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IT WASN'T ME!
VISIBILITY AND FREE RIDING IN WASTE SORTING*

Alessandro Bucciol[†], Natalia Montinari[‡] and Marco Piovesan[§]

Abstract

Free riding problems can be more severe in multiple-person social dilemmas than in two-person dilemmas, since agents can hide their actions behind the veil of anonymity. In this paper, we use field data on waste sorting to study the effect of visibility in social dilemmas. We compare the sorting behavior of households sharing (or not) their bin for unsorted waste. Since households have to pay a fee proportional to their unsorted waste production, sharing the bin means sharing the fee. We find that, on average, household unsorted waste production is higher if three or more households share the same bin. Surprisingly, when only two households share the same bin, and therefore the household sorting behavior can be identified, unsorted waste production decreases compared to users not sharing the bin. Our interpretation is that shame and fear of punishment may play a role between the two sharing users.

Keywords: Social Dilemmas, Free Riding, Visibility, Waste Management.

JEL codes: D01, D78, Q53.

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1. Introduction

Social dilemmas are situations in which the rational behavior of an individual leads to suboptimal outcomes from the collective standpoint. The dilemma arises because the dominant strategy for each individual – i.e., the strategy representing her best reply regardless of what anyone else does – yields to a Pareto inferior equilibrium. Social scientists have modeled social dilemmas using different *games*. Kollock (1998) classified these games as two-person dilemmas (prisoner's dilemma, assurance game and chicken game) and multiple-person dilemmas (public goods and tragedy of the commons). Dawes (1980) pointed out that moving from two-person to multiple-person dilemmas crosses a threshold in which *anonymity* becomes possible and free riding becomes more significant, because not all the actions are *visible* to all the actors. In addition, as the number of players increases, the cost one can impose on those who fail to cooperate are diffused and diluted, thus having less threatening impact (Olson, 1965; Isaac and Walker, 1988).

In this paper we test if the free riding problem is equally important in two-person and multiple-person dilemmas or if the visibility of the action may reduce (or even eliminate) the free riding problem. Previous results from behavioral and experimental economics have in fact shown a more virtuous (and socially optimal) behavior when individual action is visible: for instance, contribution increases not only in *repeated* public good games (Bigoni and Suetens, 2012 and Samek and Sheremeta, 2014) but also in *one shot* public goods games (Andreoni and Petrie, 2004 and Rege and Telle, 2004). The intuition behind this result is that through a feeling of *shame* and consequently *fear of punishment* a norm of cooperation may be established.

With this purpose in mind, we leave the controlled but abstract environment of the lab and we go to the field. More in detail, we use a unique dataset on waste production at the household level over five years: the households in our dataset pay a per-unit fee (or pay-asyou-throw; PAYT[1] hereafter) based on the amount of unsorted waste produced[2]. We exploit the fact that when individual measurement of households' unsorted waste is unpractical the municipality makes some households share the same bin for unsorted waste with one or multiple other households. This is typically the case for condominiums with insufficient space to store individual bins or for the truck to collect them. When a bin is shared among two or more neighbors, PAYT is also shared in fixed proportions. Thus, for these households the decision to sort their waste – and therefore reduce the amount of residual waste – becomes a social dilemma and a free riding problem can emerge. In fact, the benefit of sorting (i.e., a lower PAYT fee to pay) is shared with the neighbors using the same bin while the cost of sorting (i.e., the time and effort devoted by the household) is borne entirely by the household.

Exploiting a variation in the number of households sharing the same bin we are able to exactly identify the effect of visibility on free riding, in a context where the norm prescribes to sort waste following the instructions defined by the waste management company[3]. A deviation from this norm implies an inappropriate sorting behavior and therefore additional costs to the other(s) household sharing the same bin. When two households share the same bin their actions are visible to each other and a feeling of shame may arise; in contrast, if more than two households share the same bin, the action is not (or less) visible and therefore there is no (or less) shame involved.

[1] PAYT is commonly used to promote sorting under a variety of different models depending on the region and municipality (see Kinnaman, 2006; Bucciol et al., 2014).

[2] Since PAYT directly links the actual costs for waste disposal and individual households' production of unsorted waste, it makes disposal of unsorted waste costly just like other utilities (such as electricity or water) that are charged by unit of consumption.

[3] The guidelines about waste sorting are defined at a central level by a consortium managing the waste collection for all the municipalities we study. The consortium is also responsible for informing citizens (by means of monthly newspaper, informational campaigns and public meetings) about how to correctly sort waste and about the results obtained (in terms of ratio of waste sorted) by the municipality as well as the target to be met in the future.

We find that visibility and shame are crucial factors in determining the outcome of a social dilemma situation. After controlling for household, municipality and time characteristics, we provide evidence that, compared to bins with just one user, the production of waste falls when two users share a bin (-37.6%), while it rises when three or more users share the same bin (+90.6% with three-six users and +107.3% with seven or more users). If it is not surprisingly that increasing the number of users highlights the free riding problem, it is less obvious the negative effect on unsorted waste production when only two users share the bin. Our results show that the visibility of actions induces a feeling of shame and/or fear of punishment, that leads households to increase their effort and attention in sorting compared to the case in which they do not share the waste bin.

Several papers have investigated the role of visibility in individual decision making using field data. In particular, on charitable giving, visibility of actions has a positive effect on donations to charities (Soetevent, 2005) and individuals are indeed more likely to donate in a door-to-door campaign when the solicitor can observe their donation (Soetevent, 2011). Blood donations also increase when donors receive publicly announced awards (Lacetera and Macis, 2010). Moreover, in the contest of voting, Panagopoulos (2010) finds that the shame to be in a public list of non-voters is effective to mobilize voters. However, to the best of our knowledge, we are the first to test the effect of visibility on (strategic) cooperation in social dilemmas.

Our paper contributes to the literature on behavioral and experimental economics. In particular, we provide field evidence in support to the effect of visibility on social dilemmas previously found with lab experiments. Several papers have highlighted that increasing the visibility of actions can i) activate the enforcement of social norms through shame and social disapproval (Masclet et al., 2001) and ii) determine such feelings as guilt or remorse that work as internal enforcing mechanisms for internalized norms of cooperation[4]. Other papers have demonstrated that visibility is fundamental to have an effective punishment mechanism in public goods games. In particular, the benefits of costly punishment diminishes when there is uncertainty regarding the realized endowment of subjects (Bornstein and Weisel, 2010; Patel et al., 2010) or when contributions are not perfectly observed (Grechenig et al., 2010; Ambrus and Greiner, 2012).

The rest of the paper is organized as follow: Section 2 describes the dataset and the environment we study. Section 3 presents our main results and discusses some robustness checks; finally, Section 4 concludes. The Appendix provides details on waste collection and further robustness checks.

2. Data

We use administrative panel data on unsorted waste bin emptyings at the household level in six municipalities belonging to the district of Treviso (Italy) over the period 2004-2008[5]. The six municipalities have between 10 and 20 thousand inhabitants each, and are those in the district where households more frequently live in condominiums rather than free-standing residential buildings (59.85 percent of household units overall). The consortium that administers waste collection in all these municipalities aims at providing each household with one personal waste bin. However, there are logistic and practical external conditions[6] under which it may be more efficient to let two or more households share the same bin. Nonetheless, conditional on these external conditions, a bin can still be assigned to either

[4] In the first case, when visibility by others is possible, the decision maker adjusts her behavior to avoid shame; in the second case the emotional mechanism involved is guilt, which acts internally in those individuals who have internalized the norm and therefore adjust their behavior irrespective of the possibility of being identified (Charness and Schram, 2013).

[5] The six municipalities are: Casier, Paese, Ponzano, Preganziol, Silea and Villorba. More details about these municipalities are reported in Appendix A.

[6] For instance, this happens in some condominiums when there is not enough space outside the building where to place a bin for each single households or it is dangerous for the truck to park and empty all the bins.

single or multiple households, in a way that is not under the household's control and thus not related to the household preferences on waste sorting[7]. Consequently, we have data on both households that sort waste in their personal waste bin and households that share the bin with two or more households. Appendix Section A reports a detailed description of the environment and the collection system.

Our unit of reference is each household *i* in a given year *t*. The dataset contains such information as the type of dwelling (free-standing house or condominium), the volume, number of emptyings (for waste bins), age, nationality, and number of household members (for households). Importantly, the dataset also informs on which households share the same bin and in which building they live. In this way we can also further split our observations between households living in a condominium developing *horizontally* (i.e., with separate entrances and street numbers for each household, as in the case of duplex houses or multi-unit buildings) and households living in a condominium developing *vertically* (i.e., with a common entrance and street number for several households, as in the case of apartment buildings). This distinction is important to us because it allows separating households living in different types of homes, with likely different characteristics and lifestyle. For example, we may expect that a typical household in a vertical condominium lives in a small apartment in high-density buildings, is less wealthy, and has different consumption and waste habits than the rest of the sample. This household is also more likely to share a bin because of the small space for bins to be collected by the trucks. Table C.1 in the Appendix confirms that this is indeed the case. To deal with this selection problem, we obtain our main results using only the data of households living in vertical condominium. In principle, they are all equally likely to share a bin but, depending on the factors discussed above, we observe both households

[7] In line with this, the robustness checks we perform in Section 3.1 and Appendix Section C, using samples of households with different characteristics, always confirm our benchmark findings.

sharing the bins with two or more households as well as households sharing the bin with nobody else.

In our analysis, we create a variable measuring the average volume of unsorted waste per day that can be attributed to a single household (*UW*). This variable is defined as the bin volume (*VOL*, in liters) times the household size (*SIZE*) and the number of bin emptyings (*EMPT*) in a year, and then divided by the number of days (*DAYS*) of use by all the individuals in the $J \geq 1$ households sharing the same bin[8]:

$$UW_{i,t} = \frac{VOL_{i,t} \times EMPT_{i,t} \times SIZE_{i,t}}{\sum_{j=1}^{J} SIZE_{j,t} \times DAYS_{j,t}}.$$

In particular notice that, if the bin is associated to more than one household (i.e., if $J > 1$), the formula leaves room for free riding. This formula may seem a rough estimate of the average production of unsorted waste; however, it is coherent with the one municipalities actually apply to compute the fee. Everything else being equal, a lower level of *UW* indicates that the household accumulates less unsorted waste, because either it produces less waste overall, or it is efficient in waste sorting (i.e., it sorts a high proportion of waste for a given amount produced).

Our dataset comprises 15,102 observations on 6,098 households living in vertical condominiums, with an average of 2.48 annual observations per household. To have a precise estimate and a more conservative analysis we ignored observations with the 2.5% lowest and the 2.5% highest levels of *UW* (for instance low levels of *UW* may indicate that the apartment is rarely used, whereas high levels of *UW* may indicate that the household is not fully aware of the waste pricing system). For the same reason we also exclude observations with household heads outside the 20-80-age range, which may have peculiar lifestyle (therefore

[8] Households may move, coming in an apartment (or leaving it) in any day of the year. The fee applied for the use of the waste management service is therefore adjusted for the number of days of effective use.

waste) habits. However, the analysis based on the full age range and without sample truncation provides the same conclusions (available upon request).

Table 1 reports summary statistics on our sample, overall and separately by number of users. It can be noticed that most of the observations (89.64%) regard households living in vertical condominiums but sharing the bin with nobody else, while 7.38% of the observations concern bins shared by two users (visibility) and the remaining 2.98% involve bins shared by three or more users (no visibility). Ideally, we would like to consider each number of bin users separately. However, the policy implemented by the municipalities makes it infrequent to observe the same number of users sharing a bin: for instance, we have only 64 observations on bins shared by three households, and 65 observations on bins shared by four households.

For this reason we consider four groups: one user per bin (no free riding), two users per bin (free riding and visibility), three-six users (free riding with high degree of visibility) and seven or more users (free riding with low degree of visibility). We defined the last two groups in such a way to have (roughly) a similar number of observations, but different degrees of visibility.[9]

TABLE 1. Average statistics

N. bin users	**All**	**1 user**	**2 users**	**3-6 users**	**7+ users**
Unsorted waste (liters per user per day)	2.111	2.002	1.784	6.425	5.952
Head age	38.495	38.698	36.289	37.664	38.053
Head foreign	0.216	0.202	0.328	0.363	0.368
Household moved to different location	0.017	0.008	0.123	0.031	0.026
N. household members	1.936	1.934	2.067	1.857	1.509
N. households in the building	6.727	6.722	6.372	4.341	11.110
N. bin users	1.294	1	2	4.381	12.303
Year	2006.687	2006.695	2006.715	2006.377	2006.368
Municipality 1: *Casier*	0.163	0.169	0.145	0.031	0.022
Municipality 2: *Paese*	0.194	0.193	0.196	0.377	0.053
Municipality 3: *Ponzano*	0.164	0.160	0.183	0.135	0.333
Municipality 4: *Preganziol*	0.193	0.201	0.166	0.040	0
Municipality 5: *Silea*	0.096	0.097	0.097	0.072	0.061
Municipality 6: *Villorba*	0.190	0.180	0.214	0.345	0.531
N. observations	15,102	13,537	1,114	223	228

[9] It may be that the number of bin users is larger than the number of households in the building. In fact, households may also share the bins with households living in a contiguous building.

3. Results

Table 2 reports the results of a regression analysis on the variable under investigation, using a pooled OLS model (Column 1), a panel random-effect model (RE, Column 2), and a panel fixed-effect model (FE, Column 3). In all the cases the dependent variable is the logarithm of *UW*. The specification includes dummy variables informing whether the household shares the bin with one or more other households, characteristics of the household (age and nationality of the head, household size, whether it moved from a different place during the year), number of other households in the building, and year. The three models provide similar findings with respect to our key variables (the number of users sharing the same bin). The statistical tests reported in the bottom part of Table 2 suggest that, among the three models, we should prefer the FE model of Column (3); this model is also more robust to wrong specification as it allows to remove unobservable household-specific effects on waste behavior[10]. For this reason, in the following we comment on the fixed-effect estimates only.

Our analysis shows that compared to bins with just one user, the production of waste falls when two users share a bin (-37.6%), while it rises when three or more users share the same bin (+90.6% with three-six users and +107.3% with seven or more users). The latest two effects are insignificantly different from each other according to an F test with a 5% significance level (statistic: 3.39; p-value: 0.07).

Figure 1 plots the average production of unsorted waste per day per household, predicted using the FE model, conditional on the number of users sharing the same bin and the average of the other explanatory variables. From the figure it is clear that the production of waste, which on average amounts to 1.88 liters per day for a single user, falls to 1.29 liters

[10] As a robustness check, we replicated the same analysis where the dependent variable is now the logarithm of *UW* normalized by household size using different equivalence scales. The results, reported in Appendix Section B, are consistent with our benchmark findings.

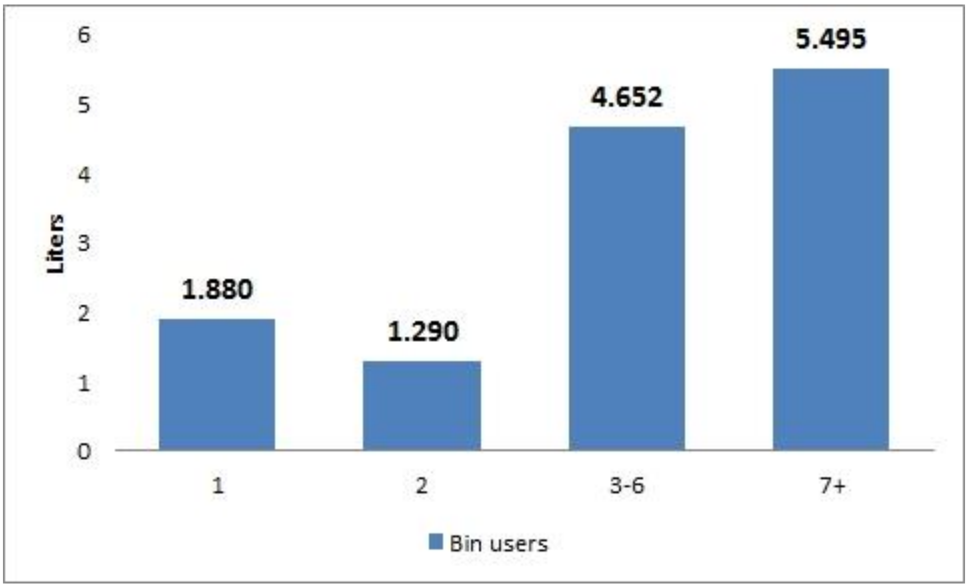
for 2 users sharing the same bin, and rises for multiple users (4.65 for 3-6 users and 5.50 for 7 or more users.)

TABLE 2. Free riding and visibility: benchmark analysis

Method	**(1) OLS**	**(2) RE**	**(3) FE**
Bin shared by 2 users	-0.269***	-0.330***	-0.376***
	(0.022)	(0.019)	(0.024)
Bin shared by 3-6 users	1.132***	1.023***	0.906***
	(0.047)	(0.049)	(0.079)
Bin shared by 7 or more users	1.157***	1.119***	1.073***
	(0.047)	(0.050)	(0.083)
Age/10	-0.168***	-0.105***	0.714**
	(0.030)	(0.040)	(0.285)
$(Age/10)^2$	0.016***	0.010**	-0.084***
	(0.003)	(0.004)	(0.018)
Foreign	-0.003	0.020	
	(0.014)	(0.019)	
Household moved to different location	-0.011	0.000	0.003
	(0.045)	(0.038)	(0.049)
Ln(No. household members)	0.537***	0.452***	0.226***
	(0.012)	(0.014)	(0.027)
Ln(No. households in the building)	-0.035***	-0.052***	-0.100***
	(0.008)	(0.011)	(0.024)
Year 2006	-0.055***	-0.037***	-0.020
	(0.018)	(0.013)	(0.031)
Year 2007	-0.142***	-0.115***	-0.085
	(0.017)	(0.013)	(0.054)
Year 2008	-0.178***	-0.144***	-0.106
	(0.017)	(0.014)	(0.078)
Municipality: Casier	-0.092***	-0.103***	
	(0.019)	(0.027)	
Municipality: Ponzano	0.007	-0.000	
	(0.019)	(0.027)	
Municipality: Preganziol	-0.176***	-0.166***	
	(0.018)	(0.026)	
Municipality: Silea	-0.117***	-0.127***	
	(0.022)	(0.031)	
Municipality: Villorba	-0.024	-0.027	
	(0.018)	(0.026)	
Constant	0.718***	0.632***	-0.882
	(0.067)	(0.087)	(0.932)
Observations	15,102	15,102	15,102
Number of users	6,098	6,098	6,098
R^2	0.205	0.203	0.107
R^2 within-group		0.067	0.076
Fraction of variance due to user effects		0.570	0.681
Test for random user effects		4,686.30	
(OLS vs. RE; chi-squared with 1 d.o.f.)		[0.000]	
Test for fixed user effects			25,790.31
(OLS vs. FE; chi-squared with 6,098 d.o.f.)			[0.000]
Test for random vs. fixed user effects			128.34
(RE vs.FE; chi-squared with 11 d.o.f.)			[0.000]

*Note: The dependent variable is the logarithm of the average unsorted waste (in liters per user per day). Standard errors in round brackets; p-values in square brackets; *** p < 0.01, ** p < 0.05, * p < 0.1.*

FIGURE 1. Predictions of unsorted waste per user conditional on the number of bin users



Our results thus suggest that free riding is severe only when visibility is not possible (in groups of three or more users). The visibility of the action can not only mitigate free riding but also trigger a more virtuous behavior: such factors as *shame* or *fear of punishment* may indeed induce even less motivated households to increase their effort and attention in sorting. In groups of three or more users these factors are less relevant, since the lack of visibility of one's action prevents from detecting the actual behavior of each user. Interestingly, we observe that the free riding effect is identical in groups of different size whenever imperfect information is involved. Therefore, based on this finding, we argue that the key element for the emergence of free riding is visibility, which makes it impossible for a mechanism based on shame and fear of punishment to motivate individual behavior.

One might argue that our finding that the production of waste falls when two users share the bin is spurious and it depends on characteristics of the dwellings that we do not observe. In fact, a potentially important omitted variable in our dataset is the dwellings size. However, it is reasonable to assume that dwellings size is highly correlated with household size – which we observe and use as control variable in the analysis. We also think (as the consortium managing waste collection) that it is the number of people living in the house that should determine waste production. From Table 1 we know that the average number of household members is similar (and insignificantly different) in observations where the bin has one or two users (respectively 1.98 and 2.08). In contrast, the average number of household members is statistically smaller in observations with three-six bin users and especially with seven or more bin users (see again Table 1), which may suggest that users sharing the bin with more than one other user indeed live in smaller apartments. Since we find that more waste is produced in apartments where three or more users share the bin, controlling for the fact that apartments are likely smaller we would find even larger free riding effects under anonymity than we do.

3.1. Robustness checks

A possible concern with our analysis is that households are not randomly selected for bin sharing, and are instead selected for logistic reasons. Typical bin sharers are households living in high-density buildings; these households are likely less wealthy, live in smaller apartments, and have different consumption and waste habits than the rest of the sample. Our sample selection strategy, i.e., our decision to focus on vertical condominiums only, should limit this problem.[11]

In this subsection we run two robustness checks. Table 3 compares our benchmark results (Column 1) with those where the sample includes only households who changed bin sharing mode over time (Column 2) and those where the sample excludes single bin users (Column 3.) The purpose is to focus on the same households experiencing different bin

[11] In Appendix Section C we discuss the case where the sample is extended to also include households in horizontal condominiums and free-standing buildings. Our findings remain unchanged.

sharing modes[12] (Column 2) and households with likely more similar characteristics as opposed to single bin users (Column 3).

TABLE 3. Free riding and visibility: robustness checks

Sample	(1) All	(2) Movers	(3) Sharers
Bin shared by 2 users	-0.376***	-0.323***	
	(0.024)	(0.034)	
Bin shared by 3-6 users	0.906***	0.835***	0.756***
	(0.079)	(0.100)	(0.210)
Bin shared by 7 or more users	1.073***	0.998***	1.043***
	(0.083)	(0.106)	(0.225)
Age/10	0.714**	0.217	-2.516
	(0.285)	(0.852)	(2.053)
$(Age/10)^2$	-0.084***	-0.214***	0.027
	(0.018)	(0.068)	(0.159)
Household moved to different location	0.003	-0.150*	-0.275
	(0.049)	(0.084)	(0.258)
Ln(No. household members)	0.226***	0.203***	0.710***
	(0.027)	(0.077)	(0.261)
Ln(No. households in the building)	-0.100***	-0.229***	-0.304
	(0.024)	(0.074)	(0.220)
Year 2006	-0.020	0.055	0.144
	(0.031)	(0.087)	(0.216)
Year 2007	-0.085	0.118	0.034
	(0.054)	(0.152)	(0.376)
Year 2008	-0.106	0.201	0.087
	(0.078)	(0.221)	(0.547)
Constant	-0.882	2.954	9.222
	(0.932)	(2.555)	(6.199)
Observations	15,102	2,573	1,565
Number of users	6,098	1,142	1,292
R^2 within-group	0.076	0.229	0.180
Fraction of variance due to user effects	0.681	0.919	0.934

*Note: The dependent variable is the logarithm of the average unsorted waste (in liters per user per day). Estimates are obtained with a fixed-effect regression model. Column (1) reports the benchmark case of Table 2; Column (2) focuses on the households who changed user condition within the sample; Column (3) focuses only on the households who share the bin with at least one other household. Standard errors in round brackets; p-values in square brackets; *** p < 0.01, ** p < 0.05, * p < 0.1.*

Despite the large sample reduction – the sample size in Columns (2) and (3) is around one sixth and one tenth of that in Column (1), respectively – our findings are preserved, both qualitatively and quantitatively: those who share the bin with one other user produce less waste (-32.3% in Column 2) than single users; those who share the bin with two or more users instead produce more waste, with an increase in the order of +80-100% (Columns 2 and 3.) This evidence makes us confident that our results are robust to sample selection.

[12] Transitions more frequently arise from single users to two users (1,049 observations).

In the Appendix Sections B and C we run two further robustness checks, using equivalence scale correction for *UW* and extending the sample to include households living in different types of building. Our results are preserved in all the cases.

4. Conclusion

In this paper we use field data to investigate if visibility limits the free riding problem in social dilemmas. For this purpose, we use a unique dataset on waste production at the household level and we estimate the net effect of free riding controlling for household, municipality and time characteristics. In particular, we test how visibility affects free riding by comparing household waste production when a household shares the same bin with one other user (where the author of misbehavior is indirectly observable) and when it shares the bin with multiple users (where visibility is lower and therefore misbehavior cannot be clearly identified).

We find that free riding is present when multiple households share the same bin. On the contrary, when only two households share the same bin, average household waste production decreases compared to households not sharing the bin. Our results in fact show that, when each agent can (indirectly) observe the behavior of the other, not only the free riding problem is limited or disappears, but also households exert more effort and attention in sorting compared to the situation when they do not have to share the bin. Therefore, our findings suggest that visibility fosters shame and thus can promote a more virtuous behavior.

We use these data on waste sorting to test the external validity of some recent findings on the effect of visibility in social dilemmas provided by the literature in behavioral and experimental economics. In addition, our findings are line with the evidence of several studies suggesting that providing households with information about peers fosters norm compliance and conformity (see, Cialdini, 2008.) Energy saving, electricity and water consumption are classical examples in environmental economics (see, e.g., Alcott, 2011; Ayers et al., 2012; Costa and Kahn, 2013; Ferraro and Price, 2013); work effort, charitable giving, and tax compliance are broader example (see, e.g., Fortin et al. 2007; Mas and Moretti, 2009; Soetevent, 2005). In all these case, visibility of individual actions can reduce or even eliminate the free riding problem typical of social dilemmas and induce the (socially) optimal behavior through norm adherence.

Finally, we believe that future research should continue on this direction and provide additional support on the effectiveness of visibility. In particular, we think it is important to identify what is the psychological mechanism behind this result. Are people differentiating more because they want to avoid *shame* or because of the *fear of punishment* from their neighbors? These questions are in our future research agenda.

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APPENDIX

A. Waste Collection and Municipalities

Some municipalities in the district of Treviso (Italy) are implementing a per-unit billing system for the management of municipal solid waste. Households pay, once every year, a fee according to a formula made of two parts: a fixed part – equal to everybody and proportional to the number of household members – and a variable part proportional to the number and the size of the bins for unsorted waste that are presented for emptying. The purpose of this monetary incentive is to limit the accumulation of unsorted waste.

In general, each household is endowed with its own bins. Waste collection follows a regular schedule; households willing to get rid of their waste just place the bins out of their door in the scheduled days of the week. A transponder in the bin keeps track of all the emptyings attributed to a given household. The only exception is the case where two or more households share the same bin. This frequently arises in the context of condominiums for practical reasons – essentially related to the lack of enough space for the bins or for the collecting truck. Even when the bin is shared, it is placed out of the building for collection every time it is full. Since it is not possible to identify the contribution of each household to the production of waste, the fee is determined by dividing the total cost of emptyings among the households sharing the bin, in a way proportional to household size. This imputation gives rise to a potential free riding problem, in that households might have a lower incentive to reduce the accumulation of waste, because their monetary penalty would then be split with one or more other households.

In this study, we consider six municipalities of the district: Casier (10,921 inhabitants in 2008); Paese (21,208 inhabitants in 2008); Ponzano (11,769 inhabitants in 2008), Preganziol (16,596 inhabitants in 2008); Silea (9,897 inhabitants in 2008) and Villorba (17,994 inhabitants in 2008). The number of inhabitants, as well as further information about other characteristics of these municipalities can be obtained from the online statistical database of the Veneto region.[13] Households in our sample are expected to have similar experience with the per-unit billing system, that in all the six municipalities was implemented between 2001 and 2002, i.e., between 2 and 3 years before the beginning of our sample period.

B. Robustness Check: Equivalence Scale

We replicate the benchmark analysis shown in Table 2, correcting the *UW* measure by the household size through equivalence scales. In general, there is no accepted method for determining equivalence scales, and for this purpose we use three alternatives: two OECD equivalence scales for consumption (modified and square root), as well as a scale derived from our data.

Regarding the OECD modified scale, we cannot measure it exactly because we do not have information on the number of adults and children present in the households. For this reason, we give to each member in addition to the head a weight of 0.5 – which corresponds to the weight of an adult in the OECD modified scale, and to the weight of a child in the old OECD scale (a.k.a. Oxford scale).

Due to this complication, in addition to the modified OECD equivalence scale we also consider the squared root OECD equivalence scale (we correct household waste production by the squared root of the number of household members), and a "data-driven" equivalence scale that we construct on our own from the data. We derive this scale from the regression of the logarithm of the number of liters per user over dummy variables on household composition (2, 3, 4 or more members), plus age, age squared, foreign nationality, year and municipality dummies as control variables. The regression focuses only on those who do not

[13] http://statistica.regione.veneto.it/banche_dati_societa.jsp

share the bin with other users (13,537 observations) to neutralize potential free riding effects. The scale based on this regression gives a weight of 1 to a household made of one member, a weight of 1.13 to a household made of two members, a weight of 1.29 to a household made of three members, and a weight of 1.32 to a household made of four or more members.

Appendix Table B.1 reports the estimates of the coefficients in the fixed-effect regression model using the three definitions of equivalence scale. Our results remain virtually unchanged. In particular, we keep predicting a reduction of the production of unsorted waste in the case of two users, and a generalized increase in the case of three or more users – disregarding the actual number of users.

TABLE B.1. Free riding and visibility: equivalence scale correction

Equivalence scale	(1) Modified	(2) Squared-root	(3) Data-driven
Bin shared by 2 users	-0.376***	-0.376***	-0.376***
	(0.024)	(0.024)	(0.024)
Bin shared by 3-6 users	0.902***	0.906***	0.905***
	(0.079)	(0.079)	(0.079)
Bin shared by 7 or more users	1.076***	1.073***	1.071***
	(0.083)	(0.083)	(0.083)
Age/10	0.695**	0.714**	0.696**
	(0.285)	(0.285)	(0.285)
$(Age/10)^2$	-0.082***	-0.084***	-0.082***
	(0.018)	(0.018)	(0.018)
Household moved to different location	0.004	0.003	0.002
	(0.049)	(0.049)	(0.049)
Ln(No. household members)	-0.419***	-0.274***	0.021
	(0.027)	(0.027)	(0.027)
Ln(No. households in the building)	-0.099***	-0.100***	-0.101***
	(0.024)	(0.024)	(0.024)
Year 2006	-0.020	-0.020	-0.020
	(0.031)	(0.031)	(0.031)
Year 2007	-0.085	-0.085	-0.084
	(0.054)	(0.054)	(0.054)
Year 2008	-0.107	-0.106	-0.105
	(0.078)	(0.078)	(0.078)
Constant	-0.823	-0.882	-0.835
	(0.932)	(0.932)	(0.932)
Observations	15,102	15,102	15,102
Number of users	6,098	6,098	6,098
R^2 within-group	0.110	0.092	0.074
Fraction of variance due to user effects	0.682	0.681	0.681

*Note: The dependent variable is the logarithm of the average unsorted waste (in liters per user per day), corrected using a different equivalence scale in each column. Estimates are obtained with a fixed-effect regression model. Standard errors in round brackets; p-values in square brackets; *** p < 0.01, ** p < 0.05, * p < 0.1.*

C. Robustness Check: Residential Buildings

Our benchmark analysis focuses on households living in vertical condominiums to have a sample with similar characteristics. However, these households account to about 49% of the households in the six municipalities we analyze. Nearly 11% of the households live in horizontal condominiums, and the remaining 40% live in free-standing residential buildings. As Appendix Table C.1 clarifies, the frequency of households sharing the bin with others is smaller in horizontal condominiums and especially in free-standing buildings. Nonetheless, it is not null.

TABLE C.1. Proportion of bin users by home unit type

N. bin users	Observations	1 user	2 users	3-6 users	7+ users
Vertical condominiums	15,102	0.896	0.074	0.015	0.015
Horizontal condominiums	3,284	0.970	0.018	0.009	0.002
Free-standing residential buildings	12,333	0.959	0.036	0.002	0.003
All	30,719	0.930	0.053	0.009	0.009

Note: Proportions sum to one by row.

Appendix Table C.2 compares our benchmark results based on households living in vertical condominiums (Column 1) with those based on households living in vertical or horizontal condominiums (Column 2) and those based on all the households (Column 3). In Columns (2) and (3), we control for the type of building including a "vertical condominium" dummy variable. In Column (3), we cannot add one further dummy variable (for instance, one identifying horizontal condominiums) for collinearity: the reason is that households' movements arise only between vertical and horizontal condominiums. Of course households in free-standing buildings may also move, but in our sample they always move from a free-standing building to another.

Our findings are preserved, both qualitatively and quantitatively. Compared to a household sharing the bin with nobody else, households sharing the bin with one or more households produce less waste (about -37%) while households sharing the bin with 2 or more other households produce more waste (at least +82% for 3-6 users, and at least +104% for 7 or more users.) Interestingly, we also observe a small increase in waste production (+6.2%) when the household lives in a vertical condominium.

TABLE C.2. Free riding and visibility: home unit type

Home unit	**(1) Vertical condominiums**	**(2) Condominiums**	**(3) All**
Vertical condominium		0.062**	0.062**
		(0.027)	(0.025)
Bin shared by 2 users	-0.376***	-0.373***	-0.376***
	(0.024)	(0.022)	(0.018)
Bin shared by 3-6 users	0.906***	0.933***	0.822***
	(0.079)	(0.073)	(0.066)
Bin shared by 7 or more users	1.073***	1.067***	1.038***
	(0.083)	(0.081)	(0.073)
Age/10	0.714**	0.648***	0.589***
	(0.285)	(0.229)	(0.172)
$(Age/10)^2$	-0.084***	-0.083***	-0.085***
	(0.018)	(0.016)	(0.012)
Household moved to different location	0.003	-0.061	-0.097***
	(0.049)	(0.043)	(0.033)
Ln(No. household members)	0.226***	0.262***	0.254***
	(0.027)	(0.024)	(0.018)
Ln(No. households in the building)	-0.100***	-0.109***	-0.108***
	(0.024)	(0.022)	(0.017)
Year 2006	-0.020	-0.018	-0.009
	(0.031)	(0.025)	(0.019)
Year 2007	-0.085	-0.081*	-0.057*
	(0.054)	(0.043)	(0.033)
Year 2008	-0.106	-0.101	-0.077*
	(0.078)	(0.062)	(0.047)
Constant	-0.882	-0.734	-0.431
	(0.932)	(0.741)	(0.566)
Observations	15,102	18,386	30,719
Number of users	6,098	6,971	11,657
R^2 within-group	0.076	0.078	0.068
Fraction of variance due to user effects	0.681	0.683	0.717

*Note: The dependent variable is the logarithm of the average unsorted waste (in liters per user per day). Estimates are obtained with a fixed-effect regression model. Column (1) reports the benchmark case of Table 2, focusing on vertical condominiums only; Column (2) focuses on vertical and horizontal condominiums; Column (3) focuses on vertical and horizontal condominiums, as well as free-standing residential buildings. Standard errors in round brackets; p-values in square brackets; *** p < 0.01, ** p < 0.05, * p < 0.1.*