



Public policies for household recycling when reputation matters

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Abstract

An important strand in the economic literature focuses on how to provide the right incentives for households to recycle their waste. A growing number of studies, inspired by psychology, seek to explain waste sorting and pro-environmental behavior, and highlight the importance of social approval and the peer effect. The present theoretical work explores these issues. We propose a model that considers heterogeneous households that choose to recycle, based on three main household characteristics: their environmental preferences, the opportunity costs of their tax expenditures, and their reputations. The model is original in depicting the interactions among households, which enable them to form beliefs about social recycling norms, allowing them to assess their reputation. These interactions are explored through Agent-based simulations. We highlight how individual recycling decisions depend on these interactions and how the effectiveness of public policies related to recycling are affected by a crowding-out effect. The model simulations consider three complementary policies: provision of incentives to recycle through taxation; provision of information on the importance of selective sorting; and an ‘individualized’ approach that takes the form of a ‘nudge’ using social comparison. Interestingly, the results regarding these policies emerging from households interactions at the aggregate level cannot be fully predicted from “isolated” individual recycling decisions.

Keywords Household recycling · Waste · Environmental regulation · Behavioral economics · ABM · Social interaction

JEL Classification D100 · D030 · Q530 · Q580

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1 Introduction

In its “Roadmap to a resource efficient Europe” (European Commission 2011), 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.¹ The European Commission believes “their purchasing choices will stimulate companies to innovate and to supply more resource efficient goods and services”. This is not the only solution proposed by the European Commission to reduce waste but it is illustrative of the importance of households in the Commission’s approach to resource efficiency, and its view in the various European waste directives, of households as the ‘holders of waste’. In Europe, the amount of municipal waste generated is estimated, on average, at 483 kg per capita in 2017 (Eurostat 2017). However, within EU member countries, a strong contrast in the municipal waste production exists. For instance, in 2016, Romania had the lowest amount of waste (about 260 kg per capita), and Denmark, with 777 kg per capita, was the largest producer. However, 47% of municipal waste was recycled or composted in Denmark in 2015, against less than 15% in Romania (Eurostat 2015). Composting and recycling municipal waste has steadily increased over time in Europe to reach 45% in 2016. However, landfilling is still widely used.

An important stream of the economic literature examines how to provide the right incentives for households to recycle their waste. Households tend to overlook the external benefits of their recycling activity (savings on natural resources, 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 consider the value they attribute to the environment in their choices, the literature suggests that appropriate price signals (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 are the main drivers of public waste policies. The issue of extending product-life, in order to face a situation of increasing waste is also explored (Brouillat 2009). In this perspective, a necessary co-evolution (Janssen and Jager 2002) between firms’ strategies (the producers of waste) and consumers’ behavior (the holders of waste) is underlined.

The notion of consumers choosing the recycling effort that maximizes their self-interest seems unrealistic. In their everyday lives, consumers engage in selective sorting without any government/policy intervention. Although the level of this activity may be sub-optimal, it is generally not zero. Classical consumer theory, which predicts that egoistic individuals will behave opportunistically, does not explain this observed public goods provision (Andreoni 1988). Furthermore, individual waste recycling is (even partially) observable by others, and each household can (even partially) see what others do. Therefore, selective sorting is seen as a behavior where

¹Households’ behaviors impact on the environment and the importance of household choices are also stressed in OECD (2014).

social considerations are particularly important (Alpizar and Gsottbauer 2015). This has led to a strand of work that draws its inspiration from psychology (Ajzen and Fishbein 1980; Hopper and Nielsen 1991; Andersson and von Borgstede 2010) 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 on individual motives (Hornik et al. 1995; Brekke et al. 2003, 2010; Nyborg et al. 2006; Viscusi et al. 2011; Abbott et al. 2013; Czajkowski et al. 2015). Taking account of these elements has important policy implications (Gsottbauer and Van den Bergh 2011). In particular, the importance of non-monetary instruments is explored (see Van den Bergh (2008) for a survey).

These works differ in relation to how others “enter” individual preferences. For example, evaluating the ‘warm glow’ effect requires individual familiarity with the social norm. In Brekke et al. (2003) and Nyborg (2011), individuals gain from proximity to what they perceive individually as an *ideal* behavior. This *ideal* behavior is defined in Brekke et al. (2003) 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 validate the role of social norms systematically. 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.

An important body of the related literature discusses the crowding-out effect (Frey 1997). 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 that peers might view their contribution as motivated purely by self-interest (e.g. to avoid paying a tax), and ultimately might work to reduce their contribution. The introduction of a monetary incentive has an ambiguous effect on the reputation payoff in Bénabou and Tirole (2006), which could create a crowding-in/out effect, and could result in the individual optimal contribution being enhanced or reduced as a consequence. In Brekke et al. (2003), the introduction of a fee to finance the provision of a public good could reduce the individual contribution and result in a no contribution equilibrium. Ferrara and Missios (2012) explore this issue considering recycling.

This paper contributes to the theoretical part of this literature. Our model considers heterogeneous households that decide to recycle, taking into account 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 reputation. Therefore, the model borrows some elements of the reviewed works (the introduction of intrinsic and extrinsic values and a reputation motive into the household utility functions) but is different by some original features. In particular, we do not conceive the problem of selective sorting through a public good game in which a potentially large number of agents are involved in strategic interactions in deciding about their recycling level. Furthermore, we assume, in contrast to the literature cited,² that households do not have *a priori* beliefs about what is socially expected, but make efforts to find the relevant information. The novelty of our paper is that it models the interactions among households that enable their beliefs about recycling norms. The model is based on agent-based simulations (ABM). The focus on social recycling norms reflects the idea that individuals attach importance to appearing to be concerned about the environment. Therefore, the interactions among individuals are important in our model but for a reason other than strategic. The model described is close to the concept of *descriptive norm* defined by psychologists (Cialdini et al. 1990).

We show how individual recycling decisions depend on these interactions, and the consequences these interactions have on the effectiveness of public policies for 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 conditions under which social influence matters in the individual recycling decisions, as well as at the aggregate level, are assessed and compared. The same is completed for the crowding-out effect and two nudges.

Considering myopic households that try to identify recycling norms by observing others’ actions demonstrates the formation of a “descriptive norm” and adds an evolutionary perspective to our model. Since the social norm perceived evolves and enters the household’s preferences, a part of the utility function (the reputation part) is context-dependent. As in other works that use ABM to study how agents can influence each other (Dijk et al. 2013; Tedeschi et al. 2014), our model includes three important characteristics that distinguish it from the models in the literature.³ First, recycling at the aggregate level is determined by the interactions of heterogeneous households at the micro level. Second, the regularities of the system at the aggregate level (for instance, the effect of taxes and provision of information on the social influence and crowding-out effects) that emerge from households’ interactions, cannot be predicted based only on ‘isolated’ individual recycling decisions calculated according to a given social norm (or a ‘representative household’). For example, the augmenting effect of the social norm on individual contributions – an idea that has been challenged in the empirical literature – is not automatic in our model, even if this result is guaranteed in ‘isolated’ individual recycling decisions. Third, since households are not able to identify all of the different recycling rates adopted by others, and

²For instance, in the study by Brekke et al. (2003), individuals are able to state their *ideal* pro-social behavior.

³ABM is particularly appropriate to study complexity, heterogeneity, evolving norms (or institutional environment), etc. In the evolutionary literature, ABM allows new perspectives on financial (Leal et al. 2016; Veryzhenko et al. 2017) and macroeconomic issues (Dosi et al. 2015; Haldane and Turrell 2018).

have limited knowledge derived from the observation of direct contacts, they form different beliefs about others' actions. Different individual beliefs will have different consequences on the implications for recycling of the policy mix at the aggregate level. In return, modifications to public policies will affect households' recycling decisions, with feed-back effects for the social norm perceived.

The paper is organized as follows. Section 2 describes the model. Section 3 presents the results of the analysis of social influence and crowding-out effects on recycling at the micro level. Section 4 focuses on households' interactions, and presents the aggregate level results based on computer simulations. Finally, Section 5 concludes.

2 The model

2.1 Households' selective sorting without public policy

The model depicts a simplified economy composed of N households indexed by i for a finite number of time periods. It is grounded in the economic literature on household recycling, and borrows some of the characteristics of the utility functions used to deal with impure altruism and peers effect from the behavioral economics literature.⁴ We consider that a household " i " consumes a composite good c_i in each time period. This consumption creates waste that can be recycled (a_i) or disposed of as garbage (g_i). For simplicity, we consider a "mass balance" situation where $c_i = a_i + g_i$, and we normalize consumption to one unit, so that $a_i = 1 - g_i$. The unit of consumption awards α units of utility to each household. Recycling requires effort, time, materials and space. Thus, it implies a cost denoted $c_i a_i^2$.

We introduce the notion of "prosocial behavior" by assuming that the household derives satisfaction from its 'environmental preferences', or derives intrinsic value v_i^a from selective sorting. When a tax on garbage is introduced, recycling permits a household to limit the tax paid. Therefore, recycling in such a context can be driven by another (monetary) concern valued by an extrinsic value v_i^t (discussed further below in Section 2.2). Both the intrinsic and extrinsic values for recycling are supposed to belong to $[0, 1]$.⁵

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 \underline{a}_i :

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

so that:

$$\underline{a}_i = \frac{v_i^a}{2c_i} \quad \text{if } c_i > \frac{v_i^a}{2}, \quad (2)$$

$$\underline{a}_i = 1 \quad \text{otherwise.} \quad (3)$$

⁴See the discussion in the introduction.

⁵In the model simulation presented in Section 4, we suppose that v_i^a , v_i^t , and c_i are normally distributed.

If the household's intrinsic values and costs are fixed, the total amount of garbage realized at each time period due to the household's intrinsic values, $G = \sum_{i=1}^N (1 - a_i)$, will remain constant.

2.2 Public policies

We consider that, at the global level, government has to deal with the waste of resources created by insufficient levels of individual recycling, or with an external effect due to unsorted waste. We suppose that households ignore the external effect of their individual decisions, and that the externality experienced at the individual level is negligible.⁶ The government aims to encourage selective sorting in order to tackle the loss of welfare implied by total amount of garbage G with the help of three kinds of policy: tax, information, and nudges.

2.2.1 Tax on residual waste

We assume implementation by the regulator of a “pay-as-you-throw” scheme t on garbage. This tax scheme has two incidences on the payoff function. First, household i pays $t(1 - a_i)$ for its unsorted waste. Second, as the tax paid is diverted from consumption, households suffer from a loss of utility.⁷ This loss of utility forms the opportunity cost of the tax paid. However, consumption is normalized to one in our model. As a consequence, the opportunity cost of the tax expenditure is explicitly introduced in households' payoff function as a function of garbage: $t(1 - a_i)v_i^t$, where v_i^t represents the opportunity cost of one euro spent on tax. Therefore, under this pay-as-you-throw policy, the payoff function is:

$$U_i(a_i) = v_i^a a_i - c_i a_i^2 - t(1 + v_i^t)(1 - a_i) + \alpha \quad (4)$$

2.2.2 Information policy

The second type of policy delivers information $\eta \in [0, 1]$ on the social importance of selective sorting. This information underlines the reduced loss of resources 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 $v_i^{a(1-\eta)^2}$.⁸ Somewhat unrealistically, we suppose that delivering information does not imply a cost. Therefore, the regulator's choice should be to deliver the maximum level of information $\eta = 1$. However, in the model simulation we allow information to take intermediate values. Indeed, our results for

⁶Note that introducing this externality in our model would not change qualitatively our analytical results (Section 3), nor our simulations results (Section 4).

⁷As in Fullerton and Kinnaman (1995), for example.

⁸This functional form implies that the environmental value is increasing at a decreasing rate in the information η and reaches its maximum level “1” when $\eta = 1$.

the policy mix “tax plus information” show that the measures for the social influence on households’ decisions are highly sensitive to information changes.

Household i utility function with the policy mix information policy and tax is:

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

The level of recycling effort that maximizes household utility (5) is denoted by \hat{a}_i :

$$\hat{a}_i = \frac{v_i^{\alpha(1-\eta)^2} + t(1 + v_i^t)}{2c_i} \quad \text{if } c_i > \frac{v_i^{\alpha(1-\eta)^2} + t(1 + v_i^t)}{2}, \quad (6)$$

$$\hat{a}_i = 1 \quad \text{otherwise.} \quad (7)$$

In what follows, the recycling rate \hat{a}_i is described as an “isolated decision”. It corresponds to a decision guided only by individual intrinsic and extrinsic values v_i^{α} and v_i^t , without considering others.

2.2.3 Nudge

A policy that acts as a nudge (see Thaler and Sunstein (2008) and Bovens (2009) for a presentation) is introduced. A nudge is generally considered to be an element that would be ignored by an individual maximizing his utility as narrowly defined but works to modify real observed behaviors. Following a field experiment conducted by Schultz (1999), we test two nudges using “social comparison”.⁹ This green nudge consists of providing information about what others do in order to incite individuals to adopt pro-environmental behaviors. It is being used increasingly to encourage households to reduce their energy consumption, for example. In our model (see Section 4), at each time period, households meet other people in order to get information on the recycling norm. In this context, the first nudge considered, which we describe as a “broadened visibility” (BV) nudge, consists of delivering information on the recycling of a larger number of households than the set a household can possibly meet at each time period.¹⁰ If, when making its decision, household i cares about what others do in terms of recycling, or thinks that others’ recycling decisions influence what they think about his own intrinsic v_i^{α} and extrinsic v_i^t values, this nudge can influence households’ selective sorting.¹¹ The second nudge, which we describes

⁹See Croson and Treich (2014) for a presentation of this kind of nudges in the field of environmental preservation. Another important type of “green nudges” consists in providing green default option. See Sunstein and Reisch (2013).

¹⁰This allows us to explore the idea of Thaler and Sunstein (2008) according to which “If choice architects want to shift behavior and to do so with a nudge, they might simply inform people about what other people are doing”.

¹¹Schultz (1999) shows that this type of nudge resulted in an increase in the volume of recycled waste that persisted over time, even after the experiment stopped.

as a “selective visibility” (SV) nudge, consists of delivering information only on the best recycling rates observed within the larger set of individuals.¹²

2.3 Households’ selective sorting with public intervention

Three characteristics imply 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 others. Third, we assume that households care about a peer effect, their reputation, and their self-image, as underlined in Section 1. As a consequence, a reputation payoff is introduced in household i ’s utility payoff function, according to what others believe about its environmental preferences when observing household’s recycling level a_i .

As discussed in Section 1, households do not know the social recycling norm. In the absence of relevant information, they form their beliefs about the social recycling norm by ‘looking around’ (i.e. meeting other households in our model, as described in Section 4), observing the different recycling rates of the people met, 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:

$$R_i(a_i) = x_i \gamma_i (a_i - \bar{a}_i)^2 \quad (8)$$

Deviation from the social norm is evaluated with the gap between the household recycling level a_i and the mean of others’ observed recycling levels \bar{a}_i , as in Nyborg et al. (2006). We borrow from Brekke et al. (2003) the idea that individuals gain from the proximity to what they perceive as the ideal behavior (the social norm in our work). However, in our reputation function, the difference between the household’s recycling and the norm is weighted by the visibility x_i of household i ’s decision,¹³ as well as by an individual parameter γ_i standing for the importance attached by household i to reputation. In the agent-based model simulations presented in Section 4, x_i is a function of the number of household i ’s contacts (the “neighbors”). Reputation is subtracted from utility. As a consequence, it forms a cost that a household will try to alleviate, aligning recycling effort on the social norm (see Section 2.3). The quadratic form introduced in our model allows us to deal with the crowding-out effects. Thank to this assumption, the derivative $-\partial R_i(a_i)/\partial a_i = -r_i(a_i)$ in the first order condition for maximization of (9) depends on a_i . It reacts negatively to the tax rate at the optimum, implying a crowding-out effect ($-\partial r(a_i^*(t))/\partial t < 0$).

¹²This nudge might deliver biased information since only the best household recycling rates observed are communicated (the top 50% of the observed recycling rates). This nudge might cause the household to overestimate the mean of others’ recycling rates. Therefore, the risk of failing to comply with “consumer sovereignty”, the nudges’ major drawback, is a serious issue for this kind of nudge.

¹³As in Bénabou and Tirole (2006).

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

$$U_i(a_i, t, \eta) = v_i^{a(1-\eta)^2} a_i - t(v_i^t + 1)(1 - a_i) - c_i a_i^2 - x_i \gamma_i \left(a_i - \frac{1}{2} \bar{a}_i\right)^2 + \alpha \quad (9)$$

The recycling effort a_i^* maximizing (9) is given by:

$$a_i^* = \frac{v_i^{a(1-\eta)^2} + t(v_i^t + 1) + x_i \gamma_i \bar{a}_i}{2(c_i + x_i \gamma_i)} \quad \text{if } c_i > \frac{1}{2} \left(v_i^{a(1-\eta)^2} + t(v_i^t + 1) + 2x_i \gamma_i (\bar{a}_i - 1)\right) \quad (10)$$

$$a_i^* = 1 \quad \text{otherwise.} \quad (11)$$

Finally, note that the difference observed between a_i^* and \hat{a}_i is due to the reputation motive in household i 's recycling decision. Therefore, $a_i^* - \hat{a}_i$ captures the impact of *social influence* on the individual decision.

2.4 Households' heterogeneity

Households are supposed heterogeneous in relation to v_i^a , v_i^t , γ_i , x_i , and c_i . We suppose that $v_i^a \in [0, 1]$, $v_i^t \in [0, 1]$, and $\gamma_i \in [0, 1]$ for $i = 1, \dots, N$. These parameters are all normally distributed. Depending on their values, several types of households can be distinguished.

First, some households always choose not to develop recycling activity in the absence of a tax on residual waste, or in the absence of information (i.e. when maximizing (1)), because their intrinsic value is zero ($v_i^a = 0$). However, as soon as a tax is implemented, these households' optimal decisions maximizing (5) or (9) are strictly positive. Note that an information policy has no effect on the recycling behavior of these households.

Second, some households do not care about reputation ($\gamma_i = 0$). Their recycling decisions are never influenced by peers. Furthermore, since their reputation payment is always 0, they never try to discover the social recycling norm.

Finally, a large part of households recycle without policy, and are sensitive to tax and information policies, and to reputation.

3 Individual recycling decisions for a given social norm

Exploring the properties of individual recycling decisions a_i^* and \hat{a}_i captures the first analytical results on the impact of the reputation motive on households' decisions. These results are derived based on the condition (10) ensuring that a_i^* is less than 1, and for a given norm \bar{a}_i . Proofs are given in the Appendix A. These results characterize the individual recycling decision for a given norm. Then, they will be compared to the outcomes arising at the "global level" when households interact and are influenced by others, moving the recycling norm (Section 4). A table summarizing the results at the micro and aggregate level is presented in Appendix F.

3.1 The impact of social influence on households’ recycling decisions

The impact of social influence on households’ recycling decisions is captured by the difference between a_i^* (the recycling decision under tax plus information policies taking account of the reputation payment), and \hat{a}_i (the recycling decision under tax and information policies without taking account of the reputation payment). The difference $a_i^* - \hat{a}_i$ can be both positive and negative. When negative (positive), it reveals that taking account of reputation reduces (increases) household i ’s recycling rates. A first result is that the sign of social influence is governed by a single condition implying a household’s characteristics only: the perceived norm, and the “isolated decision” \hat{a}_i .

Proposition 1 *Reputation gives rise to a positive social influence ($a_i^* - \hat{a}_i > 0$) only if $\hat{a}_i < \bar{a}_i$*

In other words, the reputation payment has a positive effect on recycling rate for households characterized by relatively low recycling rates. By contrast, when a household, outside any interaction with others, recycles more than the norm, the reputation payment has a negative impact on the household’s recycling rate.

3.2 The impact of the pay-as-you-throw tax and of the information delivery on social influence

We can note that social influence $a_i^* - \hat{a}_i$ is a function of the pay-as-you-throw tax, as well as of the information η . We can show (the proof is given in Appendix A) that both the tax and the information systematically impact social influence in the same direction, as stated by the following proposition:

Proposition 2 *The impact of the pay-as-you-throw tax and of the information delivery on social influence is always negative.*

As a consequence, a positive social influence decreases with the tax and information, whereas a negative one increases in absolute value with the tax and information. The combination of the two first propositions allows consideration of the two different cases presented in Table 1 below.

A household that considers itself to be a bad recycler (case a in Table 1) is positively influenced by its peers, although this influence decreases with the tax. By

Table 1 Social influence on a household’s decision and the tax

(a) $\hat{a}_i < \bar{a}_i$	(b) $\hat{a}_i > \bar{a}_i$
Positive social influence ($a_i^* - \hat{a}_i > 0$) decreasing with the tax ($\frac{\partial(a_i^* - \hat{a}_i)}{\partial t} < 0$)	Negative social influence ($a_i^* - \hat{a}_i < 0$) increasing with the tax ($\frac{\partial(a_i^* - \hat{a}_i)}{\partial t} < 0$)

contrast, a household that considers itself to be a good recycler is negatively influenced by others, a situation exacerbated by the pay-as-you-throw tax (case *b* in Table 1).

3.3 Nudge and household recycling

An additional result concerning the first nudge tested in this paper can be demonstrated. This nudge consists of delivering more information on others' recycling. It is implemented increasing the households' visibility x_i (and therefore the number of households' contacts).

Proposition 3 *A nudge (BV) delivering information on others' recycling effort has the following properties:*

1. *The BV nudge positively (negatively) impacts the social influence at a decreasing rate only when $\hat{a}_i < \bar{a}_i$ ($\hat{a}_i > \bar{a}_i$).*
2. *The BV nudge increases at a decreasing rate the absolute value of the negative effects on social influence of both the pay-as-you-throw tax and the information delivery.*
3. *The crowding-out effect in absolute value increases at a decreasing rate under the effect of the BV nudge.*

As shown in the proof in Appendix A, the impact of x_i on a_i^* is of the same sign as $a_i^* - \hat{a}_i$. In light of the Proposition 3, such a nudge has different consequences in the two cases presented in Table (1). In the case of a household recycling less than the norm when isolated (case *a*), it improves the positive social influence. In the case of a household recycling more than the norm when isolated (case *b*), the BV nudge reinforces the negative social influence (since it decreases a_i^*). In both cases, the BV nudge strengthens the negative impacts of the tax and of information delivery on social influence. This effect contradicts the positive impact of the nudge on social influence in case (*a*), and worsens its negative impact in case (*b*). Finally, in both cases (*a*) and (*b*), the crowding-out effect raised by the tax is enlarged (at a decreasing rate) by the BV nudge. These results clearly indicate that the interrelation between the pay-as-you-throw tax (understood as a monetary incentive policy) and a nudge communicating a descriptive norm (understood as a non-monetary incentive policy) are complex and vary between households.

Note that the three propositions and Table (1) assume that the recycling norm \bar{a}_i evaluated by the household concerned is fixed. However, the descriptive norm changes when households observe others, and becomes sensitive to any variation in the policy mix. For example, we can move from case (*a*) to case (*b*) not only because of a change in a_i^* and \hat{a}_i , but also because of a change in what others do (\bar{a}_i). To grasp the simultaneous changes in the descriptive norms and the households' decisions requires the model simulations of households' interactions presented in the next section. Interestingly, some of the regularities that will emerge from these simulations at the "global level" are not predictable with the help of the analytical results presented in this section.

4 Agent-based simulation results

The presence of a reputation payment in the household payoff function has an important consequence. Since households care about their reputations, and care also about others' recycling levels, in order to make their own selective sorting decisions, they need to know what is the recycling social norm. Indeed, to calculate $R(a_i)$ requires information on what others do, since others' recycling decision average \bar{a}_i has to be computed.

We suppose that households have limited capacity to perceive the selective sorting propensity of others and are conscious of this limitation. A maximum of four other households is observable ($x_i \in \{0, 1, 2, 3, 4\}$). Thus, households will seek to discover the social norm by meeting other people in what we call a 'socialization process'. During this process, household i meets other households at random and calculates \bar{a}_i as the mean of others' observed selective sorting propensities. Each time, a household can have between zero and four "new" observable contacts. These new observations allow refining the mean of the observed sorting propensities. As a consequence, the social norm constructed by a household evolves along the socialization process.

This process lasts 300 time periods.¹⁴ At each time period, two different situations can emerge for the household's desire to commit to further social meetings. The first situation is when the mean of others' recycling rates \bar{a}_i , calculated by the household based on what has been observed so far, is equal to its own selective sorting propensity a_i^* .¹⁵ In this situation, we suppose that the household feels its behavior is in line with its neighborhood and will not seek further information (i.e. doesn't try to meet other households). The second situation arises when $\bar{a}_i \neq a_i^*$. In this case, the household feels "out of kilter" with others, and, as a result, will make efforts to get more information on others' recycling activities (i.e. tries to meet other households). Note that information delivery and tax are public policies that are kept fixed during these household interactions. Figure 1 depicts the dynamics of the simulation model. Appendix D provides a graph of the evolution of the recycling rate over the 300 time periods in the simulation.

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 , γ_i^a , γ_i^t , and c_i . As these parameters are normally distributed, it is necessary to specify the means and standard deviations for each parameter.¹⁶ These initial conditions for the "population parameters" allow consideration of different configurations of the model simulation. In what follows we consider the situation in which $\bar{v}^t (= 0.7) > \bar{v}^a (= 0.3)$.¹⁷ Finally, in order to observe the constraint over c_i appearing in equation (10), c_i s are normally distributed around $\bar{c} = 15.5$.

¹⁴This duration ensures that the socialization process and the recycling decisions are stable.

¹⁵In the model simulation, a tolerance threshold of $\pm 3\%$ is introduced.

¹⁶The values used for the means and standard deviations of each parameter are presented in Table (2) in Appendix B.

¹⁷Simulation results for the configuration corresponding to $\bar{v}^t (= 0.3) < \bar{v}^a (= 0.7)$ are presented in online supplementary materials.

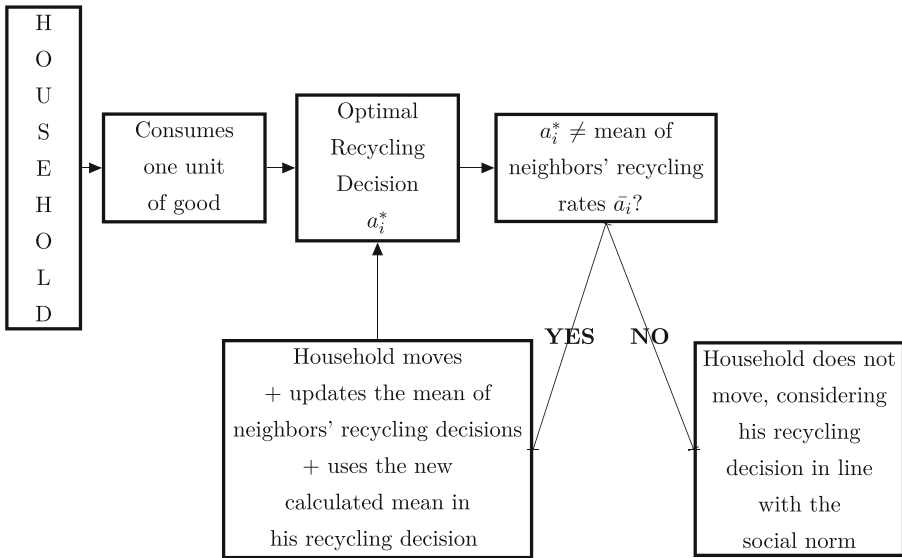


Fig. 1 Dynamics of Agent-based simulation

The simulations are repeated for every conceivable policy mix (t, η) . Both tax t and information policy η take 10 values between 0 and 10, and 0 and 1, respectively. Therefore, 100 policy mixes (t, η) are considered. Each configuration (t, η) is simulated 100 times with 300 time periods per simulation. The two configurations and the parameter values used in the model simulation are summarized in Appendix B Table 2. Below, we present the impact of policy on the optimal recycling decision, and discuss the social influence of neighborhood, crowding-out effect issues, and the consequences of introducing a nudge. These results represent regularities that emerge at the “global level”. They complement the results found exploring the properties of the individual decision rules. Robustness checks are presented in Appendix C.

4.1 Results for optimal recycling decisions

Figure 2 considers averages of \hat{a}_i (in blue) maximizing (5) under public policies without social interaction, and a_i^* (in yellow) maximizing (9) under public policies with social interaction. We observe a real distinction between the two recycling levels. The average of the a_i^* is systematically higher than the average of the \hat{a}_i , except for low values of the tax. This figure highlights that, when the desire to avoid others’ disapproval is introduced in individual decisions, reputation has an overall positive effect.¹⁸ Proposition (1) states that, at the individual decision level, a negative effect of reputation on household recycling should not be disregarded (when $\hat{a}_i > \bar{a}_i$). Compared to this result, Fig. 2 exhibits a regularity at the global level. On average

¹⁸This result is confirmed in the other situation where $\bar{v}^t < \bar{v}^a$ depicted in figures provided in online supplementary materials.

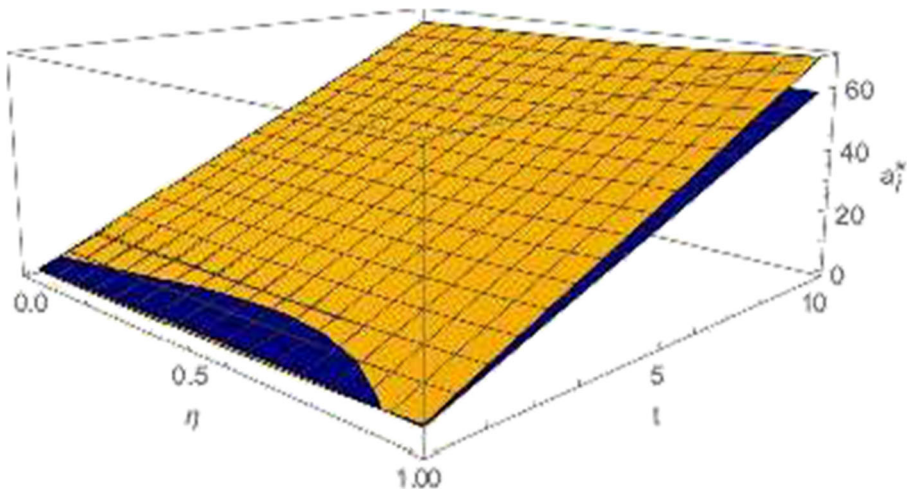


Fig. 2 Averages of recycling rates \hat{a}_i (blue) and a_i^* (yellow)

the positive effect of social influence dominates. The social interactions tend to erase situations where negative social influence prevails. Further, we note that both recycling rate averages are increasing with the pay-as-you-throw tax and provision of information. Thus, a substitution between the two policies is possible to a certain extent. Finally, we can observe that, as the tax grows, the difference between a_i^* and \hat{a}_i increases. We address this point in more detail in the next sub-section.

4.2 Results for social influence and the crowding-out effect

We compute the impact of social influence on the household's decision as the mean of the difference between $a_i^* - \hat{a}_i$ for all possible policy mixes (t, η) . A negative mean suggests that negative social influence dominates positive social influence in the entire population (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 information on the number of negative and the number of positive individual social influence effects observed. These two estimations highlight not only the sign of the overall social influence but also how the impact of social influence on decisions evolves with changes in the tax and information policies.

Figure 2 suggests that social influence measured as the average of the $a_i^* - \hat{a}_i$ observed is generally always positive. The differences observed between the means of a_i^* and \hat{a}_i are plotted in Fig. 3. Two main results emerge.¹⁹ First, the positive gap between the means of a_i^* and \hat{a}_i increases with the tax. Interestingly, Proposition (2) finds the opposite result at the individual level, stating that positive social influence decreases with the tax. Second, the gap between a_i^* and \hat{a}_i decreases and then

¹⁹These results are confirmed in the other configuration (where $\bar{v}^a > \bar{v}^t$) in online supplementary materials

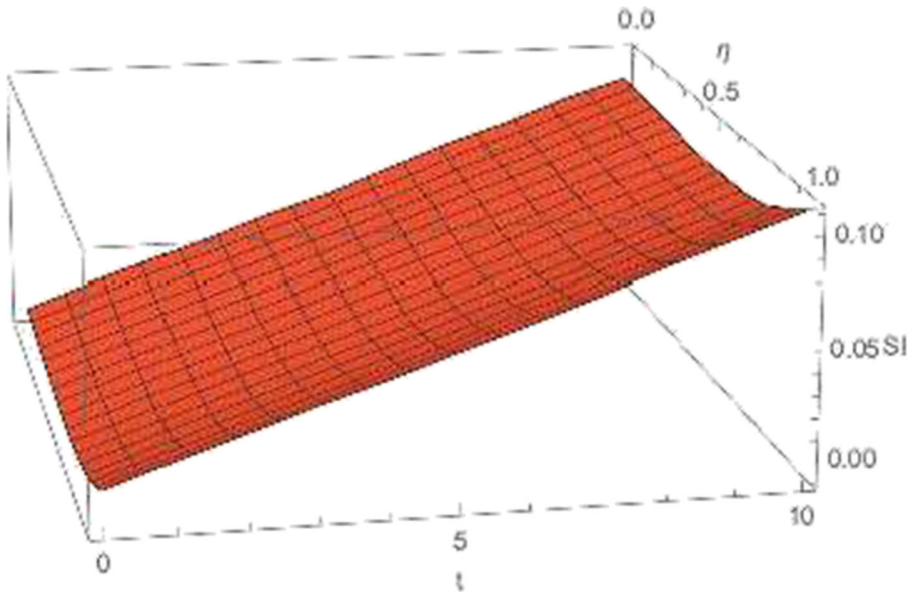


Fig. 3 Social influence expressed by the gap between the means of a_i^* and \hat{a}_i

increases slightly with information delivery, a result that cannot be fully anticipated with Proposition (2).

Social influence is captured from another perspective in Fig. 4, which reports the number of positive differences $a_i^* - \hat{a}_i$ observed (in red) and also the number of negative influences (in blue). As expected based on Fig. 3, we observe that the number of positive differences is systematically higher (i.e. whatever the policy mix), except for low values of the tax. Information delivery seems to have limited effect except when combined with low values of the tax (it increases the number of positive influences observed).

A negative impact of the tax on the difference between a_i^* and \hat{a}_i suggests a crowding-out effect. The model simulation allows us to estimate the magnitude of this effect. By definition (cf. Section 2.3), a crowding-out effect emerges because the derivative $\partial r(a_i^*(t))/\partial t$ is negative. Using the model simulation results, we can compute averages of the $\partial r(a_i^*(t))/\partial t$ observed in Fig. 5. Two main results emerge at the global level. First, the tax has the effect of reducing the crowding-out effect (at a decreasing rate). Second, the crowding-out effect slightly decreases with the information delivery policy. Importantly, note that these results could not be grasped at the individual level since $\partial r(a_i^*(t))/\partial t$ used to reveal the crowding-out effect does not depend on the tax, nor on information.²⁰ Interestingly, the result according to which the crowding-out effect is attenuated with sufficiently high monetary incentives is empirically supported in a field experiment using positive monetary incentives by Beretti et al. (2013).

²⁰We have $\partial r(a_i^*(t))/\partial t = -(\gamma_i x_i (1 + v_i^t))/(c_i + \gamma_i x_i)$.

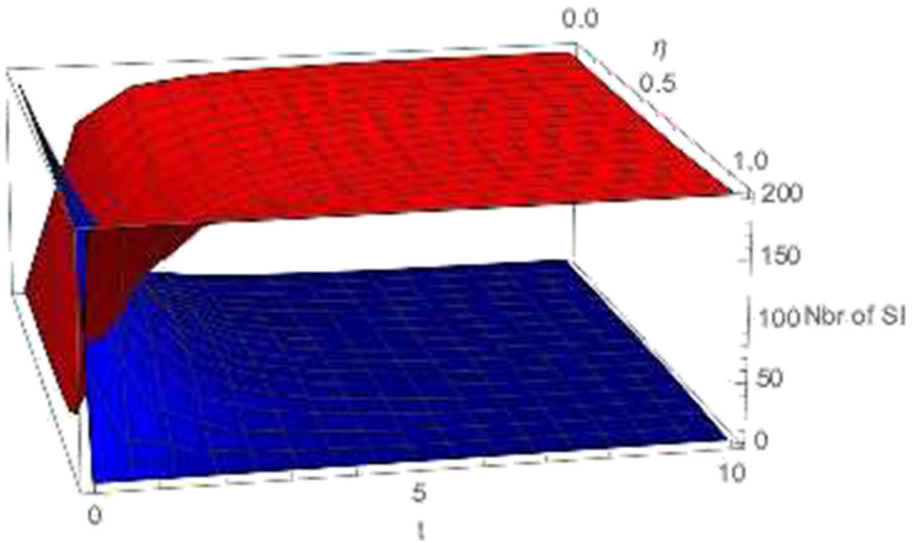


Fig. 4 Number of positive (red) and negative (blue) $a_i^* - \hat{a}_i$ observed

4.3 Measuring the nudges impact

Following Schultz (1999) experiment, we introduce in the simulations a first nudge (BV) consisting of delivering more information on others' recycling. Based on this nudge, households form their evaluation of the social norm \bar{a}_i using the a_i^* for eight contacts instead of four. The nudge is activated as soon as 75% of the population

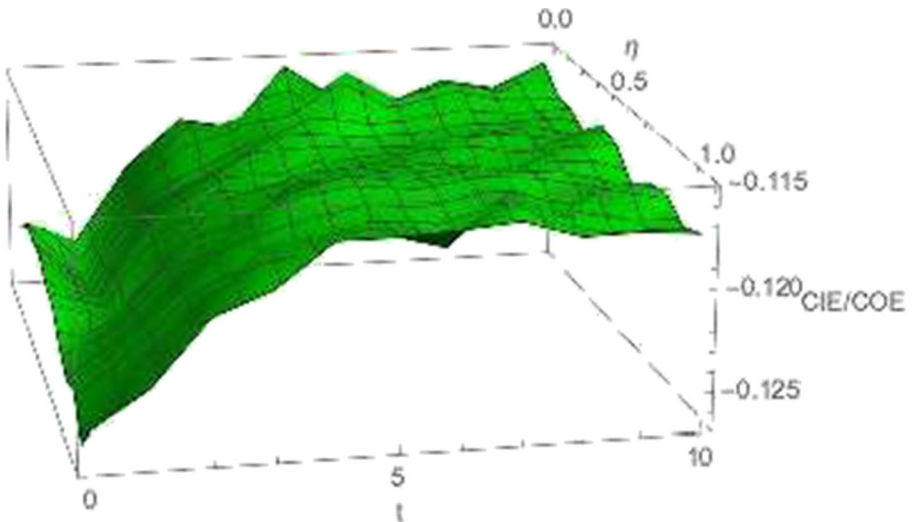


Fig. 5 Averages of the $\partial r(a_i^*(t))/\partial t$ observed

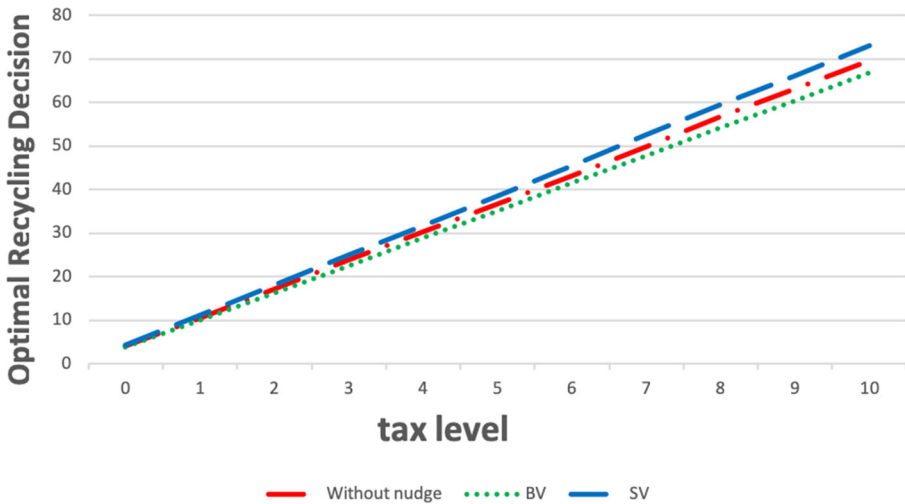


Fig. 6 Averages of a_i^* with and without nudges for $\eta = 1$

no longer engages in the socialization process (i.e. households that do not search for information on the social norm no longer interact with others).²¹ It targets only households outside of the socialization process.

A second nudge (SV) is also tested. As with the first one, it involves providing information on others' recycling rates considering a larger number of contacts (to a maximum of eight contacts). However, the information delivered is filtered: Only the best recycling rates observed (i.e. the habits of the majority of these eight contacts) are communicated, which introduces a bias. Also, contrary to the BV nudge, the SV one does not mean systematically increasing households' visibility. The household's visibility is increased only if it is one among the majority of the good recyclers in a given set of contacts.

From an analytical perspective, Proposition (3) states that the effect of the BV nudge on individual recycling rates is ambiguous (its effect on a_i^* is of the same sign as social influence and can be positive or negative). This ambiguity does not emerge at the aggregate level, as shown in Fig. 6. A first striking result (Fig. 6) is that increasing the number of contacts a household can possibly meet at each time period (and, therefore, each household's visibility) deteriorates the averages of a_i^* observed. However, note that, if we use the SV nudge focused on the best recycling rates observed rather than the BV one, a_i^* s are enhanced. The effect of the SV nudge is intuitive: since the SV nudge overestimates the mean formed by a household in relation to what others do, the frequency of the situations where the visibility x_i has a positive impact on recycling (i.e. where $\bar{a}_i > \hat{a}_i$) increases. By contrast, the BV nudge seems to increase the frequency of situations in which the visibility has a negative impact on recycling at the micro level, leading to a reduced aggregate level

²¹75% may appear a quite high threshold; however, this value ensures that the nudge reinforces tax and information delivery policies, reactivating an almost stable socialization process.

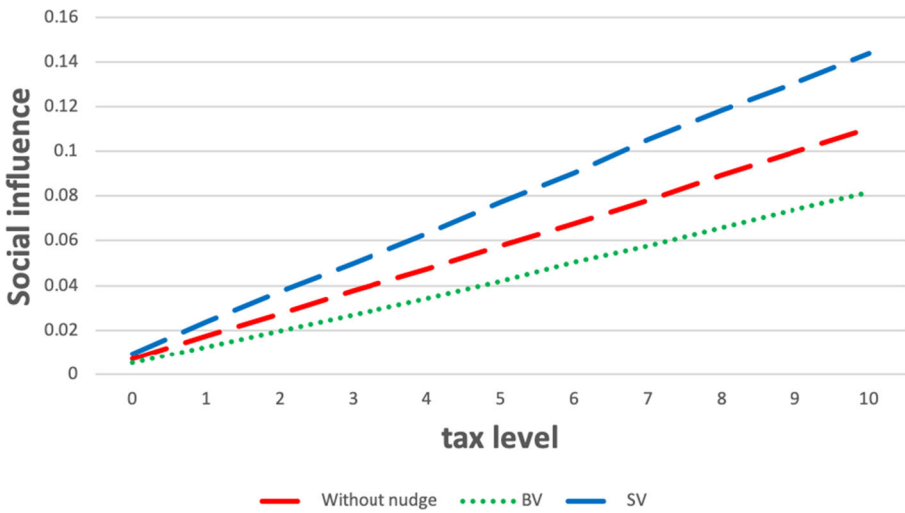


Fig. 7 Social influence $a_i^* - \hat{a}_i$ with and without nudge for $\eta = 1$

of recycling . This is depicted in Appendix E Fig. 28, which compares the evolution of the means of recycling decisions and of households’ beliefs about the recycling norm in the presence of the BV nudge. In this interaction, the mean of beliefs is initially below the effective recycling mean, which tends to decrease the recycling mean. After some time, the means converge but at a lower level than the original level of the recycling decision mean. Figure 6 shows that the higher the tax level, the greater this depressing effect of the BV nudge.

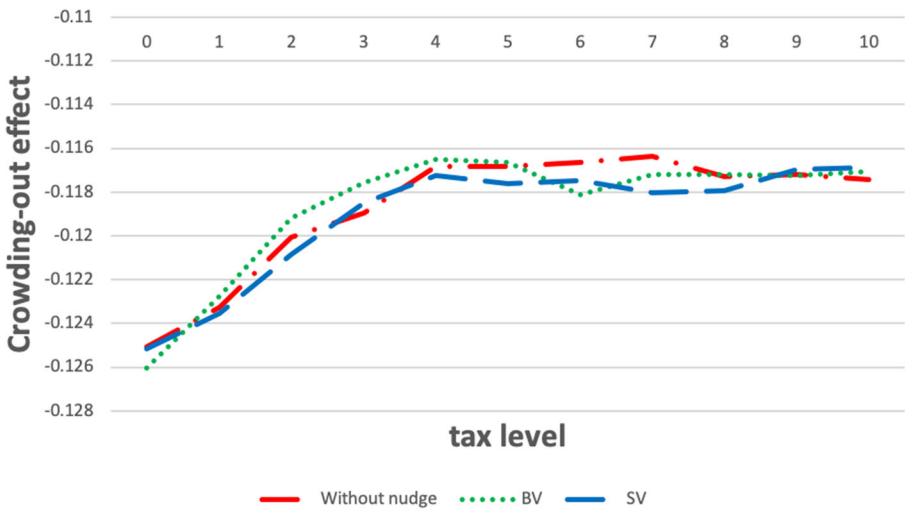


Fig. 8 Means of $\partial r(a_i^*(t))/\partial t$ with and without nudges for $\eta = 1$

Figure 7 compares the social influence with and without the nudges. The positive social influence observed at the aggregate level in this figure increases with the tax and is influenced by both nudges: it is affected positively by the SV nudge, and negatively by the first BV nudge. Note that the magnitude of these effects in absolute terms increases as the tax increases.

An assessment of the impact of the two nudges on the crowding-out effect is provided in Fig. 8. At the individual level, Proposition (3) states that the absolute value of the crowding-out effect increases at a decreasing rate under the effect of the BV nudge. At the global level, Fig. 8 does not exhibit such an enhancement effect of the BV nudge. The same observation applies for the SV nudge.

5 Conclusion

This work explored the peer effect on households' recycling decisions. In addition to intrinsic and extrinsic values, we included a reputation motive for recycling in the household utility function. This introduced a context-dependency for household decisions, which distinguishes our model from the rest of the literature. Using this framework, 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. We distinguish between the micro level and aggregate level results. At the micro level, the results highlight optimal household recycling decision properties. They show, first, that the impact of social influence on the household recycling decision is governed by the comparison of the perceived recycling norm with the household's recycling efforts decided without taking account of others. Only the decision of a "bad recycler" benefits from social influence. The first nudge (BV) using social comparison has positive effects only on the decisions of "bad recyclers". Finally, the results of the analysis capture the idea that a "pay-as-you-throw" tax increases recycling but has an adverse effect on social influence and implies a crowding-out effect.

Because the perceived recycling norm may differ from one household to another, and evolves when a household meets other households, these analytical results must be complemented by simulations where the norms forged by households evolve over time. This allows an assessment of the impact of a policy mix "tax plus information" at the aggregate level. The agent-based simulations results show, first, that the overall peer effect is generally positive, except for low values of the tax and information. The simulation results also show that, at the aggregate level, the overall positive social influence increases with the tax. Information provision first decreases social influence and then increases it. These regularities observed at the global level could not be captured at the micro level with the first results. The simulation results also revealed that the crowding-out effect is smaller with high tax values. The result found at the micro level, according to which the crowding-out effect increases with the BV nudge, could not be found at the aggregate level, where no systematic effect of the BV nudge is observed. Finally, the BV nudge considered diminished the peer effect, whereas the second one tested had the opposite consequences.

These simulation results suggest that government aiming at promoting recycling should choose nudges using social comparison with care. It is clear that nudges should not be applied indiscriminately. A BV type nudge would be counterproductive with already high recycling rates, especially if a high “pay-as-you-throw” tax has been implemented. However, these districts should be used as the reference in the case of a SV nudge to ensure a complementary positive peer effect to the tax effect on recycling.

Compliance with ethical standards

Conflict of interests The authors declare that they have no conflict of interest.

Appendix A: Proofs of the Propositions and Corollary

Proof of Proposition 1

We consider the case where the condition $c_i > \frac{1}{2} \left(v_i^{a(1-\eta)^2} + t(v_i^t + 1) + 2x_i\gamma_i(\bar{a}_i - 1) \right)$, ensuring that both a_i^* and \hat{a}_i are less than 1, is satisfied. Social influence is defined by $a_i^* - \hat{a}_i$ with \hat{a}_i and a_i^* defined respectively in Eqs. 6 and 10. Developing $a_i^* - \hat{a}_i > 0$ gives $\frac{v_i^{a(1-\eta)^2} + t(1+v_i^t)}{2c_i} < \bar{a}_i$ (or $\hat{a}_i < \bar{a}_i$).

Proof of Proposition 2

With \hat{a}_i and a_i^* defined in Eqs. 6 and 10, $\partial(a_i^* - \hat{a}_i) / \partial t = -\frac{x_i\gamma_i(1+v_i^t)}{2c_i(c_i+x_i\gamma_i)}$. This derivative is always negative. The same holds true for $\partial(a_i^* - \hat{a}_i) / \partial \eta$.

Proof of Proposition 3

1. The impact of x_i on a_i^* (and on social influence) is given by $\partial a_i^* / \partial x_i = \gamma_i \frac{2c_i\bar{a}_i - v_i^{a(1-\eta)^2} - t(1+v_i^t)}{2(c_i+x_i\gamma_i)^2}$. It is positive when $2c_i\bar{a}_i - v_i^a - t(1+v_i^t) > 0$, or when $\bar{a}_i > \hat{a}_i$. It is negative otherwise.
2. The impact of the tax on social influence is given by $\partial(a_i^* - \hat{a}_i) / \partial t = -\frac{x_i\gamma_i(1+v_i^t)}{2c_i(c_i+x_i\gamma_i)}$. The effect of x_i on it is given by $\partial^2(a_i^* - \hat{a}_i) / \partial t \partial x = -\frac{2\gamma_i(1+v_i^t)}{(2c_i+2x_i\gamma_i)^2}$. This effect is always negative. As $\partial^3(a_i^* - \hat{a}_i) / \partial t \partial x^2 = \frac{\gamma_i^2(1+v_i^t)}{(c_i+x_i\gamma_i)^3}$, this effect is decreasing in absolute value.
3. Calculated in a_i^* , $\partial r(a_i^*(t)) / \partial t$ is equal to $-\frac{x_i\gamma_i(1+v_i^t)}{c_i+x_i\gamma_i}$. The impacts of x_i on $\partial r(a_i^*(t)) / \partial t$ is measured by $\partial^2 r(a_i^*(t)) / \partial t \partial x = -\frac{c_i\gamma_i(1+v_i^t)}{(c_i+x_i\gamma_i)^2}$, and is negative. It is easy to check that $\partial^3 r(a_i^*(t)) / \partial t \partial x^2 = \frac{2c_i\gamma_i^2(1+v_i^t)}{(c_i+x_i\gamma_i)^3}$ is positive. So that the

effect of x_i on the absolute value of the crowding-out effect is always positive at a decreasing rate.

Appendix B: Parameter values used in the model simulations

Table 2 Parameter values used in the model simulations

Description	Symbol	Config.1	Config. 2
Benchmark parameters			
Replications	MC	100	100
Time sample	T	300	300
Number of households	N	200	200
Mean of normal distribution intrinsic value parameters	\bar{v}_i^a	0.3	0.7
Mean of normal distribution extrinsic value parameters	\bar{v}_i^t	0.7	0.3
Mean of normal distribution gamma parameters	$\bar{\gamma}_i$	0.5	0.5
Mean of normal distribution of cost parameters	\bar{C}_i	15.5	15.5
Selective visibility nudge (SV)	x_i	[0 ; 4]	[0 ; 4]
Broadened visibility nudge (BV)	x_i	[0 ; 8]	[0 ; 8]
Policy experiment parameters			
Incentive rate	t	[0 ; 10]	[0 ; 10]
Info level	η	[0 ; 1]	[0 ; 1]

Appendix C: Robustness check

In the two configurations presented in this article, the mean values \bar{v}^a , \bar{v}^t , and $\bar{\gamma}$ used in the normal distributions of these individual parameters are fixed at, respectively, 0.7, 0.3, 0.5, and 0.3, 0.7, 0.5. However, we also tested the separate impact of a variation in the individual parameters (keeping the other parameters fixed) on the results (optimal decision to recycle, social influence and crowding-out effect). We performed extensive Monte Carlo simulations to exclude simulation variability. The results presented below refer to averages over several replications. All the simulation results refer to 1000 independent Monte Carlo simulations, each involving 300 time steps (households' moves in the model). The simulations are run for four different cases. The first case considers a 'low' policy mix ($t = 2$ and $\eta = 0.2$), the second a 'medium' policy mix ($t = 4$ and $\eta = 0.4$), and the last two cases, a 'high' policy mix ($t = 6$ and $\eta = 0.6$) and a 'very high' policy mix ($t = 8$ and $\eta = 0.8$).

Regarding the impact of \bar{v}^a and \bar{v}^t on the optimal recycling decision, Figs. 9 and 10 indicate, as expected, an increasing relation between the intrinsic value of the population mean and the optimal recycling decision, regardless of the policy level. The

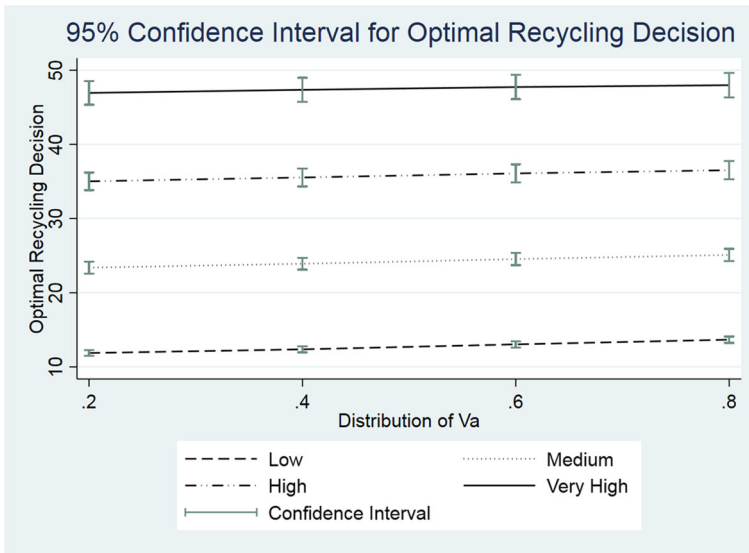


Fig. 9 The impact of \bar{v}^a 's variations on a_i^*

confidence intervals observed for the different values of the optimal recycling decisions show that the variations in \bar{v}^a do not significantly affect the optimal recycling (since the confidence intervals overlap). By contrast, the variation in \bar{v}^t significantly affects the optimal recycling decision. Similarly, the policy mix level has a significant effect on the optimal recycling decisions, in the expected direction.

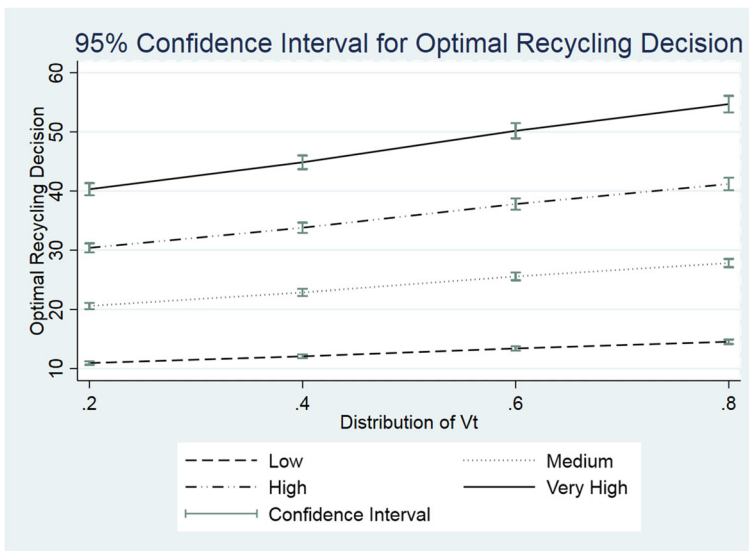


Fig. 10 The impact of \bar{v}^t 's variations on a_i^*

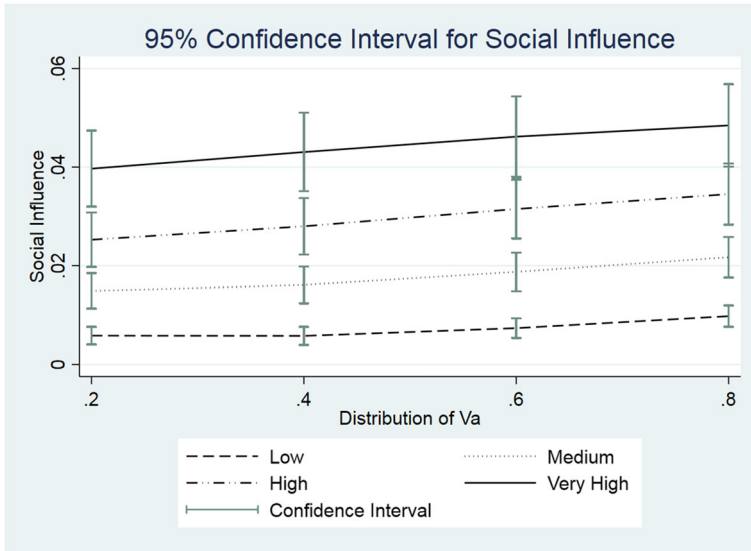


Fig. 11 The impact of \bar{v}^a 's variations on $a_i^* - \hat{a}_i$

The confidence intervals observed in Figs. 11 and 12 depict the same results for social influence. In fact, the different values of social influence show that the variations in \bar{v}^a and \bar{v}^j have no significant effect on social influence. However, it appears that the different policy mix levels have a significant effect on social influence.

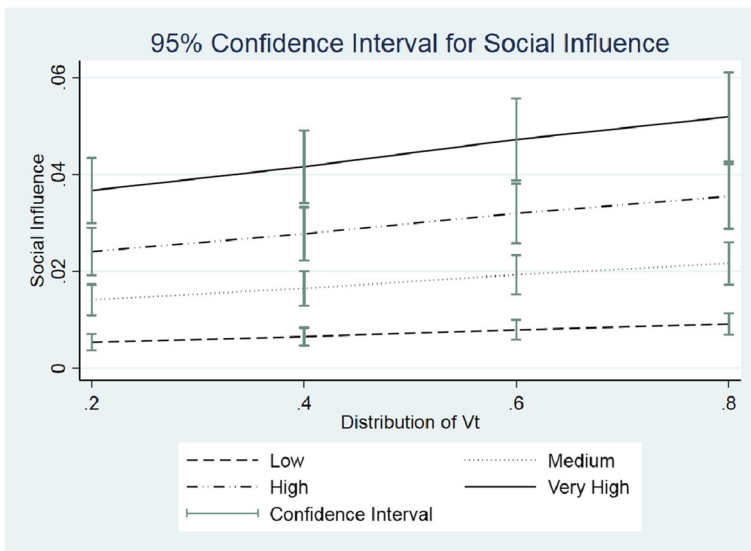


Fig. 12 The impact of \bar{v}^j 's variations on $a_i^* - \hat{a}_i$

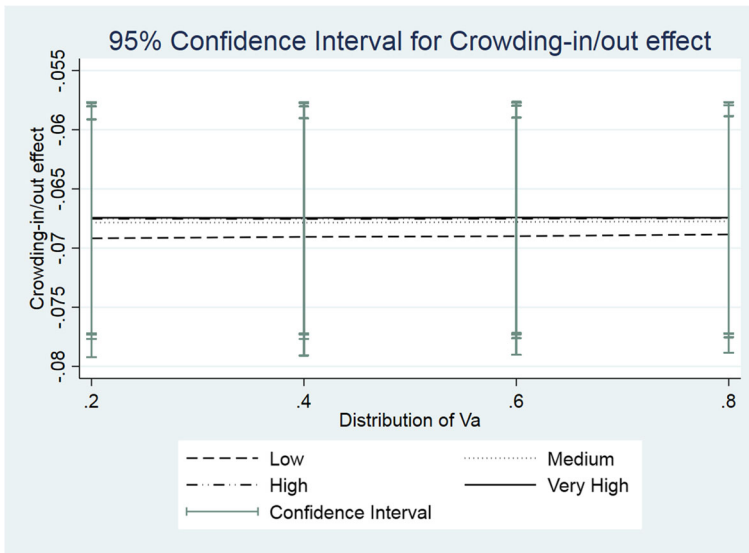


Fig. 13 The impact of \bar{v}^a 's variations on $\partial r(a_i^*(t))/\partial t$

Figures 13 and 14 refer to the crowding-out effect. The different values for the crowding-out effect show that the variation in \bar{v}^a (see Fig. 13) has no effect on the crowding-out effect. Similarly, the policy mix level has no effect on the crowding-out effect. Figure 14 indicates, as expected a decreasing relation between the extrinsic value of the population mean, and the crowding-out effect, regardless of the policy

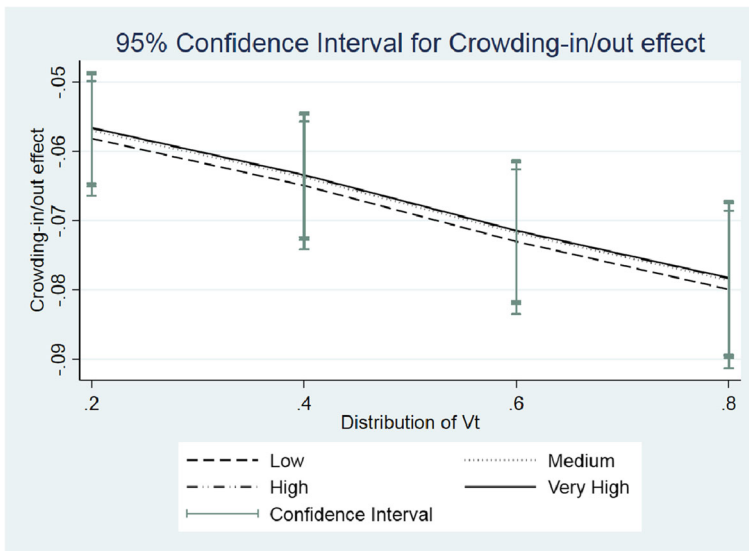


Fig. 14 The impact of \bar{v}^t 's variations on $\partial r(a_i^*(t))/\partial t$

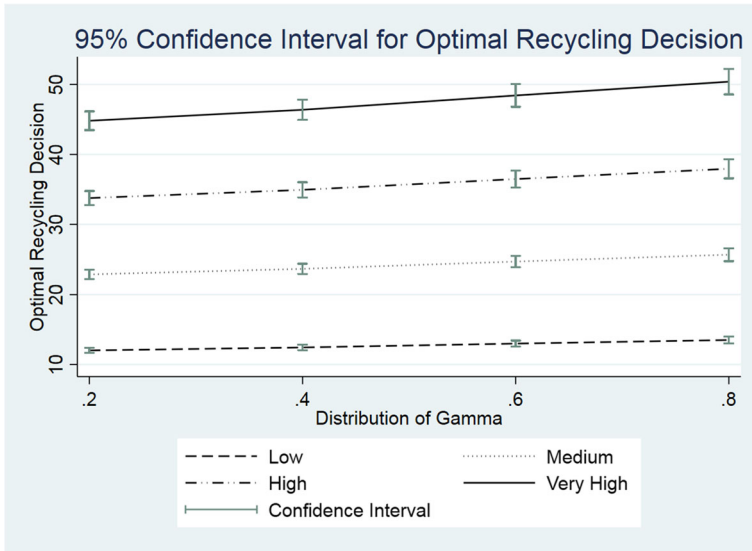


Fig. 15 The impact of $\bar{\gamma}$'s variations on a_i^*

level. The confidence intervals observed for the different values of the crowding-out effect show that the variations in \bar{v}^t do not significantly affect the crowding-out effect.

The impacts of $\bar{\gamma}$ on the optimal recycling decision and the social influence and crowding-out effect are presented in Figs. (15, 16, 17, 18, 19). Note that the policy

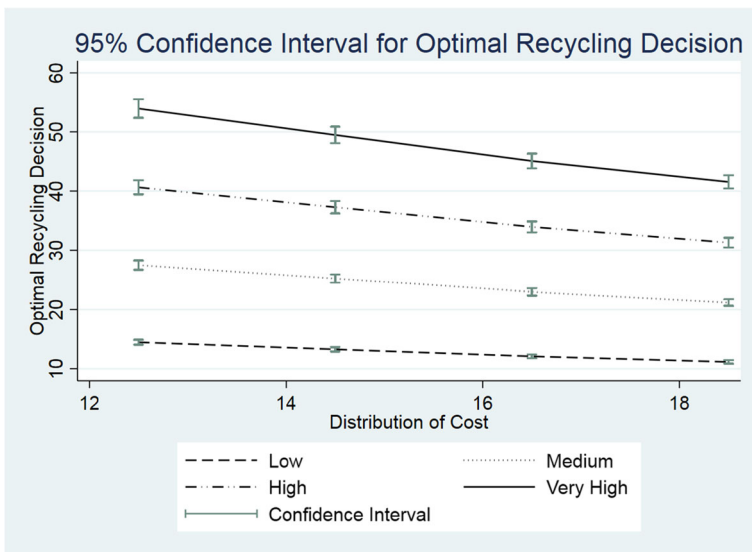


Fig. 16 The impact of \bar{C} ' variations on a_i^*

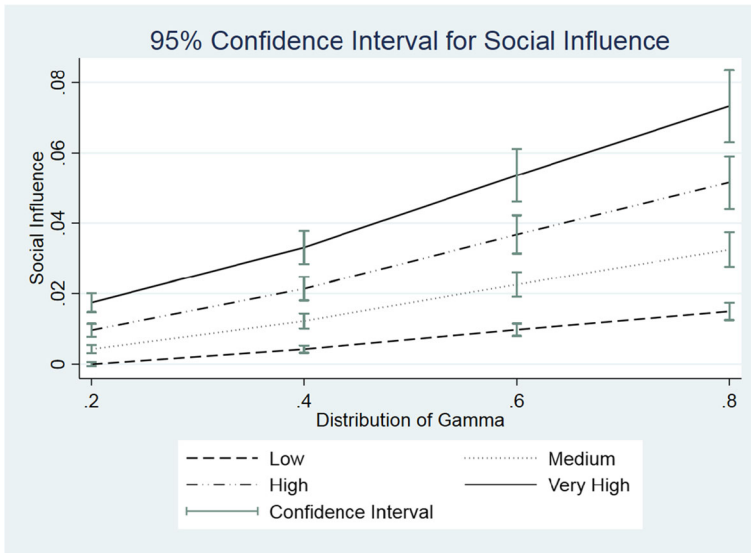


Fig. 17 The impact of $\bar{\gamma}$'s variations on $a_i^* - \hat{a}_i$

level has a significant effect on the optimal recycling decision. However, the variations in $\bar{\gamma}$ do not affect the optimal recycling decision significantly (Fig. 15). We observe that both the policy level and the variations in $\bar{\gamma}$ have a significant effect on

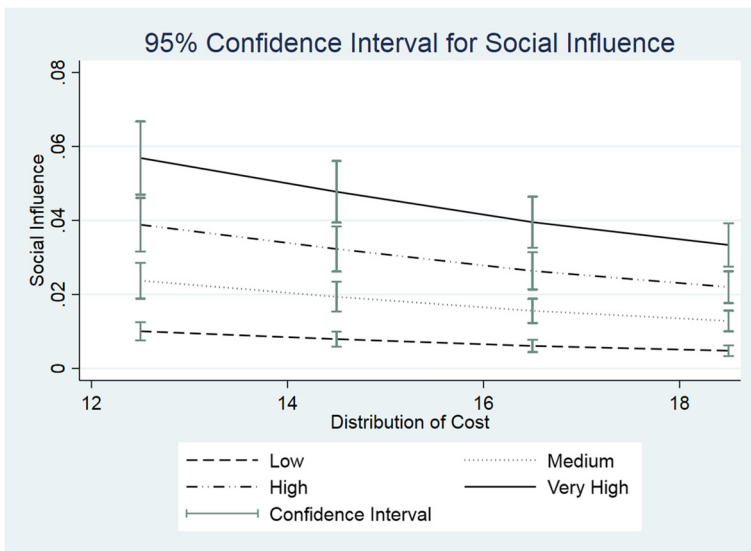


Fig. 18 The impact of \bar{C} ' variations on $a_i^* - \hat{a}_i$

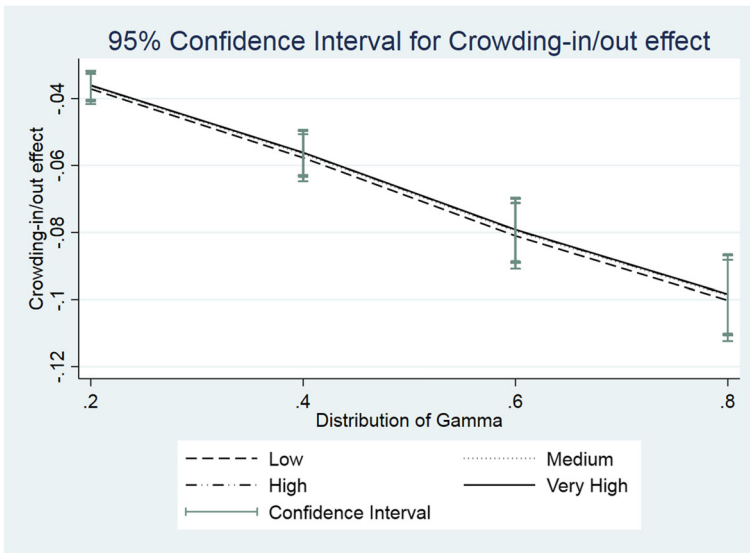


Fig. 19 The impact of $\bar{\gamma}$'s variations on $\partial r(a_i^*(t))/\partial t$

social influence (Figure 17). In relation to the crowding-out effect (Fig. 19), the variations in $\bar{\gamma}$ have a significant effect. By contrast, variations in the policy level have no significant effect on the crowding-out effect.

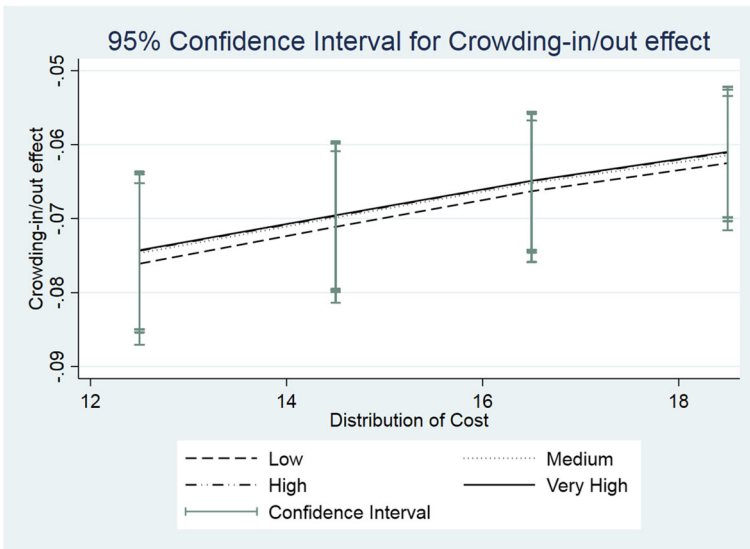


Fig. 20 The impact of \bar{C} ' variations on $\partial r(a_i^*(t))/\partial t$

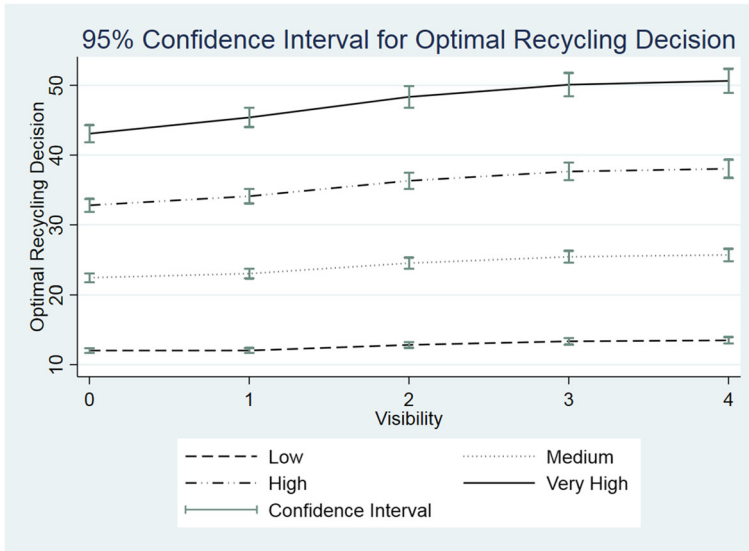


Fig. 21 The impact of x_i variations on d_i^* without nudge

In relation to the cost parameter c , we observe that it has no significant impact on the optimal recycling decision, social influence and the crowding-out effect (Figs. 16, 18, 20). We observe a relation only between policy level and crowding-out effect.

Finally, we observe that the variations in visibility do not significantly affect optimal recycling (Figs. 21 and 22). These results are observed without a nudge (Fig. 21)

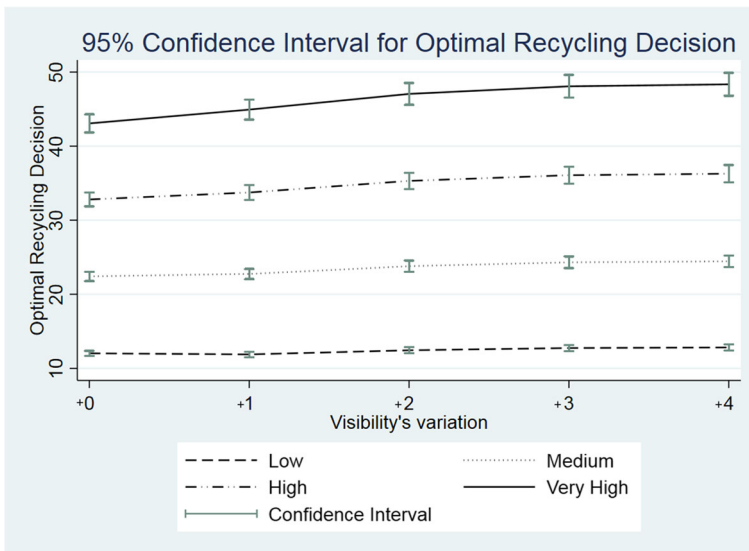


Fig. 22 The impact of x_i variations on d_i^* with the BV nudge

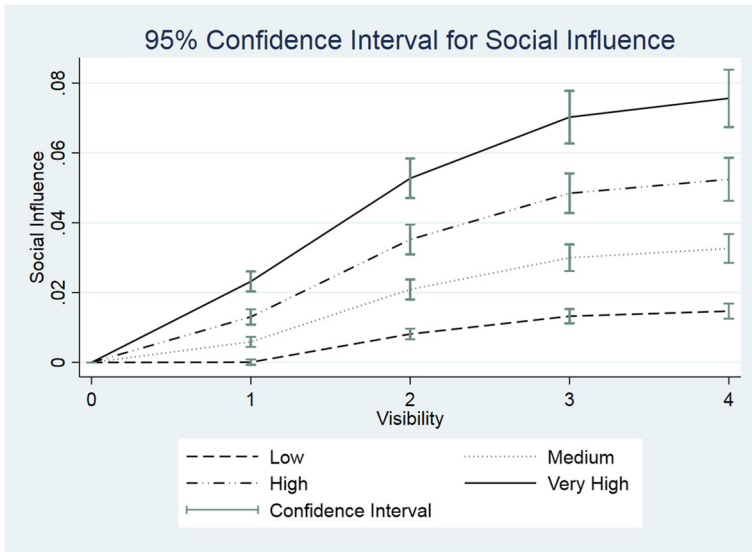


Fig. 23 The impact of x_i variations on $a_i^* - \hat{a}_i$ without nudge

and with the BV nudge (Fig. 22), which latter increases the number of contacts to four. In the case of social influence (Figs. 23 and 24), the low variations in visibility (between 0 and 2) have a significant effect on social influence. For both optimal recycling and social influence, the policy level differences significantly affect the

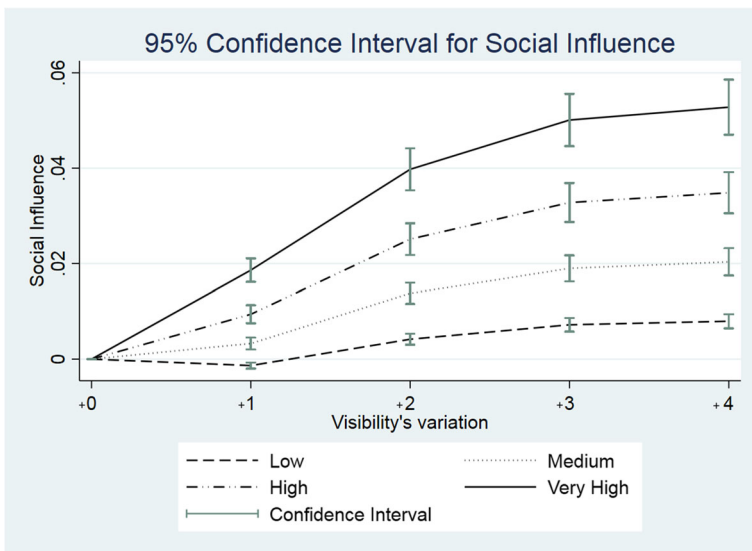


Fig. 24 The impact of x_i variations on $a_i^* - \hat{a}_i$ with the BV nudge

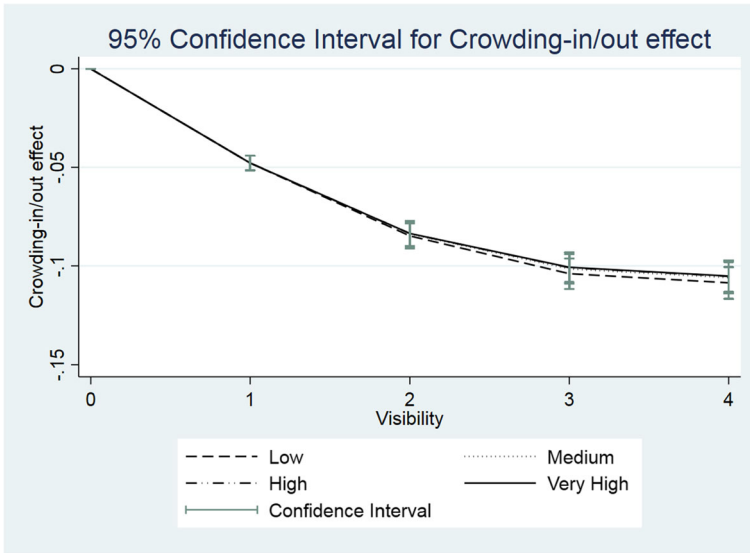


Fig. 25 The impact of x_t variations on $\partial r(a_i^*(t))/\partial t$ without nudge

impact of visibility. In relation to the crowding-out effect (Figs. 25 and 26), the policy level variations do not have a significant effect on the impact of visibility (the curves cannot be distinguished). With the exception of ow values (between 0 and 2), the variations in visibility do not significantly affect the crowding-out.

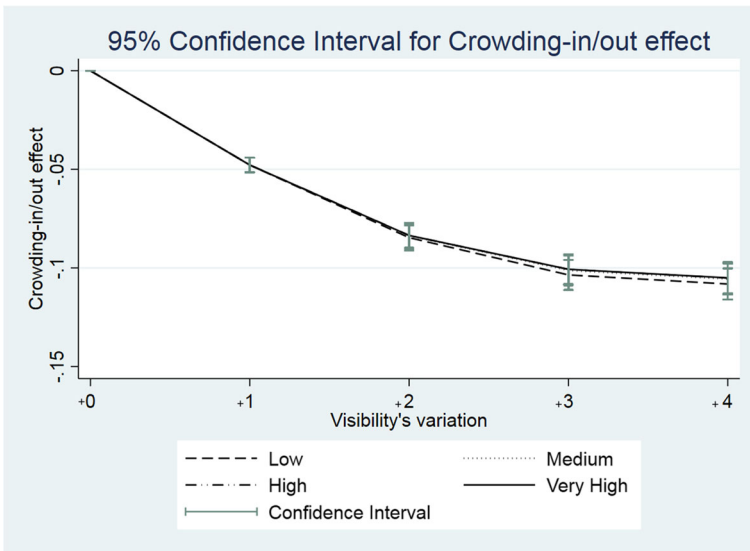


Fig. 26 The impact of x_t variations on $\partial r(a_i^*(t))/\partial t$ with the BV nudge

Appendix D: The evolution of the recycling rate over time of the simulation

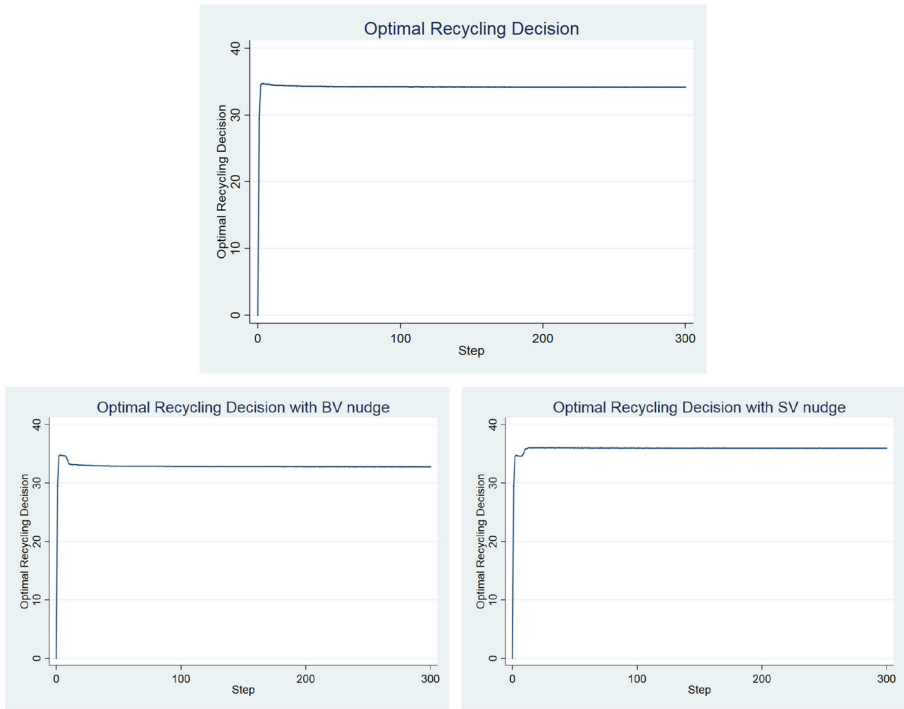


Fig. 27 Optimal recycling decision without and with nudge over time

Appendix E: Mean of beliefs on the recycling norm vs. the mean of optimal recycling decisions under the BV nudge

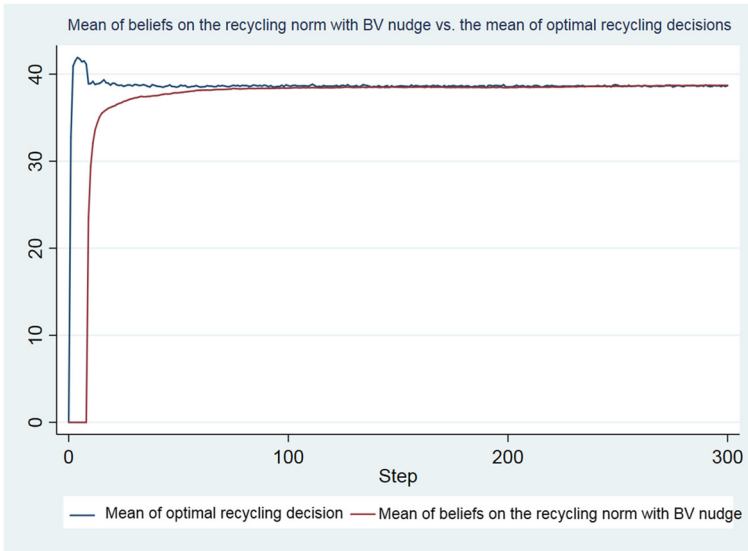


Fig. 28 Evolutions of the mean of beliefs on the norm and of the mean of optimal recycling decisions under the BV nudge

Appendix F: Micro level results vs. aggregate level results

Micro level	Aggregate level
<p>The sign of social influence is governed by a single condition implying only household characteristics: perceived norm, and “isolated decision”.</p>	<p>On average, the positive effect of social influence dominates. The social interactions tend to erase situations where negative social influence prevails. The mean of recycling rates is increasing with the pay-as-you throw tax and provision of information.</p>
<p>The reputation payment has a positive effect on recycling rates for households characterized by relatively low recycling rates.</p>	<p>Pay-as-you-throw tax increases recycling and implies a crowding-out effect.</p>
<p>A household that considers itself to be a bad (good) recycler is positively (negatively) influenced by its peers, although this influence decreases (increases) with the tax.</p>	<p>The overall positive social influence increases with the tax.</p>
<p>The BV nudge strengthens the negative impacts on social influence of the tax and provision of information.</p>	<p>Information provision first decreases, then increases social influence.</p>
<p>The crowding-out effect induced by the tax is increased (at a decreasing rate) by the BV nudge.</p>	<p>The overall peer effect is generally positive except for low values for the tax and information.</p>
<p>The BV nudge improves the positive social influence for households recycling less than the norm when isolated. It reinforces the negative social influence for households recycling more than the norm when isolated.</p>	<p>The BV nudge diminishes social influence, while the SV nudge has the opposite effect</p>
<p>The BV nudge has good results only on the decision of a “bad recycler”.</p>	

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