



# Just tell me what my neighbors do! Public policies for households recycling

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## Abstract

An important stand of the economic literature focuses on how to provide the right incentives for households to recycle their waste. This body of work includes a growing number of studies inspired by psychology that seek to explain waste sorting, and pro-environmental behavior more generally, and highlight the importance of social approval and peer effect. The present theoretical work explores this issue. We propose a model that considers heterogeneous households that choose to recycle based on three main household characteristics: environmental preferences, opportunity cost of their tax expenditure, and their self-image. The model is original in depicting the interactions among households which enable them to form beliefs on recycling and allows them to assess their self-image. These interaction are explored through the model simulations. We point to how individual recycling decisions depend on these interactions, and how the effectiveness of public policies related to recycling is affected by a crowding-out effect. We consider three complementary policies in the model simulations: provision of incentives to recycle through taxation, provision of information on the importance of selective sorting, and a ‘localized’ approach that takes the form of a ‘nudge’. We use the results of the simulations to quantify the consequences of the crowding out effect on total residual waste. This paper makes an original contribution by showing that when the individual decision is influenced by an internalized peer attention, beliefs about others’ intrinsic and extrinsic values can be more important than others’ observed behaviors.

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# 1 Introduction

In its “Roadmap to a resource efficient Europe”, the European Commission discusses the “the possibilities of using waste as one of the EU’s key resources”. In this communication, sustainable consumption and production are presented as general goals to be achieved in the near future, with households at the center of the proposed framework. The European Commission believes “their purchasing choices will stimulate companies to innovate and to supply more resource efficient goods and services”. However, this is not the only solution proposed by the European Commission to reduce waste but it is illustrative of the importance of householders in the Commission’s approach to resource efficiency, and its view in the various European waste directives of households as the ‘holders of waste’.

An important economic literature adopts this perspective on how to give households the right incentives to recycle their waste. Households tend to ignore the external benefits of their recycling activity (savings on natural resources, and reductions in the external costs related to residual waste), and are concerned more by its cost (time, necessary materials and space, inconvenience, etc.). Although the concept of Green consumerism is becoming more widespread causing people to take account of the value they attribute to the environment in their choices, appropriate price signal (Fullerton and Kinnaman, 1996; Jenkins, 1993; Ferrara and Missios, 2005) and provision of information (Iyer and Kashyap, 2007; Oskamp et al., 1991) on the importance of selective sorting is considered in the literature as the main drivers of waste public policies. The implicit image of consumers pursuing their self-interests tends not to apply or only to a limited extent in the context of waste management. Individual waste recycling is (even partially) observable by others, and each household can see (even partially) what others do. Selective sorting is seen as a behavior in which social considerations are particularly important. This has led to a strand of work that draws its inspiration from psychology (Ajzen and Fishbein, 1980; Hopper and Nielsen, 1991) and seeks to explain waste sorting (and pro-environmental behavior more generally), highlighting the importance of social approval, peer effect, moral considerations, and the “warm glow” effect in individual motives (Hornik et al., 1995; Brekke et al., 2003; Nyborg et al., 2006; Brekke et al., 2010; Viscusi et al., 2011; Abbott et al., 2013; Viscusi et al., 2014).

Our theoretical work investigates the issue of recycling and the above described effects. The model considers heterogeneous households that decide to recycle, considering four main characteristics: their environmental preferences (represented by the intrinsic value they put on the environment), the opportunity costs of the related expenses (represented by extrinsic money value), sorting costs, and self-image. The self-image motive is evaluated in relation to the attention households pay to what others think about their intrinsic and extrinsic values, in line with Benabou and Tirole (2006). This requires house-

holds to be familiar with the recycling social norm. The originality of our paper lies in modeling the interactions between households that enable them to form beliefs about this recycling norm. We show how individual recycling decisions depend on these interactions, and how this affects the effectiveness of public policies on recycling. We consider three complementary policies: provision of tax incentives to recycle, provision of information on the importance of selective sorting, and localized ‘nudge’ approaches. These three tools are then considered within a policy-mix.

The paper is organized as follows. Section 2 discusses the positioning of this study in the existing literature on the recycling decisions of ‘socially responsible’ individuals. Section 3 describes the model. Section 4 presents and interprets the results of the computational simulations of the model. Section 5 concludes.

## 2 Related literature

This paper contributes to a strand in the literature which starts from a series of observations. First, individuals in their everyday lives are involved in the provision of certain environmental public goods with no necessity for government intervention. Although the level of supply may be sub-optimal, it is generally not zero. Second, classical consumer theory that predicts egoist individuals will behave opportunistically falls short in explaining this observed provision of public goods (Andreoni, 1988). Third, the explanation that individuals seek the social approval of others through their behaviors, is not the whole solution to the problem since, even in this case, a no-contribution equilibrium cannot be ruled out (Rege, 2004).

In order to tackle the problems raised, some recent economic works (Benabou and Tirole, 2006; Brekke et al., 2003; 2010; Nyborg et al., 2006) consider individuals with more elaborate rationality which gives rise to ‘impure altruism’ (Andreoni, 1990). These works consider situations where the responsibility for contributing to a public good is not formally allocated within a regulatory framework. Thus, individual responsibility is a subjective motive within the individual’s utility functions. In this context, the ‘warm glow effect of giving’ has been explored within the public good framework where individual contribution to the public good, although socially desirable, yields less than its cost to the individual. To evaluate the ‘warm glow’ effect requires individual familiarity with the social norm.

These works differ in how social norm is conceived and used in the theoretical models. In Benabou and Tirole (2006), a reputation payoff is added to utility to capture the idea that individuals value others’ opinions of them. This payoff is written as:  $R(a_i) = x_i [\gamma_a E(v_a | a) - \gamma_y E(v_y | a)]$ . Where  $v_a$  and  $v_y$  are the intrinsic (environmental) and extrinsic (for money) values,  $\gamma_a$  and  $\gamma_y$  are respectively the importance attached

by individuals to appearing to be concerned about the environment and also of not appearing as greedy, and  $x_i$  stands for the visibility of individual decisions. Note that to calculate the two mathematical expectations defining reputation payment, we need the means of the  $v_a$  and the  $v_y$  in the relevant population. In other words, individuals have common beliefs about how their society values both the environment ( $\bar{v}_a$ ) and money ( $\bar{v}_y$ ). In Brekke et al. (2003), individuals gain from proximity to what they perceive individually as an ideal behavior. This ideal behavior is defined as the individual decision maximizing a social welfare function given that everyone else does the same. In Nyborg et al. (2006), the social dimension is introduced based on a reward associated with *self image* which takes account of the external benefits of the individual decision. In both cases, referring to the social norm introduces the social benefit of the individual decision in the utility. This necessarily enhances the incentive to contribute to the public good.

Note that empirical works do not systematically validate the role of social norm. Viscusi et al. (2011)'s empirical contribution distinguishes two types of norms: personal (i.e. the norms one individual imposes on others) and external (i.e. those norms people perceive as being imposed by others). External norms take the form of a societal reference for appropriate behavior or pressure to adopt environmentally friendly behavior. The authors show that, although the "internal private value" variable is important, the "social norm" variable, reflecting individual guilt about not recycling compared to the behavior of neighbors, is not statistically significant. The empirical analysis in Brekke et al. (2010) shows the importance of the quality of the information used to form beliefs about others' recycling behaviors. If the information is perceived as uncertain, then the impact on the individual of 'social learning about their responsibility' will be lower. In the study by Brekke et al. (2003) individuals are able clearly to state their ideal pro-social behavior but in the study by Nyborg et al. (2006) they have only imperfect knowledge of their self image which leads them to revise their choices on the basis of payments received, giving rise to a dynamic adoption process.

An important body of the related literature discusses the crowding-out effect. As soon as individuals care about what others think about their contribution to a public good, external incentives stimulate individual contributions but also can work to contradict internal motivation. Individuals wishing to appear responsible and not greedy might be afraid of their contribution appearing to peers as motivated purely by self-interest (e.g. to avoid paying a tax), and may ultimately work to reduce their contribution. The introduction of a monetary incentive has an ambiguous effect according to  $R(a_i)$  in Benabou and Tirole (2006) and could create a negative crowding-out effect, and could result in the individual optimal contribution  $a_i$  being enhanced or reduced as a consequence. In Brekke et al. (2003) the introduction of a fee to finance the furnishing of a public good could reduce the individual contributions and result in a no contribution equilibrium.

In our model, in contrast, households do not have *a priori* beliefs about what is socially expected. They form their beliefs on the social norm from observing the people in their neighborhood. This is close to the concept of *descriptive norms* defined by Aronson et al. (1999)<sup>1</sup>. The augmenting effect of social norm on individual contributions is not automatic since the household's neighborhood does not necessarily contribute more to the public good. Since households form their beliefs about the social norm based on information obtained from within a limited neighborhood, we suppose that they will be keen to encounter more neighbors in order to improve their knowledge. This gives rise to a dynamic process in our model. More precisely, we assume that if the household observes a different recycling rate in its immediate neighborhood, it will revise its estimation of the social norm and make efforts to meet other neighbors, obtain more information, and refine its estimation of the social norm. We contribute to the literature by showing that if the individual decision is influenced by an internalized peer attention, beliefs about others' intrinsic (environmental) and extrinsic (for money) values may be more important than others' observed behaviors.

### 3 The model

#### 3.1 Households' selective sorting without public policy

The model depicts a simplified economy composed of  $N$  households indexed by  $i$  for a finite number of periods. A household creates one unit of waste at each period because of its consumption. Consumption awards one unit of utility to each household. A unit of waste can be entirely or partially recycled depending on the level of the household's recycling  $a_i$ . Recycling gives the household satisfaction based on its 'environmental preference' or intrinsic value  $v_i^a$  related to selective sorting. It also implies a cost  $C_i = c_i a_i^2$  due to the effort, time, materials, and area dedicated to this activity. Households are supposed to be heterogeneous in relation to both  $v_i^a$  and  $c_i$ . The intrinsic value  $v_i^a$  is supposed to belong to  $[0, 1]$ .<sup>2</sup> The cost parameter  $c_i$  can take two alternative values: 0 or a strictly positive value.<sup>3</sup>

Without public policy, depending on the value of the cost parameter  $c_i$  household  $i$  maximizes the following utility payoff to choose its level of recycling activity  $a_i$ :

$$U(a_i) = v_i^a a_i - c_i a_i^2 + 1 \quad (1)$$

The total amount of recycled waste realized at each period due to the household's

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<sup>1</sup>Cited in Nyborg et al. (2006).

<sup>2</sup>In the model simulation presented in Section 4 we suppose that these values are distributed uniformly on  $[0, 1]$ .

<sup>3</sup>In the model simulation we suppose that  $c_i \in \{0, 2\}$ .

intrinsic values is  $A = \sum_i^N \underline{a}_i$ . If the household's intrinsic values and costs do not change from period to period, this amount will remain constant.

Since each unit of waste is not entirely recycled (or since  $A \leq N$ ) an external effect is created by the total residual waste  $N - \sum_{i=1}^N \underline{a}_i$ . This external effect is due to pollution and waste of natural resources implied by residual waste. Note that, for two reasons the household's intrinsic value for recycling cannot be seen as the individual valuation of the associated external cost (or external benefit). First, we assume that households do not know the exact form of the external cost. Second, intrinsic values can be related to more general objectives (preservation of the environment in general, or to altruistic motives). Thus, we suppose that, although they have intrinsic values, households believe the amount of waste not recycled (their residual waste) is 'individually' negligible regarding the stock-externality. As a result, the total waste recycled will be insufficient (suboptimal) and public policies will be needed.

### 3.2 Public policies

An impartial regulator aims to encourage selective sorting in order to tackle the external costs implied by total residual waste  $N - \sum_{i=1}^N a_i$ , taking account of total welfare. For convenience, we present the external cost as a function of the global amount of recycled waste in the economy:  $EC\left(\sum_{i=1}^N a_i\right)$ . We suppose that the external cost decreases with the global amount of recycled waste at a decreasing rate (or increases with the global residual waste at an increasing rate):

$$EC'\left(\sum_{i=1}^N a_i\right) < 0 \quad \text{and} \quad EC''\left(\sum_{i=1}^N a_i\right) < 0 \quad (2)$$

The specification for the external cost used in the model simulation developed in Section 4 is  $EC\left(\sum_{i=1}^N a_i\right) = \left(\frac{1}{\sum_{i=1}^N a_i} - \frac{1}{N}\right) NG$ , where  $G$  is a constant as discussed below.<sup>4</sup>

Taking account of the external cost, the regulator promotes households' selective sorting in order to maximize total welfare, with the help of three kinds of policy: tax, information, and nudges.

#### 3.2.1 Tax on residual waste

We assume implementation of a "pay-as-you-throw" scheme  $t$  by the regulator. This tax scheme imposes a double burden on households: first, household  $i$  pays  $t(1 - a_i)$  for its

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<sup>4</sup> $G$  corresponds to the number of households always choosing to recycle the entire unit of waste, even without public policies. Thus, at the minimal total recycling ( $\sum_{i=1}^N a_i = G$ ) the external cost is positive ( $EC(G) = N - G$ ). Note that for a maximal recycling (i.e.  $\sum_{i=1}^N a_i = N$ ), the external cost is 0 ( $EC(N) = 0$ ).

unsorted waste, and second, it bears the opportunity cost  $t(1 - a_i)v_i^t$  of this expense.<sup>5</sup> Under this policy, the payoff function if  $c_i > 0$  becomes:<sup>6</sup>

$$U(a_i) = v_i^a a_i - c_i a_i^2 + 1 - t(1 + v_i^t)(1 - a_i) \quad (3)$$

Finally, note that the tax on residual waste takes the form of a revenue transfer, so that the total tax paid  $\sum_{i=1}^N t(1 - a_i)$ , is introduced into the total welfare. Therefore, the total welfare is written as:

$$W(a_1, \dots, a_N) = \sum_{i=1}^N U_i(a_i) + \sum_{i=1}^N t(1 - a_i) - \left( \frac{1}{\sum_{i=1}^N a_i} - \frac{1}{N} \right) NG \quad (4)$$

Note that maximizing this welfare function should not result in a zero residual waste situation. Furthermore, as we show in Section (3.5), the recycling effort required of households will differ according to their individual characteristics.

### 3.2.2 Information policy

The second form of policy delivers information  $\eta > 0$  on the social importance of selective sorting. This information underlines reduction of the residual waste externality implied by recycling, and waste recovery. This information is supposed to modify households' environmental preferences. The environmental value  $v_i^a$  increases as the information is delivered, and is transformed into  $v_i^{a(1-\eta)^2}$ . Thus, the household  $i$  utility function with information policy and tax is:

$$U(a_i) = v_i^{a(1-\eta)^2} a_i - c_i a_i^2 + 1 - t(1 + v_i^t)(1 - a_i) \quad (5)$$

The recycling activity level maximizing (5) is denoted by  $\hat{a}_i$ . The information level  $\eta > 0$  is supposed to belong to  $[0, 1]$ . Rather unrealistically, we suppose that delivering information does not imply a cost. Therefore, the regulator's choice should be to deliver the maximum information level  $\eta = 1$ . However, in the model simulation we allow information to take intermediate values. Indeed, our results on the policy-mix "tax plus information" show that the crowding-out effect measures implied by the tax are highly sensitive to the level of information  $\eta$ . This allows us to address the question of whether information delivery mitigates the crowding-out effect.

### 3.2.3 Nudge

A policy that acts as a nudge (see Thaler and Sunstein (2008) for a presentation) is introduced. A nudge is generally considered to be an element that would be ignored by

<sup>5</sup>Thus,  $v_i^t \in [0; 1]$  represents the opportunity cost of 1 euro spent on tax.

<sup>6</sup>Note that if  $c_i = 0$ , the payoff function is not fundamentally changed since household  $i$  always chooses  $\underline{a}_i = 1$  and does not incur any tax.



an individual maximizing his or her utility narrowly defined but works to modify real observed behaviors. Following a field experiment conducted by Schultz (1999), the nudge in our model consists of delivering information about what others recycle in an enlarged neighborhood.<sup>7</sup> If when making its decision household  $i$  cares about what its neighbors do in terms of recycling, or thinks that others' recycling decisions influence what others think about its own values  $v_i^a$  and  $v_i^t$ , this nudge can influence the household's selective sorting.

Before studying the effect of different policies, it should be noted that in this model, the introduction of regulatory attention on waste recycling will *on its own* (i.e. whatever the chosen policy or policy mix) modify households' recycling behaviors.

### 3.3 Households' selective sorting with public intervention

Three characteristics introduce a profound modification to the way households choose their respective selective sorting levels. First, we suppose that as soon as the regulator implements a policy to promote household recycling, *public information* on the social importance of selective sorting is delivered. Second, we suppose that individual selective sorting is (partially) observable by neighbors. Third, we assume that households care about a peer effect, their reputation, and their self-image, as underlined in Sections 1 and 2. As a consequence, a reputation payoff is introduced in household  $i$ 's utility payoff function, depending on what others believe about its environmental preferences while observing the household's recycling decision  $a_i$ .

When a tax is implemented, household  $i$  may also care about how others link its recycling level  $a_i$  to its valuation of money  $v_i^t$ . We suppose that, as in Benabou and Tirole (2006), households will not wish to appear greedy and that this motive will be taken into account in their reputation payments. As discussed in Section 2, households do not know the social recycling norm. We suppose that households have only common beliefs about how their society values the environment ( $\bar{v}_a$ ) and cares about money ( $\bar{v}_t$ ). These parameters help households to anticipate how others estimate their intrinsic and extrinsic values when observing their recycling decisions, and thus enter the reputation payment. In the absence of more information, they form their beliefs about the social recycling norm by 'looking around' (as described in 3.4) and observing the different recycling rates of their neighbors, and calculating their mean,  $\bar{a}_i$  in order to estimate the social norm.

The model simulations are developed in Section 4 with the following specification for the reputation payment function:

$$R(a_i) = x_i \left( \gamma_i^t \bar{v}_t - \gamma_i^a \bar{v}_a \right) (a_i - \bar{a}_i)^2 \quad (6)$$

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<sup>7</sup>Schultz (1999) shows that this nudge resulted in an increase in the volume of recycled waste which persisted over time, even after the experiment stopped.

$\gamma_i^a$  and  $\gamma_i^t$  are respectively the importance attached by household  $i$  of appearing concerned about the environment, and the importance attached by household  $i$  of not appearing greedy. The parameter  $x_i$  is the visibility of household  $i$ 's decision. In the agent-based simulations of the model,  $x_i$  is a function of the number of neighbors of household  $i$ .

In this function,  $\gamma_i^a \bar{v}_a (a_i - \bar{a}_i)^2$  denotes the attention paid to appearing responsible when choosing the recycling rate  $a_i$ , and  $\gamma_i^t \bar{v}_t (a_i - \bar{a}_i)^2$  denotes to the attention paid to not appearing greedy. This reputation payment exhibits some interesting properties. First, when  $\bar{v}_a / \bar{v}_t$ , the relative importance of the environment to society is higher than the relative importance of not appearing greedy  $\gamma_i^t / \gamma_i^a$  for household  $i$ , the reputation is increasing with  $a_i$  when  $a_i < \bar{a}_i$ . In other words, in a “relatively green society” a household will be incited to choose a recycling decision that is as close as possible to the norm  $\bar{a}_i$  it perceives. However, in a “relatively greedy society” (i.e. when  $\bar{v}_t / \bar{v}_a > \gamma_i^a / \gamma_i^t$ ) a household will be incited to choose the highest possible recycling rate to maximize its reputation, since reputation is increasing for  $a_i > \bar{a}_i$ . Second, a given recycling rate generates more reputation in a more greedy society since  $\frac{\partial R}{\partial \bar{v}_t} > 0$ . However, if the value society attaches to environment increases, reputation implied by a given recycling rate decreases (since  $\frac{\partial R}{\partial \bar{v}_a} < 0$ ). Finally, reputation increases in the perceived norm  $\bar{a}_i$  if  $a_i > \bar{a}_i$  in a “relatively green society”, and if  $a_i < \bar{a}_i$  in a “relatively greedy” society. Finally, note that the impact of the tax  $t$  on the derivative of the reputation payment with respect to  $a_i$  is ambiguous.

The total payoff function that household  $i$  is supposed to maximize in order to choose its individual recycling rate is therefore as follows:

$$U_i(a_i, t, \eta) = v_i^{a(1-\eta)^2} a_i - t(v_i^t + 1)(1 - a_i) - c_i a_i^2 + 1 + x_i(\gamma_i^t \bar{v}_t - \gamma_i^a \bar{v}_a)(a_i - \bar{a}_i)^2 \quad (7)$$

The recycling rate  $a_i^*$  maximizing (7) is given by:

$$a_i^* = \frac{v_i^a + y(v_i^t + 1) + 2x_i \bar{a}_i(\gamma_i^t \bar{v}_t - \gamma_i^a \bar{v}_a)}{2c_i + 2x_i(\gamma_i^t \bar{v}_t - \gamma_i^a \bar{v}_a)} \quad (8)$$

Note that the impact of the tax  $t$  on the derivative of the reputation payment with respect to  $a_i$  when  $a_i = a_i^*(t)$  is ambiguous, so that a crowding-out effect may appear in households' decisions.

### 3.4 Agent-based simulation

The presence of a reputation payment in the household payoff functions has an important consequence. Since households care about what others think about their motivations, and care also about others' recycling levels, in order to make their own selective sorting decisions they need to know what the recycling social norm is. Indeed, to calculate  $R(a_i, t, \eta)$  requires information on what others do:  $\bar{a}$  the average of others' recycling decision  $a_i^*$ .

We suppose that households have limited capacity to perceive the selective sorting propensity of others and are conscious of this limitation. Thus, households will seek to discover the social norm  $\bar{a}$  by meeting people in what we call a ‘socialization process’. During this process a household  $i$  counts the number of other households she meets and calculates the mean of others’ observed selective sorting propensities  $\bar{a}_i$ .

This process is described using a dynamics *à la* Schelling (1969). At each period, two different situations can emerge for the household’s desire to commit to further meetings. The first situation is when the mean of others’ selective sorting propensities  $\bar{a}_i$  calculated by the household is equal to its own selective sorting propensity  $a_i^*$ .<sup>8</sup> In this situation we suppose that, feeling in line with her neighborhood, the household does not seek further information. The second situation arises when  $\bar{a}_i \neq a_i^*$ . If the household feels out of kilter with its neighbors, we suppose that it will make efforts to get more information on others’ recycling activity. Note that information delivery and tax are public policies that we keep fixed during these household interactions. The nudge which consists of giving information on others’ recycling rates in a wider neighborhood, will be activated when at least 75% of the  $N$  households decide to stop interacting with others, and affects only these households.

Figure 1 illustrates the dynamics of the simulation model.

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<sup>8</sup>In the model simulation a tolerance threshold of  $\pm 3\%$  is introduced.

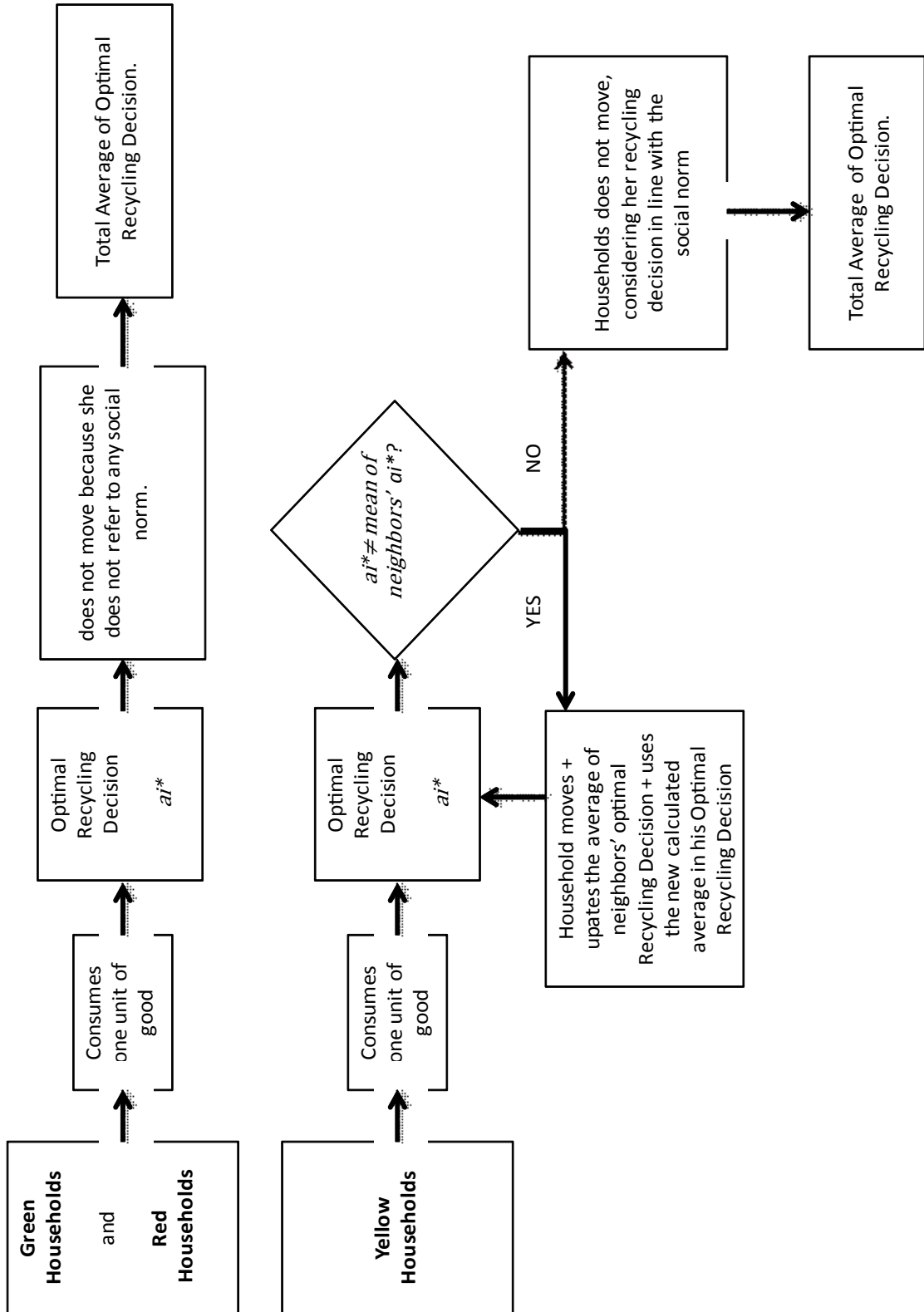


Figure 1: Dynamics of Agent-based simulation

### 3.5 Three types of households

Households are supposed heterogeneous on both parameters ‘ $i$ ’. Depending on the configuration of these parameters, three types of households can be distinguished.

First there are  $G$  *Green households* characterized by:

$$0 < v_i^a \leq 1, \quad 0 < v_i^t \leq 1, \quad c_i = 0, \quad \text{and} \quad \gamma_i^a = \gamma_i^t = 0, \quad \text{for} \quad i = 1, \dots, G \quad (9)$$

The assumptions in (9) imply that *Green households* are not concerned about what others think about their intrinsic valuation of the environment ( $\gamma_i^a = 0$ ) or whether they appear greedy ( $\gamma_i^t = 0$ ).<sup>9</sup> Under these assumptions, and taking account of tax and information policies, the payoff function of *Green households* is given by:

$$U_i(a_i, t, \eta) = v_i^{a(1-\eta)^2} a_i - t(v_i^t + 1)(1 - a_i) + 1 \quad (10)$$

Without public policies, and whatever the value of  $v_i^a$ , *Green households* always choose to recycle the entire unit of waste:  $a_i = 1$  maximizing (1) or (10). As a result, public policies have no effect on them. *Green households* will never pay the ‘pay-as-you-throw’ tax, and even if provision of information increases *Green households*’ intrinsic values, this does not imply a decision about a higher level of recycling. Finally, since  $\gamma_i^a = \gamma_i^t = 0$ , *Green households* do not attach importance to what others think about them, and will never engage in the dynamics allowing an opinion on the social recycling norm.

The second group comprises the  $R$  *Red households* characterized by:

$$v_i^a = 0, \quad 0 < v_i^t \leq 1, \quad c_i > 0, \quad \text{and} \quad \gamma_i^a = \gamma_i^y = 0, \quad \text{for} \quad i = 1, \dots, R \quad (11)$$

The assumptions in (11) imply that *red households* do not value the environment. Thus, information policy has no effect on their behaviors. Since they do not care what others think about them ( $\gamma_i^a = \gamma_i^t = 0$ ), they never try to discover the social recycling norm. Their recycling activity cost is strictly positive ( $c_i = 2$  in the model simulation) resulting in their always choosing not to develop recycling activity if no tax on residual waste is implemented (i.e. maximizing (1)). However, as soon as a tax is implemented, *Red households*’ optimal recycling decisions are  $a_i^* = \frac{t(v_i^t + 1)}{2c_i}$ , maximizing their payoff functions as shown below:

$$U_i(a_i, t) = -t(v_i^t + 1)(1 - a_i) - c_i a_i^2 + 1 \quad (12)$$

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<sup>9</sup>Note that these *Green Households* are different from the ‘green consumers’ in ?. These green consumers choose to preserve the environment because of moral norms and beliefs about others’ behavior. This implies a high level of  $v_i^a$  in absolute terms. In our model, *Green Households* choose a high level of recycling because its benefits are greater than its costs.

Finally, the  $Y$  *Yellow households* are the third group whose members are characterized by:

$$0 < v_i^a < 1, 0 < v_i^t < 1, c_i > 0, 0 < \gamma_i^a \leq 1, \text{ and } 0 < \gamma_i^t \leq 1, \text{ for } i = 1, \dots, Y \quad (13)$$

*Yellow households* value the environment and selective sorting, as well as money. They care about what other people think about their environmental commitment and whether they appear self-interested. This requires information on the social recycling norm which they try to discover by interacting with others. If both a tax and an information policy are implemented, the group's utility functions are given by (7) and their recycling decisions by (8).

### 3.6 Measuring the Social influence

We compute the impact of social influence for the *Yellow households* population as the mean of the difference between  $a_i^* - \hat{a}_i$ . A negative mean suggests that negative crowding out dominates positive crowding effect (and *vice versa*). This measure is imperfect since positive differences between  $a_i^*$  and  $\hat{a}_i$  are compensated by negative ones. However, it captures a net effect. For a better appreciation of social influence we complete this first quantitative measure with qualitative information on the number of negative individual social influence effects and the number of positive ones. This highlights how the composition of the *Yellow households* population regarding social influence evolves with tax changes.

### 3.7 Measuring the crowding-out effect

The presence of the reputation payment in the *Yellow households*' utility function (7), suggests a crowding-out effect. In the first order conditions, the derivative of the reputation payment,  $\partial R(a_i, t)/\partial a_i = r(a_i, t)$  can react differently to the tax rate:  $\partial r(a_i, t)/\partial t$  can be either positive or negative. Thus, an increase in the tax rate has ambiguous consequences for *Yellow households*' recycling decisions  $a_i^*$ . A crowding-out effect occurs when the decision  $a_i^*$  solution of the maximization of (7) is smaller than the decision  $\hat{a}_i = \frac{v_i^a(1-\eta)^2}{2c_i}$  maximizing (5) without reputation payment (i.e. with  $x_i = 0$ ). Note that *Yellow households* do not systematically exhibit a crowding-out effect. This possibility depends on the value of  $t$  and on the household's position in the socialization process (i.e. on what others in the household's neighborhood do).

The model simulation allows us to estimate the magnitude of the crowding-out effect. Another way to appreciate the crowding-out effect is by looking at the signs of the different individual  $\partial r(a_i, t)/\partial t$  and their averages.

## 4 Results

The simulations are implemented using Netlogo, an Agent-Based Modeling Platform. Each simulation considers 200 households with randomly drawn individual parameter values  $v_i^a$ ,  $v_i^t$ ,  $\gamma_i^a$ , and  $\gamma_i^t$ . The initial conditions for the “population parameters” are  $\bar{v}_a = 0.45$ , and  $\bar{v}_y = 0.5$ .

The model is simulated on four different configurations. In the first configuration the household population is composed 10% Red households, 20% Green households, and 70% Yellow households. In the second configuration the respective shares are 33% Red households, 33% Green households, and 34% Yellow households. In the third configuration there are 60% Red households, 20% Green households, and 20% Yellow households. In the fourth configuration there are 20% Red households, 60% Green households, and 20% Yellow households.

In this framework, each household can have 0, 1, 2, 3, or 4 neighbors and calculates  $\bar{a}_i$  observing the different  $a_i^*$  in the neighborhood thus defined. In order to maximize its utility, a *Yellow household* has to know the social recycling norm and tries to estimate it according to the socialization process described in Section (3.4). The process lasts 200 periods (runs).

Each tax and information policy,  $t$  and  $\eta$ , takes 10 values between 0 and 1, so that 100 couples  $(t, \eta)$  are considered. Each configuration  $(t, \eta)$  is simulated 100 times with 200 runs per simulation.

Below, we first present the policy impact on welfare. We then discuss the increase in the crowding-out effect and the consequences of introducing a nudge.

### 4.1 Results on welfare

The possibility to set a tax maximizing total welfare is depicted in figure (2) which shows the simulation results for welfare in the configuration of 70% *Yellow*, 20% *Green*, and 10% *Red households*. Figure (2) confirms the complementarity between tax and information policies. There is a clear optimal policy mix. Under the selected population parameters it corresponds to a moderate tax rate combined with a high level of information. Note that this result is linked to the fact that, in the model, information delivery is costless for government. The results are similar results for the other population configurations.

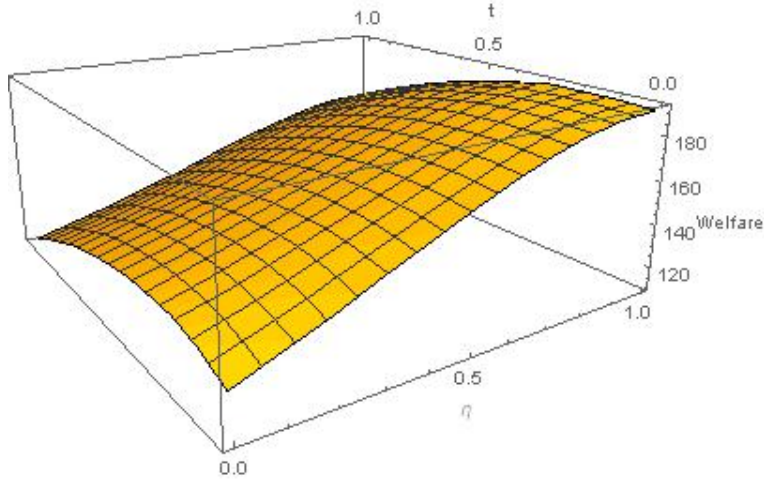


Figure 2: 10% Red - 20% Green - 70% Yellow

The total welfare

## 4.2 Results for households' recycling decisions

Figure (3) considers averages of  $\underline{a}_i$  (in red) maximizing (1) without public policies,  $\hat{a}_i$  (in blue) maximizing (5) under public policies without social interaction, and  $a_i^*$  (in yellow) maximizing (7) under public policies with social interaction, for a population composed of 10% Red, 20% Green, and 70% Yellow households. When the population composition exhibits a sufficiently large share of *Yellow households* (figure 3), we observe a real distinction between the three recycling levels. A striking result is that the average of the  $a_i^*$  is systematically higher than the average of the  $\hat{a}_i$ . This result confirms previous results which show that the effect of social influence on recycling is positive. However, it is obtained for the selected population parameters  $\bar{v}_a (= 0.45) < \bar{v}_y (= 0.5)$ . What happens with a change of parameters? The robustness checks presented in Section 4.5 show that the average of the  $a_i^*$  are sensitive to variations of  $\bar{v}_a$  and  $\bar{v}_y$ , making it possible for configurations where  $a_i^* - \hat{a}_i$  on average to be negative. If households believe that  $\bar{v}_a > \bar{v}_y$  this result can appear. This situation is depicted in Figure (4) which depicts the simulation results with  $\bar{v}_a = 0.6$  and  $\bar{v}_y = 0.4$ .



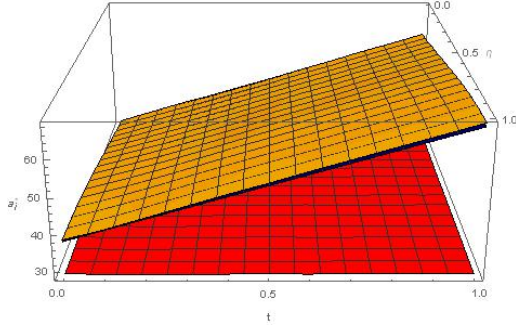


Figure 3: 10% Red - 20% Green - 70% Yellow with  $\bar{v}_a = 0.45$  and  $\bar{v}_y = 0.5$

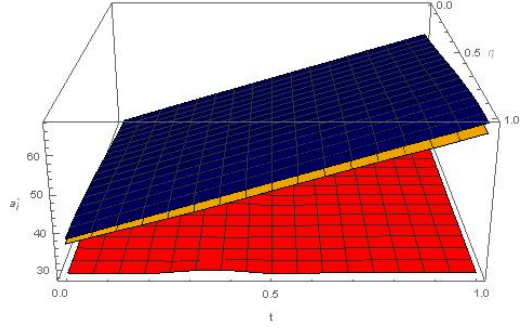


Figure 4: 10% Red - 20% Green - 70% Yellow with  $\bar{v}_a = 0.6$  and  $\bar{v}_y = 0.4$

Averages of recycling rates  $\underline{a}_i$ ,  $\hat{a}_i$ , and  $a_i^*$

### 4.3 Results for Social influence and the Crowding-out effect

In order to explore the impact of social influence on recycling we measure the difference between households' recycling decisions when households' interact with proximate households ( $a_i^*$  maximizing (7), i.e. recycling decisions that take account of neighbors), and when they do not ( $\hat{a}_i$  maximizing (5), i.e. isolated recycling decisions). In these two situations households face the same policy mix (tax plus information provision) so that the differences observed in their recycling decisions is attributable to neighborhood influence. The results are represented in Figures (5)-(8). In the four population configurations considered, the evolution profiles of the average of  $a_i^* - \hat{a}_i$  observed are similar, although the absolute values (i.e. the magnitude of the gap between  $a_i^*$  and  $\hat{a}_i$ ) are different. Figure (5) confirms our previous observation in figure (3) that the largest gap is observed for high values of residual waste tax in the presence of more *Yellow households*. In each of the configurations considered, information provision delays the impact of the social influence because of the implied increase in households' intrinsic values. Finally, comparing Figures (7) and (8), we observe that social influence is greater for green rather than red neighborhoods.

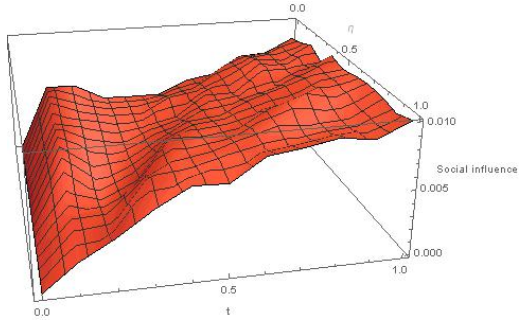


Figure 5: 10% Red - 20% Green - 70% Yellow

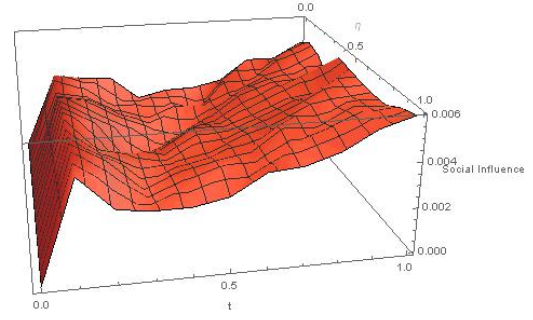


Figure 6: 33% Red - 33% Green - 34% Yellow

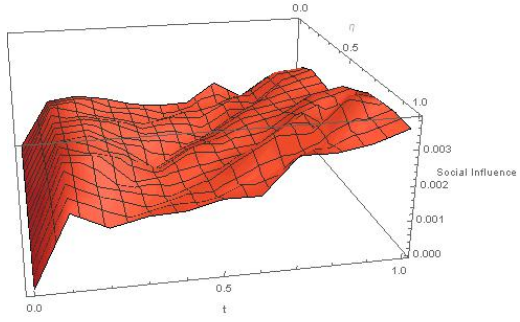


Figure 7: 60% Red - 20% Green - 20% Yellow

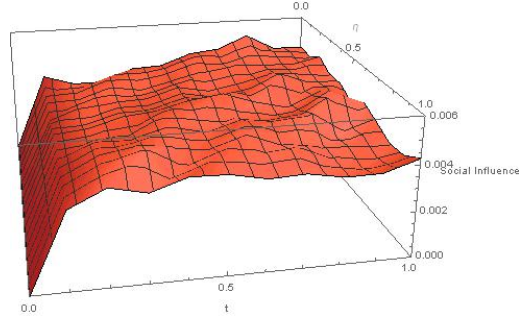


Figure 8: 20% Red - 60% Green - 20% Yellow

Social Influence: Average of  $a_i^* - \hat{a}_i$

The average of  $a_i^* - \hat{a}_i$  is always positive. This does not mean that every individual  $a_i^* - \hat{a}_i$  is also positive. It indicates only that the sum of the positive households, in absolute value, is greater than the sum of the negative ones. This is confirmed in Figure (9)-(10) which reports the number of negative  $a_i^* - \hat{a}_i$  observed.

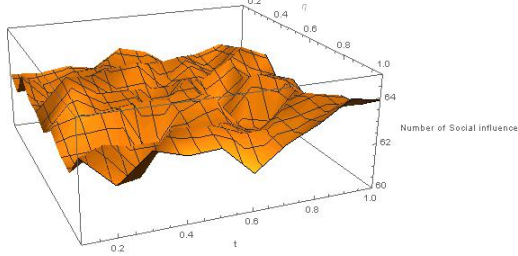


Figure 9: 10% Red - 20% Green - 70% Yellow

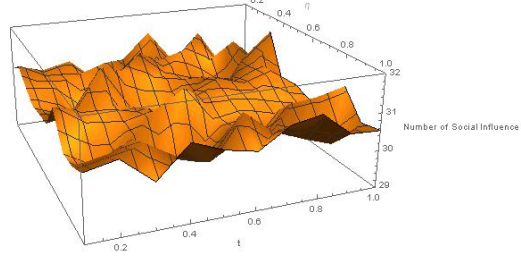


Figure 10: 33% Red - 33% Green - 34% Yellow

Number of negative  $a_i^* - \hat{a}_i$  observed

Figures (9)-(10) show clearly that the negative social influence effect is dominated by a positive effect. For example, in the first situation (Figure 9), social influence has a negative effect on 60-64 households among the 200 *Yellow households* that care about social influence in this population configuration. However, whatever the configuration observed, there are always negative gaps between individual  $a_i^* - \hat{a}_i$ .<sup>10</sup>

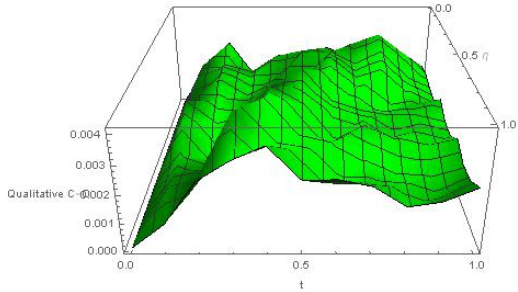


Figure 11: 10% Red - 20% Green - 70% Yellow

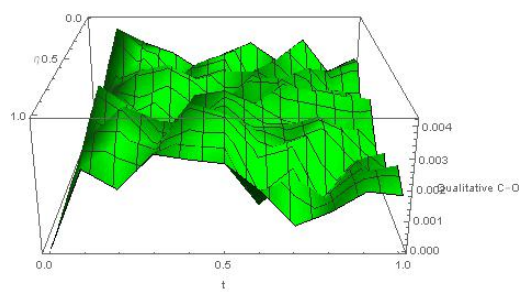


Figure 12: 33% Red - 33% Green - 34% Yellow

Crowding-out effect: Average of  $\partial r(a_i, t)/\partial t$

Figures (11)-(12) give information on the crowding-out effect. We concentrate on the average of the derivatives  $\partial r(a_i, t)/\partial t$  observed. By definition (cf. Section 3.7), a crowding-out effect emerges if this derivative is negative. Therefore, the observed mean gives information on the sign of the *net* crowding-out. Profiles seem similar in both

<sup>10</sup>In the second configuration (figure 10), social influence negatively affects 29-32 households among the 68 *Yellow households* that care about social influence.

configurations. In both configurations, the crowding-out effect increases with low tax rates and then decreases. Furthermore, in both cases the information policy seems to have ambiguous effect on the crowding-out effect.

Another way to evaluate the crowding-out effect is depicted in Figures (13) - (14) which report the numbers of positive (in red) and negative (in blue)  $\partial r(a_i, t)/\partial t$  in the first and the second configurations.<sup>11</sup> We observe that both negative and positive crowding-out coexist within the population, and that a positive effect dominates with the population parameters chosen.

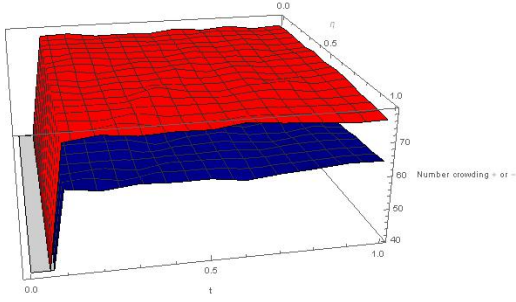


Figure 13: 10% Red - 20% Green - 70% Yellow

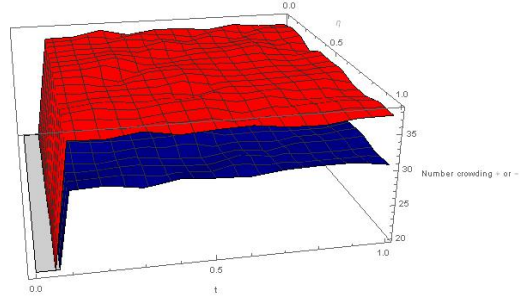


Figure 14: 33% Red - 33% Green - 34% Yellow

Crowding-out effect: Number of positive (red) and negative (blue)  $\partial r(a_i, t)/\partial t$

So far we have used  $\bar{v}_a (= 0.45) < \bar{v}_y (= 0.5)$ . These value were calculated on a population of 1000 uniformly distributed households. In the following experiment, we have the situation where the households beliefs are such that  $\bar{v}_a > \bar{v}_y$  with  $\bar{v}_a = 0.6$  and  $\bar{v}_y = 0.4$ . In other words, households believe that the population is more environmentally friendly and less greedy. The results are presented in Figures (16) and (15). We observe that the social influence and crowding-out effects, on average have a negative impact (Figures 16 and 15). Figure 15 shows that social influence decreases with a tax, and that the largest gaps between  $a_i^*$  and  $\hat{a}_i$  are observed for high values of a tax on residual waste. Figure (16) shows a clear negative crowding-out effect. This crowding-out effect is stable until intermediate values of the tax, and increases in absolute value for higher tax rates.

#### 4.4 Measuring the nudge impact

Following Schultz (1999)'s experiment, a nudge consisting of information provision on what others recycle in an enlarged neighborhood, is introduced in the model. In the "socialization process" *Yellow households* form their evaluation of the social norm  $\bar{a}_i$  using the  $a_i^*$  for eight neighbors instead of four. The nudge is activated for a given household as soon as it stops the socialization process, while 75% of the population does not change.

<sup>11</sup>Observations are similar in the two other configurations.

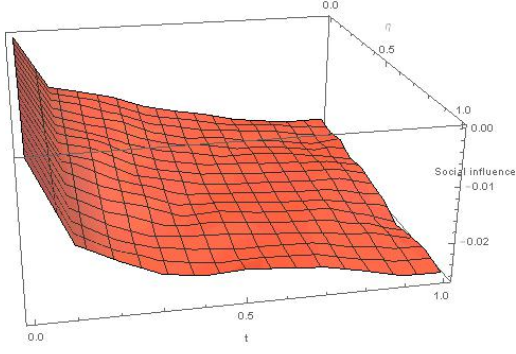


Figure 15: Social Influence: Average of  $a_i^* - \hat{a}_i$

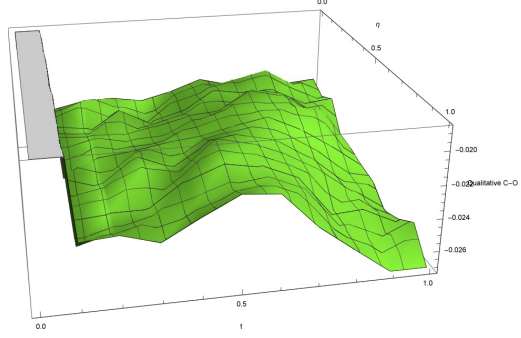


Figure 16: Crowding-out effect: Average of  $\partial r(a_i, t)/\partial t$

10% Red - 20% Green - 70% Yellow with  $\bar{v}_a = 0.6$  and  $\bar{v}_y = 0.4$

The nudge targets households which recycle at a level under than a threshold fixed by the regulator. In our simulations this threshold is fixed at  $\frac{(1+\bar{v}_a)}{2c_i}$ .

Figures (17)–(18) derive from the first configuration of the population composition (10% Red - 20% Green - 70% Yellow). Figure (17) depicts the effects of a nudge on crowding-out via  $\partial r(a_i, t)/\partial t$ . Figure (17) shows that a nudge moderate the crowding out effect, especially when the tax is high. Figure (18) confirms this result presenting the effect of a nudge on social influence measured by  $a_i^* - \hat{a}_i$ . This “negative” result might seem surprising but confirms what Schultz (1999)’s experiment shows: A nudge having the effect of enlarging the neighborhood involved in constructing social influence does not necessarily imply an increase in the volume of waste recycled. A “positive” result depends on the neighborhood recycling more than the individual household seeking peer approval.

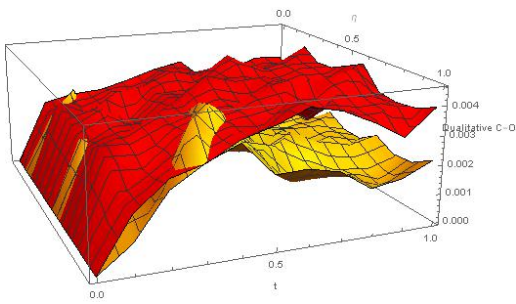


Figure 17: Average of  $\partial r(a_i, t)/\partial t$  with (yellow) and without (red) the nudge

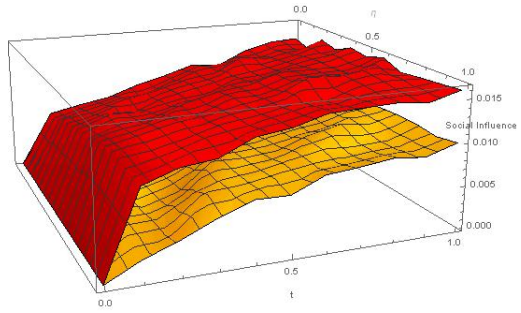


Figure 18:  $a_i^* - \hat{a}_i$  with (yellow) and without (red) the nudge

#### 4.5 Robustness checks

In the baseline scenario the mean values of  $v_i^a$ , and  $v_i^t$  are fixed respectively at 0.5 and 0.45. These values were obtained by calculating the mean observed values on a randomly



uniformly distributed population of 1000 individuals. We also tested the impact of a variation in each of the parameters separately (holding the others fixed) on our results (optimal decision recycling, qualitative crowding-out and social influence). We perform extensive Monte Carlo simulations to get rid of simulation variability. The results presented below refer to averages over several replications. All the simulation results refer to 1000 Monte Carlo independent runs, each involving 200 time steps (households' moves in the model). The simulations are run for three different cases. The first case (discussed below) considers an 'intermediate' policy mix ( $t = \eta = 0.6$ ). The other two cases, a 'weak' policy mix ( $t = \eta = 0.1$ ), and a 'strong' policy mix ( $t = \eta = 1$ ), focus on an extreme policy mix and are presented in the appendix.

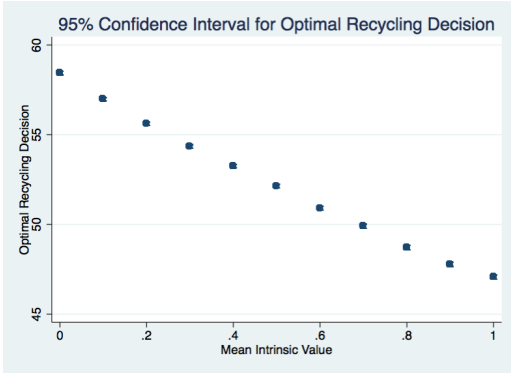


Figure 19: The impact of  $\bar{v}_a$  on  $a_i^*$

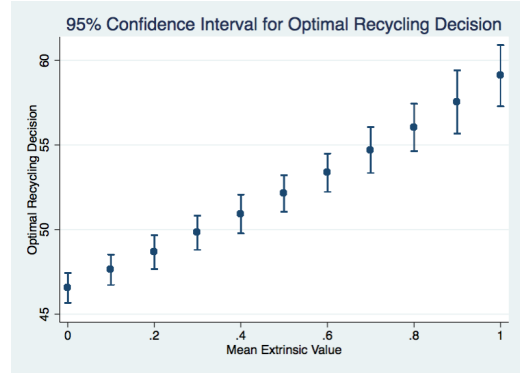


Figure 20: The impact of  $\bar{v}_t$  on  $a_i^*$

The impact of parameters' variation on Optimal Recycling Decision ( $a_i^*$ ) with  $t = \eta = 0.6$

Regarding the impact of these two parameters on the optimal recycling decisions, we observe a decreasing relation between the population mean intrinsic value and (regardless of policy level) the optimal recycling decision (figure 19). If individuals believe that their society has a high  $\bar{v}_a$ , they expect to gain less in terms of reputation from adoption of a high recycling level. This effect decreases the mean recycling decision observed. The confidence intervals observed for the different values of the optimal recycling decisions show that the variations in  $\bar{v}_a$  significantly affect the optimal recycling decision.

The variations in  $\bar{v}_a$  have a similar impact social influence ( $a_i^* - \hat{a}_i$ ) (Figure 21), since the  $\hat{a}_i$ s do not depend on  $\bar{v}_a$ . As a consequence we can conclude that the difference observed between  $a_i^*$  and  $\hat{a}_i$  in absolute value is increasing with  $\bar{v}_a$ .

We observe a increasing relation between the mean extrinsic value of the population  $\bar{v}_y$  and the decision about recycling level (figure 20). Variation of  $\bar{v}_y$  has a positive effect on the reputation payment. The confidence intervals observed clearly confirm this finding. Thus, we can conclude that the variations in  $\bar{v}_y$  significantly affect individuals' recycling decisions. This result is confirmed in Figure (22) which depicts the impact of  $\bar{v}_y$  on  $a_i^* - \hat{a}_i$ . We observe also that  $a_i^* - \hat{a}_i$  can be positive or negative. Thus, social influence is positive

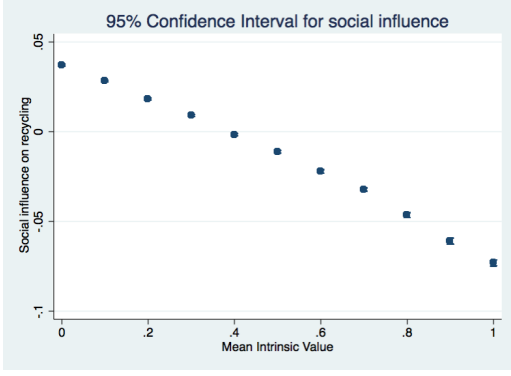


Figure 21: The impact of  $\bar{v}_a$  on  $a_i^* - \hat{a}_i$

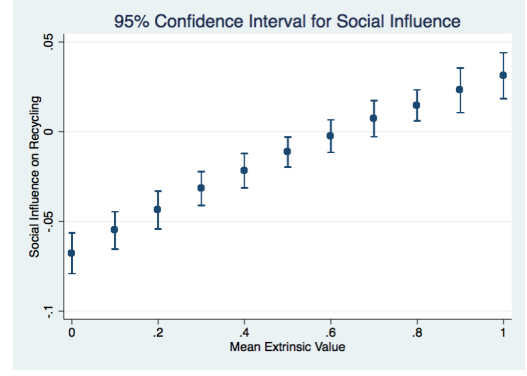


Figure 22: The impact of  $\bar{v}_t$  on  $a_i^* - \hat{a}_i$

The impact of parameters' variation on Social influence ( $a_i^* - \hat{a}_i$ ) with  $t = \eta = 0.6$

for low values of  $\bar{v}_a$  and high values of  $\bar{v}_y$  but is negative for high values of  $\bar{v}_a$  and low values of  $\bar{v}_y$ .

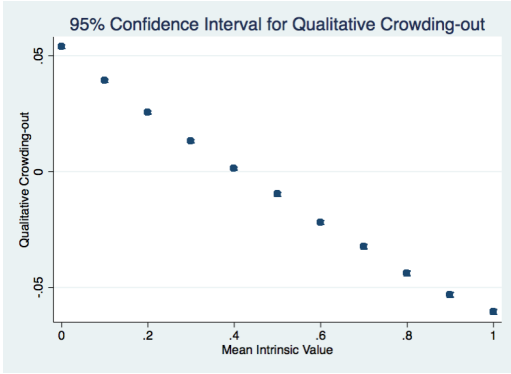


Figure 23: The impact of  $\bar{v}_a$  on  $\partial r(a_i, t)/\partial t$

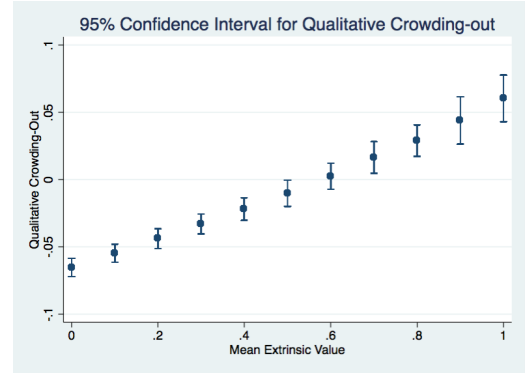


Figure 24: The impact of  $\bar{v}_t$  on  $\partial r(a_i, t)/\partial t$

The impact of parameters' variation on Crowding-out ( $\partial r(a_i, t)/\partial t$ ) with  $t = \eta = 0.6$

The trends are similar for the crowding-out effect. The increase in the population mean intrinsic value  $\bar{v}_a$  exacerbates the crowding-out effect (figure 23). For low values of the mean intrinsic value we observe a positive crowding-out which becomes negative when the mean intrinsic value is fixed at a sufficiently high level. The results are reversed for an increase in the population mean extrinsic value  $\bar{v}_y$  in Figure (24). As  $\bar{v}_y$  increases, the negative crowding-out effect diminishes in absolute value and becomes positive.

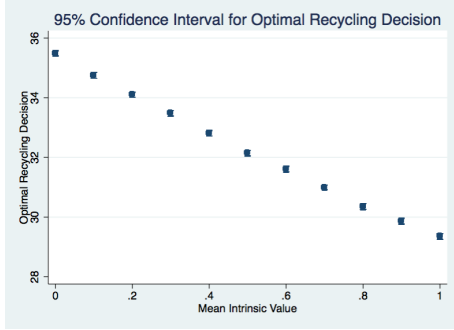
## 5 Conclusion

This work explored the issue of the peer effect and the influence of social approval on households' recycling decisions. We consider a policy mix composed of a “pay-as-you-throw” tax, provision of information on the social importance of recycling, and a 'nudge' in the form of information on others' recycling activity. Using a model and computational simulations, our results show that the peer effect is not systematically positive. Indeed, this effect depends on the environmental policies implemented, and on the composition of the population considered (i.e. the importance of households sensitive to the crowding-out effect in the population considered), and on households' beliefs about whether society is more environmentally friendly than it is greedy. Our results show that the sign of average social influence depends on the population parameters. If households believe that the mean extrinsic value is greater than the mean intrinsic value  $\bar{v}_y > \bar{v}_a$ , social influence is positive, as well as the crowding-out effect. In the reverse setting these effects are negative. The nudge policy is tested as a complementary policy to tax and information. This policy yields mixed results. On the one hand, it intensifies the importance of social influence on individual recycling decisions, and increases the responsiveness of individual decisions to the tax. On the other hand, it moderates the crowding-out effect.

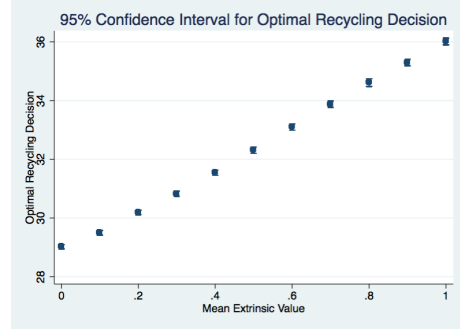
## 6 Appendix

### Complementary robustness checks

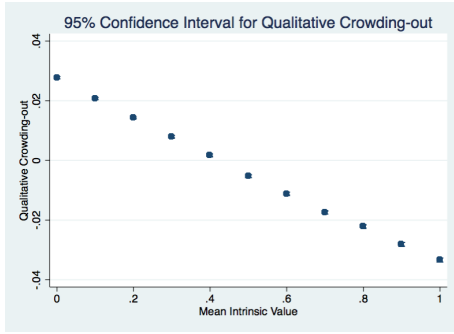




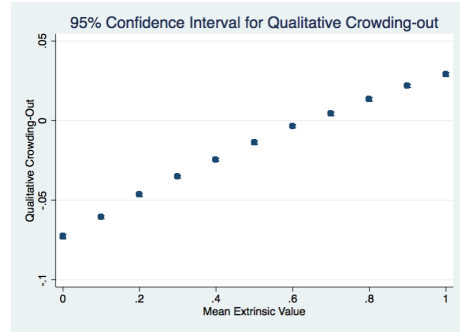
The impact of parameters  $(\bar{v}_a)$ ' variations on Optimal Recycling Decision ( $a_i^*$ )



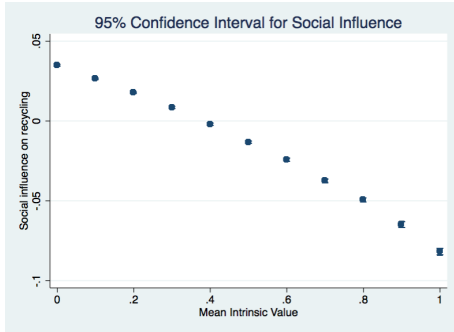
The impact of parameters  $(\bar{v}_y)$ ' variations on Optimal Recycling Decision ( $a_i^*$ )



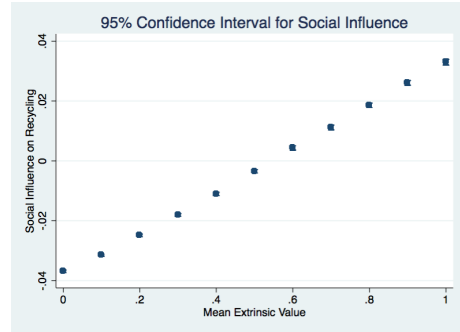
The impact of parameters  $(\bar{v}_a)$ ' variations on Crowding-out ( $\partial r(a_i, t)/\partial t$ )



The impact of parameters  $(\bar{v}_y)$ ' variations on Crowding-out ( $\partial r(a_i, t)/\partial t$ )

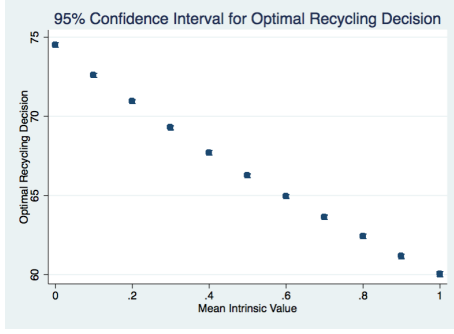


The impact of parameters  $(\bar{v}_a)$ ' variations on Social influence ( $a_i^* - \hat{a}_i$ )

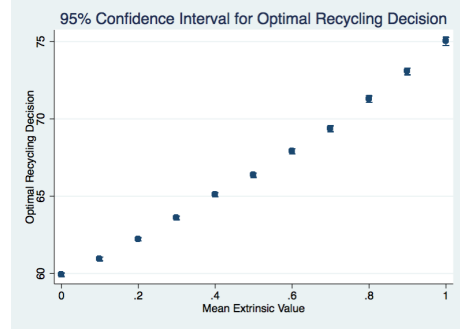


The impact of parameters  $(\bar{v}_y)$ ' variations on Social influence ( $a_i^* - \hat{a}_i$ )

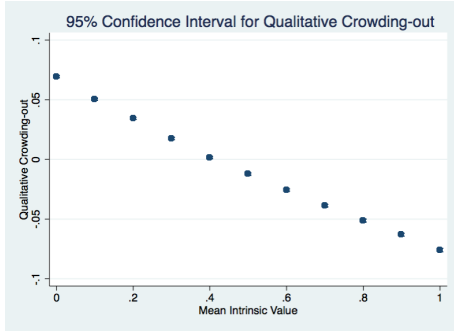
Figure 25: With lower public policies  $t = \eta = 0.1$



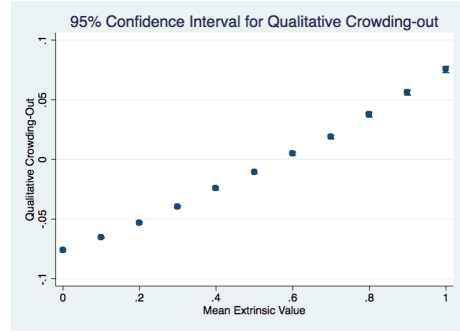
The impact of parameters  $(\bar{v}_a)$ ' variations on Optimal Recycling Decision ( $a_i^*$ )



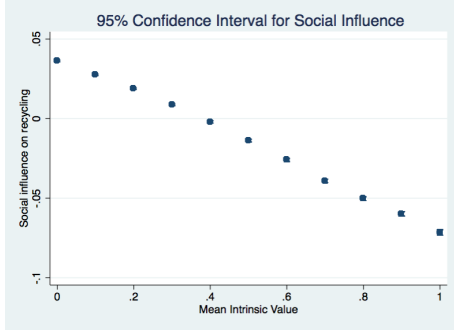
The impact of parameters  $(\bar{v}_y)$ ' variations on Optimal Recycling Decision ( $a_i^*$ )



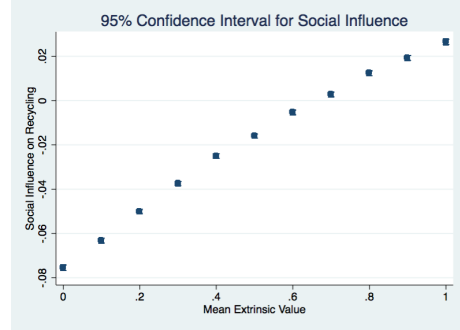
The impact of parameters  $(\bar{v}_a)$ ' variations on Crowding-out ( $\partial r(a_i, t)/\partial t$ )



The impact of parameters  $(\bar{v}_y)$ ' variations on Crowding-out ( $\partial r(a_i, t)/\partial t$ )



The impact of parameters  $(\bar{v}_a)$ ' variations on Social influence ( $a_i^* - \hat{a}_i$ )



The impact of parameters  $(\bar{v}_y)$ ' variations on Social influence ( $a_i^* - \hat{a}_i$ )

Figure 26: With lower public policies  $t = \eta = 1$

## References

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