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**The Integration of Altruistic Motives and Crowding-Out into
Policy Making for Regenerative Common Pool Resource Use
Dilemmas**

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Master Degree Project No. 2012:55
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Acknowledgement

Firstly, I would like to thank my supervisor for the valuable advice and ongoing encouragement! But also many thanks to Mia, Fritz, Jonatan and the Bunker Crew for mental and culinary support ☺

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Introduction

Within the framework of this research it will be looked at how a voluntary incentive mechanism in the form of a linear subsidy can be formulated to encompass the presence of moral concerns in the utility functions of individuals. Specifically the focus will be directed on the incorporation of impure altruism, which motivates individuals to contribute to the conservation of a given common pool resource for future generations and prevent the negative externalities from over-appropriation. The incorporated type of altruism is impure, because individuals receive utility from the act of giving itself and because the received utility is dependent on the presence of governmental intervention, indicating that the individuals not only care about their own deed, but also about its perception in society.

The exploration of the policy options is based on the literature on mechanism design. Mechanism design is a tool from microeconomics and game theory that is used to determine incentives structures under which a given policy outcome can be achieved. This approach also takes the presence of incomplete information to the policy maker into consideration, but in contrary to the use in this paper, traditional economic mechanism design has largely focused on setting incentives for self-interested agents.

The tradition of treating actors in a society as self-interested was formally introduced in the 18th century by the Scottish philosopher David Hume and has been corroborated by many economists ever since.

Only during the past decade, there has been a reconsideration of the behavioural characteristics of economic agents and the resulting consequences for efficient policy making. Among others, behavioural economist Bruno Frey (1997) initiated this discussion by claiming that a constitution for self-interest individuals might itself actually produce this type of individuals within a society, and that strict governmental control through regulation and supervision would crowd out internal motivations. Frey's finding was empirically confirmed by a large number of laboratory- and real-life experiments, which were conducted subsequently (e.g. on tax compliance by Anderoni et al (1998)). Given these results, it seems reasonable to consider all types of present goals and interests of individuals in a society, before creating a fitted policy.

Adjusting the approach of policy making is also relevant in the area of common pool resource (CPR) governance, in which individuals might have preferences for inter-society equity and inter-generational equity by making somewhat equitable and sustainable choices (e.g. Velez, 2009) on their individual appropriation level of a resource that is accessible to all. The awareness of society's actual preferences might not only facilitate the achievement of the goals that the regulator aims for, but can also reduce the substantial costs involved in monitoring, sanctioning or, as in the case at hand, compensating individuals. Hence, the consideration of behavioural aspects can generate policy both more effective and more efficient.

In the first section of this paper, the theoretical background for choosing policy mechanisms based on results from behavioural economic research will be given. Subsequently the evaluated scenario will be described in more detail and the utility function of agents in the society will be modelled and discussed.

After this, the actors and their best response functions to a policy mechanism will be analysed in detail.

Subsequent to the analysis section different cases will be modelled to clarify the effect of parameter changes on the participation decision of the individuals. The findings of this section will then be applied to the determination of the optimal policy in an artificially created example, which serves as a numerical example.

Before drawing conclusions, there will be a brief consideration of how policy would differ if the policy maker did not consider behavioural aspects all together.

Last but not least the concluding section will evaluate the relevance of including behavioural economic aspects into policy making in CPR dilemmas. This final section will also review potential limitations and extensions to the paper.

Theoretical Framework

The over-appropriation of natural resources, openly accessible to the broad population is a frequently discussed topic in the past and present of economic literature. In the light of overfished waters or the destruction of natural habitats with high biodiversity, through

deforestation or land use conversion, it is necessary to look at ways to efficiently govern and protect these commons, either by way of collective action or institutional design.

By definition of Gardener et al (1990), CPRs are sufficiently large natural or manmade resources, which can be appropriated for benefit, while it is costly to exclude potential beneficiaries from the process of appropriation.

Traditional approaches to the discussion of CPR dilemmas model the situation by means of game theory, which predicts the outcome to be a non-cooperative Nash equilibrium, in which all individuals will either over-appropriate or under-invest in the resource. (e.g. Gordon, 1954) The concept of the CPR dilemma and its non-cooperative result were originally described in detail in an article by Hardin (1968), but CPR dilemmas were already identified as problems much earlier by scholars such as Thomas Malthus (1798) and Paul Ehrlich (1968), among others.

A non-cooperative outcome, leading to a ‘tragedy of the commons’, rests on the characterization of individuals as being self-interested and monetary-profit maximizing ‘homo economicus’, who does not internalize the costs of the externalities, created from appropriating the CPR at a rate above the regeneration rate.

This assumption about human preferences and its devastating consequences for cooperation have been heavily criticized for being at odds with the findings from research in experimental economics, psychology, sociology and evolutionary biology.

Researchers from these fields have investigated on the objectives that agents pursue in social and economic interactions and have found a range of relevant goals, aside from the maximization of individual profits. These goals are characterized as representing the ‘bounded self-interest’ of the individual’s action in the market and are grouped into three main categories: fairness, reciprocity and altruism.

The importance of fair outcomes to agents can be seen by a preference for relatively equal outcomes, in contributions or profits, over relatively unequal ones and has been documented through laboratory experiments by Roth et al. (1991), Fehr et al (1993) and Forsythe et al (1994), among others.

Reciprocity, in turn, can be defined as an ‘in-kind response to beneficial or harmful acts’ (Fehr and Gächter, 2000). Subsequent to the work of Ostrom et al (1994), reciprocity has been introduced to the research on CPR governance, and has played a large role in explaining

cooperation in CPR appropriation scenarios (Elster (1989), Ostrom (1998), Panchanathan and Boyd (2004), Santos- Pinto and Doruk (2011))

Finally, altruism can be defined as the unselfish concern for the welfare of others and it entails that an individual undertakes a costly action without the prospect of material gain from doing so (Levine (1998)).

Research on observed altruistic behavior has attempted to find reasons for the contribution to public goods, the donations for charitable causes or the contribution to CPR protection.

The results of such research show that in many cases altruism is impure. In the literature two main explanations that for such phenomena can be found. Firstly, it is assumed that people aim to win ‘prestige, respect, friendship, and other social and psychological objectives’ (Olson (1965)) or seek to avoid the disregard of their peers (Becker, 1974).

The second explanation rests on the idea that individuals receive utility from the beneficial act, itself. This type of altruistic giving was termed ‘warm glow giving’ by James Andreoni (1990) but its notion has been incorporated into economic models before (e.g. Arrow (1975)). Making the distinction between pure and impure altruism is important with regards to the policy implications. If an altruistic individual contributes to a charitable cause because he likes himself and others to see him as a benevolent and generous person then the introduction of an incentive mechanism might crowd out his internal motivation. Expressed differently, under impure altruism, the own contribution to a charitable cause and the contribution from a different source are ‘imperfect substitutes’ (Andreoni, 1990).

The problem of crowding out of internal motivations, caused by positive governmental incentive mechanisms, was theoretically investigated for the case of public good provision in combination with governmental grants by Warr (1982) and Roberts (1984) and for the case of subsidies for contributions, by Bernheim (1986) and Andreoni (1988). The latter research finds that the joint provision of public goods together with the government ‘can have virtually no effect on the total supply of the public good’ as there is almost dollar-for dollar crowding out.

Empirically, the presence of crowding out is shown by Abrams and Schmitz (1984) and by Clotfelter (1985), but the magnitude is smaller than predicted by the theoretical models.

The research on CPR problems and efficient governance of the latter has been expanding rapidly over the past decades. While initially research documented and explained scenarios in which the joint management of CPRs failed, research in the 1980 and 1990s documented counter-examples in which institutional arrangements for resource use developed successfully

without the external imposition of taxes or the introduction of private ownership (Anderies et al, 2011). Furthermore, it has also been shown that top-down approaches to the government of commons can fail (Ostrom, 1992) and that the social governance of a CPR can lead to superior outcomes, when compared with outcomes under governmental control (Ostrom (1990), Cardenas et al (2000)) with respect to sustainability and inter-societal equity, but also with regard to efficiency (Agrawal, 2001).

In line with the theory from the former paragraph, the relative success of social governance can be explained with the notion that the allocation of subsidies for the pro-social behavior can crowd out the intrinsic moral motivations, which are inherent in many communities (Titmus, 1971) and detach individuals from their sense of social responsibility (Ostman, 1998), by changing the way a decision is framed (Tversky & Kahneman, 1981), changing the long-term development of endogenous preferences, reducing the individual's sense of autonomy or by conveying information about the regulators intentions which are displeasing to the agent and therefore alter his behavior (Bowels & Hwang (2008)).

Despite this somewhat optimistic prediction for the social governance of a CPR, this does not mean that it is always better to refrain from institutionally governing the resource in question. Fisher, Irlenbusch and Sadrieh (2004) find that while preferences for inter-generational resource conservation exist, the resulting altruistic restraint in exploitation might not be strong enough to preserve a socially optimal amount. In their experiment the authors test the *intergenerational altruism hypothesis*, according to which agents should decrease resource appropriation, as they recognize that their activity also creates negative externalities for the following generations.

The tested hypothesis is rejected within the given experiment, mainly because resource appropriators are too optimistic about the choices of their peers, and consequently conserve an insufficient amount of resource by choosing their own appropriation levels above the social optimum.

The lesson to be drawn from this result is that there is a clear preference for resource conservation across generations, but in scenarios with incomplete information about the behavior of others, or less interaction in society, it might be impossible to realize conservation without institutional intervention. Hence, there exists an argument for thinking about policy creation and mechanism design in this case.

According to Bowels (2008) the shortfall of conventional mechanism design is that it overlooks the fact 'that economic incentives may diminish ethical or other reasons for

complying with social norms', because this type of policy rests on the 'assumption of separability'. This assumption entails that the consequences of material interests and 'moral sentiments' for behavior are additive instead of interactive.

Several studies examined the separability assumption and found that it doesn't hold in practice (Bowles, 2008a). Conversely, it was determined that explicit incentives either work as complements or substitutes to ethical motives. Hence, they occasionally support the pro-social behavior, but tend to undermine it more frequently.

In line with this finding, Cardenas et al (2000) suggest that economic theory alone will be insufficient for designing environmental policies, unless it explicitly allows for the presence of other-regarding motivations, and the possibility that these motivations can be affected by the outset of institutional arrangements. Cardenas et al (2000) derived their conclusions from an experiment, conducted in a common forest in rural Columbia.

In a treatment without policy influence, Cardenas et al recorded significant instances of altruistic behavior, in line with the society's interests and morals, while under restrictive policy, appropriation levels converged to the self-interested, profit-maximizing level.

The results from this study point out the presence of the crowding out problem and the difficulty of mechanism design that weighs the achievement of a certain goal with the effect on the structure of intrinsic motivations in a given group of individuals.

While the current literature is rich in the description of the social preferences that affect the behavior of the agents who are involved in the management of the commons, on the one hand, and although research on policy options has been extensive, on the other hand, there are relatively few explicit approaches to model the behavior of agents in a public good provision/protection dilemma and discuss the implications for mechanism design.

An example of related research is the paper by Bowles and Hwang (2008) who look at mechanism design for public good provision. Similarly to the approach in this paper, they incorporate social preferences that depend on incentives as well as a notion of crowding in and crowding out. Major difference in the approach is that it concerns public good provision and that it assumes a linear utility function with constant returns to monetary and moral payoffs.

In turn, this paper will look at mechanism design for the governance of a regenerative common pool resource, which is exploited by agents that have monetary preferences and whose utility is also affected by a warm glow and the presence of crowding in or crowding

out. These two latter components of the utility function will be referred to as moral preferences.

In difference to the model by Bowles and Hwang, agents in this research will face decreasing returns to both monetary and moral payoffs. The added value of incorporating diminishing marginal returns in utility from monetary income is that it increases the probability of making a realistic prediction. Justification for the inclusion of decreasing returns to scale from monetary income can be taken from a wide variety of studies, investigating this scenario in different scenarios and across various cultures (e.g. Easterlin 1973 & 1995, Veenhoven, 1991; Diener, Sandvik, Seidlitz & Diener, 1993).

The relevance of including the notion of diminishing marginal returns to altruistic behavior can be found in Rabin (1993).

Scenario Example

Before deriving the model, the type of analyzed scenario will be quickly illustrated.

The model aims to depict a rural setting in which individuals have to choose between allocating their working time to resource appropriation and an alternative occupation. The common pool resource that can be appropriated is either a forest in which the appropriator cuts trees, a common land on which he can graze livestock or commonly owned waters in which he can fish.

The efficiency of appropriators is assumed to differ, as these occupations require a specific skill or equipment. For example, it seems reasonable to consider that fishermen might possess boats of different sizes, which enable them to harvest different quantities of fish.

The regulator (or policy maker) is aware of the proportion of more efficient and less efficient individuals, but he cannot distinguish one from the other, hence he can't set a policy that is directly tied to the efficiency level.

In this scenario without a governmental policy, despite some self-restriction aimed at preserving resource for future generations, individuals would consume at a rate higher than the respective resource's regeneration rate and over-appropriate the resource in question.

As the actions of individuals are symmetric and not repeated, there is no interaction that could

lead to a common action, based on reciprocity or the anticipation of future gains or losses based on cooperation.

The regulator wants to ensure that there is sustainable consumption and therefore introduces a voluntary incentive mechanism in the form of a subsidy, which is paid out to the resource appropriator, if he allocates working time away from resource appropriation, towards the alternative occupation.

The challenge for the regulator is to set the subsidy in such a way, to realize the appropriation level that ensures sustainability of the resource.

The Model

In the model we have N individuals who are involved in the appropriation of a certain common pool resource. Due to their primary occupation it will be referred to the individuals as ‘appropriators’ throughout this section to distinguish them from the policy maker. The policy maker, in turn is not part of the N individuals, but rather a governmental regulator, who is concerned with the implementation of an incentive mechanism to affect the level of appropriation, of the common pool resource.

All N appropriators are endowed with the same, commonly known, amount of working time which they can allocate to appropriating the common pool resource or to an alternative occupation.

The time available for working is normalized to 1 throughout the paper. The utility function of each appropriator can be expressed in the following way:

$$\underbrace{[(c - \alpha) - \beta]}_{\text{monetary utility}} / \underbrace{[1 - (c - \alpha)]}_{\text{‘moral’ utility}} \quad (1)$$

Where u is the utility of one given appropriator, U , in the society, $(c - \alpha)$, indicates the amount of working time dedicated to resource appropriation and β represents the amount of time reallocated to the alternative occupation, $[1 - \beta]$.

The parameter β { $\beta \in [0, 1]$ }, represents the appropriator’s level of efficiency at resource appropriation, which can either take a relatively high value, $\beta \rightarrow 1$, or a low

one, β . All individuals are less, but equally efficient at the alternative occupation and the efficiency parameter is considered to be equal to 1.

The parameter α [α] represents the linear subsidy¹ which is paid out by the regulator, to compensate the appropriator for every unit of time that he allocates away from common pool resource appropriation, towards the alternative occupation.

Parameter γ [γ] represents the ‘warm-glow’ and measures the positive utility that is derived per unit of reallocated appropriation time.

The remaining parameter δ [δ] is referred to as ‘crowding out parameter’, and it measures the effect of the subsidy on the appropriator’s moral utility.

The utility function consists of two parts, a monetary component and a ‘moral’ component. In the first part, monetary utility is derived from the profit, incurred during resource appropriation, $(\pi - \alpha t)$, the profit from the alternative occupation, βt , and the revenue, γt , from receiving a linear subsidy for reallocating working time to the alternative occupation. The sum of all monetary receipts gives positive utility, which is assumed to be decreasing at the margin.

The second part of the utility function is denoted ‘moral’ utility, as it captures the non-monetary addition to π ’s utility. Moral utility is derived from making a ‘socially beneficial’ choice and contributing to the conservation of the CPR for future generations. The effect of the second part of the function to overall utility is also assumed to be positive and marginally decreasing.

In detail, the first part of the moral component of the utility function, γt , is strictly positive, whereas the sign of the second part, the ‘crowding out’ part is ambiguous.

Due to the presence of the square root, it must be assumed that the sum of the two parameters is positive at all times, $(\gamma - \delta t) > 0$. In order to satisfy this non-negativity constraint and limit the minimum value of π , we introduce a lower boundary for α , α_{min} and an upper boundary for the subsidy, α_{max} , such that $\alpha_{min} \leq \alpha \leq \alpha_{max}$.

¹ Stating that the subsidy in this case is linear means that it is proportional for all levels of reallocation and the policy maker is not able to discriminate between appropriators. The fact that the regulator chooses a linear subsidy is made in order to simplify the analysis in this research, not because it is an appropriate representation of reality.

In reality tax- and subsidy schemes are often progressive or regressive, meaning that the tax or subsidy, as a percentage of the base, increases or decreases with the tax- or subsidy base. This is often not a continuous process, but rather different groups are divided into a certain amount of brackets according to the level of tax-or subsidy base.

Assuming a proportional subsidy here implies that there is a concern for horizontal equity (which prescribes that all those with equal reallocation levels will receive equal amounts of compensation/ subsidy), but not for vertical equity (which would require those who have allocated particularly large amounts of working time to the alternative occupation to receive a relatively higher per-unit compensation/subsidy, than those who have only reallocated small amounts). (See Case & Fair, “Principles of Economics”, 2004, Chapter 16)

Economically the limit on the subsidy makes sense, as it allows for the complete compensation of the loss from reallocating time to the alternative occupation. At the same time it does not allow for subsidies that generate revenue, that is itself greater than the revenue from the alternative occupation and that are unlikely to occur in reality.

Similarly to the approach by Bowles and Hwang (2008), a crowding parameter of signifies that there is crowding in and indicates that the appropriator feels better about participating in the CPR conservation program in the presence of a subsidy. This is the case since the appropriator feels supported in the idea of doing the ‘morally right thing’.

If in turn it is the case that , the subsidy and the appropriator’s warm glow are no longer complements, but rather substitutes. Hence, there is crowding out.

Last but not least, in the extreme case of , we say that there is strong crowding out. As mentioned before, extreme cases of strong crowding out are ruled out here.

The model does not contain a part which accounts for the utility from the actually preserved part of the resource. Justification for this omission is that the inclusion of a third term would have made the determination of an analytical solution impossible and prevented an analysis of the sort conducted in this paper.

In terms of interpretation, the lack of utility from the amount of overall conserved resource implies that appropriators are actually indifferent towards the total amount of preserved CPR and the other appropriator’s actions.

This is possibly the strongest assumption, as it requires appropriators to have individual preferences for ‘doing the right thing’, but no preferences concerning the outcome on the social level. Such a scenario is relatively unlikely, but possible when appropriators have very little information on the actions of others, on the total amount of appropriation that takes place and when effects from over-appropriation crystallize relatively late. Especially for small rural communities in developing countries, this setting is plausible.

Policy maker:

The objective of the governing body, also referred to as policy maker, is to reduce the appropriation of the natural resource to the sustainable level, at which the regeneration rate of the resource equals the appropriation rate. This is done in order to conserve the resource for the following generation.

Therefore the policy maker wants to reach **at most** target level of overall appropriation, T^* . In order to achieve this goal he will offer a subsidy of to compensate each appropriator for

every time unit, reallocated to the alternative occupation.

The sequence of actions is such that the subsidy level is set first and subsequently the appropriator makes his decision on the amount of time he dedicates to the alternative occupation.

In order to determine the way in which the subsidy will be set it needs to be looked more closely at the heterogeneity of appropriators in the society. As mentioned before the society is made up of relatively more productive appropriators and relatively less productive appropriators. The policy maker is aware of the size of both efficiency levels α and β , as well as of the proportion of each group within the society. He knows that there is a share of θ appropriators that are highly productive and the remaining share of $(1 - \theta)$ appropriators is less productive. This implies that the policy maker is not able to discriminate between the different types of appropriators, but is able to set a subsidy that is optimal for the degree of heterogeneity in the society.

When looking at the optimal policy it is assumed that the policy maker also can determine the magnitude of the warm glow parameter, γ , and the crowding out parameter δ .

A further assumption that is made here is that every individual appropriator is small, therefore he cannot by himself influence the regulator's choice on the incentive mechanism, but rather has to take it as given when making his choice on the appropriation level.

Analysis

As the individual can only allocate time between the two given alternatives and cannot choose to opt-out of working entirely, the individual will maximize his utility by choosing t , the amount of time he spends at the alternative occupation, rather than at resource appropriation.

This is important as the mechanism is voluntary and the appropriator will only enter this 'compensation contract' with the government if he is strictly better off by doing so, hence if the contract matches his participation constraint.

$$[(1 - \theta) \alpha + \theta \beta] / [(\alpha - \beta)] \geq \gamma / \delta \quad (2)$$

$$- \frac{c_1}{c_2} = \frac{c_1}{c_2} \left[\frac{c_1}{c_2} \right] / \left[\frac{c_1}{c_2} \right] - \left[\frac{c_1}{c_2} \right] / \left[\frac{c_1}{c_2} \right] \quad (3)$$

Solving for α , we get the best-response function of the appropriator to a given subsidy level, as well as the corner solutions:

$$\left\{ \begin{array}{l} \frac{c_1}{c_2} \\ \frac{c_1}{c_2} \\ \frac{c_1}{c_2} \end{array} \right. \left[\frac{c_1}{c_2} \right] / \left[\frac{c_1}{c_2} \right] \left(\frac{c_1}{c_2} \right) \left(\frac{c_1}{c_2} \right) \right. , \text{ otherwise} \quad (4)$$

(where: $\frac{c_1}{c_2} > 1$, to guarantee that the denominator does not become equal to zero)

The best responses for the highly efficient appropriator and the less efficient appropriator are respectively:

$$\frac{c_1}{c_2} \left(\frac{c_1}{c_2} \right) \left(\frac{c_1}{c_2} \right) , \quad \frac{c_1}{c_2} \left(\frac{c_1}{c_2} \right) \quad (5)$$

Given the previously mentioned restrictions on the parameters, the conditions for receiving an interior solution for the less efficient appropriator are given by²:

$$/ \left(\frac{c_1}{c_2} \right) \text{ and} \quad (6)$$

$$\frac{c_1}{c_2} \sqrt{\left(\frac{c_1}{c_2} \right) \left(\frac{c_1}{c_2} \right) \left(\frac{c_1}{c_2} \right)} \quad \frac{c_1}{c_2} \sqrt{\left(\frac{c_1}{c_2} \right) \left(\frac{c_1}{c_2} \right) \left(\frac{c_1}{c_2} \right)} \quad (7)$$

Where the first condition ensures that the chosen share of reallocated time is larger than zero and the second condition ensures that not all time is reallocated to the alternative occupation.

The conditions for receiving an interior solution for the relatively more efficient appropriator and a given subsidy level, α , are³:

$$\text{---} \text{ and} \quad (8)$$

$$\frac{c_1}{c_2} \sqrt{\left(\frac{c_1}{c_2} \right) \left(\frac{c_1}{c_2} \right) \left(\frac{c_1}{c_2} \right)} \quad \frac{c_1}{c_2} \sqrt{\left(\frac{c_1}{c_2} \right) \left(\frac{c_1}{c_2} \right) \left(\frac{c_1}{c_2} \right)} \quad (9)$$

After having derived the conditions for an interior solution, it must now be determined how the subsidy, α , affects the reallocation choice in the case of an interior solution.

² For calculations, see appendix section 1

³ See appendix section 2

Setting τ to zero we find that in the case of the highly efficient appropriator⁴ $\tau > 0$. In the case of the less efficient appropriator the best response function is undefined as the denominator becomes zero. If instead τ is a positive infinitesimally small number, $\tau > 0$, hence $\tau > 0$, indicating that the less efficient appropriator will not allocate any time at all to the alternative occupation.

The consequences from gradually increasing τ , can be seen from the comparative statics of the best response function:

$$\frac{\partial \tau}{\partial \tau} = \frac{[(1 - \tau)(1 - \tau)](1 - \tau) - [(1 - \tau)(1 - \tau)]}{[(1 - \tau)(1 - \tau)]} \quad (10)$$

Given that τ and τ are only taking on positive values, in the case of the less efficient appropriator, this term becomes negative at $\tau = 1/(1 - \tau)$. This indicates that for subsidy values above this level, the time which is reallocated by the less efficient appropriator decreases in the value of τ . As seen before this coincides with the level of τ at which there is an interior solution for the less efficient appropriator. Hence, whenever there is an interior solution, the time reallocation will be decreasing in the subsidy.

Furthermore it can be seen that this certain level of τ increases both in the warm glow parameter, τ , and in τ as long as there is no strong crowding in. It can therefore be concluded that the threshold level of τ is lower in the case of crowding out than in the case of crowding in.

The effect of an increase in τ on the optimal time reallocation of the highly efficient appropriator is positive if⁶:

$$[(1 - \tau)(1 - \tau)](1 - \tau) > [(1 - \tau)(1 - \tau)] \quad (11)$$

And becomes negative if:

$$[(1 - \tau)(1 - \tau)](1 - \tau) < [(1 - \tau)(1 - \tau)] \quad (12)$$

In order to determine more closely how the reallocation choice of the appropriators changes with different subsidy levels, in different scenarios, and in order to give a more detailed

⁴ Since $\frac{\partial \tau}{\partial \tau} = \frac{[(1 - \tau)(1 - \tau)](1 - \tau) - [(1 - \tau)(1 - \tau)]}{[(1 - \tau)(1 - \tau)]}$

⁵ See appendix section 3

⁶ See appendix section 4

understanding of the model, the next section will look at different types of scenarios and analytically derive and then interpret the change in the reallocation behavior.

Cases

In order to determine how the time spent on the alternative occupation changes with different subsidy levels, it will now be looked at different scenarios. The differences in the scenarios are characterized by varying sizes of the individual parameters.

While the magnitude of the warm glow parameter is held constant at $\mu = 0.125$, it will be looked at cases of crowding in and crowding out, first, when actors don't differ much in efficiency and later when actors differ strongly in efficiency.

Subsequently the analysis will be extended to the case when the warm glow parameter changes.

Case 1: No crowding out, relatively high warm glow

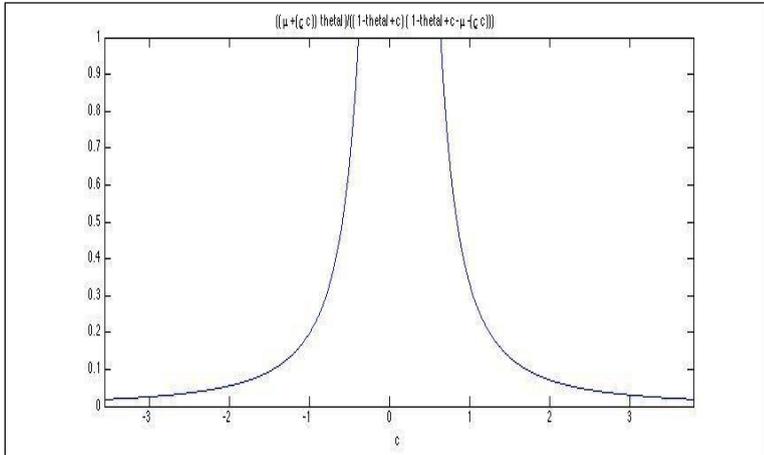


Figure 1: Optimal reallocation time for the less efficient appropriator when there is no crowding in or crowding out

Figure 1 displays what will be referred to as the benchmark case. It shows the optimal reallocation time for a given level of θ . Since a negative ζ would imply the presence of a tax, rather than a voluntary incentive mechanism or subsidy, this part of the graph will be omitted for the rest of the section and only internal solutions will be discussed.

When looking at the overall function, it can be seen that the reallocation rate of the less efficient appropriator, between zero and 0.125 increases as ζ gets larger and subsequently

decreases⁷ at a slowing rate⁸, for the remainder of the subsidy range.

The increase and decrease for t-values below zero are part of a parabolic shape, until $c = 1$, at which the function jumps to a t-value above 1 and continues its decrease.

For the appropriator, this jump corresponds to a change from completely spending his time appropriating the CPR to exclusively undertaking the alternative occupation.

It is important to be aware of this part of the curve, when interpreting the derivative of t with respect to c and account for it as a subsidy range at which the reallocation is equal to zero, and we don't have an internal solution, according to (4).

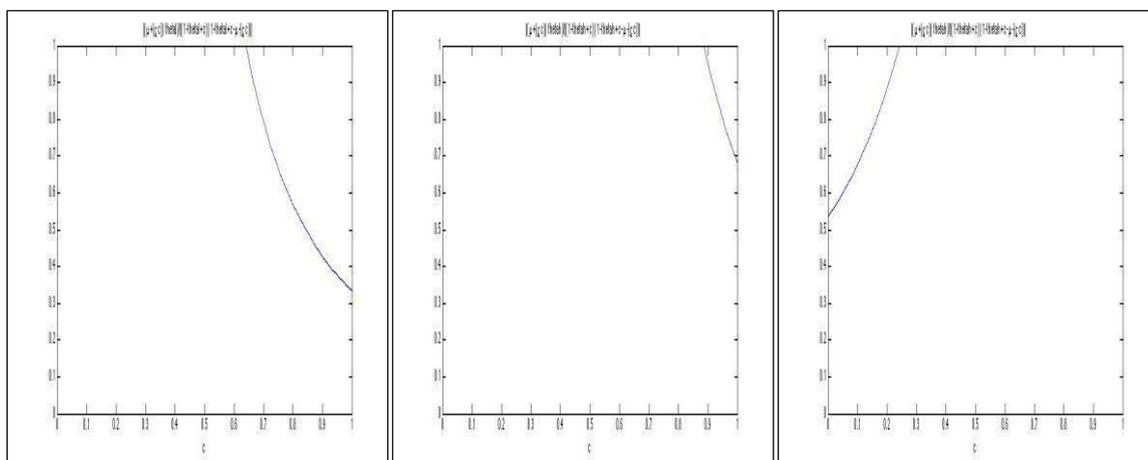


Figure 2: Optimal reallocation choices for the less efficient appropriator (left), the highly efficient appropriator when the difference between appropriators is small (middle) and large (right) when there is no crowding out

In line with the analysis section, it can be determined for which range of values the appropriator reallocates no time, all his time or a value between zero and one. The numerical values of these ranges are summarized in table 1, with the blue column representing the subsidy levels for which an interior solution exists. It shows that when there are large differences in efficiency, it is not possible to design a policy under which both types of appropriators reallocate some time.

		Reallocation		
No crowding out:				

Table 1: Summary of reallocation choices for the different types of appropriators

Figure 2 shows that in case of an internal solution, when holding c constant, and in the absence of crowding out, an increase in the efficiency level of the appropriator, will shift the

⁷ See Appendix section 5

⁸ See appendix section 6

time-reallocation curve to the right.

Analytically, this can be seen from the first derivative of τ with respect to the efficiency parameter, η , which is positive⁹. Knowing the shape of the curve, this means that the subsidy range for which there is no reallocation at all, moves to higher subsidy levels, the more efficient the respective appropriator is. The range of subsidy values for which there is complete reallocation is similar for the relatively less efficient appropriator and the very efficient appropriator, while the intermediate case reallocates completely at very low and very high subsidy values.

As efficiency increases, the range of subsidy values for which there is an internal solution first moves to higher values of τ and subsequently moves to lower ones, as the upward sloping part of the function enters the internal solution.

A possible interpretation for this is that monetary gains are relatively more important to the less efficient appropriator's utility than to the efficient one's (since he gets more from the resource appropriation). Therefore the highly efficient appropriator will reallocate time at low subsidy values in order to receive moral utility, which gives him relatively more utility than an extra unit of monetary gain. Therefore he only requires slight compensation for the forgone income. As the subsidy increases, the highly efficient appropriator reallocates more time to the alternative occupation because the monetary utility from reallocation increases. If the highly efficient appropriator is only slightly more efficient, he will reallocate completely at low subsidy values as they, as warm glow initially gives him relatively more utility, than an extra unit of monetary payoff. It is difficult to find an economic explanation for the period when he goes back to dedicate all time to appropriation and not reallocate at all. The less efficient appropriator will reallocate completely when the utility from the subsidized income and the warm glow will be higher than the utility from any combination of the two activities.

Counterintuitive is the fact that the less efficient individual decides to reallocate to resource appropriation at high subsidy values. It would be expected that the individual would completely reallocate as well at low subsidy values as he would then simultaneously gain monetary and moral utility. Analytically this finding can be verified by plugging the case values of the parameters into equation (6).

The observation, of the curve's shifts to the right for increasing efficiency, can also be indirectly confirmed when looking at the slope of the reallocation curve for the case of an

⁹ See appendix section 7

internal solution ($\frac{\partial \tau}{\partial c} < 0$). This slope is negative for the less efficient appropriator and positive (upward-sloping part of the curve) for appropriators with a relatively high efficiency¹⁰.

Case 2: Crowding out, relatively high warm glow

Figure 3 shows that, for a given level of efficiency and warm-glow, the introduction of crowding out steepens the slope of the reallocation curve¹¹ for positive values of μ and increases the convex curvature for negative values of μ .

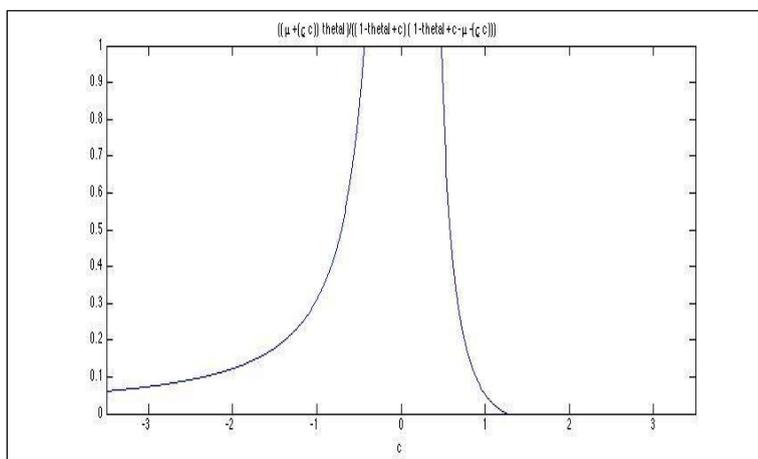


Figure 3: shows the optimal choice of time reallocation for the less efficient appropriator when there is crowding out

This change in slope causes the less efficient appropriator to reduce his reallocation time relatively more, per unit increase in the subsidy, than in the benchmark case without crowding out. He also starts gradually reallocating at a lower subsidy level, as reallocation now also bears a cost in terms of negative utility from the policy maker’s involvement which can’t be outweighed by the positive utility from warm glow and monetary compensation after a certain point.

On the other hand, table 2 shows that the relatively less efficient appropriator starts reallocating completely at a lower level of c . This result can be analytically verified when looking at condition (6).

The highly efficient appropriator on the other hand increases his time reallocation relatively more slowly than in the benchmark case. This is because he requires a relatively higher subsidy to compensate him financially and in terms of warm glow for the foregone income

¹⁰ See appendix section 8

¹¹ See appendix section 9

and the disutility from the involvement of the policy maker, incurred when reallocating his time to the alternative occupation.

Analytically, the change from the benchmark case can be identified when looking at the derivative of the reallocation share with respect to the crowding out parameter. It can be identified that for any positive level of α , the reallocation share is increasing in α in the internal solution¹². This is intuitive as crowding out relatively decreases the utility gain from reallocation at any subsidy level.

As in the benchmark case, keeping all else constant, it can be seen that also in the case of crowding out, an increase in efficiency shifts the reallocation curve to the right.¹³

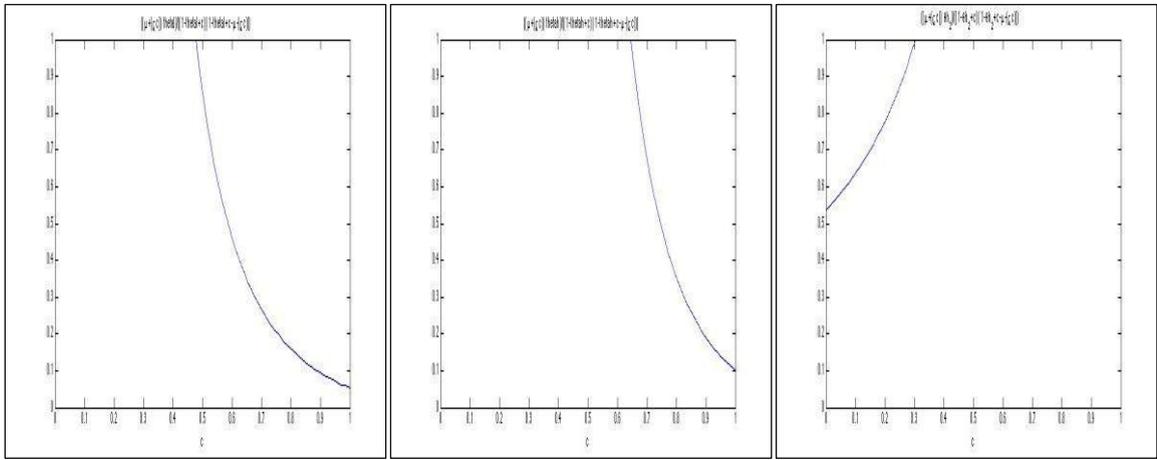


Figure 4: Optimal reallocation choices for the less efficient appropriator (left), the highly efficient appropriator when the difference between appropriators is small (middle) and large (right) when there is some crowding out

Table 2 gives information on the numerical range of the reallocation choices in the presence of crowding out. The comparison with the results presented in table 1 confirms the findings from comparing plots and comparative statics¹².

		Reallocation		
Crowding out:				

Table 2: Summary of reallocation choices for the different types of appropriators in the case of crowding out

¹² See appendix section 10
¹³ See appendix section 11

Case 3: Crowding in, relatively high warm glow

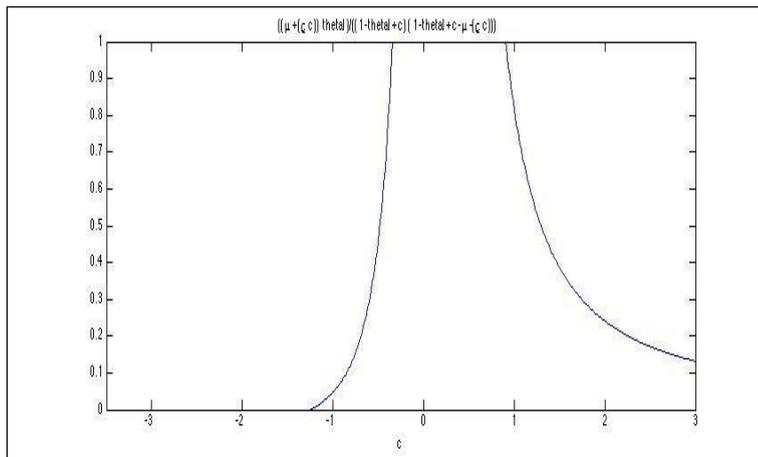


Figure 5: shows the optimal choice of time reallocation for the less efficient appropriator when there is crowding in

Figure 5 displays the same scenario, with the difference that now appropriators display crowding in. The shape of the curve has now changed in the opposite way as before. It has become much steeper for negative values of c and the convex curvature has increased for positive values of c .

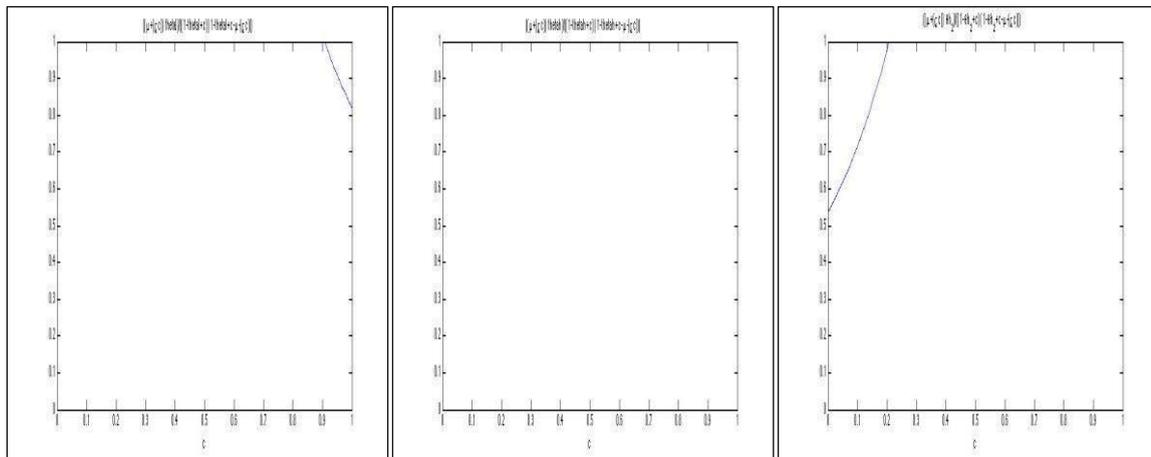


Figure 6: Optimal reallocation choices for the less efficient appropriator (left), the highly efficient appropriator when the difference between appropriators is small (middle) and large (right) when there is some crowding in

Figure 6 shows that also in the case of crowding in, an increase in efficiency of the appropriator shifts the reallocation-curve to the right, unfortunately showing this movement in an analytical way becomes impossible as the term under the root becomes negative for $c > 1$. Plotting the function for multiple cases can give an idea of the movement.

The increased convexity of the right half of the curve decreases the range of internal solutions for subsidy values between zero and one.

In line with the previous scenario, the reallocation choice for every subsidy level in the internal solution is now relatively higher than in the case of crowding out and the benchmark

scenario¹², since appropriators receive relatively more utility than in the benchmark case, for every unit of time they reallocate to the alternative occupation.

Table 3 gives the reallocation choices of the appropriators in the case of crowding in. As expected, allowing for crowding in increases the threshold subsidy level beyond which the appropriators of low efficiency start reducing their reallocation level and it reduces the subsidy level beyond which highly efficient appropriators completely reallocate their time to the alternative occupation.

		Reallocation		
Crowding in:				
				/

Table 3: Summary of reallocation choices for the different types of appropriators in the case of crowding in

After looking at the effect of changes in the crowding out parameter and in efficiency, the analysis is now repeated for a lower value of the warm- glow parameter, , to determine the effect of changes in warm glow on the reallocation decision on the appropriators.

Case 4: No crowding out, relatively low warm glow

The reallocation curve for the less efficient appropriator is represented in figure 7. It can be seen that keeping all else constant, a decrease in the warm glow parameter renders the curve narrower and steeper. This increases the potential for having an internal solution.

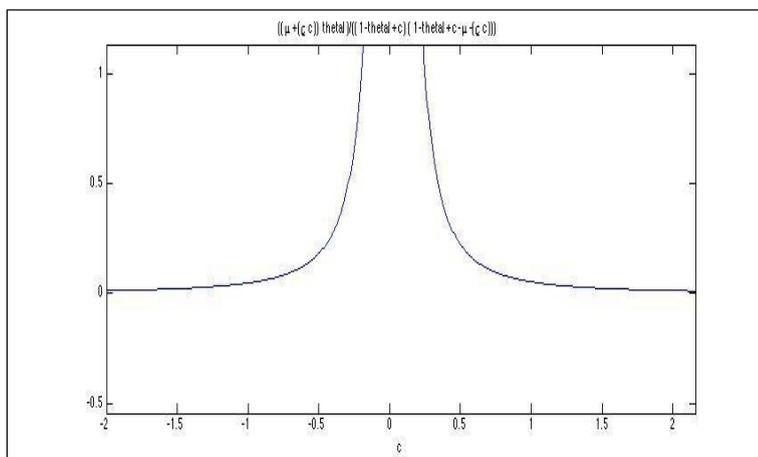


Figure 7: Optimal reallocation time for the less efficient appropriator when there is no crowding in or crowding out

Figure 8 shows that the movement of the curve for changing efficiency parameters is still the same as at the higher warm glow level. Through the changed form of the curve, a subsidy between α and β now causes the less efficient and the much more efficient agent to reallocate some, but not all time. Hence, it is now possible for the policy maker to design an instrument with which both agents are reallocating some time to the alternative occupation.

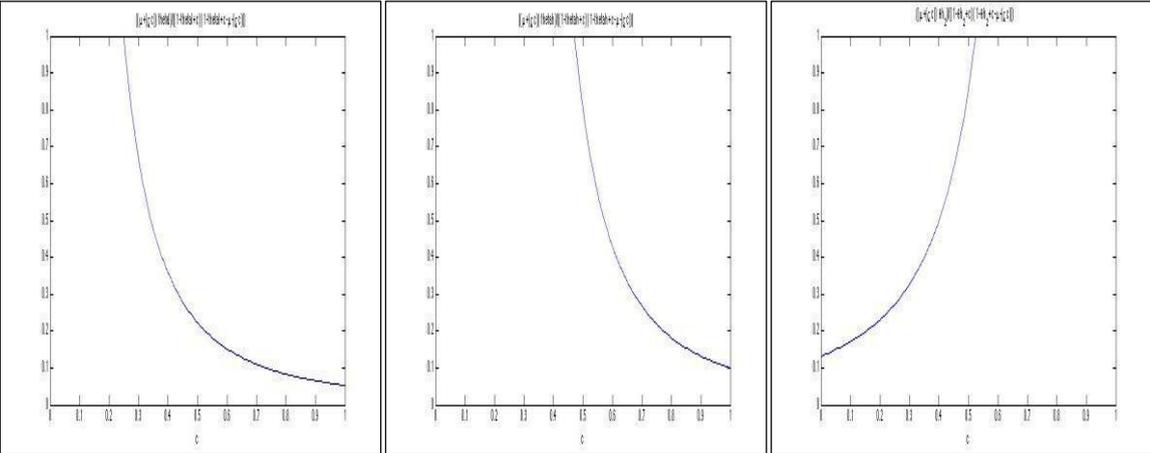


Figure 8: Optimal reallocation choices for the less efficient appropriator (left), the highly efficient appropriator when the difference between appropriators is small (middle) and large (right) when there is no crowding out

More precisely, the change in shape can be classified as a downward shift of the downward sloping part of the curve, for the less efficient appropriator¹⁴, meaning that he already starts reallocating less time to the alternative occupation at lower subsidy values. It is intuitive that the reduced warm glow reduces the attractiveness of the alternative occupation by reducing the ‘moral utility’ derived from engaging in the alternative occupation. Furthermore the less efficient and the somewhat more efficient appropriator start reallocating completely at lower subsidy levels than in the benchmark case.

When the efficiency difference in the society is large, the highly efficient appropriator, decreases the time he chooses to reallocate at any given level of α in the interior solution, as compared to the benchmark case¹⁵ and in turn the reallocation curve in shifts downwards. The explanation of the changed incentives is analogous to the explanation for the less efficient appropriator.

¹⁴ See appendix section 12

¹⁵ See appendix section 13

		Reallocation		
No crowding out:				

Table 4: Summary of reallocation choices for the different types of appropriators at the lower warm-glow level

Case 5: Crowding out, relatively low warm glow

Introducing crowding out to the case with the lower warm glow value, changes the shape of the reallocation curve similarly as it has done in Case 2 when crowding out was added to the benchmark case. At the lower warm glow factor, the convex curvature of the left part becomes even stronger and the slope of the right hand side becomes even steeper. The function now has a local minimum below zero.

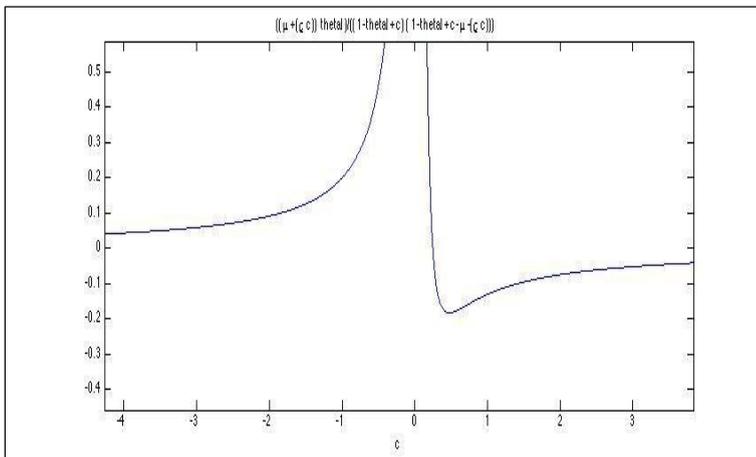


Figure 9: Optimal reallocation time for the less efficient appropriator when there is crowding out

Inference on the effect of crowding out, on the reallocation curve can be taken from the notes 15 and 16. It can be confirmed that the effect of an increase in the warm glow factor on the reallocation share is increasing in μ .

Hence, in the scenario presented here, the effect of the decrease in the warm glow factor on the reallocation share is smaller when there is crowding out ($\mu < \mu_c$) and larger when there is crowding in ($\mu > \mu_c$). The interpretation of this is that the relative decrease in the per-unit utility gain from reallocation, caused by the lower warm glow factor, will be smaller for appropriators who have a ‘moral’ cost associated with reallocation (and the associated subsidy), as these appropriators already weigh between the costs and benefit for reallocation reallocate relatively less for every given unit of subsidy. At any given reallocation level, these individuals will be relatively less affected by a decrease in the warm glow factor.

Appropriators that crowd in do not substitute utility from reallocation-warm-glow for disutility from crowding out, but receive positive utility from both factors. They will therefore react relatively stronger to a decrease in the magnitude of the warm glow factor.

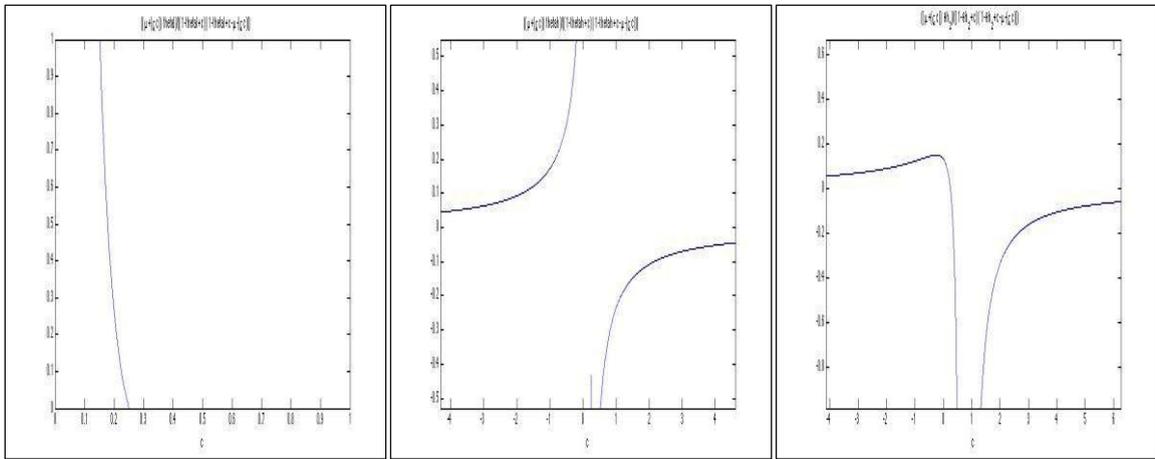


Figure 10: Optimal reallocation choices for the less efficient appropriator (left), the highly efficient appropriator when the difference between appropriators is small (middle) and large (right) and when there is some crowding out

From figure 10 it can be seen that for the less efficient appropriator, the finding is in line with what was expected from the derivatives. Furthermore table 5 shows that the less efficient appropriator will not reallocate at all from a subsidy value of . This shows that beyond this level increases in utility from subsidy and warm glow are completely outweighed by the disutility from crowding out.

		Reallocation		
Crowding out:				

Table 5: Summary of reallocation choices for the different types of appropriators at the lower warm-glow level, in the presence of crowding out

It can be seen that for the slightly more efficient appropriator, there is no internal solution at this lower warm glow value and he will only decide between allocating all his time, at relatively low subsidy values, or no time at all, at relatively high subsidy values, to the alternative occupation.

The very efficient appropriator now also decreases his reallocation with increases in the subsidy. The interpretation is that the increase in the monetary utility from the compensation weighs relatively less because of the diminishing-returns structure of the utility function and due to the relatively small utility increase form the warm glow. Hence the positive effects

from reallocation are completely offset by the utility decrease from crowding out and an increase in the subsidy level actually has a negative effect on reallocation in this scenario.

Case 6: Crowding in, relatively low warm glow

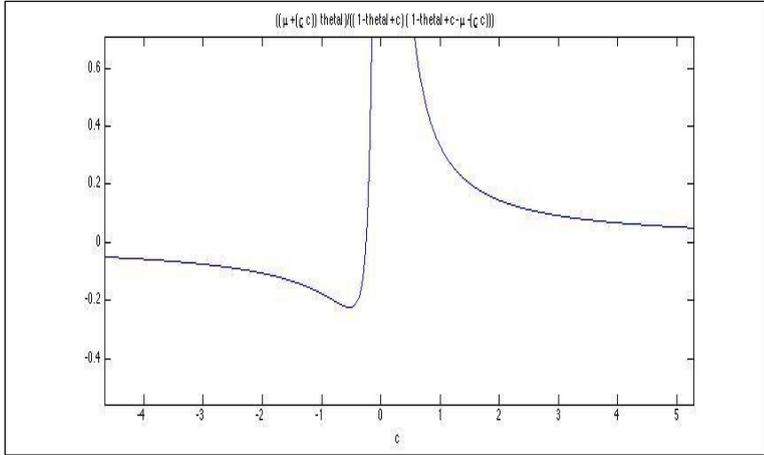


Figure 11: Optimal reallocation time for the less efficient appropriator when there is crowding in

In line with the previous analysis we can find Figures 10 and 12 to show opposite movements for the individual efficiency cases, similarly to the changes in reallocation between crowding in and crowding out at the higher level of .

Compared to Case 5, and from the results reported in table 6, it can be determined that the reallocation level for every given level of in the case of an internal solution is higher than in the cases where

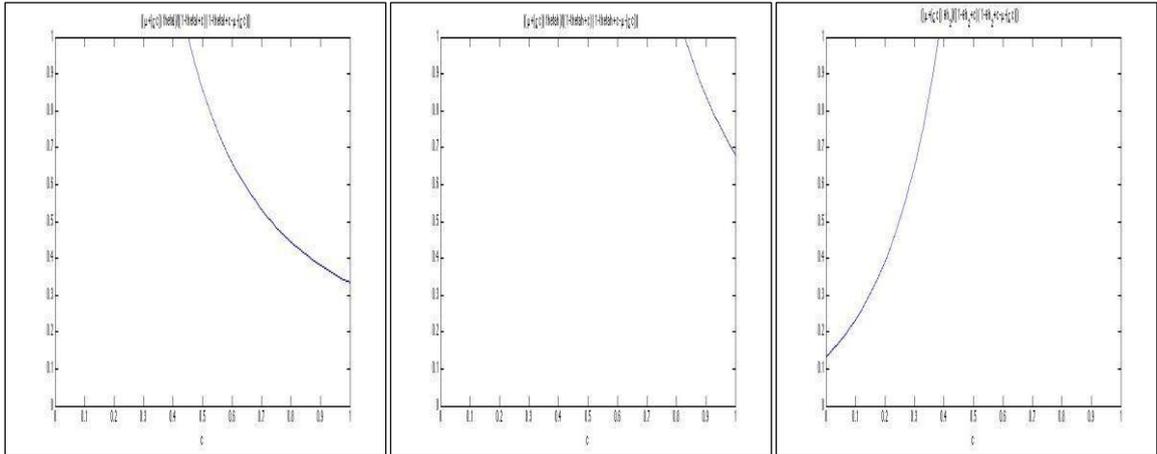


Figure 12: Optimal reallocation choices for the less efficient appropriator (left), the highly efficient appropriator when the difference between appropriators is small (middle) and large (right) and there is some crowding in

		Reallocation		
Crowding in:				

Table 6: Summary of reallocation choices for the different types of appropriators at the lower warm-glow level, in the presence of crowding in

The Policy Maker's Perspective

As mentioned before, the governing body or policy maker has the incentive to ensure the sustainability of the CPR at stake. In detail, this means that the policy maker derives utility from realizing a level of appropriation that is **at the most** equal to the amount of resource that is regenerated. If appropriation is higher than the sustainable level, this is a source of disutility to the policy maker as resource depletion bears large social and economic costs. On the other hand, the policy maker is indifferent to appropriation that is lower than the regenerative level. In the case the policy maker reaches his target level of appropriation and reallocation, he has a preference for **spending as little money as possible** for achieving the desired outcome.

The policy maker affects the action of the appropriators by offering a linear subsidy for every unit of time that is reallocated away from resource appropriation towards the alternative occupation. As outlined in the past scenarios, the reaction to a subsidy is very different, according to the magnitude of the warm-glow parameter, the presence of crowding in or crowding out and the individual efficiency level of each of the two groups of appropriators. This shows that the policy maker must consider these characteristics of the two types in his attempt for policy creation. In order to achieve his goals, he can pick one of three options: choose the minimum subsidy level at which only the highly efficient type reallocates completely, the minimum subsidy for which the less efficient type completely reallocates or a solution at which one or both types reallocate a certain share of their time to the alternative occupation.

In order to gain an understanding of the impact of changing behavioral parameters, the following section will reevaluate the previously outlined cases in terms of their implication for the optimal policy choice. The underlying assumption here is that the policy maker is

aware of the present ‘efficiency types’ and their share in the population. The considered numerical example is based on a community size of N , where the desired maximum level of appropriation is \bar{a} . The population is made up of a small proportion of efficient appropriators (α) and a large proportion of less efficient appropriators ($1 - \alpha$).

Subsequently the optimal policy choice in the numerical example will be compared to the choice of a ‘naïve’ policy maker who completely fails to incorporate behavioral attributes in his policy choice.

Case 1/ Benchmark Case: No crowding out, relatively high warm glow

At first we will consider a society in which the differences in efficiency between the appropriators are relatively small.

In the case at hand solutions that involve simultaneous reallocation of both groups are found at higher subsidy levels, indicating that they will be relatively more expensive. The optimal policy in the case of the numerical example can be found in the first column of table 7.

The cheapest possibility to reach the policy target of staying below \bar{a} is by offering a subsidy of s_1 . At this subsidy the less efficient type will completely reallocate and the resulting appropriation level would be a_1 at a total cost of C_1 .

The alternative mixed solutions allow for a higher appropriation level while still meeting the target, but on the downside these mixed solutions are much more expensive to the policy maker. Since it was assumed that the policy maker has a preference for reaching his goal at minimum cost, he should choose the lower level subsidy in this case.

Increasing the difference in efficiency between the two types of appropriators renders both, policy that only encourages one group to reallocate, and mixed solutions more expensive. For the expense-minimizing appropriator, it is now optimal to choose the minimum subsidy at which both types of appropriators reallocate completely and no time at all is spent on resource appropriation in the particular society.

Case 2: Crowding out, relatively high warm glow

Introducing crowding out into the scenario with small efficiency differences between the two types, while keeping all other parameters constant, decreases the cost of optimal policy

compared to the benchmark case. This counterintuitive finding has to do with the disutility that is now caused by the subsidy, which reduces the importance of the second part of the utility function. The type of optimal policy, nonetheless, is the same as in the benchmark case, without crowding out.

When looking at the change in the optimal subsidy for the scenario in which groups differ largely in efficiency, it can be seen that the introduction of crowding out enables solutions that affect both types of appropriators at very low levels of τ .

This is caused by the left/downward shift of the less efficient group's reallocation curve, as a consequence of the relative gain in importance of the warm-glow parameter. Hence, optimal policy affects both appropriators and causes the less efficient ones to reallocate completely and the highly efficient ones to reallocate part of their working time. Compared to the case the benchmark case optimal policy required now less funds.

Case 3: Crowding in, relatively high warm glow

As expected, the presence of crowding in, in the appropriators' utility functions, has an exactly opposite effect on the optimal policy.

The previous section outlined how allowing for the presence of crowding out and crowding in shifts the reallocation curves in opposite directions. Consequently, policy solutions that cause the less efficient type to reallocate completely now require a relatively higher level of the subsidy and demand a higher level of public funds to be financed. Still, the optimal subsidy level remains the smallest possible level of τ , for which the less efficient group reallocates while the efficient group continues to appropriate.

Furthermore, at higher efficiency differences in the society, the minimum subsidy level for which a solution affecting both types is available, increases compared to the benchmark case. Here, the optimal policy is similar to the one for the benchmark case when there are large efficiency differences. Hence, it is optimal to choose the lowest possible level of τ at which neither group appropriates the resource.

Case 1		Case 2		Case 3	
Small efficiency differences	Large efficiency differences	Small efficiency differences	Large efficiency differences	Small efficiency differences	Large efficiency differences

Table 7: Summary of optimal subsidy values, Cases 1-3

Case 4: No crowding out, relatively low warm glow

Reducing the warm glow factor of all appropriators in the model renders the required subsidy level for achieving the policy target lower, as compared to the benchmark case. If efficiency differences are small, the optimal policy is a subsidy that causes all inefficient appropriators to reallocate, just like in the benchmark case.

When the difference in efficiency becomes large and individuals have a relatively low level of warm glow optimal policy is a mixed solution at which both groups reallocate some time.

Policy costs are much lower than in the benchmark case. A possible interpretation for this is that as there is very little utility available from reallocation, the utility derived from monetary gains becomes relatively more important.

Finding the costs of subsidies to be lower is also in line with the analysis of the cases.

Comparing table1 and table4 shows that the range of partial reallocation choices gets broader at a lower warm-glow value and the subsidy-level at which there is complete reallocation moves to lower values. In combination, this increases the number of policy options for the policy maker, especially at low subsidy levels.

Case 5: Crowding out, relatively low warm glow

Similarly to Case 2, the introduction of crowding out moves the reallocation curve to the left and reduces the subsidy level, required to meet the policy maker's goal.

When comparing Case 2 and Case 5 it can also be seen that in the presence of crowding out, the reduction of the warm glow factor reduces the subsidy level required to achieve the policy

goal. This is similar to the effect that a reduction of the warm glow factor has on the required subsidy level in the benchmark case and it holds for policy options that affect both types of appropriators and those that only affect the less efficient type.

At a relatively low efficiency difference in the society it is optimal to choose a low subsidy level at which both types reallocate completely.

When efficiency differences are larger in the economy, the required subsidy level to achieve the goal is, as in all previous cases, slightly higher. Nonetheless, it is lower than in the higher warm-glow case with crowding out. Optimal policy now affects both types of appropriators.

Case 6: Crowding in, relatively low warm glow

As pointed out before, the introduction of crowding in renders the minimum subsidy at which the policy maker’s goal can be achieved slightly higher in the scenario with small differences in the efficiency level and even higher in the scenario in which the appropriators differ largely in efficiency.

The type of optimal policy is similar to the case of crowding out with lower warm glow, meaning that at small efficiency differences it is optimal to choose a policy that leads to complete reallocation of all appropriators, and in case the efficiency difference is large it is optimal to pick a subsidy that causes both types to engage in reallocation.

Although the implied optimal policy is different from the case with the higher warm glow, the minimum subsidy at which the policy maker’s goal can be achieved is lower in the case at hand.

Case 4		Case 5		Case 6	
Small efficiency differences	Large efficiency differences	Small efficiency differences	Large efficiency differences	Small efficiency differences	Large efficiency differences
				50	

Table 8: Summary of optimal subsidy values, Cases 4-6

The main conclusions that can be drawn for the optimal policy mechanism are as follows:

Keeping all else constant, a reduction in the warm glow parameter, measuring the altruistic value from a reallocating time, reduces the level of the optimal policy mechanism.

Similarly, the introduction of crowding out also reduces the magnitude of the optimal subsidy.

On the other hand the effect from introducing crowding in, on the size of the optimal policy mechanism is ambiguous.¹⁶

The efficiency difference between the different types of appropriators in one society often doesn't have an effect on the level of the optimal subsidy, since the subsidy is set in such a way that the policy that only the less efficient group of appropriators responds to it.

The 'naïve' policy maker

After looking at the implication of changes in different behavioral parameters on the optimal subsidy, it is left to inquire what would happen if the regulator had not only imperfect information on the magnitude of the individual parameters, but would completely fail to incorporate behavioral aspects into his policy decision.

Effectively he would set his policy in anticipation that the appropriators only maximize a monetary utility function:

$$[()] / \quad (13)$$

As a result he expects the appropriators to have the following best response functions¹⁷:

$$\frac{ }{ () }, \quad \text{---} \quad \text{---} \quad (14)$$

Consequently the policy maker expects that the less efficient appropriator will never reallocate any time to the alternative occupation for any subsidy level between zero and one.

The more efficient appropriator is expected to increase his reallocation in the with subsidy

¹⁶ This is in line with the difficulties of finding the results of the derivatives for this case in the analysis/case section.

¹⁷ See appendix section 14

level, as long as (). More importantly, the naïve best-reply function implies that the more efficient appropriators will completely reallocate when the subsidy is equal to zero.

Hence, a naïve policy maker will always focus his policy consideration on the efficient appropriator and set the subsidy level to zero and not reach his target. The naïve policy maker's approach is in contrast to the optimal policy suggestion in all six analyzed cases in which optimal policy relies on partial or complete reallocation of the less efficient appropriator.

Concluding Remarks and Extensions

From the analysis of the model it can be firstly concluded that the effect of the level of the voluntary incentive mechanism is strongly affected by the additional parameters in the system.

The model was designed in a way to create a trade-offs between monetary payoffs, moral payoffs from warm glow and moral cost or payoff from crowding in or crowding out, as have been documented by the evidence from real world experiments. The particularity about the results is how these defined effects interplay with each other and with the efficiency of the agent.

This paper has shown that the optimal policy level that a cost-minimizing policy maker would set, varies strongly with the amount of warm-glow from his altruistic deed, as well as with the magnitude of crowding in and crowding out.

In detail a reduction in the warm glow parameter was found to generally reduce the level of the optimal policy mechanism. And reduce the overall cost of the policy in the numerical example. Similarly, the introduction of crowding out also reduces the magnitude of the optimal subsidy and overall costs to the policy maker in most cases of the example.

On the other hand the effect from introducing crowding in and increases in the efficiency difference in the society, on the size of the optimal policy mechanism is ambiguous.

It has also been discussed that irrespective of the difference in optimal policy, generated by the changes in any of the parameters, a naïve policy maker generally tends to set his policy

mechanism below the optimal level in the scenario.

Overall it can be said that the introduction of incentive mechanisms or policy is important for the governance of a CPR, especially when groups get too large or too anonymous to govern their resources. While these incentives perform relatively well in many cases, a policy maker who considers not only the presence of moral considerations, but also the effect of the incentive mechanism on the appropriators' preferences could improve the effectiveness and/or efficiency of the policy.

A considerable contribution of this research is that it incorporates the possibility of diminishing returns to both, moral and monetary payoffs. As mentioned in the literature review, there are strong arguments for the presence of decreasing marginal returns in the monetary, as well as in the moral part. While this rendered the analysis of the model more difficult, it became more realistic.

While this result seems to simplify the solution of the majority of all global environmental problems, it must be accounted for the shortfalls of the model which render its application to reality difficult or at least require some extensions.

First and foremost it must be mentioned that the policy maker in many instances does not actively choose to be naïve, but suffers from a considerable information asymmetry about the mentioned parameters. Information asymmetries about the efficiency could be come by with an economic research, but the determination of the parameters affecting the moral part of the utility function is more difficult and will require extensive surveys, the result of which can be imprecise.

Another source of potential problems with the model at hand are the relatively strong assumptions on which it relies.

The fact that appropriators do not derive utility from the overall conservation of the resource within society, but just from their very own altruistic deed, might not be met in reality. While this assumption was mainly made to simplify the model and its analysis, it is an assumption that is hard to justify in reality. The omission of the assumption would have a large effect on the derived results. This is the case since then the utility derived from CPR conservation would largely depend on the time reallocation choice of the other appropriators in society. A possible justification for this assumption is that appropriators in this one-period model know about the symmetry of contributions of others with the same efficiency level, and therefore don't derive an extra utility from the overall resource conservation. Alternatively this

assumption can be justified in a scenario in which appropriators are not aware of the dimensions of the CPR and their fellow appropriators, and then only derive utility from their own altruistic deed.

Nonetheless a valuable extension to model would try to incorporate the overall CPR conservation in society into the individual appropriator's utility function and look at the change in results.

A further extension to the model could look at the effect of the type of subsidy. It is rather uncommon for a subsidy to be completely linear, as this is more difficult to administer and to justify from an equity-concerned point of view. Allowing for subsidy brackets could generate interesting insights and could render the model closer to reality.

Undoubtedly, the results of the model would be rather different if individual appropriators could affect the policy maker's choice on the magnitude of the subsidy. Dropping this assumption can lead to a more realistic scenario, in which there are many very small appropriators and only few large ones. This is often the case when some appropriators are large corporations and many are private individuals.

Looking at a special case in which this type of "lobbying" is possible will add a game theoretic notion to this model and lead to potentially interesting conclusions.

On a technical perspective, it could provide valuable information to transform the model in such a way that a complete analysis can be conducted. While this would probably only be possible at the expense of the decreasing-returns-to-scale structure of the utility function, this would reduce the explanatory power of the model, but it could deliver a more consolidated policy advice.

When looking at the perspective of the policy maker, there are also possibilities for extensions that could render the model more realistic.

The first one concerns the assumption that the policy maker doesn't have a preference for economic efficiency. In the policy advice, it has been assumed that the policy maker is indifferent on whether the reallocation is done by the less efficient appropriator or the more efficient one. In a real world application of this scenario this is unlikely, as the policy maker cares for overall economic output and the 'sustainable' use of the resource.

Appendix

1. In order for the share of relocated time to be zero, given the previous definition of τ , and given the assumption that $\tau < 1$, the denominator must be negative.

From (4), it can be seen that this requires $(1 - \tau)(1 - \alpha) < 0$, hence we need $\alpha > 1$ and $[\tau < 1]$ $| (1 - \tau)(1 - \alpha) |$. Since $\alpha > 1$ and in the case of the less efficient appropriator, the denominator becomes negative when $[\tau < 1]$ $(1 - \tau)(1 - \alpha) < 0$, which becomes $(1 - \tau) > 0$ only becomes zero if $\tau = 1$.

The solutions for the complete reallocation of time towards the alternative occupation are found by looking at $(1 - \tau) = 0$ $[\tau = 1]$, and solve for c : $(1 - \tau) = 0$, then

$$\frac{(1 - \tau) \sqrt{(1 - \tau)(1 - \alpha)}}{(1 - \tau)} = \frac{(1 - \tau) \sqrt{(1 - \tau)(1 - \alpha)}}{(1 - \tau)}$$

2. $[\tau < 1]$ $(1 - \tau) < 0$ $(1 - \alpha) > 0$
 $(1 - \tau) < 0$

For the highly efficient appropriator the decision on reallocating any time at all depends on whether the subsidy fulfills the following condition: $\tau < 1$

Time is completely reallocated to the alternative occupation if: $(1 - \tau) < 0$ $[\tau < 1]$ $(1 - \alpha) > 0$. In the case of the relatively more efficient appropriator, this means that complete allocation will occur when the subsidy is such, that:

$$\frac{(1 - \tau) \sqrt{(1 - \tau)(1 - \alpha)}}{(1 - \tau)} = \frac{(1 - \tau) \sqrt{(1 - \tau)(1 - \alpha)}}{(1 - \tau)}$$

3. $\tau = \frac{[(1 - \tau)] (1 - \alpha) [\tau]}{[(1 - \tau)]}$, find c for which the nominator becomes either positive or negative, $\tau < 1$

4. $[\tau < 1]$ $(1 - \tau) < 0$ $(1 - \alpha) > 0$ $[\tau < 1]$ $(1 - \tau) < 0$
 $(1 - \tau) < 0$ $(1 - \alpha) > 0$
 $\frac{(1 - \tau) \sqrt{(1 - \tau)(1 - \alpha)}}{(1 - \tau)} = \frac{\sqrt{[(1 - \tau)] (1 - \alpha) } [\tau] [(1 - \tau)] (1 - \alpha) [\tau]}{[(1 - \tau)]}$

5. Taking the derivative of τ in (5) with respect to c , for $\tau < 1$:
- $$\tau = \frac{(1 - \tau) \sqrt{(1 - \tau)(1 - \alpha)}}{(1 - \tau)}$$

6. $\tau = \frac{(1 - \tau) \sqrt{(1 - \tau)(1 - \alpha)}}{(1 - \tau)}$

7. Solving (4) for τ , we get: $\tau = \frac{(1 - \tau) \sqrt{(1 - \tau)(1 - \alpha)}}{(1 - \tau)}$
 $\tau = \frac{(1 - \tau) \sqrt{(1 - \tau)(1 - \alpha)}}{(1 - \tau)}$

8. For low efficiency case, see footnote 7, for the highly efficient appropriator, in the case with $\tau < 1$ take the derivative of τ with respect to c , from (5):

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