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Regulation of morally responsible agents with motivation crowding

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Abstract: We study the regulation of a morally responsible agent in the context of a negative consumption externality and motivation crowding. In particular, we analyze how various governmental interventions affect the agent's motivation to assume moral responsibility. Employing a motivation-crowding model, we find that morally motivated behavior will, in general, not ensure Pareto efficiency without intervention. A Pigouvian tax may be efficient under motivation crowding. But the efficient taxe rate needs to be higher, which may lead to a full crowding-out of moral motivation. By contrast, an inefficiently low taxe rate may increase the market failure due to motivation crowding. Provision of information is efficient only in very specific cases but may be effective in reducing the extent of market failure. A complementary tax-and-information policy approach is superior to a tax as single instrument if its aim is to reduce consumption and if provision of information raises moral motivation.

JEL Classification: D03, D11, D62, H23, Q58

Keywords: Altruism, externality, moral motivation, motivation crowding, Pareto efficiency, regulation, responsibility, taxes, provision of information

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1 Introduction

Many environmental problems, such as climate change or the loss of biodiversity, are driven by negative externalities. Essentially, such externalities cause market failure for which conventional economic wisdom suggests introducing governmental policies in the form of taxes or subsidies (e.g. Pigou 1932, Baumol 1972). These suggestions rely on the assumption of purely self-centered human behavior. However, this assumption is not generally justified since human beings often assume moral responsibility, that is in their actual behavior they respond to moral obligations (e.g. Sen 1977, Brekke et al. 2011, Perino et al. 2011). Furthermore, Motivation Crowding Theory (e.g. Deci 1971 or Frey 1997, 2001) suggests that extrinsic interventions, such as governmental policies, severely affect individuals' motivation to assume moral responsibility. In this paper, we study the regulation of a morally responsible individual with motivation crowding in the context of a negative consumption externality.

In the case of environmental policies, command and control instruments, but also incentive-based instruments such as tradable emission rights or Pigouvian taxes, tend to undermine moral motivation, while information, appeals and participation enhance moral motivation (Frey and Jegen 2001). Empirical evidence is plentiful,[1] but there are few theoretical studies on the issue and these do not simultaneously consider negative externalities and motivation crowding. Heyes and Kapur (2011) analyze how moral motivation, in the context of negative externalities, affects the optimal specification of particular policy instruments. Their focus, however, is on motivational heterogeneity and they do not consider the case of motivation crowding. Further literature on moral motivation has mainly focused on the voluntary provision of public goods by morally motivated individuals (e.g. Andreoni 1988, 1990, Brekke et al. 2003, Nyborg and Rege 2003). Moral motivation is generally modeled as a warm-glow, based on a utilitarian norm by which an optimal level of giving is defined. Something like motivation crowding occurs in those models when environmental policies influence the optimal level of giving.

We contribute to the literature in three ways: First, we consider the case of externalities which is more general than the case of public goods. Second, we focus on responsible behavior rather than behavior driven by a warm-glow or self-image. Third, we model motivation crowding as a psychological phenomenon (in the sense of the self-determination theory of Deci and Ryan 1985), and not as a purely economic phenomenon driven by changes in the optimal allocation. Altogether, this allows us to identify fundamental psychological determinants for the efficiency of taxes, provision of information and a policy mix of the two instruments.

More specifically, we analyze the regulation of a morally responsible individual in the context of a negative consumption externality and motivation crowding, focusing on the moral principle: 'You ought not to consciously harm others against their will'. Against this

[1] For an economic survey of the issue see Bowles and Hwang (2008) or Gneezy et al. (2011).

background, we focus on two questions: (1) Is responsibility – understood as moral motivation of individual actors – sufficient for Pareto efficiency in a decentralized economy when individual action causes negative externalities? (2) Can a Pigouvian tax, provision of perfect information, or a complementary policy combining both instruments lead to Pareto efficiency when moral motivation is subject to motivation crowding?

For this analysis, we use a simple model: there are two goods, one numeraire good and one polluting good, and two individuals, *A* and *B*. *A* derives utility from private consumption of both goods and a morally weighted disutility from her knowledge about her causing the externality. *B* derives utility from the numeraire good and disutility from *A*'s consumption of the polluting good. We thus have an asymmetric, unidirectional power structure, as *A* is responsible for the harm inflicted on *B*.[2] The moral weight in *A*'s utility function reflects the personal desirability of responsible behavior and is affected by policy measures (motivation crowding): it decreases with a tax, and increases with provision of information. The model thus allows us to study the effects of regulatory policies with respect to Pareto efficiency: price regulation through a Pigouvian tax on the polluting good, descriptive information provisioning as lowering uncertainty about the externality, and a complementary policy combining both instruments.

Our results show that morally responsible behavior will in general not lead to Pareto efficiency without governmental intervention as it may diminish or exacerbate market failure. Intervention through taxation leads to crowding-out of moral motivation, but there always exists a tax rate so that the equilibrium allocation is efficient. However, such a tax-only policy has three weaknesses due to motivation crowding: First, crowding requires a higher tax rate which may be difficult to implement due to political pressure. Second, setting the tax rate inefficiently low may exacerbate the market failure. And third, an efficient tax rate may fully crowd-out moral motivation if there are motivational spill-overs. Intervention through provision of information is only efficient for very restrictive assumptions, but can be effective in reducing the market failure. Intervention through a complementary tax and information approach is an efficient instrument just as a tax-only policy, and may overcome the weaknesses of a tax-only policy for some (but not for all) parameter values. Altogether, our study highlights the need for the development of new policy instruments in the face of externalities and motivational crowding.

The paper is organized as follows. Section 2 prepares the conceptual basis for the analysis. Section 3 introduces the model. Section 4 presents our results. Section 5 concludes.

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[2] Such structures are particularly important when future generations (*B*) are affected by the behavior of the present generation (*A*).

2 Conceptual foundations: moral responsibility and motivation crowding

In this section, we prepare the conceptual basis of the paper by first defining the concepts of moral responsibility and motivation crowding. Second, we link both concepts.

Responsibility is a multifarious notion. In the philosophical discussion of responsibility, at least three different aspects of the notion have been distinguished. (1) The primary meaning of responsibility is being the perpetrator of one's own actions, that is, "[…] one ascribes an action to oneself and allows for it to be thus ascribed" (Baumgärtner et al. 2006: 227). The primary meaning is purely descriptive and has no moral relevance by itself. It simply states that *A* is responsible for *X* if and only if *A* is the perpetrator of *X*. This is a precondition of morality, as one can only be morally praised or blamed for an action that can be ascribed to oneself. (2) When we speak of 'responsibility', we often use 'responsibility' as a synonym for 'obligation' (Williams 2008: 458). This is what Baumgärtner et al. (2006) call the secondary meaning of responsibility. In this meaning, responsibility attains a moral significance when obligations exist which a person morally has to accept, that is, *A* ought to do *X* or ought not to do *X* for moral reasons. (3) Williams (2008) defines a third meaning of responsibility: "Responsibility represents the readiness to respond to a plurality of normative demands" (Williams 2008: 459). In other words, responsibility is important whenever individuals are facing a plurality of normative obligations[3]. One specific suggestion as to how to ethically balance two rivaling normative obligations is due to the utilitarianist Peter Singer (1972). He suggests that two obligations ought to be balanced to the point of marginal utility at which both obligations are equally met at the margin.

In line with the above reflection, we consider the responsibility of an agent for (the consequences of) her actions [aspect 1], as facing a moral obligation [aspect 2] while also striving [aspect 3] for personal happiness. An individual assuming responsibility for her actions is self-negotiating two aims: the obligation to herself to have a good life, and the moral obligation not to harm others against their will. This act of assuming responsibility requires that an individual is motivated to act responsibly.

To be motivated means to be moved to do something. An individual who feels no inspiration to act is characterized as unmotivated, whereas an individual who is activated toward an end is considered motivated (Ryan and Deci 2000: 54). Individuals may have different levels, but also different kinds of motivation. The psychological literature distinguishes between intrinsic and extrinsic motivation. One is said to be *intrinsically* motivated to perform an activity when one receives no apparent rewards except the activity itself (Deci 1971). Kunda and Schwartz (1983) consider the will to fulfill a moral obligation and to assume responsibility as a special type of intrinsic motivation. Such intrinsic motivation might be either innate or learned (White 1959), and may thus change. *Extrinsic* motivation comes from outside the individual. All forms of monetary reward or threat (e.g.

[3] With "obligation" we here refer to what Williams (2008) describes as "normative demand".

taxes, subsidies, fines) are examples of extrinsic motivation. Such extrinsic rewards or threats can lead to overjustification and a subsequent reduction of intrinsic motivation (Kunda and Schwartz 1983). For example, Titmuss (1971) finds that paying individuals for donating blood might decrease the willingness to donate blood.[4] The reason simply is that individuals wish to donate blood because they are intrinsically motivated to do so. If they are offered a monetary reward, this intrinsic motivation is replaced, or crowded-out, by the extrinsic motivation to receive money. If the intrinsic motivation was stronger than the subsequent extrinsic motivation, the willingness to donate blood decreases.

In the late 1990's, the work of Frey (1997, 2001) put motivation crowding on the research agenda of economics. By now, there exists plenty of empirical evidence for economic instruments crowding-out[5] intrinsic motivation in the economic[6] and in the psychological[7] literature. Still open is the question of how the extent of motivation crowding depends on the quantity of monetary compensation or taxes. Frey and Oberholzer-Gee (1997) find that individuals' willingness to accept a nuclear waste facility in their neighborhood does not increase with monetary compensation levels. This suggests that the crowding effect of monetary compensation increases with the compensation offered. In contrast, Gneezy and Rustichini (2000b) find that higher compensations for previously unpaid tasks increase effort levels, which suggests that higher compensation levels do not have stronger crowding effects. Therefore, we leave the relationship between the quantity of the extrinsic intervention and the extent of the crowding effects open. Shedding more light on this relation remains an interesting task for empirical research.

To summarize, individuals want to assume moral responsibility and their intrinsic motivation is the key to understand how they react to governmental policies. Yet, this intrinsic motivation is prone to crowding – both positive and negative – from regulatory intervention. This is the starting point for the analysis in this paper. In the following section, we set up a model of motivation crowing which allows us to study the relationship between people's intrinsic motivation and different policy instruments.

[4] Mellström and Johannesson (2008) recently confirmed the Titmuss result, but only for women. For men they did not find crowding effects.

[5] Charness and Gneezy (2009) is one of the few studies finding crowding-in through monetary incentives. However, they do not analyze morally motivated behavior, but the motivation to exercise in a gym.

[6] See e.g. Frey (1999, 2001), Nyborg (2003b), Goeschl and Perino (2012) and Perino et al. (2011), d'Adda (2011), Ariely et al. (2009), or Falk and Kosfeld (2006). See Gneezy et al. (2011) for a recent overview of the literature.

[7] See e.g. Deci et al. (1999), or Heyman and Ariely (2004).

3 Model

There are two individuals, *A* and *B*, and two goods, *X* and *Y*, where *Y* is a numeraire good that is consumed by both individuals. Let $y^j \geq 0$ denote the consumption of *Y* by individual *j* $(j = A, B)$. In contrast, *X* is only consumed by individual *A*. *A*'s consumption of *X*, denoted by $x \geq 0$, causes a negative externality on *B*'s utility, $d(x)$, with $d(0) = 0$, $d'(x) > 0$, and $d''(x) \geq 0$ for all $x \geq 0$.

Government may intervene to regulate the externality through either one, or both, of the following two policy instruments: (1) a Pigouvian tax with tax rate *t* on the polluting good *X*, where *t* may be greater or smaller than zero, i.e. it may be a tax or a subsidy[8]; (2) provision of perfect information *i* on the actual extent of damage *d*(*x*).

In this unidirectional power structure, in which *A*'s behavior has consequences for *B*'s well-being, we assume that *A* is morally motivated to act responsibly. In the utility function that determines her actual behavior, she is thus self-negotiating two obligations: the moral obligation not to harm *B*, and the obligation to maximize her self-directed well-being:[9]

$$U^A\left(x, y^A\right) = y^A + u(x) - m(t,i)k(i)d(x). \tag{1}$$

The first part of this additively separable utility function, $y^A + u(x)$, denotes *A*'s quasi-linear self-directed utility[10] from private consumption of both goods, with $u'(x) > 0$, and $u''(x) < 0$ for all $x \geq 0$. We further assume that $\lim_{x \to 0} u'(x) \to +\infty$, which ensures that *A* always consumes a strictly positive amount of the polluting good *X*.

This self-directed utility is reduced by $m(t,i)k(i)d(x)$, which represents *A*'s moral motivation not to harm *B*. This second part depends on consumption of the polluting good *X*, and on the level of government intervention through taxes, *t*, and information, *i*. $k(i)d(x)$ denotes *A*'s expectation of the externality on *B*'s utility from her consumption of *x*. The term differs from the actual harm to *B*, $d(x)$, by a factor of $k(i)$, which measures *A*'s knowledge about the externality. For $k(i) < 1$, *A* underestimates the externality, while for $k(i) > 1$, she overestimates the externality. We assume that without any provision of information, *A* has

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[8] We assume that the tax income is lump-sum redistributed by the government, and that subsidies are paid from government funds that are raised in a non-distortionary manner.

[9] We thus apply the dual preferences model of Brekke et al. (2003) and extend it for the case of externalities and for the idea of motivation crowding from the model of Frey and Oberholzer-Gee (1997).

[10] One may consider the numeraire good *Y* as a composite good, such as money left for all other goods. *Y* will thus account for the major part of *A*'s utility.

some knowledge of the externality, $k(0) = \kappa \geq 0$. The government can influence *A*'s knowledge by providing perfect information $i = i^*$, such that individual *A* is perfectly informed about the externality, i.e. $k(i^*) = 1$. The government's aim is thus to fully inform individual *A*, so that *A* becomes fully aware of the harm her consumption of *X* inflicts on *B*.[11] When *A* is perfectly informed, the expected damage equals the actual damage. Altogether, it is the knowingly inflicted harm on *B* which reduces *A*'s utility.

Assuming responsibility for herself and for *B*, person *A* self-negotiates her self-directed utility and the known externality with a moral-motivation factor $m(t,i)$ [12] that expresses her intrinsic motivation to act responsibly:

$$m(t,i) = \max\{n(t,i), 0\}. \tag{2}$$

A has a basic level $m(0,0) = \mu \geq 0$ of intrinsic motivation not to harm *B* when there is no government intervention. If the government imposes extrinsic incentives, the total intrinsic motivation $m(t,i)$ is affected. A Pigouvian tax t on the polluting activity *X* reduces the intrinsic motivation, $n_t < 0$[13] for $t > 0$ and $n_t > 0$ for $t < 0$.[14,15] For the provision of perfect descriptive information i^*, we follow Reeson and Tisdell (2008) and assume crowding-in of intrinsic motivation, i.e. $n(t,i^*) > n(t,0)$, because such a policy acknowledges the freedom

[11] In order to maximize welfare, a government could use information strategically to reach a Pareto-efficient state in the short-run (Asheim 2010). We do not consider this possibility, because information cannot be used strategically in the long-run, as Abraham Lincoln stated: "You may fool all the people some of the time; you can even fool some of the people all the time; but you can't fool all of the people all the time."

[12] Frey and Oberholzer-Gee (1997) introduced a somewhat similar model. Our motivation-crowding model for $m(t,i)$ extends theirs as, firstly, they analyzed the effect of only one instrument, which secondly was not a tax or information, but monetary compensation for the willingness to accept a hazardous facility in one's neighborhood.

[13] Subscripts denote partial derivatives, in this case $n_t = \partial n(t,i)/\partial t$.

[14] Note that, given the evidence from Perino et al. (2011), we assume crowding-out effects not only for positive tax rates but also for subsidies ($t < 0$).

[15] Frey and Oberholzer-Gee (1997) find evidence for linear crowding of rewards to accept nuclear facilities in one's neighborhood, i.e. ($n_t = \text{const.}$), assuming that there is a constant elasticity of income. To our knowledge, this is the only evidence for the curvature of motivation crowding.

and self-determination of individuals.[16] The government provides i^* at no cost. Lacking empirical evidence, we leave it open whether there are cross effects between the two policy instruments on motivational crowding, $n_{ti} \gtreqqless 0$. Furthermore, we assume that $m(t,i)$ cannot become negative. To sum up, the term $m(t,i)$ expresses that *A* is intrinsically motivated not to harm *B*. A tax *t* crowds-out this motivation while provision of information *i* crowds-in this motivation.

Individual *B*'s utility function also has two parts: the linear utility he derives from his own consumption of *Y* and the harm caused by *A*'s consumption of *X*:

$$U^B\left(y^B, x\right) = y^B - d\left(x\right). \tag{3}$$

Let us further assume that both individuals have exogenous income $I^j > 0$ ($j = A, B$). By choice of units, the market price of the numeraire good *Y* equals one, while the market price of *X* is *p*. As individual *B* only consumes the numeraire good, he maximizes his utility (Eq. (3)) spending all his income for it: $I^B = y^B$. Individual *A* maximizes her utility function (Eqs. (1) and (2)) subject to the budget constraint: $I^A = px + y^A$.

4 Analysis and Results

Let us start with the equilibrium conditions with and without government intervention:

Lemma 1

For every government intervention $(t,i) \in \mathbb{R} \times \left\{0, i^*\right\}$ there uniquely exists an equilibrium allocation of good *X*, $x^*(t,i) > 0$, which is characterized by the following first order condition:

$$u'\left(x^*\right) = p + t + m(t,i)k(i)d'\left(x^*\right). \tag{4}$$

Proof: See Appendix A.1

Lemma 1 shows that, in equilibrium, *A*'s marginal utility of consuming *X* equals *A*'s marginal opportunity cost of consumption, *p*+*t*, plus *A*'s marginal moral costs. The latter are the product of *A*'s moral motivation and the expected marginal damage. Both terms of this product are contingent on government intervention. First, *A*'s moral motivation $m(t,i)$ takes

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16 Nyborg (2011) argues that it can be rational for moral agents to remain ignorant or even pay for not being provided with information, as information may reduce their utility. In contrast, we focus on genuinely responsible agents, who also have a responsibility to actively seek information (see Baumgärtner et al. 2007: 240ff).

on a different value for every level of government intervention. Second, the expected marginal damage $k(i)d'(x^*)$ is contingent on the government's information policy *i*.

To assess individual behavior and government policies from a societal perspective, we employ the criterion of Pareto-efficiency. An allocation is called *Pareto-efficient* if and only if it is not feasible to improve the well-being of one person without lowering the well-being of the other person. We do not use a social welfare function to assess social optimality, but rather stay with the weaker efficiency criterion, because any welfare function implies some position on distributive justice, which we do not study here. A second reason for employing the Pareto-efficiency criterion is that our basic concept of moral obligation is that it is wrong to consciously harm others against their will, or in other words, it is wrong to benefit in terms of well-being from doing harm to, that is reducing the well-being of, others. The Pareto-efficiency criterion captures this moral obligation very well.[17] The criterion of Pareto-efficiency, as a criterion of societal choice, is thus in line with the moral responsibility that individual agents feel obliged to comply with.

There has been a discussion as to whether the moral-motivation term in person *A*'s utility function should be included in the Pareto-efficiency criterion. We follow the predominant view expressed by Hammond (1978) and Diamond (2006) who argue against including this term for a number of reasons.[18] All taken together, Diamond (2006) advocates using the moral-motivation model for positive (i.e. descriptive) purposes only, while staying with the standard model of self-directed well-being for evaluating Pareto-efficiency.[19]

Lemma 2

There uniquely exists a Pareto-efficient allocation of good *X*, $\hat{x} > 0$, which is characterized by the following first order condition:

$$u'(\hat{x}) = p + d'(\hat{x}). \tag{5}$$

Proof: See Appendix A.2.

The first-order condition for Pareto-efficiency requires that *A*'s marginal utility of consuming *X* equals *A*'s marginal opportunity cost of consumption plus the marginal costs of the consumption of *X*, that is, the marginal harm on *B*.

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[17] This is in contrast to, for example, the utilitarian welfare criterion, according to which it may well be socially desirable to increase one person's individual well-being at the cost of reducing someone else's individual well-being.

[18] First, the analysis of moral motivation would always be incomplete and thus misleading. Second, the outcome of moral motivation would be very sensitive to the framing, since moral motivation is highly context dependent. Third, including the moral-motivation term leads to double counting of the externality which was not justified.

[19] Based on these arguments, Heyes and Kapur (2011) do not include the moral-motivation term in their welfare analysis of how to regulate altruistic agents.

An equilibrium allocation x^* is Pareto-efficient if and only if it equals $\hat{x}$: $x^* = \hat{x}$. Any deviation of x^* from $\hat{x}$ indicates a market failure. Large (small) deviations yield large (small) market failure in the following sense.

Definition 1

The *extent of the market failure* under government intervention (t, i) is measured by

$$\Phi(t,i) = \left| x^*(t,i) - \hat{x} \right|. \tag{6}$$

The extent of the market failure is thus defined as the absolute deviation of the equilibrium allocation x^* from the efficient allocation $\hat{x}$. This definition allows comparing the extent of the market failure induced by any two government interventions *t* and *i*.

For future reference, we define one special case. A shift from one government intervention (t_1, i_1) to another one (t_2, i_2) that shifts the equilibrium allocation from $x_1^*(t_1, i_1)$ to $x_2^*(t_2, i_2)$ with $x_1^* > \hat{x} > x_2^*$ and $\Phi(t_1, i_1) < \Phi(t_2, i_2)$ (or likewise the other way round) is called a *strong reversal of market failure*. Strong reversals of the market failure increase the extent of the market failure.

In light of the first-order conditions for the equilibrium and the Pareto-efficient allocations, we now study four different policy scenarios: (1) a “laissez-faire” scenario in which government does not intervene at all; (2) a “tax policy” scenario in which government levies a Pigouvian tax *t* on the consumption of good *X* that causes the negative externality, but does not provide any information *i* on the actual damage caused by the consumption of *X*; (3) an “information policy” scenario in which government provides perfect information i^* about the negative externality caused by good *X*, but does not levy a tax *t*; and (4) a “complementary policy” scenario in which government levies a tax *t* on the consumption of good *X* that causes the negative externality and also provides perfect information i^*.

4.1 Laissez-faire

To start with, we consider the laissez-faire scenario without government intervention, i.e. $t = 0$ and $i = 0$.

Proposition 1

The laissez-faire equilibrium allocation, $x^{\mathrm{LF}} = x^*(0,0)$, is Pareto efficient if and only if $\mu = 1/\kappa$. Thus, morally motivated behavior alone is, in general, not sufficient for Pareto efficiency in the presence of externalities, and government intervention remains necessary to achieve Pareto efficiency. However, moral motivation may diminish or exacerbate the extent of the market failure:

$$\frac{\mathrm{d}\Phi(0,0)}{\mathrm{d}\mu}\begin{Bmatrix}<\\>\end{Bmatrix}0 \text{ for } \mu\begin{Bmatrix}<\\>\end{Bmatrix}\frac{1}{\kappa}. \tag{7}$$

Proof: See Appendix A.3

Whenever individual *A* faces a moral obligation, she has to self-negotiate it with her desire for personal consumption. In our model, *A* self-negotiates her moral obligation not to harm *B* with her personal consumption desire, by having a certain level of moral motivation $m(t,i)$. It is, however, purely coincidental whether her level of moral motivation (μ) in combination with her knowledge (κ) lead her to consume an efficient amount of *X*. Hence, for all combinations of basic moral motivation and knowledge but one ($\mu = 1/\kappa$), individual *A*'s basic moral motivation is either too low in relation to her knowledge ($\mu < 1/\kappa$) or too high ($\mu > 1/\kappa$), so that the outcome is not Pareto-efficient. In the following, we refer to the case of $\mu < 1/\kappa$ as individual *A* being "undermotivated" and to the case of $\mu > 1/\kappa$ as her being "overmotivated".

Given that moral motivation alone does not preclude the existence of a market failure, Proposition 1 also makes a statement about the effect of moral motivation on the extent of the market failure. The extent of market failure decreases with the level of basic moral motivation if moral motivation is inefficiently small, that is for $\mu < 1/\kappa$, and increases otherwise. In other words, if individual *A* is undermotivated, every increase in her basic moral motivation shifts the Laissez-faire equilibrium level x^{LF} closer to the efficient level $\hat{x}$ as $\mathrm{d}x^{\mathrm{LF}}/\mathrm{d}\mu < 0$. If individual *A* is overmotivated, further moral motivation shifts the equilibrium away from the efficient level. Moral motivation may thus diminish or exacerbate the market failure in the presence of externalities.

4.2 Tax policy

In this scenario, government introduces a Pigouvian tax *t* on good *X*, but provides no information ($i = 0$). The consumer price of *X* becomes $p + t$. Besides the relative price effect, we have motivation crowding-out, as the tax reduces *A*'s moral motivation.

Proposition 2

There exists at least one tax rate $\hat{t} \le d'(\hat{x})$, so that the equilibrium allocation $x^t = x^*(t,0)$ is Pareto-efficient. All efficient tax rates are characterized by the following first order condition:

$$\hat{t} + \left(m(\hat{t},0)\kappa - 1\right)d'\left(x^t\right) = 0 \ . \tag{8}$$

If $m\left(d'(\hat{x}),0\right) > 0$, $\hat{t}$ is unique and positive (negative) for $\mu < (>) 1/\kappa$.

If and only if $m\left(d'\left(\hat{x}\right),0\right)=0$, Eq. (8) holds for $\hat{t}=d'\left(\hat{x}\right)$. There exist two further solutions if $\mu>1/\kappa$ or if $\mu<1/\kappa$ and $m_{tt}\ll 0$.

Increasing the tax rate at inefficiently low levels may exacerbate the market failure:

$$\frac{\mathrm{d}\Phi\left(t,0\right)}{\mathrm{d}t}>0 \qquad \text{iff (1) } m_t<-1/\kappa d'\left(\hat{x}\right) \text{ and} \qquad (9)$$
$$\text{(2) } \mu<1/\kappa .$$

Proof: see Appendix A.4

The first order condition given by Eq. (8) reveals that without moral motivation ($m\left(t,0\right)\equiv 0$) we obtain the standard result: there exists a Pigouvian tax rate which must equal marginal damage $d'\left(\hat{x}\right)$. As we include moral motivation in the analysis, there exists at least one efficient tax rate, which may, however, differ considerably from $d'\left(\hat{x}\right)$.

Furthermore, Eq. (8) reveals that there cannot exist an efficient tax rate larger than $d'\left(\hat{x}\right)$. This is intuitive, as there are only two possibilities: either a tax rate $t=d'\left(\hat{x}\right)$ does not crowd-out all intrinsic motivation ($m\left(d'\left(\hat{x}\right),0\right)>0$), from which it follows that $t=d'\left(\hat{x}\right)$ is inefficiently high; or a tax rate $t=d'\left(\hat{x}\right)$ fully crowds-out all intrinsic motivation ($m\left(d'\left(\hat{x}\right),0\right)=0$), which renders $t=d'\left(\hat{x}\right)$ an efficient tax rate.

We keep differentiating these two cases for the further discussion. $m\left(d'\left(\hat{x}\right),0\right)>0$ implies relatively weak crowding effects as $t=d'\left(\hat{x}\right)$ does not crowd-out all intrinsic motivation. In this case, we find that there uniquely exists an efficient tax rate $\hat{t}$. Intuitively, $\hat{t}$ is positive if and only if individual *A* is undermotivated ($\mu<1/\kappa$). $\hat{t}$ is negative if and only if *A* is undermotivated ($\mu>1/\kappa$).

$m\left(d'\left(\hat{x}\right),0\right)=0$ implies that at a tax rate $t=d'\left(\hat{x}\right)$ all intrinsic motivation is crowded-out and the crowding effect is relatively strong. In this case, it follows that $t=d'\left(\hat{x}\right)$ is an efficient tax rate because individual *A* reacts on it as if she was not morally motivated at all. But there are more possible solutions in this case.

First, if and only if individual *A* is undermotivated ($\mu<1/\kappa$) and the crowding effect is highly concave ($m_{tt}\ll 0$), there further exist one or two positive, efficient tax rates smaller than $d'\left(\hat{x}\right)$. The intuition is that highly concave crowding implies that the crowding effect is very weak for low taxes which allows for the possibility of one or two low efficient tax rates.

Second, if and only if individual *A* is overmotivated ($\mu>1/\kappa$), there also exists a negative tax rate, so that the equilibrium allocation is efficient. More surprisingly, there also exists an efficient, positive tax rate smaller than $d'(\hat{x})$. In this case the crowding effects are much stronger than the price effect of the tax, such that *A*'s consumption increases with the tax to the efficient level. Hence, strong crowding effects may allow for low tax rates instead of subsidies if *A* is overmotivated.

Motivation crowding does, in principle, not jeopardize the efficiency of Pigouvian taxes. With motivation crowding, Pigouvian taxation has some side effects, though, which deserve further attention:

First, motivation crowding may lead to a higher efficient tax rate than if individual *A* was not prone to motivation crowding ($m(t,0)=\mu$ if and only if $\mu<1/\kappa$). This may be problematic if the government faces political pressure by, for example, industrial lobby groups which lobby for low taxes (see e.g. Aidt 1998 or Fredriksson 1997).

Second, if taxes are set inefficiently low, they may exacerbate the market failure (Eq. (9)). Standard theory suggests that even an inefficiently low Pigouvian tax is an improvement compared to no taxation. If there are crowding effects however, inefficiently low taxation may actually increase the extent of the market failure. This is a serious problem as in reality Pigouvian taxes are frequently set too low.

Third, the efficient tax rate may completely crowd out moral motivation ($m(d'(\hat{x}),0)=0$). This is a problem if there are motivational spill-over effects such that the crowding-out effect spreads to unregulated areas of behavior.[20]

We thus conclude at this point that despite the efficiency of taxes, it remains necessary to investigate alternative policy instruments which are superior to taxes or complement them such that the described side effects are mitigated.

4.3 Information policy

We analyze the effect of the provision of perfect information *i* as an alternative policy instrument. We now assume that rather than levying a tax, the government provides perfect descriptive information i^*, such that $k(i^*)=1$ and individual *A* is perfectly informed of the externality. The aim of the government is thus to enable *A* to consume responsibly based on all available information. We now examine whether this policy can be Pareto-efficient.

Proposition 3

The equilibrium allocation under provision of perfect information, $x^i = x^*(0,i^*)$, is Pareto-efficient if and only if

[20] Such motivational spill-over effects are described in Frey (1999). He states that when intrinsic motivations are linked across areas, an instrument may work efficiently in the area where it is applied but at the same time reduce the positive effect of moral motivation at other areas of behavior.

$$m\left(0,i^{*}\right)=1. \tag{10}$$

Thus, perfectly informing morally motivated individuals is, in general, neither necessary nor sufficient for Pareto-efficiency.

Perfect information may reduce the extent of the market failure compared to the Laissez-faire:

$$\Phi\left(0,i^{*}\right)<\Phi\left(0,0\right), \text{ iff (1) } \mu<(>)\frac{1}{\kappa} \text{ and}$$
$$\text{(2) } \kappa<(>)\frac{m\left(0,i^{*}\right)}{\mu} \text{ and} \tag{11}$$
$$\text{(3) there is no strong reversal of market failure.}$$

Proof: see Appendix A.5

The provision of information has two effects on moral motivation: a direct crowding effect and an indirect information effect. The direct crowding effect raises person *A*'s moral motivation. The indirect information effect occurs because the provision of information changes *A*'s knowledge of the externality, which may either increase or decrease. If *A* underestimates the externality in the Laissez-faire scenario, $\kappa<1$, information provision increases *A*'s knowledge of the externality and hence the impact of *A*'s moral motivation increases. If *A* overestimates the externality in the Laissez-faire scenario, $\kappa>1$, the indirect information effect weakens the effect of *A*'s moral motivation as *A*'s knowledge decreases. The direct and the indirect effect of the provision of information are hence additive for $\kappa<1$ and cause a net increase of moral motivation. For $\kappa>1$, they are countervailing and cause a net increase (reduction) of moral motivation if the crowding effect is stronger (weaker) than the information effect.

Furthermore, Eq. (10) holds under very specific conditions only, as the crowding-in effect must be of a given extent. For strong (weak) crowding-in, that is for $m\left(0,i^{*}\right)>(<)1$, provision of information does not lead to efficiency. Since all variables in Eq. (10) are exogenous to the government, it would be purely coincidental for Eq. (10) to hold. Therefore, the provision of perfect information is, in general, not an efficient single instrument.

However, perfect information may be effective in reducing the market failure as compared to the Laissez-faire ($\Phi\left(0,i^{*}\right)<\Phi\left(0,0\right)$, Eq. (11)). This requires in any case that perfect information does not lead to a strong reversal of the market failure. Further, for *A* being undermotivated ($\mu<1/\kappa$), perfect information reduces the market failure if its motivation effect is larger than its information effect ($m\left(0,i^{*}\right)/\mu>\kappa$). For A being overmotivated ($\mu>1/\kappa$), perfect information reduces the market failure if its motivation effect is smaller than its information effect ($m\left(0,i^{*}\right)/\mu<\kappa$).

4.4 Complementary policy

Frey (1999) proposes a third policy option as efficient alternative: a complementary policy approach. He argues that "[…] where an instrument tends to crowd out the intrinsic motivation […], an instrument tending to crowd in environmental morale should be used" (Frey 1999: 412). His argumentation remains intuitive, lacking a clear analytical or empirical proof or test. In this section, we use our model to test his hypothesis analytically.

More specifically, we analyze whether a complementary policy, that is a tax t complemented with provision of perfect information $i = i^*$, leads to efficiency and overcomes the problems discussed in Section 4.2 which tax policies may cause when there are motivation crowding effects.

Proposition 4

There exists at least one complementary tax rate $\hat{t}^{\mathrm{c}} \leq d'(\hat{x})$ so that the equilibrium allocation $x^{\mathrm{c}} = x^*\left(\hat{t}^{\mathrm{c}}, i^*\right) > 0$ is Pareto-efficient. The corresponding first order condition is given by

$$\hat{t}^{\mathrm{c}} + \left(m\left(\hat{t}^{\mathrm{c}}, i^*\right) - 1\right) d'(\hat{x}) = 0 \ . \tag{12}$$

Compared to $\hat{t}$ (discussed in Proposition 2), $\hat{t}^{\mathrm{c}}$ has the following properties:

(1) $\hat{t}^{\mathrm{c}}$ is smaller than $\hat{t}$, if and only if the motivation effect of perfect information is larger than its information effect:

$$\hat{t}^{\mathrm{c}} < \hat{t} \quad \text{iff } \frac{m\left(\hat{t}^{\mathrm{c}}, i^*\right)}{m\left(\hat{t}, 0\right)} > \kappa \, . \tag{13}$$

(2) An inefficiently low tax rate $t^{\mathrm{low}} < \hat{t}, \hat{t}^{\mathrm{c}}$ yields a smaller extent of market failure in the complementary setting than in the tax-only setting, if and only if the motivation effect of perfect information is larger than its information effect and there is no strong reversal of market failure:

$$\Phi\left(t^{\mathrm{low}}, i^*\right) < \Phi\left(t^{\mathrm{low}}, 0\right) \quad \text{iff} \quad (1) \ \frac{m\left(t^{\mathrm{low}}, i^*\right)}{m\left(t^{\mathrm{low}}, 0\right)} > \kappa \text{ and} \tag{14}$$

(2) there is no strong reversal of market failure.

(3) $\hat{t}^{\mathrm{c}}$ does not fully crowd-out moral motivation while $\hat{t}$ does, if the motivation effect from the complementary information is strong:

$$m\left(\hat{t}^{\mathrm{c}}, i^*\right) > m\left(\hat{t}^{\mathrm{c}}, 0\right) = 0 \quad \text{iff } \frac{m\left(\hat{t}^{\mathrm{c}}, i^*\right)}{m\left(\hat{t}, 0\right)} > 0 \, . \tag{15}$$

Proof: see Appendix A.6

Proposition 4 shows that combining a tax with the provision of perfect information leads to Pareto efficiency for all parameter values. But more interestingly, a complementary policy may be superior or inferior to a tax-only policy with respect to the three weaknesses discussed in Section 4.2.

First, an efficient complementary policy may require a lower, equal or higher tax rate than a tax-only policy (Eq. (13)). Consider the case when individual *A* is overmotivated ($\mu > 1/\kappa$). In this case, we find that a complementary policy requires a higher subsidy rate or a higher taxe rate than a tax only policy except when the provision of information causes a net reduction of moral motivation.[21] In other words, in a situation in which *A* is overmotivated, complementing a tax with an instrument which further crowds-in moral motivation, does not make sense as this requires an even higher taxe rate. Now, consider the case when individual *A* is undermotivated ($\mu > 1/\kappa$). In this case, we find that a complementary policy allows for a lower or equal tax rate than a tax-only policy except, again, the provision of information causes a net reduction of moral motivation. The equality of the tax rates occurs if and only if a tax rate at the level of marginal damage crowds-out all moral motivation with and without provision of moral motivation. This result shows that, even in this case, a complementary policy may or may not be an improvement over a tax-only policy with respect to allowing for a lower tax rate. Yet, it allows for a lower tax rate in the special case in which *A* is undermotivated, underestimates the externality and in which the marginal crowding effect of the tax is smaller than its relative price effect.

Second, at the same inefficiently low tax rate, a complementary policy may yield a smaller extent of market failure than a tax-only policy (Eq. (14)). The intuition is the following: if *A* is undermotivated and provision of information causes a net increase in moral motivation for every given tax rate, then complementing any tax with perfect information must reduce x^*. This reduction in x^* is also a reduction of the market failure if there is no strong reversal of market failure. In other words, an inefficiently low complementary tax may still exacerbate the market failure but less than a tax-only policy.

Third, there exists an efficient complementary policy which does not fully crowd out moral motivation while an efficient tax-only policy would do so, if the provision of information causes a strong net increase in moral motivation and/or a strong cross reduction in the marginal crowding of taxes such that $m\left(d'\left(\hat{x}\right),0\right)=0$ and $m\left(d'\left(\hat{x}\right),i^*\right)>0$ (Eq. (15)).

The superiority of a complementary policy approach as hypothesized by Frey (1999) can thus only be confirmed for specific parameter constellations. Our results suggest that, first, a tax should be complemented with the provision of perfect information if and only if *A* is undermotivated. Second, such a complementary policy reduces the risk of exacerbating the market failure by inefficiently low taxes. Third, for certain parameter constellations, an

[21] Remember that this requires that individuals overestimate the externality and that the marginal information effect of the provision of information is stronger than its marginal crowding effect.

efficient complementary policy does not fully crowd-out moral motivation while the efficient tax-only policy does.

5 Conclusion

We have studied motivation-crowding to analyze the influence of governmental policies on individual responsibility in a situation of negative consumption externalities and motivation crowding. To this end, we have formulated a model where we model motivation crowding as a preference change due to extrinsic intervention, namely taxes and provision of information. We have shown that in the absence of government regulation, responsible behavior will, in general, not lead to Pareto efficiency. Only if the individuals' basic moral motivation and knowledge meet a very restrictive condition, responsible behavior leads to Pareto-efficiency. It is much more likely that individuals' are either under-motivated or over-motivated. If individuals are under-motivated, moral motivation diminishes the extent of the market failure. The necessity for governmental intervention then remains, but becomes less urgent than if there was no moral motivation. If individuals are over-motivated, moral motivation increases the market failure.

Further, we have shown that a Pigouvian tax as a single instrument is Pareto efficient in all situations. There may exist more than one efficient tax rate. Motivation crowding thus does not question the efficiency of taxes. But it creates three problems with taxation: first, crowding requires a higher tax rate which may be difficult for a government to implement due to political pressure. Second, setting a tax rate inefficiently low may exacerbate the market failure. And third, an efficient tax rate may fully crowd-out moral motivation which is harmful if there are motivational spill-overs.

For the provision of descriptive information, our analysis shows that it might lead to Pareto efficiency under very restrictive assumptions. But it may be well suited to diminish the extent of the market failure. The instrument should be used with caution since its effectiveness is contingent on several parameter values: individuals' knowledge, their basic moral motivation and the extent the information crowding effect. For example, when individuals consume excessive amounts of a polluting good and underestimate the externality, provision of information diminishes the market failure if the crowding effects are not too strong.

Since both instruments, taxes and provision of information, have serious weaknesses when applied on their own, we considered a third policy option: a complementary policy, consisting of both instruments (as e.g. proposed by Frey 1999). Such a complementary policy may require a lower taxe rate, may reduce the risk of exacerbating the market failure by inefficiently low taxes, and may lead to efficiency without fully crowding-out moral motivation. The drawback is that these effects are highly contingent on parameter values. We thus can recommend a complementary policy for some but not for all cases.

For decision makers facing externalities, our study shows that the extent of crowding effects should be tested before implementing a policy regime. It is necessary to find out if there are one or more efficient tax rates to be able to choose the one with the most desired side effects, such as tax income level or incentive distortions. Further, governments should know if provision of information is at least effective in diminishing the market failure or if it is counterproductive. If there are motivational spill-overs to be expected, governments should consider a complementary policy if crowding effects from information are strong enough. Lastly, governments should be aware that they should not implement a tax at all rather than implementing an inefficiently low tax which may increase the problem.

For economists, our study has two major implications. First, empirical research needs to further investigate in how far higher taxes or levels of information cause stronger crowding than lower taxes or levels of information, and in how far complementary instruments affect the crowding effects of taxes. These insights will be crucial in understanding the efficiency and effectiveness of taxes and other instruments. Second, our analysis suggests that economists should re-think existing market based instruments. One seemingly fruitful starting point is a paper by Mellström and Johannesson (2008). They show that crowding effects of taxes are contingent on the redistribution regime. The full effects of ecological tax reforms may thus depend on whether the tax income is e.g. spent for environmental innovation or for pension funds. Still, it may even be necessary to think of new instruments or draw more attention to the use of command and control instruments, since their effectiveness is not contingent on crowding effects.

6 Appendix

A.1 Proof of Lemma 1

Definition

For given income distribution $\left(I^A, I^B\right)$ and government policy $\left(t, i\right)$, an allocation $\left(y^{A*}, y^{B*}, x^*\right)$ and price system $\left(1, p\right)$ is an *equilibrium* if and only if it has the following properties:

Both individuals *A* and *B* take prices $\left(1, p\right)$ and income $\left(I^A, I^B\right)$ as given.

For both individuals, the equilibrium allocation is a utility maximum s.t. the respective budget constraint:

a.
$$\max_{y^A, x} \; U^A\left(x^*, y^{A*}\right) \text{ s.t. } I^A = y^A + \left(p+t\right)x \tag{16}$$

b.
$$\max_{y^B} \; U^B\left(y^{B*}\right) \text{ s.t. } I^B = y^B \tag{17}$$

Supply equals demand in the markets for both goods:

$$y^{A*}\left(I^A, p\right) + y^{B*}\left(I^B, p\right) = y^S \tag{18}$$

$$x^*\left(I^A, p\right) = x^S \tag{19}$$

Equilibrium conditions

Utility maximization of individual *A* leads to the following Lagrangian:

$$L\left(y^A, x, \lambda^A\right) = y^A + u(x) - m(t,i)k(i)d(x) + \lambda^A\left(I^A - y^A - (p+t)x\right). \tag{20}$$

Differentiating with respect to y^A, x and λ^A yields three first-order conditions, from which it is apparent that $\lambda^A = 1$. With this, the two remaining first-order conditions are:

(A) $$u'\left(x^*\right) = p + t + m(t,i)k(i)d'\left(x^*\right) \ , \tag{21}$$

(B) $$I^A = y^{A*} + (p+t)x^*. \tag{22}$$

Utility maximization of individual *B* leads to the following Lagrangian:

$$L\left(y^B, \lambda^B\right) = y^B - d(x) + \lambda^B\left(I^B - y^B\right). \tag{23}$$

The resulting first-order condition requires that B spends all his income on y^B:

(C) $$I^B = y^{B*}. \tag{24}$$

As above, let x^S and y^S denote total supply of good *X* and *Y*. Market clearing conditions are given by:

(D) $$y^{A*} + y^{B*} = y^S \tag{25}$$

(E) $$x^*(p) = x^S \tag{26}$$

Conditions (A) – (E) characterize the equilibrium.

Solution

We now show that conditions (A) – (E) hold for the assumptions of our model.

Condition (A):

The left-hand side of condition (A) is positive and decreasing. Per assumption, for all I^A, t, i, p, it is characterized by:

$$u'(x) > 0,\ u''(x) < 0,\ \lim_{x\to 0} u'(x) = +\infty,\ \lim_{x\to\infty} u'(x) = 0 \tag{27}$$

The right-hand side of condition (A) is positive and increasing, given that for all I^A, t, i, p:

$$d'(x) > 0,\ d'(0) = 0,\ d''(x) > 0 \tag{28}$$

It follows that there exists a $x^* > 0$ for which condition (A) holds.

Condition (B) and (C):

Since it is possible to consume infinitively small amounts of both goods Y and X, the income of each individual must be large enough to fulfill condition (B) and (C).

Condition (D) and (E):

Per assumption, prices of both goods are exogenously given and fulfill the market clearing conditions.

Since conditions (A) – (E) are fulfilled by one $x^* > 0$, we conclude:

A unique and stable interior equilibrium with $x^* > 0$ exists for all I^A, t, i. The Equilibrium is characterized by Equation (4). □

A.2 Proof of Lemma 2

We find the necessary first-order conditions for Pareto-efficiency by solving the following maximization problem:

$$\max_{y^A, y^B, x} \; U^A\left(x, y^A\right) \text{ s.t. } \bar{U}^B = y^B - d\left(x\right) \text{ and } I^A + I^B + tx = y^A + y^B + \left(p+t\right)x \,. \tag{29}$$

The Lagrangian is given by:

$$\mathrm{L}\left(y^A, y^B, x, \lambda, \delta\right) = y^A + u\left(x\right) + \lambda\left(y^B - d\left(x\right) - \bar{U}^B\right) + \delta\left(I^A + I^B - y^A - y^B - px\right) \,. \tag{30}$$

Differentiating with respect to y^A, y^B and x yields three first-order conditions, from which it is apparent that $\lambda = 1$ and $\delta = 1$. The remaining first-order condition is:

$$u'\left(\hat{x}\right) = p + d'\left(\hat{x}\right) \,. \tag{31}$$

Since $\lim_{x \to 0} u'\left(x\right) \to +\infty$, $u'' < 0$, and $d'' > 0$ there exists a unique $\hat{x} > 0$ solving Eq. (31).

□

A.3 Proof of Proposition 1

Using Eq. (4) with $t, i = 0$, the equilibrium allocation in the laissez-faire scenario is characterized by

$$u'\left(x^{\mathrm{LF}}\right) = p + \mu\kappa d'\left(x^{\mathrm{LF}}\right) \,. \tag{32}$$

Comparison with Eq. (5) shows that the equilibrium allocation is Pareto-efficient, i.e. $x^{\mathrm{LF}} = \hat{x}$, if and only if:

$$p+\mu\kappa d'\left(x^{\mathrm{LF}}\right)=p+d'\left(x^{\mathrm{LF}}\right) \ . \tag{33}$$

Simple rearrangement yields:

$$\mu=\frac{1}{\kappa} \ . \tag{34}$$

Market failure

Using Eq. (32), the total derivative of the equilibrium level x^{LF} with respect to μ is given by:

$$\frac{\mathrm{d}x^{\mathrm{LF}}}{\mathrm{d}\mu}=\frac{\kappa d'\left(x^{\mathrm{LF}}\right)}{u''\left(x^{\mathrm{LF}}\right)-\mu\kappa d''\left(x^{\mathrm{LF}}\right)} \ . \tag{35}$$

The right hand side of Eq. (35) is clearly negative and x^{LF} decreases with μ. It follows that $x^{\mathrm{LF}}>(<)\hat{x}$ for all $\mu<(>)1/\kappa$. Since further $\mathrm{d}\hat{x}/\mathrm{d}\mu=0$ (from Eq. (5)), it follows that $\mathrm{d}\Phi/\mathrm{d}\mu<(>)0$ for $\mu<(>)1/\kappa$. Hence, the extent of the market failure decreases with μ if $\mu<1/\kappa$ and increases otherwise. □

A.4 Proof of Proposition 2

Using Eq. (4) with $i=0$ and $t\in\mathbb{R}$, the equilibrium allocation in the tax-policy scenario is characterized by:

$$u'\left(x^{t}\right)=p+t+m(t,0)\kappa d'\left(x^{t}\right) \ . \tag{36}$$

Comparison with Eq. (5) shows that the equilibrium allocation is Pareto-efficient, i.e. $x^{t}=\hat{x}$, if and only if:

$$p+\hat{t}+m\left(\hat{t},0\right)\kappa d'(\hat{x})=p+d'(\hat{x}) \ . \tag{37}$$

Simple rearrangements yield:

$$\hat{t}+\left(m\left(\hat{t},0\right)\kappa-1\right)d'(\hat{x})=0 \ . \tag{38}$$

Call $\Omega(t,0)=\Omega(t)=t+\left(m(t,0)\kappa-1\right)d'(\hat{x})$, which is the left hand side of Eq. (38). We now show that there exists at least one $\hat{t}$ such that $\Omega\left(\hat{t}\right)=0$. We know from the Laissez-faire solution that $\Omega(0)=0$ only holds for $\mu=1/\kappa$.

Suppose that $\Omega(0)>0$, which requires that $\mu>1/\kappa$. There are three possible solutions.

The first solution is a subsidy and exists for all parameter values. It is straightforward that at $\underline{t} = -m(t,0)\kappa d'(\hat{x})$, $\Omega(\underline{t}) < 0$. Due to monothonicity of $m(t,0)$, it follows from the Intermediate Value Theorem that there exists a $\hat{t}$, with $\underline{t} < \hat{t} < 0$, such that $\Omega(\hat{t}) = 0$.

The second solution is a positive tax and exists if and only if $m(d'(\hat{x}),0) = 0$, from what immediately follows that there exists a $\hat{t} = d'(\hat{x})$ with $\Omega(\hat{t}) = 0$.

The third solution is also a positive tax and also exists if and only if $m(d'(\hat{x}),0) = 0$. If and only if $m(d'(\hat{x}),0) = 0$, there must exist a t_0, with $0 < t_0 < d'(\hat{x})$, such that $n(t_0,0) = 0$ and $\Omega(t_0) < 0$. Since $\Omega(0) > 0$, there must also exist a $\tilde{t}$, with $0 < \tilde{t} < t_0$, such that $m(\tilde{t},0) = 1/\kappa$ and $\Omega(\tilde{t}) > 0$. Due to monothonicity of $m(t,0)$, it follows from the Intermediate Value Theorem that there exists a $\hat{t}$, with $\tilde{t} < \hat{t} < t_0$, such that $\Omega(\hat{t}) = 0$.

Note that solution 2 and 3 require that the marginal crowding effect of the tax is larger than its relative price effect, that is $m_t \kappa d'(\hat{x}) < -1$. Figure 1 shows the possible shapes of $\Omega(\hat{t})$ for linear crowding and the respective solutions $\Omega(t) = 0$ for $\Omega(0) > 0$:

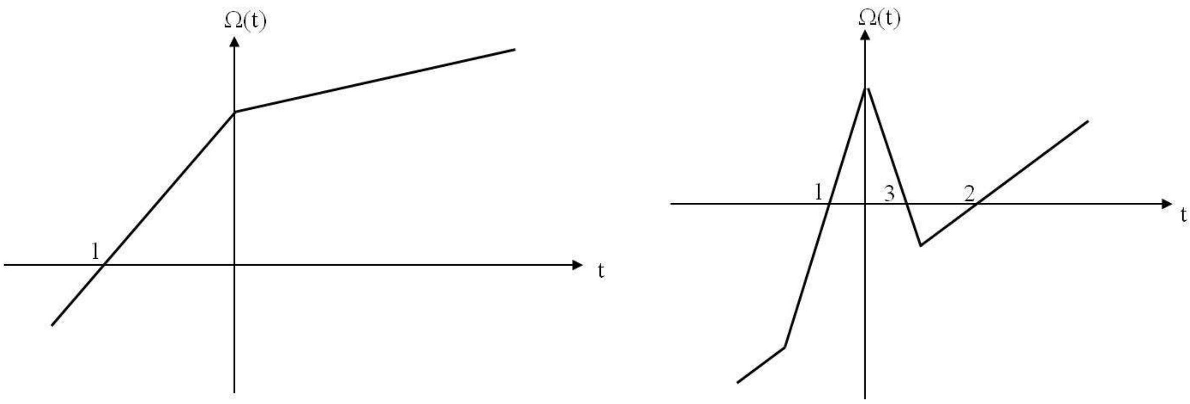

Figure 1: Possible efficient tax rates for $\Omega(0) > 0$

Now suppose that $\Omega(0) < 0$, which requires that $\mu < 1/\kappa$. There are one or two solutions:

Suppose that $m(d'(\hat{x}),0) > 0$. It follows that $\Omega(d'(\hat{x})) > 0$. Due to monothonicity of $m(t,0)$, it follows from the Intermediate Value Theorem that there exists a unique $\hat{t}$, with $0 < \hat{t} < d'(\hat{x})$, such that $\Omega(\hat{t}) = 0$.

Suppose that $m(d'(\hat{x}),0) = 0$. It follows immediately that there exists a $\hat{t} = d'(\hat{x})$ with $\Omega(\hat{t}) = 0$.

Suppose again that $m\left(d'(\hat{x}),0\right)=0$. It follows that there exists a t_0, with $0<t_0<d'(\hat{x})$, such that $n(t_0,0)=0$ and $\Omega(t_0)<0$. Now further suppose that the crowding term $m(t,0)$ is concave in *t*, such that $m_{tt}<0$. It follows that there exists a a $t_{\max}$, with $0<t_{\max}<t_0$, such that $\Omega_{t_{\max}}=0$. This implies that $\Omega(t_{\max})$ is a local maximum. If and only if $\Omega(t_{\max})>0$ there exist two $\hat{t}$, with $0<\hat{t}<t_{\max}$, such that $\Omega(\hat{t})=0$. If and only if $\Omega(t_{\max})=0$ there exists one $\hat{t}$, with $0<\hat{t}<t_{\max}$, such that $\Omega(\hat{t})=0$. Both requires a minimum degree of concavity of $m(t,0)$.

Figure 2 shows possible shapes of $\Omega(\hat{t})$ for and the respective solutions $\Omega(t)=0$ for $\Omega(0)<0$:

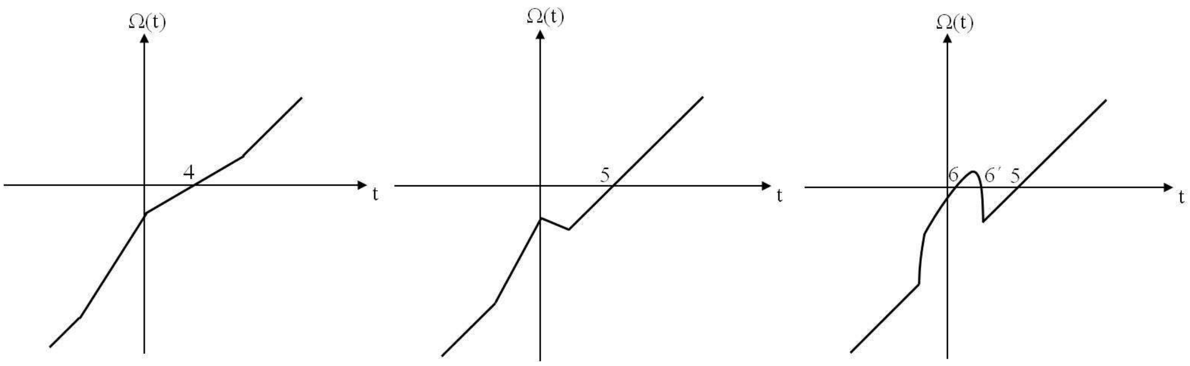

Figure 2: Possible efficient tax rates for $\Omega(0)<0$

Market failure:

Applying Eq. (6) to the tax only scenario, the market failure is given by $\Phi\left(x^t,\hat{x}\right)=\left|x^t-\hat{x}\right|$. Since $\hat{x}$ is not contingent on *t*, the total derivative of $\Phi\left(x^*,\hat{x}\right)$ with respect to *t* equals the total derivative of $\hat{x}$ with respect to *t*: $\mathrm{d}\Phi\left(x^t,\hat{x}\right)/\mathrm{d}t=\mathrm{d}x^t/\mathrm{d}t$.

Using Eq. (36), we derive the total derivative of $\hat{x}$ with respect to *t*. Rearrangements yield:

$$\frac{\mathrm{d}x^t}{\mathrm{d}t}=\frac{1+m'(t,0)\kappa d'\left(x^t\right)}{u''\left(x^t\right)-m(t,0)\kappa d''\left(x^t\right)}\ . \tag{39}$$

Eq. (39) is positive for $m'(t,0)\kappa d'\left(x^t\right)<-1$ and negative otherwise.

Inefficiently low tax rates require that $\mu<1/\kappa$ and yield $x^t>\hat{x}$. From Eq. (39) follows that increasing an inefficiently low tax rate increases x^t and thus also the market failure $\Phi\left(x^*,\hat{x}\right)$.

□

A.5 Proof of Proposition 3

Using Eq. (4) with $i = i^*$ and $t = 0$, the equilibrium allocation in the information-policy scenario is characterized by

$$u'\left(x^i\right) = p + m\left(0, i^*\right) d'\left(x^i\right) . \tag{40}$$

Comparison with Eq. (5) shows that the equilibrium allocation is Pareto-efficient, i.e. $x^i = \hat{x}$, if and only if:

$$p + m\left(0, i^*\right) d'\left(\hat{x}\right) = p + d'\left(\hat{x}\right), \tag{41}$$

which can be rearranged to:

$$m\left(0, i^*\right) = 1 . \tag{42}$$

Market failure

Information policy reduces the market failure $\Phi\left(x^*, \hat{x}\right)$ if its equilibrium allocation x^{i} deviates less from the efficient allocation $\hat{x}$ than the Laissez-faire allocation x^{LF}:

$$\left|x^{\mathrm{i}} - \hat{x}\right| < \left|x^{\mathrm{LF}} - \hat{x}\right|. \tag{43}$$

As there are 4 distinguished cases, Eq. (43) has 4 solutions as shown in Table 1:

	$x^{\mathrm{LF}} > \hat{x}$	$x^{\mathrm{LF}} < \hat{x}$
$x^{\mathrm{i}} > \hat{x}$	a) $x^{\mathrm{i}} < x^{\mathrm{LF}}$	b) $x^{\mathrm{i}} < 2\hat{x} - x^{\mathrm{LF}}$
$x^{\mathrm{i}} < \hat{x}$	c) $x^{\mathrm{i}} > 2\hat{x} - x^{\mathrm{LF}}$	d) $x^{\mathrm{i}} > x^{\mathrm{LF}}$

Table 1: Solutions of Eq. (43)

Information policies have two effects, a crowding and an information effect. If and only if $\kappa < 1 = k\left(i^*\right)$ both effects have the same direction and $x^{\mathrm{i}} < x^{\mathrm{LF}}$. However, if and only if $\kappa > 1$, the two effects are countervailing. It follows that $x^{\mathrm{i}} < (>) x^{\mathrm{LF}}$ if $\frac{m\left(0, i^*\right)}{\mu} > (<) \kappa$, i.e. if the motivation effect $\frac{m\left(0, i^*\right)}{\mu}$ is larger (smaller) than the information effect κ [22]. Case a) ($x^{\mathrm{i}} < x^{\mathrm{LF}}$) is thus solved for all $\kappa < \frac{m\left(0, i^*\right)}{\mu}$. Case d) ($x^{\mathrm{i}} > x^{\mathrm{LF}}$) is solved for all $\kappa > \frac{m\left(0, i^*\right)}{\mu}$.

[22] The full denotation of the information effect is $\kappa / k\left(i^*\right)$, which equals κ as $k\left(i^*\right) = 1$.

The cases b) and c) in Table 1 indicate that the impact of information policies on the consumption levels must not be too large in order to mitigate the market failure. If, e.g. in case c), condition $x^{\mathrm{i}} > 2\hat{x} - x^{\mathrm{LF}}$ is violated, the consumption level decreases from a inefficiently high level x^{LF} to an inefficiently low level x^{i} such that the resulting deviation from the efficient consumption level is larger than in the laissez-faire scenario. This is a strong reversal of the market failure. These cases cannot be solved analytically.

□

A.6 Proof of Proposition 4

The proof of the existence of one or several efficient complementary tax rates and their respective sign is the same as in A.4 if you set $\kappa = 1$ and if you exchange all $m(t,0)$ with $m(t,i^*)$.

Using Eq. (4) $i = i^*$ and $t \in \mathbb{R}$, the equilibrium allocation in the complementary policy scenario is characterized by

$$u'(x^{\mathrm{c}}) = p + t^{\mathrm{c}} + m(t^{\mathrm{c}}, i^*) d'(x^{\mathrm{c}}) \ . \tag{44}$$

Comparison with Eq. (5) shows that x^{c} is Pareto-efficient, i.e. $x^{\mathrm{c}} = \hat{x}$, if and only if:

$$\hat{t}^{\mathrm{c}} + \left(m(\hat{t}^{\mathrm{c}}, i^*) - 1\right) d'(\hat{x}) = 0 \,. \tag{45}$$

Property (1)

Comparison of Eq. (45) with Eq. (38) shows that $\hat{t}^{\mathrm{c}}$ is smaller than $\hat{t}$, if and only if the motivation effect of complementary perfect information is larger than its information effect:

$$\hat{t}^{\mathrm{c}} < \hat{t} \ \text{ iff } \ \frac{m(\hat{t}, i^*)}{m(\hat{t}, 0)} > \kappa \,. \tag{46}$$

This condition is fulfilled for all $\kappa < 1$ but only for some $\kappa > 1$.

Property (2)

Suppose that $\mu < 1/\kappa$ from which follows that $x^*(0,0) > \hat{x}$. Suppose further that $m'(t,0)\kappa d'(x^t) < -1$ such that $\frac{\mathrm{d}x^t}{\mathrm{d}t} > 0$ which implies that marginal increases in the tax rate yield larger market failure, until t reaches a critical level t^0 such that $m(t^0, 0) = 0$. Further increases in the tax rate will lead to a decrease in x as all moral motivation has been crowded out.

Now suppose that e.g. due to lobby pressure the government chooses a tax rate $t^{\text{low}} < t^0$ and $t^{\text{low}} < \hat{t}, \hat{t}^{\text{c}}$. Given the assumptions, this leads to a larger market failure in a tax-only scenario than in the laissez-faire scenario if there is no strong reversal of the market failure.

Equating Eq. (36) and (44) shows that t^{low} yields the same market failure in the tax-only scenario and in the complementary policy scenario, if and only if $m\left(t^{\text{low}}, i^*\right) = m\left(t^{\text{low}}, 0\right)\kappa$. Since x^{c} decreases with $m\left(t^{\text{low}}, i^*\right)$ (from Eq. (44)), it follows that the market failure at t^{low} is larger in the tax-only scenario than in the complementary policy scenario if and only if $m\left(t^{\text{low}}, i^*\right) > m\left(t^{\text{low}}, 0\right)\kappa$, or rearranged:

$$\frac{m\left(t^{\text{low}}, i^*\right)}{m\left(t^{\text{low}}, 0\right)} > \kappa \ , \tag{47}$$

and if there is no strong reversal of the market failure.

Property (3)

From Eq. (45) follows that there exists a $\hat{t}^{\text{c}}$ which does not fully crowd out moral motivation while $\hat{t}$ would if and only if:

$$m\left(\hat{t}^{\text{c}}, i^*\right) > m\left(\hat{t}, 0\right) = 0 . \tag{48}$$

□

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