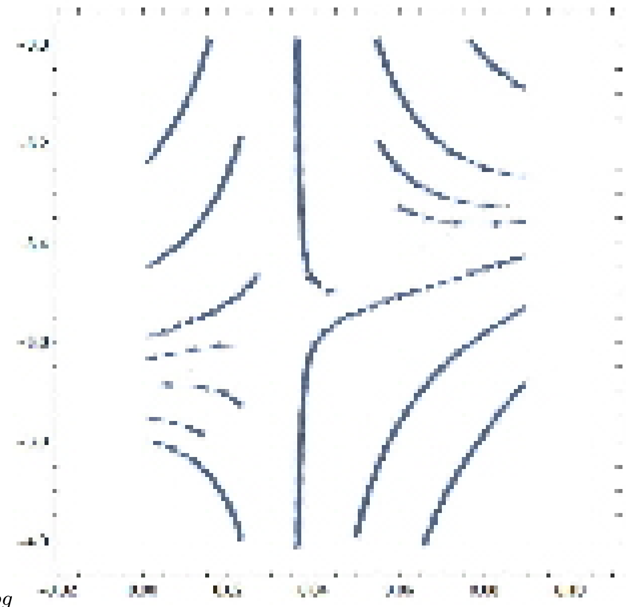
$$J = \begin{pmatrix} \frac{\partial \dot{x}}{\partial x} & \frac{\partial \dot{x}}{\partial \lambda} \\ \frac{\partial \dot{\lambda}}{\partial x} & \frac{\partial \dot{\lambda}}{\partial \lambda} \end{pmatrix}$$

Calculation of the eigenvalues of the Jacobian matrix at the two local/global optimal steady states $x^* = 0$, and $x^* = 0.036$, respectively indicates that both of them are saddle points. Figure 2, in which the horizontal axis measures values of x and the vertical values of λ, presents the phase plot of the steady state $x^* = 0.036$, which which corresponds to the global optimum.

At the globally optimal steady state $x^* = 0.036$, the regulator chooses a level of information provision $\theta^* = 0.323$ and levies a tax $\tau^* = 1,566$ on C, a policy combination that reduces the share of status seeking agents from 55.8% without policy intervention, to 3.6%. This policy intervention reduces aggregate consumption of C from $TC^*_{NP} = 0.9649$ to $TC^* = 0.0813$, yielding, the reported in Table 1, social welfare improvement over the case without policy intervention. Notice that eliminating completely the status

[26] The linearized Hamiltonian system produced two more steady states one at the boundary $x = 1$ and one interior. These steady states were not admissible because they were implying negative steady state consumption for consumers type 2.

2



$_2.jpg$

Figure 2: The globally optimal steady state $x^* = 0.036$

agents, although it presents an improvement over the no-policy case, it is not the best choice. At the globally optimal steady state a small fraction of status agents still exists.

Although these results hold for a first order expansion of the Hamiltonian around the no-policy point and higher order expansions could provide better approximations to the solution corresponding to the original non linear Hamiltonian, our results make clear the improvement in terms of the welfare indicator relative to the no-policy case and the considerable reduction of the status seeker consumers when optimal policies are adopted.

7 Epilogue

It is beyond dispute that the continuously increasing consumption of material goods is the primary driver of the resource and environmental crises, including climate change and loss of biodiversity, humanity is currently facing. Although technology continues to offer solutions, including for example renewable energy, the urgency of the crises requires much faster responses involving new and old technologies during transition, which could be achieved only with demand side adjustments. The common response of an economist would be to assign a levy through a tax or a permit scheme, in the case of climate change for example, on carbon emissions, in order to efficiently influence people's behavior towards internalizing the externalities. However, increases in fuel prices in the previous decade, both in North America and Europe, did not bring the required changes as fuel markets continue to thrive. In addition, ambitious increases in fuel prices have met considerable opposition, especially by low-income people, with the French experience over the last three years being the primary example.

In this paper we attempt to offer an explanation of why an environmental tax might not be as effective as expected and a potential remedy. We focus our attention on relatively high-income individuals whose consumption of highly polluting material goods is driven by motivations to improve their social status. Since large numbers of individuals from developing countries are continuously joining this group, the proliferation of such behavioral trends could indeed be consider a primary driver of material goods overconsumption. We develop a framework that captures these basic characteristics and, taking into account the social dimension of demand motivations, we explain first, why a tax might not be as effective as expected; and second, we show that complementing the tax with information provision aiming at moderating status seeking overconsumption improves social welfare. Convincing people, through information campaigns and/or advertisement that consuming highly polluting material goods does not improve their social status could have a substantial effect which perfectly complements taxation, improving actually its effectiveness.

The framework employed in this paper has been admittedly constrained by our intention to provide analytical solution in the first part of the paper and numerical examples in the far more complicated derivation of the optimal policy combination. The paper could be extended in a numerous ways including the following. As already mentioned in the text, considering stock pollutants will be an important extension of the current work. Extending heterogeneity in the social aspect of the demand beyond the two groups examined in this paper could also enrich the results. Another important extension would be to relax the assumption of perfect competition and explicitly model the production side. Finally, a richer structure of how information provision affects the social component of the demand could provide intuition on how to design such policies. Needless to say, empirical work on how public information affects different aspects of consumers' behavior would be extremely helpful.

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9 Appendices

9.1 Appendix 1.

First, from (12) and (13) the difference between status agent's and average consumption of C, is,

$$C_1^* - \bar{C}^* = (1 - x)\, B. \tag{23}$$

From (12) and (11) we also derive the sum of the two types of agents' consumption,

$$\sum C^* = C_1^* + C_2^* = 2\,(a_2 - \bar{p}) + B. \tag{24}$$

We can now derive (15). First, we derive the difference in the intrinsic utility between the two groups of agents,

$$\begin{aligned}
\Delta W_{\text{intrinsic}} &= a_1 C_1^* - a_2 C_2^* - \frac{1}{2}\sum C^* \Delta C^* + \mu_1 m_1^* - \mu_2 m_2^* \\
&= (a_1 - \mu_1 \bar{p})\, C_1^* - (a_2 - \mu_2 \bar{p})\, C_2^* + \Delta\mu Y - \left[(a_2 - \mu_2 \bar{p}) + \frac{B}{2}\right] B \\
&= (a_1 - \mu_1 \bar{p})\, C_1^* - (a_2 - \mu_2 \bar{p})\, C_1^* + \Delta\mu Y - \frac{B^2}{2} \\
&= (\Delta a - \Delta\mu \bar{p})\, C_1^* + \Delta\mu Y - \frac{B^2}{2} \\
&= \Delta a C_1^* + \Delta\mu\,(Y - \bar{p} C_1^*) - \frac{B^2}{2} \\
&= \Delta a C_1^* + \Delta\mu m_1^* - \frac{B^2}{2}
\end{aligned}$$

Using (23) we derive the well being status seekers obtain, at the equilibrium, from the consumption of C as status indicator,

$$\Delta W_{\text{status}} = b\left[(C_1 - \bar{C}) - \frac{1}{2}(C_1 - \bar{C})^2\right] \tag{25}$$

$$= b\,(1 - x)\left(1 - \frac{(1 - x)\,\Delta C}{2}\right)\Delta C \tag{26}$$

$$= b\,(1 - x)\left(1 - \frac{(1 - x)\,B}{2}\right)B. \tag{27}$$