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The Can Challenge: Understanding the best ways to incentive recycling through a diffusion approach

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The Can Challenge: Understanding the best ways to incentive recycling through a diffusion approach[1]

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Abstract

Understanding the best ways to incentive recycling and improve the efficiency of waste practices is a key environmental, social and economic management problem that needs addressing.
We search for solutions to this issue by implementing a field experiment with two incentive mechanisms (a piece-rate and a lottery-based systems) in three different locations; a residential, a workplace and a student environment. We model our experimental data with the Bass Model, which to the best of our knowledge has never been employed to analyse experimental data and to gather a deeper understanding of the diffusion process among individuals adopting the recycling service.
Our results indicate a high degree of heterogeneity across our trial locations. Incentivising recycling can stimulate action by those on lower incomes through opportunities for income generation. By contrast, those in workplace environments engage with or without incentives, but the latter does seem to boost activity. Our study contributes to the literature by providing evidence on how to best increase public involvement through recycling and provides important insights for policy making to address this worldwide relevant issue.

Keywords: Recycling Behaviour; Field Experiment; Monetary Incentives; Bass Diffusion Model.

JEL: C32; C93; D90; Q53.

1 Introduction

The increase in waste witnessed in modern societies poses a huge management challenge. Rethinking waste disposal and minimising those by-products directed to landfill have become major areas of focus for both businesses and policy makers. Globally, these themes are crucial to preventing environmental degradation and indeed span many of the UN Sustainable Development Goals.[2] Waste recycling programs, among many other interventions, have become key areas for local and national policy making. Although these are implemented in many communities, the engagement from individuals can often be low. For example, it is

[1] We would like to thank our research partners at Norwich City Council, Norfolk County Council and UEA Accommodation Office. We would also like to thank participants at the conferences [BIOECON 2019, ESA 2020, MEA 2021] where we have presented this paper for their insightful views and comments

[2] www.un.org

widely acknowledged that the UK population fails to engage in recycling at optimal levels[3] even when there is strong public awareness that waste by-products are recyclable. It is therefore paramount to increase our understanding of the determinants of recycling behaviour to improve public uptake and engagement (see reviews by Knickmeyer, 2020; Miafodzyeva and Brandt, 2013; Varotto and Spagnolli, 2017).

With a field experiment, we compare the effectiveness of two different types of monetary incentives, sure and probabilistic rewards, on drink cans recycling. We do so in three different locations: students' accommodations at the University of East Anglia, social housing with Norwich City Council as a landlord, and Norfolk County Council's offices. By interpreting recycling activity as a product, we borrow the Bass (1969) model from the marketing literature to study its diffusion process. To the best of our knowledge this model has never been applied to recycling behaviour.

The academic literature on recycling behaviour classifies the most important determinants into social, psychological, and economic factors (see Knickmeyer, 2020 Miafodzyeva and Brandt, 2013; Varotto and Spagnolli, 2017). Economic factors (e.g. prizes, lottery tickets, monetary rewards) have been shown to increase the engagement in recycling (see, for example, Iyer and Kashyap 2007). Luyben and Bailey (1979) found that monetary rewards increased the amount of paper recycled more than just providing easy access to the recycling facility. In two related studies, Geller et al. (1975) and Witmer and Geller (1976) found that individual raffles were more effective than group ones in increasing recycling volumes, and that both were more effective than no reward at all.

Closer to our investigation is the study by Diamond and Loewy (1991) who provide evidence that lotteries were more effective in changing recycling behaviour than sure rewards. In a subsequent quasi-experimental field study, they show that lotteries were also more effective than individualistic or group rewards in increasing recycling of glass and paper. Our study still differs from theirs in several respects. The sure reward we implement is proportional to the recycling volume rather than being a fixed amount. Our Lottery prizes are similarly determined by the amount contestants recycle rather than being exogenously determined. Finally, we implement our field experiment across three different locations, rather than just in student accommodations.

Recycling behaviour in one setting has been shown not to carry over to other settings. For example, people recycle less while on holidays (Barr et al., 2010), at university (Scott,

[3] www.packagingnews.co.uk

2009) or in the workplace (Marans and Lee, 1993; Lee et al., 1995). Despite this, household recycling has received much more attention than recycling in other settings. What is more, studies carried out in university dormitories are sometimes classified as run in the workplace (e.g., Oke, 2015). In fact, only a handful of studies have occurred in real workplaces, and most of these employ surveys as an investigative method (Marans and Lee, 1993; Lee et al., 1995). Our study offers novel and invaluable insights into employees' observed recycling behaviour, and how this compares to that of students and social housing residents. Our results show that incentives have little effect in increasing recycling among students. They boost an already present recycling activity in the working environment and are essential in the residential one. We do not find statistically significant differences between sure rewards and probabilistic ones, and results again vary depending on the location.

Viewing recycling behaviour through the marketing lens offers new tools to tackle long-standing issues of under-engagement with this service. Fuller (1978), for example, explores ways to improve reverse marketing strategies such as differentiated communications with the consumer. Shrum et al. (1994) propose a new framework in which recycling behaviour is the product that consumers wish to adopt, the price of the product is the cost of recycling to the individual and the distribution channels are the ways in which consumers can recycle (in their house for example or taking waste to disposal centres). Communication strategies, such as advertising, can then be directed to the public or tailored to specific groups. Meneses and Palacio (2005) define members of the household as consumers with different recycling tasks. Marketing strategies should then be tailored to increase the engagement with their task. We contribute to this strand of literature by making use of the Bass model to analyse our data.

The Bass Model has been traditionally employed to study the diffusion process of new products to provide long-term forecasts of sales that otherwise would be nothing more than a guess (Bass, 1969). The model classifies the potential adopters of a new product based solely on the timing of their initial purchase. Within a social system, innovators are the first adopters and only influenced by direct information about the product (e.g. advertising channels). Imitators adopt the product at a later point in time and are influenced by indirect communication channels within the social system (e.g. word of mouth).

In the model, informational exchanges play a critical role in influencing the diffusion process.[4] The greater the intensity of informal informational exchanges, the larger the

[4] For a detailed review of the Bass (1969) model and its key elements see the work of Mahajan, Muller & Bass (1990).

proportion of imitators. It is reasonable to believe that this intensity varies across social systems. In our context, employees working in open-plan offices (Working Environment - WE) might have more chances to exchange information than households living in self-contained flats (Residential Environment – RE), or even perhaps students that share an accommodation for the first time (Student Environment – SE).

In our field experiment, after implementing a 10-week Monitoring Phase, where the recycling activity is not monetarily incentivised, we implement a 10-week Incentive Phase in which monetary rewards are introduced. The introduction of a new recycling system and subsequently of monetary incentives can be thought of as the introduction of a new product in the market and a subsequent innovation. The model allows us to empirically estimate how this innovation changes the size and the shape of the population of adopters, allowing us to offer long-range forecasts of recycling activity.

Our results on the diffusion process (Section 4) show that in the Monitoring Phase, the number of potential adopters in SE and RE are not significantly different from zero, implying the absence of a growing diffusion process. In WE by contrast, we find a growing diffusion process. In the Incentive Phase, in SE we find no or very mild diffusion, while we observe a persistently growing diffusion process in WE and RE. The main difference between WE and RE is that a diffusion process in WE is also present in the Monitoring Phase. These results by and large complement our analysis of overall recycling by incentive type (Section 3). In our workplace, this suggests that incentives provide a boost but are not the main determinant of recycling. To further support this conjecture is the finding of persistent diffusion in the WE control group during Incentive Phase.

Our findings suggest that the ultimate success of any recycling program will depend on whether it is tailored to the specific environment into which is implemented. Future research should investigate the determinants of recycling in the workplace, as this environment can be the key to help mitigate the low engagement commonly observed in such settings. The Bass model suggests that the rationale for differences in the adoption of a product/service relate to informational exchange intensity within a social system. This is likely to be higher in a working environment, where individuals spend a considerable amount of time together, and interactions are a built-in feature of the workplace. Even though we can only offer some limited insight in this respect, our study is a first step towards developing a more thorough understanding of recycling diffusion processes and its determinants that will help fine tuning waste disposal programs.

The remainder of this paper is as follows: Section 2 presents the experimental design and hypotheses; Section 3 provides the results relative to the effectiveness of the monetary incentives on recycling; Section 4 explores with the diffusion process as estimated by the Bass model; Section 5 provides a discussion of our findings and their relevance for policy making.

2 Experimental Design

The field experiment involved a Monitoring Phase in which the number of cans recycled was simply observed and recorded, and an Incentive Phase that involved the implementation of monetary rewards for recycling.

In the Monitoring Phase we recorded the number of cans recycled for 10 weeks, where participants were instructed to place cans in special bins provided by the experimenters. The data collected in this phase thus provides a benchmark to evaluate the effectiveness of monetary incentives implemented in the Incentive Phase. The Incentive Phase consisted of three treatments: the No-reward treatment (NR)[5], a sure reward treatment implemented as a Pay-per-can payment (PPC) and a probabilistic reward (Lottery).

NR treatment - In NR, our control group in the Incentive Phase, we only recorded the number of cans recycled as we did in the Monitoring Phase.

PPC treatment - In the PPC treatment, participants were paid £0.10 for each can recycled.

Lottery Treatment - In the Lottery treatment, participants were assigned to *lottery-groups* and had a chance to win a prize. The size of the prize in each lottery group equals £0.1 times the total number of cans recycled in that group. Each lottery group contained $N = \{1, \dots, n\}$ members, with $n \geq 2$. Lottery-group members received a raffle ticket for each can they recycled. If the size of the prize is positive, the probability that a lottery-group member *i* Î *N* wins the prize is:

$$p_i = \frac{t_i}{\sum_{j=1}^{n} t_j}$$

in which t_i represents the number of raffle tickets member *i* received, and the denominator represents the total number tickets gained by the group. In this setting, the greater the number of cans recycled, the greater the probability of winning. Draws took place fortnightly. Setting up the lottery prize in this way was purposely chosen so that the expected earnings are the same

[5] We did not have an NR treatment in RE.

as in PPC. Therefore, for a risk neutral individual, the monetary incentive from recycling in PPC (a sure reward) or the Lottery (a probabilistic reward) treatments are equivalent.

The experiment was run in three different environments: a student environment (SE), a residential environment (RE), and a workplace environment (WE). Participants in SE were students living on the University of East Anglia campus. About 36 flats took part in the trial for a total of about 360 students (10-12 students per flat). Participants in RE were 176 households (44 flats distributed in 4 different buildings) living in two different social housing areas in Norwich. Participants in WE were Norfolk County Hall employees. This involved around 600 employees distributed more or less evenly across six floors within the building. Table 2.1 reports how the units of observation were distributed across phases and treatments. Flats or Individuals in SE, households in RE, and floors in WE are the units of observation.

Phase	Treatments	Conditions	SE	RE	WE
Monitoring	None	Individual	18 Flats	88 Households	6 Floors
		Group	18 Flats		
Incentive	NR	Individual	6 Flats	None	2 Floors
		Group	6 Flats		
	PPC	Individual	6 Flats	88 Households	2 Floors
		Group	6 Flats		
	Lottery	Individual	6 Flats	88 Households	2 Floors
		Group	6 Flats		

Table 2.1: Distribution of the units of observations across phases and conditions.
Notes: Lottery-groups consisted of 2 flats in SE, 44 flats in RE, and 2 floors in WE.

In WE, employees could not be identified and individually paid, so the money raised through the recycling activity was given to the floor manager. Floor managers then decided (with input from the employees in that floor) how to best spend those amounts. For this reason, PPC and Lottery conditions are directly comparable within WE, but not fully across environments.

Only in SE were participants assigned to two different conditions for the duration of the study, namely the Individual and Group conditions. Our reason for doing this is that it gave us a chance to compare our results with those in Diamond and Loewy (1991) as this is the study closest to ours. In the Individual condition, each student was given bags in which they were asked to place the cans they intended to recycle. They were then asked to place those bags in a cardboard bin located in the communal kitchen. To identify students (while maintaining anonymity), everyone in this condition was given a set of cable ties with different colours and lengths unique to them. Students were then asked to tie their recycling bags with the cable ties provided. Failure to do this in the Incentive Phase would result in no payment for those students taking part in the PPC or Lottery treatments. In the Group condition, students simply put the cans they intended to recycle in the cardboard bin located in their communal kitchen.

In RE, only two buildings (with 44 households each) took part in the Monitoring Phase. In the Incentive Phase, to avoid running multiple incentive treatments in any one building, we decided to run only the PPC treatment in one building and the Lottery treatment in the other one, leaving out the NR treatment. However, as we the opportunity arose, we added two additional buildings (another 88 households) in the Incentive Phase. This way we could increase the number of observations, given the very low level of engagement observed in the Monitoring Phase.

2.1 Implementation

Before data collection began, participants were informed that a new recycling scheme would be implemented, with the starting date of the Monitoring Phase. They were not informed about the Incentive Phase, to avoid any strategic postponement of recycling until this phase. In all locations, experimenters installed a new recycling bin and gave participants recycling bags. In RE, with the help of Norwich City Council, new bins were placed near the existing waste disposal areas. These new bins were clearly identified with stickers. In SE and WE, cardboard bins donated by recycling charity "Every Can Counts" were provided to each flat and floor respectively. In the RE households and the SE Individual condition, we provided instruction on how to apply the colour and length-coded cable ties (see Appendix A for the RE version). Participants were told that this would ensure anonymity, whilst enabling researchers to identify who was recycling what, in order to later pay them the correct rewards.

At the end of the monitoring weeks, participants were informed about a new phase of the trial and given detailed instructions (for the example, for SE see Appendix B) on how the new system worked. In both Monitoring Phase and Incentive Phase, cans were collected, counted and data recorded weekly. For logistic reasons, lottery draws were carried out fortnightly, and payments were carried out at the end of the Incentive Phase. All participants were aware that this would be the case.

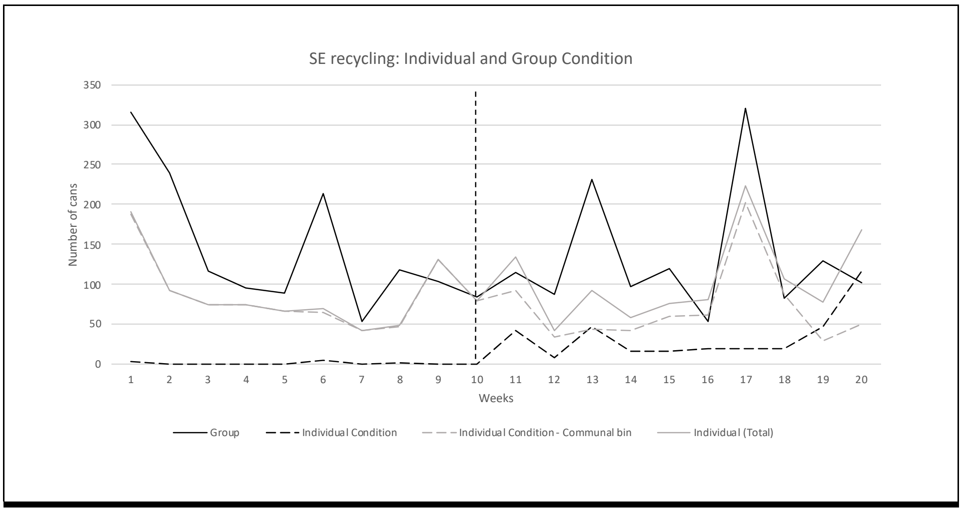
Logistic reasons also explain why the individual and group conditions were implemented only in SE. In WE this was not feasible, as we could not possibly ask each employee to recycle separately from others, and monetary rewards could not be given directly to them. In RE a first obstacle was that of identifying individual and collective units. In principle, one can think of a household both as a group and as individual unit. If we think of it as a group, the implementation of the individual condition would simply ask each individual member of the same household to recycle separately from the others. Not only did this not seem a viable option, but we did not believe data from such a trial would be representative of any household's actual recycling habits. Equally, thinking of a household as an individual unit would give rise to the same problems if one were to implement a group condition comprising of several households.

Given these key differences, along with the demographic ones, we acknowledge some limitations for comparability of behaviour across environments. What we do gain, however, is a better understanding of the specific behavioural response from each environment, offering a snapshot of how actual behaviour may differ across settings to a similar stimulus. This is something we believe could be key from a waste management policy perspective.

3 Results

3.1 Overview

Figure 3.1 shows aggregate recycling levels (number of cans) by location and phase. For comparability, the figures at this point only report data for the participants that were subsequently exposed to either PPC or Lottery in the Incentive Phase.



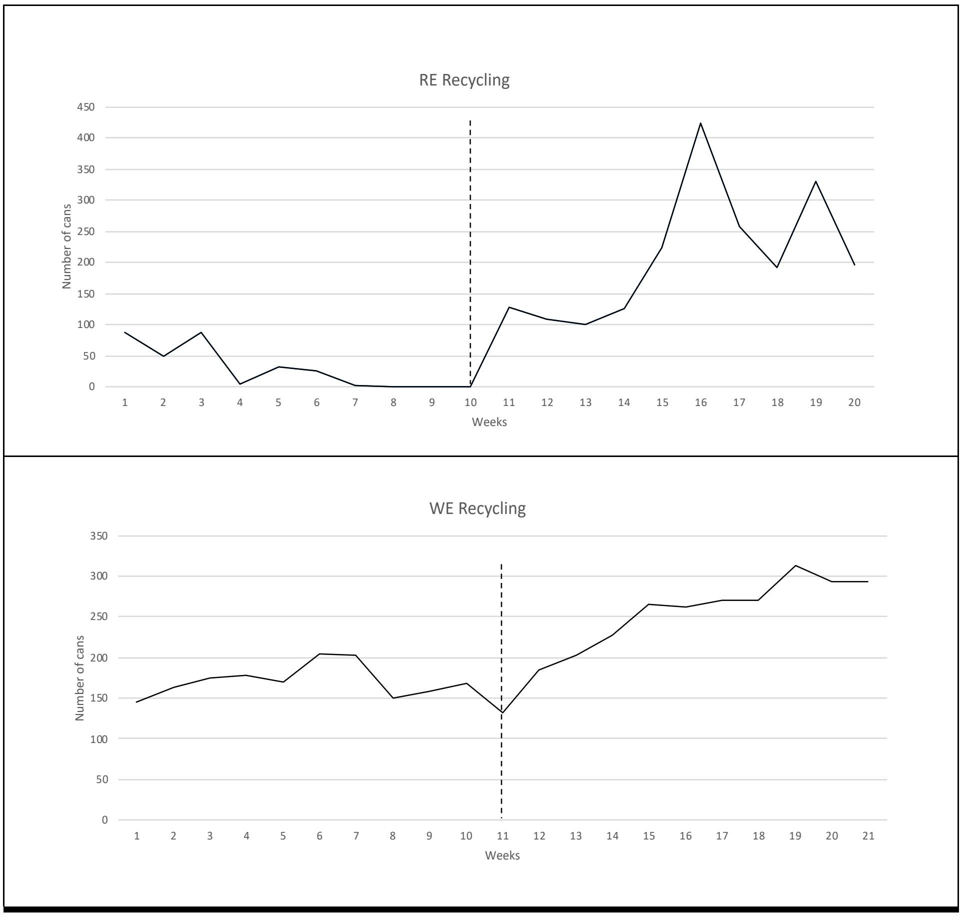


Figure 3.1: Number of cans recycled over time (only participants that were exposed to monetary incentives in IP are included)

In SE, we report the number of cans recycled for both the Group and Individual condition. The Individual condition data refer only to cans correctly recycled in individual bags. As a reminder, students in this condition were asked to recycle by placing their personal cans in individually identifiable bags. These bags should then be placed in a "communal" bin located in the kitchen. In the Incentive Phase, failure to follow this system resulted in no reward being paid. In this condition, however, students often placed loose cans (i.e. not correctly recycled[6]) directly in the communal bin. We still recorded this data, which we refer to as 'Communal Bin' cans.

In the Monitoring Phase, recycling levels are quite heterogenous across locations. For SE, the Group condition students recycled more than those in the Individual condition, where almost no recycling is observed. However, if we aggregate the number of cans recycled in 'Individual-condition' and the 'Communal Bin', groups and individuals recycle at broadly similar levels. In RE recycling levels are relatively low, similar to the Individual condition in

[6] We conjecture that this could relate to the inconvenience of placing cans in individually tied bags.

SE. In WE recycling levels are similar to the SE Group condition but lower than in the Individual condition and in RE.

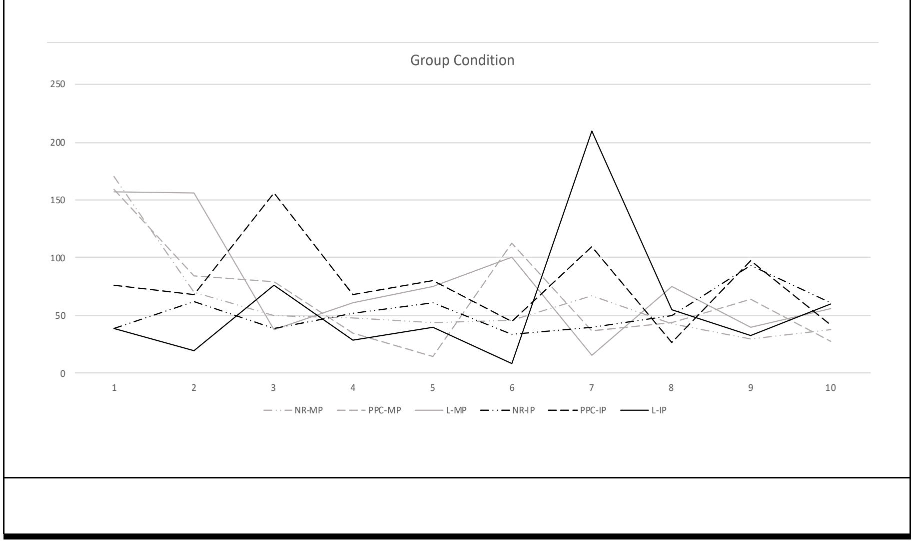
In all locations, we witness a mild negative trend over time in the Monitoring Phase. In SE we still observe some recycling in the Group and Communal bin conditions at the end of the period. In RE, the number of cans recycled decreases quickly over time and reaches zero, while in WE, the decline is only mild.

In the Incentive Phase, we observe a similar level of heterogeneity across locations. Monetary rewards do not appear to stimulate recycling for groups in SE. Students in Individual condition recycle more than before and we observe fewer cans in the communal bin. In RE, incentives lead to a sharp increase in recycling and in WE they seem to provide a boost.

Although we observe large differences in how participants respond across locations, we also find interesting similarities. In the Monitoring Phase, in We and SE (groups and Individual condition - communal bin) recycling levels are well above zero. In RE and SE Individual condition, by contrast, recycling is almost absent. In RE and WE, offering monetary rewards does increase recycling, despite the differing responses in the Monitoring Phase. However, when comparing WE and SE, monetary rewards provide an injection to recycling effort in the former, whilst this fails to occur in the latter (except for some mild effectiveness in the Individual Condition).

3.2 The Student Environment (SE)

Figure 3.2 provides a detailed picture of recycling over time and also includes participants who were not exposed to incentive treatments in either phase. The grey lines correspond to recycling levels in the Monitoring Phase and the black ones correspond to those in the Incentive Phase.



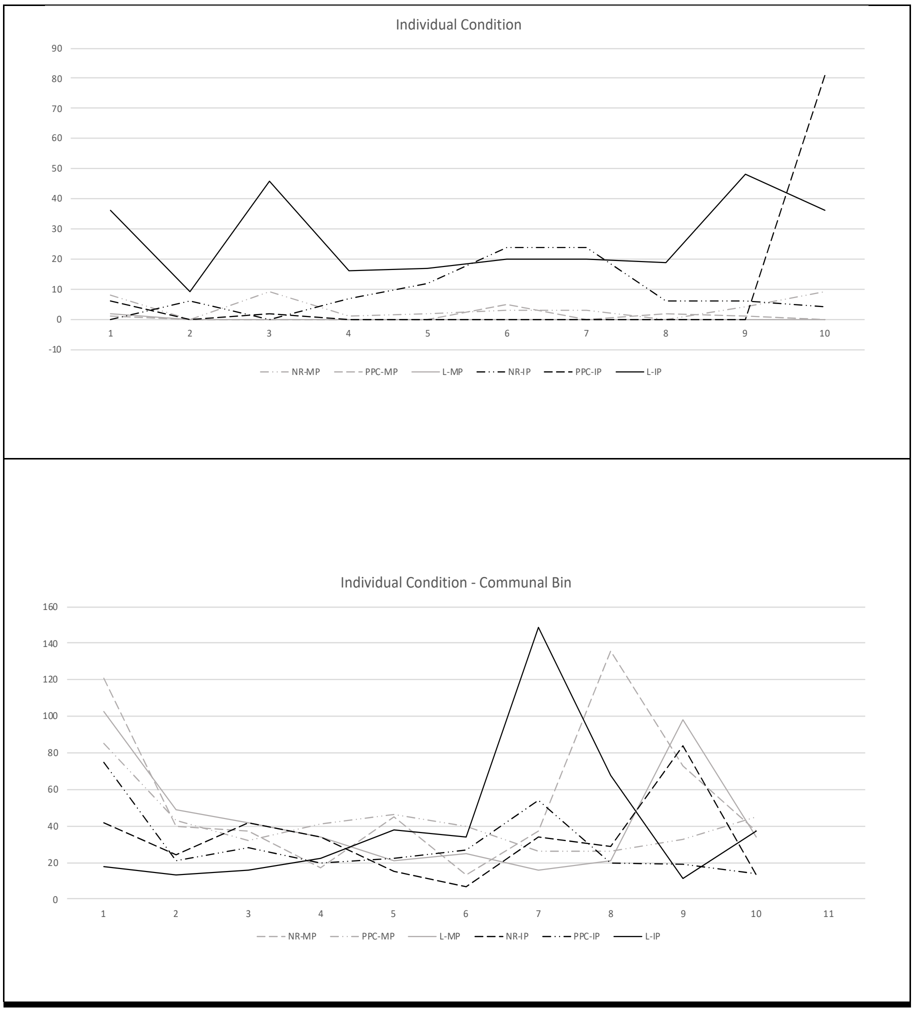


Figure 3.2: Recycling in SE by treatment and phase
Notes: NR: No Reward treatment, PPC: Pay per Can; L: Lottery treatment; MP: Monitoring Phase; IP: Incentive Phase)

The type of incentive does not seem to matter in the Group condition, while the lottery seems more effective than PPC in the Individual condition (see figure 3.2). Overall, in both phases, Groups outperform individuals no matter whether the Individual condition uses just those who recycle correctly (Mann-Whitney test - $p < 0.01$ and $p < 0.01$ in the Monitoring Phase and Incentives Phase respectively) or those who recycle using the communal bin (Mann-Whitney test - $p < 0.05$ and $p < 0.02$ in the Monitoring Phase and Incentives Phase respectively).

The clearly visible spikes in recycling observed in both conditions are likely to be attributable to external factors or events happening at the university during those weeks.

In the Individual condition we observe an increase in cans recycled in both incentive treatments[7] once the Incentive Phase begins. In the PPC treatment, we observe no recycling

[7] Note that this includes the NR treatment, in which students did not receive any monetary reward

except for week 10, and we conjecture that these students only deposited the cans in the last week to reduce the burden involved with this new recycling system. Overall, we only find partial evidence to suggest that monetary incentives can facilitate an adherence to following a new recycling procedure (here of putting cans in bags).

A note of caution must be applied when evaluating the results in the Individual condition given that the limited number of observations. Out of 192 students, only about 11 (5.73%) engaged in the recycling trial in the Monitoring Phase and about 12 (6.25%) in the Incentive Phase. These students actively recycled on average for 1.5 weeks in the former phase and for about 3.58 weeks in the latter one. Despite these low magnitudes, this does mean 'engagement' increased in the Incentive Phase, both in terms of the number of students that recycled and the frequency of their recycling.

Table 3.1 reports the results of three sets of random effects regressions. The dependent variable in Sets 1 and 2 is the number of cans recycled. Because in Set 3 we only have information on recycling at the flat level, we cluster standard errors at this level, as we do for the Group treatment. For the regressions in Set 2 we instead cluster at the individual level. We employ indicator variables for PPC, the Lottery and the NR treatments, with the latter acting as our baseline. In model (6), *Lottery* is a dummy variable taking value 1 in the Lottery treatment and zero in the PPC one. *Week* is a time trend taking values from 1 to 10. *IP* is a dummy variable that takes value of one in the Incentive Phase and zero otherwise. The row immediately below the model number reports the set of data used in the analysis.

Set 1 provides evidence that, in the Monitoring Phase, subjects recycle less cans over time in the Group Condition (model 1), but this trend vanishes once monetary incentives are provided (model 4). Aside from this, incentives do not have any other significant effect on group recycling (models 5 and 6).

In Set 2, we do not observe a significant time trend in either phase (model 1 and 4). This result should not be given too much weight, as recycling did not take place regularly (see figure 3.2, middle panel). Both incentive types appear as effective as each other in increasing recycling when we move to the Incentive Phase (model 3).

One plausible explanation is that there now exists a clear reason to start recycling via the individual bags (i.e. 'correctly') in order to obtain monetary rewards.[8]

[8] This interpretation however is not compatible with the results of Model 7 which shows a reduction in recycling also affects those students in the NR treatment.

Set 1: SE – Group Condition							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	MP	MP	MP&IP	IP	IP	IP	MP & IP – NR only
PPC		0.867			3.967	3.300	
		(4.001)			(3.905)	(4.160)	
Lottery		2.800			0.667		
		(4.001)			(3.905)		
Week	-1.508***			0.015			
	(0.300)			(0.485)			
IP			-0.767				-1.250
			(1.844)				(1.757)
Constant	19.619***	10.100***	11.933***	11.083***	8.850***	9.517***	10.100***
	(2.272)	(2.829)	(1.977)	(3.362)	(2.761)	(2.941)	(2.294)
Observations	180	180	240	120	180	120	120
Set 2: SE Individual Condition							
PPC		-0.047*			0.000	-0.278	
		(0.026)			(0.236)	(0.272)	
Lottery		-0.058**			0.278		
		(0.026)			(0.236)		
Week	-0.000			0.039			
	(0.003)			(0.026)			
IP			0.270***				0.078*
			(0.079)				(0.047)
Constant	0.027	0.061***	0.009	0.065	0.139	0.417**	0.061
	(0.018)	(0.019)	(0.079)	(0.197)	(0.167)	(0.192)	(0.062)
Observations	1,920	1,920	2,560	1,280	1,920	1,280	1,280
Set 3 : SE - Individual Condition (Communal Bin)							
PPC		-2.317			-0.400	-1.767	
		(3.667)			(3.267)	(3.879)	
Lottery		-1.883			1.367		
		(3.667)			(3.267)		
Week	-0.319			0.151			
	(0.286)			(0.402)			
IP			-1.283				-3.867*
			(1.361)				(2.184)
Constant	9.619***	9.267***	7.167***	3.551	5.400**	6.767***	9.267***
	(2.123)	(2.593)	(1.774)	(6.502)	(2.310)	(2.743)	(1.996)
Observations	180	180	240	120	180	120	120

Table 3.1: Recycling in SE - *Notes*: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1

Set 3 provides evidence that recycling of loose cans in the communal bin decreases over time in the Monitoring Phase but no such trend occurs in the Incentive Phase (model 1 and 4). However, students placed significantly fewer cans in this bin in the Incentive Phase.

3.3 The Residential Environment (RE)

As previously explained, the Incentive Phase involved four buildings (176 flats) while the Monitoring Phase only involved two (thus 88 flats). Figure 3.3 reports the number of cans recycled per building given that the allocation of participants to the treatments was done in this way. The black lines represent buildings that were assigned the PPC treatment, and the grey lines represent those assigned to the Lottery treatment. The dotted lines of the type ($\cdots$) report recycling in the Monitoring Phase while the dotted lines of the type ($\cdot\cdot -$) report recycling in the Incentive Phase for those buildings that did not take part in the first Phase.

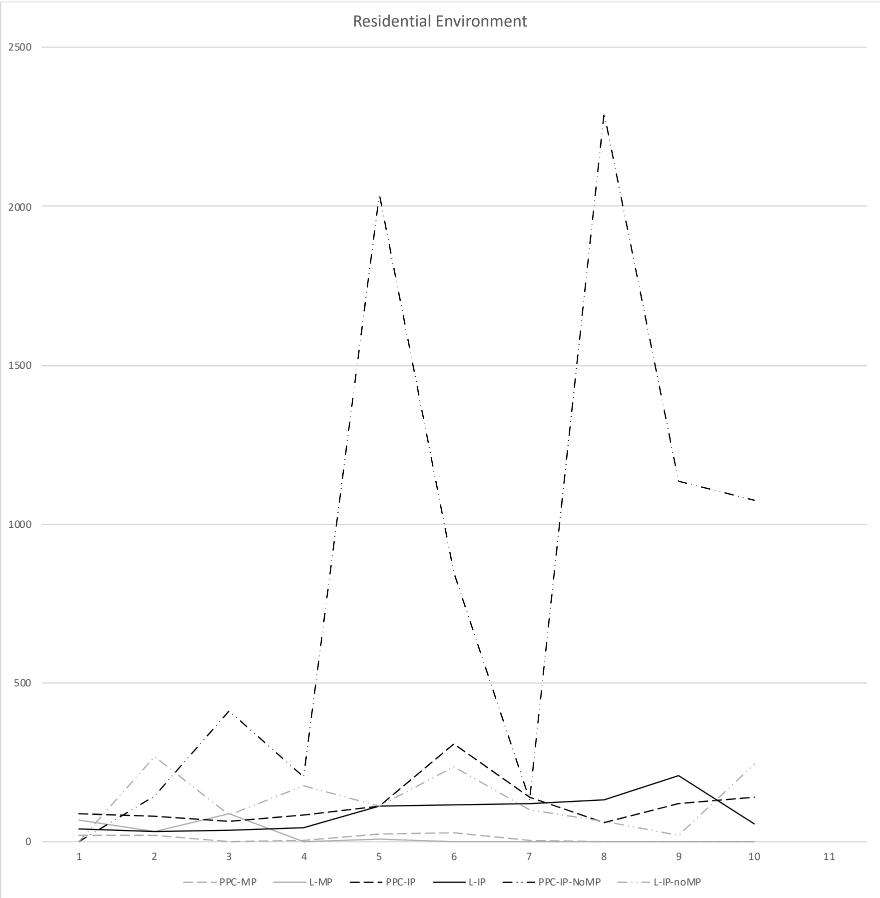


Figure 3.3: Recycling in the residential environment.
Notes: PPC-IP-noMP and L-IP-noMP refer to those buildings that did not take part in the Monitoring Phase)

Table 3.2 reports results of five regression models, each clustering observations at the flat level. Unlike in SE, we only estimate five models as we do not implement the NR treatment in the Incentive Phase. Models 1 - 3 include only the buildings that took part in both phases, whereas Models 4 and 5 include all buildings.

To reinforce the informal analysis provided in section 3.1, we confirm that recycling decreases over time in the Monitoring Phase (model 1) and increases sharply in Incentive Phase (model 3), providing evidence to support the strong effect of incentives on recycling in this setting.

In the Monitoring Phase, recycling is initially quite low and tends to zero several weeks before this phase ends. The introduction of incentives, for those buildings that took part in the Monitoring Phase, solid lines and dotted (---) lines, has a powerful effect on recycling. The residents that did not take part in the Monitoring Phase tend to recycle even more, particularly those exposed the PPC treatment.

Although incentives lead to an increase in recycling over time, our regression results indicate that the type of incentive does not matter (model 5). This is surprising given that the total number of cans recycled by the flats assigned to the PPC treatment was 9470 compared to just 2187 of those assigned to the Lottery one. This lack of significance can be the result of the large heterogeneity of recycling levels, not only across flats (many flats did not recycle at all) but also across weeks (as flats that recycled did it every few weeks). The non-parametric Mann-Whitney test carried out on the same data does show a significant difference between the Lottery and PPC treatments in the direction indicated by the data ($p < 0.03$).

VARIABLES	(1) MP	(2) MP	(3) MP&IP	(4) IP	(5) IP	(6) IP Engagement
Lottery		0.230			-8.276	-0.043**
		(0.305)			(5.410)	(0.021)
Week	-0.109***			0.967**		
	(0.0412)			(0.466)		
IP			2.041***			
			(0.366)			
Constant	0.928***	0.214	0.328	1.307	10.761***	
	(0.273)	(0.216)	(0.508)	(3.732)	(3.825)	
Observations	880	880	1,760	1,760	1,760	1,760

Table 3.2: Recycling in RE. *Notes*: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1

In terms of ‘engagement’ (measured with a dummy variable taking value one if a flat recycled and zero otherwise) we find that in the Monitoring Phase 10 out of 88 flats (11%) actively recycle. On average, they recycle once or twice over the 10 weeks. In the Incentive Phase, engagement increases to about 15% (27 flats out of 176). Of these 27 flats, 15 only took part in the Incentive Phase. On average, ‘engaged’ flats would recycle for 4 weeks out of 10. Model 6 reports the results of a logit regression with standard errors clustered at the flat level. The dependent variable takes value 1 if a flat engaged in recycling in any given week, and zero otherwise. These results provide evidence to suggest that PPC is more effective in increasing ‘engagement’ than the Lottery.

3.4 Workplace Environment (WE)

Figure 3.4 reports the number of cans recycled each week in WE. The grey lines refer to the Monitoring Phase and the black ones refer to the Incentive Phase. Although no floor received incentives in the Monitoring Phase, for ease of comparison (as was done in SE), we report recycling by the treatment floors would later be assigned to in the Incentive Phase. Although recycling is heterogenous during the Monitoring Phase, we do observe a clear ‘boost’ to recycling in all treatments once incentives are offered. This effect also extends to the NR floors, although they are not rewarded for recycling.

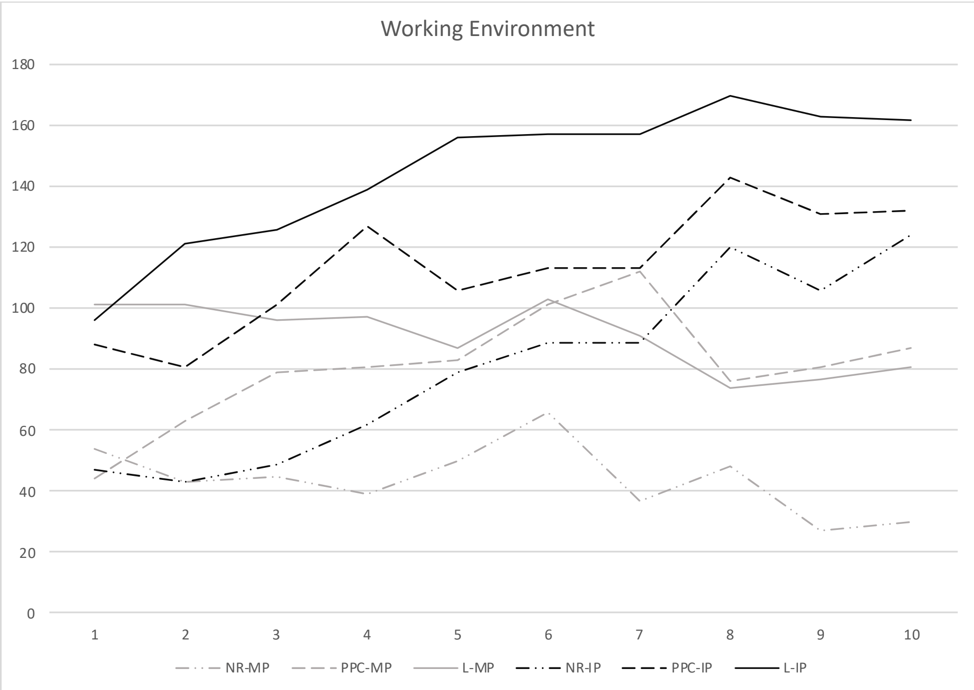


Figure 3.4: Recycling in the working environment (MP: Monitoring Phase – IP: Incentive Phase)

Table 3.3 reports estimates for seven regression models. We find that recycling does not decrease in a statistically significant way over the Monitoring Phase, unlike for SE and RE (model 1). In this phase, we do not observe any significant difference in recycling between floors, (model 2). Confirming the insight from Figure 3.4, we find that the introduction of incentives does give a significant boost to the recycling undertaken by those floors assigned to either PPC or the Lottery treatment, whose recycling also increases over time (models 3 and 4). However, recycling across the PPC and Lottery floors is no greater than NR floors (model 5) and our NR floors do increase their recycling as much as incentivised floors (model 6)[9].

VARIABLES	(1) MP	(2) MP	(3) MP & IP	(4) IP	(5) IP	(6) IP	(7) MP & IP - NR only
PPC		17.272			16.350	-15.600	
		(17.544)			(20.890)	(24.201)	
Lottery		22.682			31.950		
		(17.544)			(20.890)		
Week	-0.408			3.158***			
	(0.330)			(0.466)			
IP			22.573***				18.400***
			(2.472)				(3.583)
Constant	37.764***	22.000*	41.977***	47.183	40.400***	72.350***	22.000***
	(7.309)	(12.406)	(9.668)	(11.156)	(14.771)	(17.112)	(6.974)
Observations	66	66	84	40	60	40	40

Table 3.3: Analysis of recycling in RE. *Notes*: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1

3.5 Does Setting Matter?

We acknowledge the difficulty in making any formal comparisons between the recycling conducted across locations. This is because the units of observation do differ by location, and because the implementation of incentives also adjusts slightly across settings. Despite this, the recycling in WE and in the Group condition of SE do share some similarities. For example, in the Monitoring Phase both locations recycle at a level well above zero. This is in sharp contrast with RE and the Individual condition in SE, where recycling in this phase is very low.

In the Incentive Phase we find that monetary incentives are key drivers of recycling in the SE Individual condition and in RE, yet they do not seem to matter in the Group condition of SE. In WE, incentives not only provide a boost to recycling but also have a 'spill-over

[9] In WE the monitoring phase, the research assistant recorded recycling levels for 11 weeks. These data are not included in the graphs, but they are included in the corresponding regressions and Bass model analysis. These additional data do not affect our findings.

effect' on the NR floors. It is very possible that income generation from recycling in these two environments might matter less because any accrued 'income' would be shared among the group members. This in turn suggests a way of classifying our environments that depends on how rewards are paid. The individual condition in SE and RE represent a form of 'individual recycling, as monetary rewards are paid to a single agent (either individual or household) and the Group condition in SE and WE a form of 'group recycling', as monetary rewards are paid to a group of individuals.

In response to the question "Does Setting Matter?", our findings would suggest that alongside the 'setting' itself, it is equally important to consider whether recycling is done by an individual agent or by a group. Our results show that groups recycle more when no incentives are provided and are somewhat less responsive to incentives.

4 The Diffusion of Recycling: A Bass Model Approach

As with every service, recycling has associated costs and benefits for the individual. Whilst for many goods and services these are monetarily based, the cost of recycling is represented by the individual effort of engaging with the recycling activity itself, and the benefits are those arising from environmental preferences and psychological attitudes.[10] We add to the marketing and psychology literatures by investigating the diffusion of recycling, with particular focus on the role of incentives. We do this with the help of the Bass (1969) model, which has been widely used in the marketing literature to estimate the diffusion potential of new or innovated products in the market, thus providing a sector benchmark to be employed by companies to forecast sales. Applied to recycling, this can help to provide a benchmark based on location/demographic groups (e.g. household recycling, workplace recycling) and therefore help forecast the potential reach of new recycling programs.

In the Bass model, the key actors are 'adopters', who are classified either as innovators or imitators. Innovators' purchasing decision (or engagement with the service) is based on direct information about the product. Imitators instead base their decisions on indirect information that they might receive from innovators, such as word-of-mouth.[11] More concretely, the

[10] Meneses & Palacio (2005), among many, found that recycling behaviour is multidimensional and strongly associated with sociodemographic and psychographic causal characteristics. Psychology and environment references from this paper from past studies. Berger (1997); Derksen & Gartrell (1993); Folz (1991). Fuller. (1978).

[11] For a comprehensive description of the Bass (1969) model and its mathematical derivation please see Appendix C.

estimation of the model provides information on the proportions of adopters (p and q for innovators and imitators respectively) and the potential market (m).[12]

The diffusion process of a product is characterised by four key elements: innovations, the communication channels, time and the social system (Mahajan, Muller & Bass, 1990). In our study, the 'new product' is represented by the recycling trial implemented in the Monitoring Phase and its innovation by the introduction of monetary rewards in the Incentive Phase. 'Time' is represented by the duration of the experiment measured in weeks (10 weeks in each phase). The communication channels consist of the direct information (instructions) given to the participants about the experimental trials and the indirect information (not observable by the experimenter) that participants exchange with each other during the trial. The latter could plausibly differ among locations.

4.1 Overview

Table 4.1 presents the estimated Bass parameters[13], with the corresponding *p-values,* by location and phase. According to the Bass model, innovators (p) and imitators (q) can potentially start engaging with the service simultaneously, however, the number of innovators will monotonically decrease over time. This means that any diffusion, if present, will be driven by imitators. For the adoption of the service to positively grow over time, parameter q must be greater than p.[14] The potential market (m) is derived from the maximum number of adoptions within the timeframe employed. The variable T represents the point in time (weeks in our experiment) where the maximum level of adoption is reached. The Bass parameters are estimated using the OLS method, as is standard in the literature.[15]

Panel A reports the estimated parameters in SE, by Group (Panel A.1) and Individual (Panel A.2) condition. The units used for the estimation are the number of cans recycled. In the Group Condition we cannot report amounts recycled at the individual level. For consistency and comparability within this environment, we employ the same unit of estimation (total cans recycled per flat) in the Individual Condition. Panel B reports the parameters for RE, estimated

[12] Van den Bulte (2002) offers a comprehensive analysis of US industry sectors and the Bass parameters associated with them, "normally" range from [0-0.1] for parameter p (innovators) and [0.2-0.4] for parameter q (imitators).

[13] The Bass parameters are estimated with OLS estimation, however, NLS analysis was also performed and yielded analogous results.

[14] For further details see "Model Assumptions", Bass (1969).

[15] More details are also given in Appendix C.

using the number of flats that engaged with recycling in any given week, rather than the number of cans recycled by flat in that week. This decision is based on considerations found in the literature that view recycling in residential contexts as a household activity rather than an individual one (e.g. Meneses & Palacio, 2005). Diffusion across households is a more important measure than the increasing recycling levels within a given household. This is because, from a marketing perspective, what matters is the number of customers reached, as opposed to the number of products bought by the same customer. This is not to diminish the benefits of also looking at the total number of cans recycled, which also does measure costs and benefits useful when considering the introduction of new recycling policies.

Panel A.1: Student Environment (SE) – Group Treatment					Panel A.2: Student Environment (SE) – Individual Treatment				
	P	q	m	T		p	q	m	T
MP	0.482	0.000	1631	NA	MP	80.438	76.543	197	NA
IP	0.037*	0.125*	3848**	7.7	IP	0.084	0.412*	41	4.6
Panel B: Residential Environment (RE)					Panel C: Working Environment (WE)				
	P	q	M	T		p	Q	m	T
MP	0.22**	0.118	20***	NA	MP	0.050***	0.145***	765***	5.5
IP	0.029***	0.209*	190**	8.0	IP	0.038***	0.151***	1116***	8.7

Table 4.1: The Diffusion of Recycling – Bass Analysis. *Notes:* The present table reports the Bass parameters (p = innovators, q = imitators and m = potential market) for the three locations (SE, RE and WE). Panel A.1 and A.2 report the parameters in SE for the group and individual condition, respectively. Panel B and Panel C report the parameters for the RE and WE, respectively. The parameters, reported with their *p-values*, with *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, are estimated using an OLS calibration methodology (more details can be found in Appendix C). The parameter *T* represents the period in which the maximum level of adoption is reached. For the diffusion process to reach its peak, the density function (adoption curve) needs to be a monotonically increasing function. For the adoption curve to be monotonically increasing the condition $q > p$ needs to be satisfied. When this condition is not satisfied "T" cannot be estimated. This is indicated with "NA" in the present table. Standard errors in parentheses

Panel C presents the results for WE. The unit of observation is the number of cans recycled, again dictated by the lack of data at the individual (employee) level. Note that in WE, and in SE Groups, the notion of household 'engagement' loses any relevance for diffusion processes. This is because in these environments we find that all groups 'engage' every week. Recycling from a group could however be the result from the activity of just one person within that group. Although studying diffusion within a group over time would be relevant in our setting, this is not something we can achieve with our data. Nevertheless, the number of cans recycled is a useful approximation for the overall group uptake. In this environment we have assumed that each employee recycles 5 cans per week. Our results are robust to changes in this value.

In SE, Group condition, incentives provide a boost in the uptake of recycling (table 4.1, panel A.1, IP row). In the Individual condition, by contrast, incentives do not seem to encourage the diffusion of recycling (table 4.1, panel A.2, IP row). The imitators' parameter is positive and only mildly statistically significant whereas the innovator parameter is not statistically significant. We believe that this is because students in this condition recycle almost all cans in the final week, therefore the estimation of model is not able to pick up any diffusion process. All together the results don't allow for a full interpretation of the diffusion path.

In RE (table 4.1, panel B), incentives lead to an uptake of recycling over time. In the Monitoring Phase the adoption process monotonically decreases as $p > q$. In the Incentive Phase, by contrast, the diffusion process shows a positive growth, as $q > p$, demonstrating a positive effect of incentives on the diffusion of recycling. Findings in this location are thus consistent with those of Section 3.

In WE, we find that $q > p$ in both the Monitoring and Incentive Phases. Unlike in RE, in this location the size of the estimated parameters only mildly differs between phases. We observe a small increase in imitators and a more sizable increase in the potential market (m). Incentives do not 'change' the diffusion process but somewhat intensifies it. Broadly speaking, our initial analysis suggests that incentives positively and significantly impact the diffusion of recycling in RE and SE Group Condition, the provide mild boost within WE, and an even smaller impact on SE Individual Condition.

4.2 The impact of the type of incentive on diffusion

Figure 4.1 reports six curves for each location and type of incentive within SE. The 'real adoption curve' (black dotted line) plots the actual number of cans recycled or flats engaging with the service by week. The remaining curves are estimated using the Bass Parameters[16]: the 'adoption' curve (black solid line); the 'innovators' curve (dark solid grey) and the "imitators" curve (light grey solid). Note that except for panel A.2 the innovators,

[16] To estimate the adoption curve, we employ the standard equation developed by Bass (1969).

imitators and adoption curves almost entirely overlap, so portions of some lines are covered by other lines.

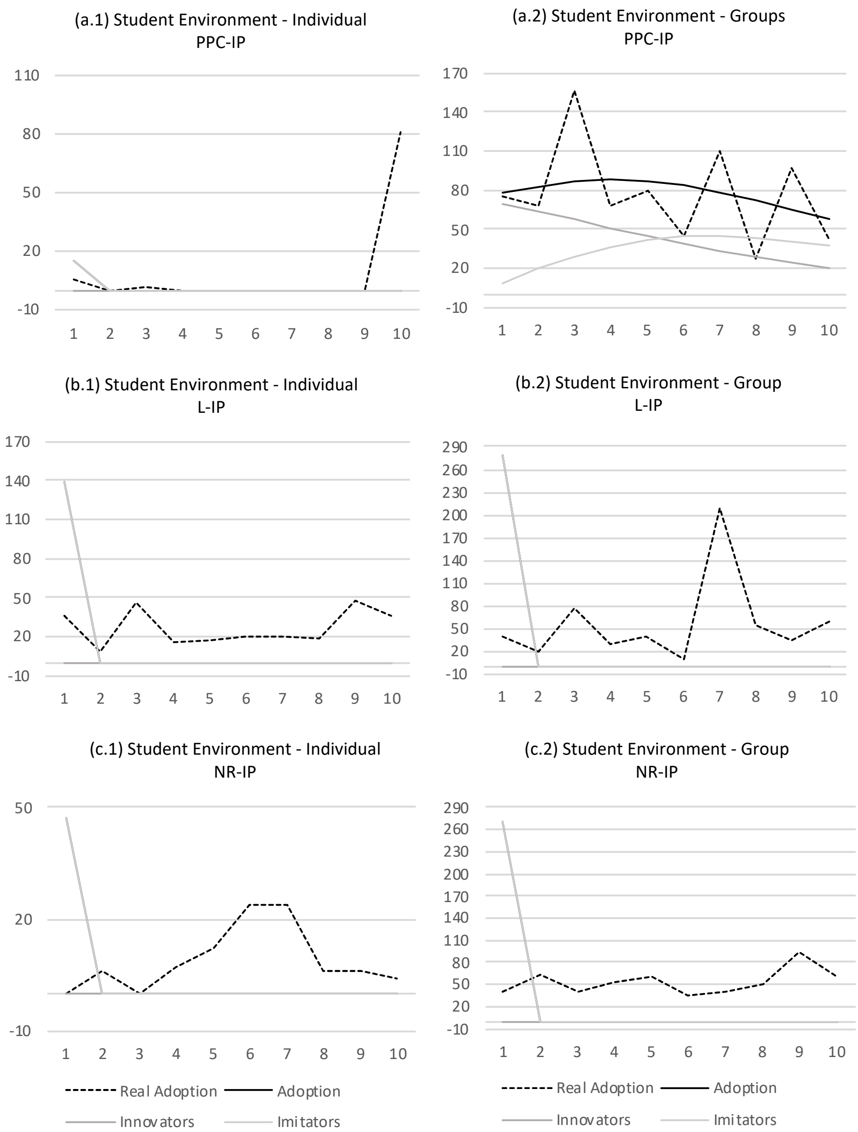
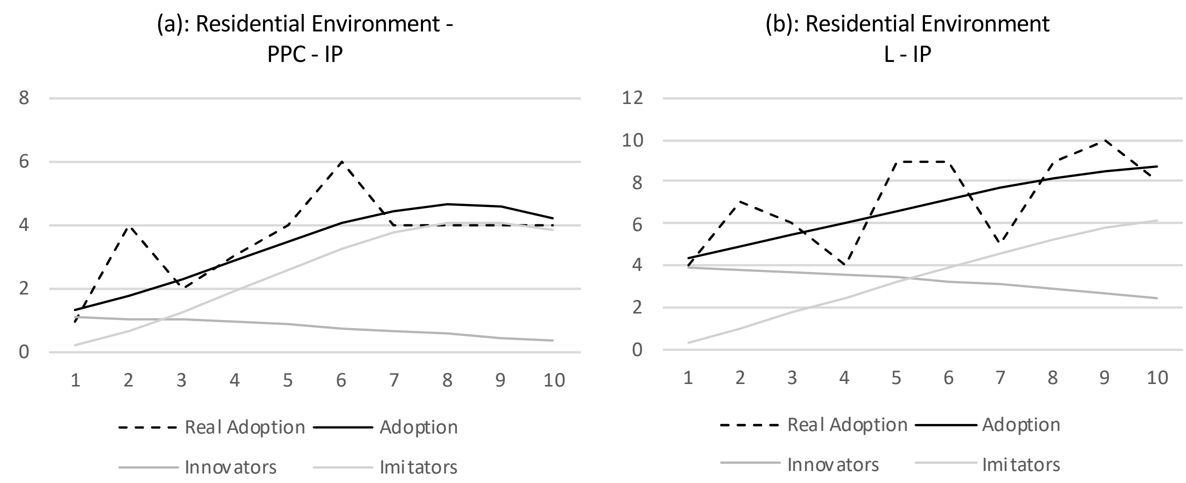


Figure 4.1: SE - Lottery vs PPC

Compatible with the results in Section 3.1, in SE Individual condition, there is no statistically significant diffusion process for either the PPC or Lottery treatment. At a group level (Panel B.2) we instead observe an increasing diffusion process in the PPC treatment. This is evidenced by the concavity of the imitators' curve, that presents a maximum in week 7. The NR treatment shows no growing diffusion process either in the Individual or Group Conditions.

In line with the results in table 4.1, in RE (figure 4.2), for both the PPC (Panel A) and the Lottery treatments (Panel B) we observe an increasing diffusion of recycling. Nevertheless, we do note one key difference - in the PPC treatment the diffusion process peaks before week 10 whereas in the Lottery treatment the maximum is not reached within the experimental time frame. It is for this reason that the estimated parameter m is greater in the Lottery treatment.

Figure 4.2: RE - Lottery vs PPC



For WE, Figure 4.3 shows a marked diffusion process in both PPC and Lottery treatments. This process peaks in week 8 for the PPC treatment (Panel A: PPC) and is outside the experimental timeframe for the Lottery treatment (Panel B: Lottery). Although both incentives prove successful in this setting, the Lottery seems marginally more successful than PPC. An unexpected and puzzling result is found in the NR treatment. Namely, a continuous growing adoption curve comparable to those in the other two treatments (Lottery and PPC). This can be seen as a spin-off effect from the incentives introduced in the other floors. This effect only applies to the WE and it is not observed in the other two locations.

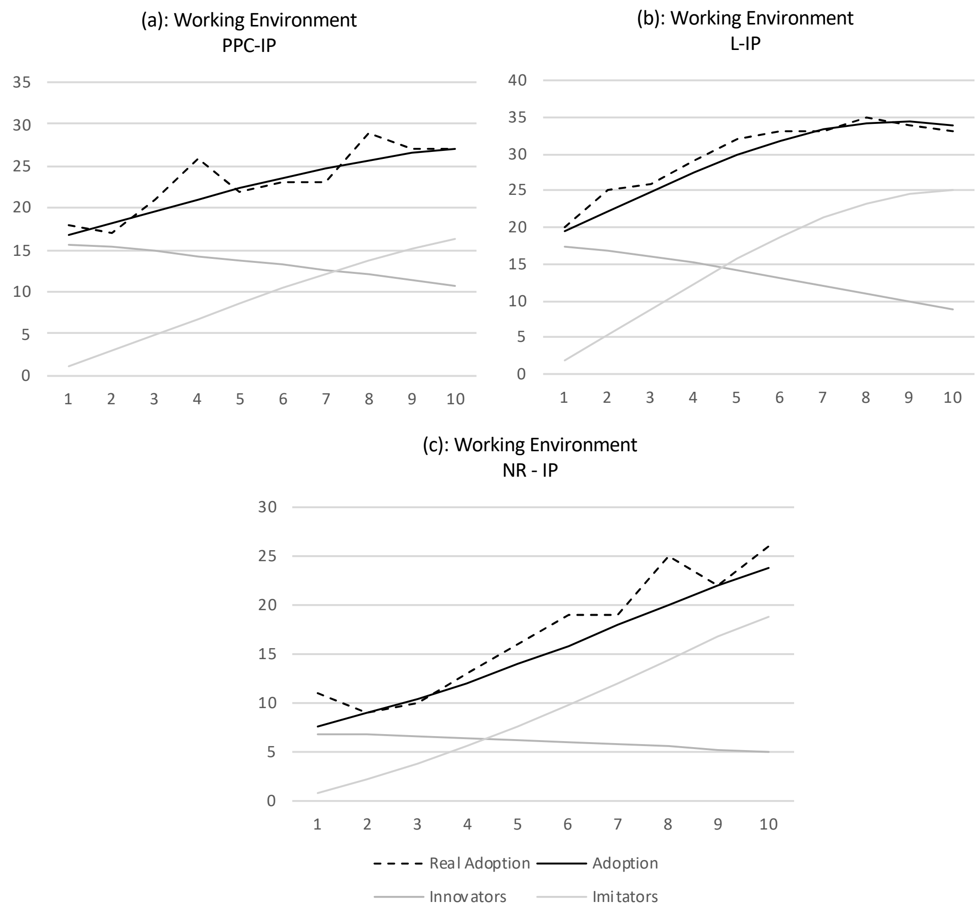


Figure 4.3: WE - Lottery vs PPC

4.3 Location Matters!

Introducing the notion of diffusion has enabled us to explore not only the role of incentives, but also how recycling habits over time take shape across each setting.

In the Monitoring Phase, our results broadly replicate those in section 3. In SE, both conditions demonstrate a mild diffusion trend in this phase. In RE we see little diffusion, which was to be expected given the disengagement in this environment. The adoption patterns in WE confirm not only positive recycling, but a diffusion process across this first ten weeks.

We are unable to comment on the nature of the diffusion process in the Individual condition in SE, as only the imitators' parament is found statistically significant. We only find a mild effect of incentives in the Group condition. In RE, incentives are essential to foster the uptake in the recycling service. In WE, incentives intensify the diffusion process, but this boost does not seem to be driven solely by the actual income that can be generated by monetary reward given that NR floors also exhibit adoption behaviour in this phase.

5 The role of incentives in recycling

Our results, although only being comparable in some ways, do exhibit interesting differences from those of Diamond and Loewy (1991). They find that both probabilistic and sure rewards increase recycling compared to when no monetary incentives are provided. In addition, individual probabilistic rewards are more effective than individual sure rewards, both of which are more effective than group sure rewards. In our group settings (SE Group Condition and WE), rewards, whether sure or probabilistic, do not seem to be the major driver of recycling. In fact, recycling levels tend to be large even without payments. We also find that sure rewards (PPC) can, in most settings, be as effective as probabilistic ones (Lottery) contrary to Diamond and Loewy. Yet, in keeping with this study, we find that offering incentives to individuals is more effective than doing so to groups.

Consistent with the literature, our results from the student environment indicate that recycling behaviour lacks responsiveness to incentives.

Monetary incentives worked most effectively in RE of our three settings. Here, we believe lower income levels could drive engagement in the Incentive Phase. RE participants found a cash payment particularly appealing, informing researchers that they collected cans from the streets to increase their “revenues”. The potential for income generation in this phase might be the main reason for success in this location. The large number of cans recycled by few flats would reinforce this assertion. This could explain why the Lottery scheme was generally not as popular among RE participants[17] as residents might prefer their behaviour to be rewarded with certainty (i.e. they display risk aversion). The analysis of the diffusion process also supports this conjecture.

In WE, both incentive schemes prove successful but, unlike in RE, we do not believe money to be the key driver. First, adoption during the Monitoring Phase highlights a strong engagement irrespective of incentives. Second, our results in the Incentives Phase show that even ‘No-Reward’ floors increased their adoption of the service. Third, any money raised by incentivised treatments was given to floor managers (as opposed to being paid to an employee) diluting the private (pecuniary) benefits of recycling.

In many countries, projections on the success of a new recycling service assume populations will respond in a largely homogenous way, despite a clear understanding within the literature of the variation in recycling uptake across individuals and demographic groups.

[17] ‘Popularity’ here being defined as the number of cans recycled

Our results suggest that introducing a monetary benefit could stimulate action in populations where recycling efforts are traditionally low or non-existent, like those with low income. However, involving businesses via workplace-based recycling systems, not necessarily monetarily based, could begin to tackle the longstanding difficulty of unsustainable ‘on-the-go’ waste disposal and develop recycling habits outside of the domestic setting.

6 Discussion & Final Remarks

Across all global economies, waste management practises are being increasingly recognised as an area of huge priority to achieve both sustainable and efficient growth. Reusing and recycling materials are important tools here, and this work explores the effects of implementing a new recycling service in three different settings. We assess the impact of two different incentive schemes on recycling. Assessing our results through the Bass model has enabled us to explore the diffusion process of each intervention and estimate parameters such as the potential market (parameter *m*) and the proportion of innovators and imitators. This has given us have a first indication of how the adoption of recycling spreads in three different environments both with and without monetary incentives. Although we would advocate for further research in this area to be conducted ito ensure robustness in our findings, we see how these estimates can be used to forecast the uptake of recycling based on the context in which new recycling policies are applied, in the same way in which industries might use diffusion models to understand the adoption of new or innovated products.

The theoretical underpinning of the model can, in addition, provide novel insights into the determinant of recycling. Other than economic incentives such as reward and punishment, the literature has, so far, identified social factors such as norms, peer pressure and observability of recycling behaviour. The Bass model suggests that informational exchanges within a social system play a critical role in stimulating the diffusion process. Based on this and our results, we propose “proximity” of potential adopters within a social system as a factor that positively influences informational exchanges and therefore, ultimately promotes recycling.

Our results are compatible with this idea. It is possible that in the workplace environment the likelihood for informational exchange is far greater than in residential settings, and possibility in a university setting. Informational exchanges might have increased the salience of the intervention and/or fostered a social pressure to recycle (Kashyap and Iyer, 2001; McCarty and Shrum, 2001). It is plausible that the novelty of a recycling trial introduced in the Monitoring Period led to conversations among employees that presumably intensified when incentives were introduced. This made recycling more salient and positively fuelled engagement with the service. Physical proximity among individuals can, however, have the additional effect of making behaviour highly observable, which makes it easier for a group to learn new behaviours or to converge to a social norm (Bandura, 1971; Barr et al., 2001). Social norms in turn influence behaviour as they create social pressure to adhere to the norm. Gamba and Oskamp (1994) find that one of the most important reasons for recycling was the social pressure from the neighbours. This explanation seems compatible with the spill-over effects observed in WE only, in which even the floors that did not receive any monetary compensation increased their recycling activities in the Incentive Period. This echoes the value placed within the recycling literature on observable behaviour and peer effects (Czajkowski et al, 2017).

The proximity hypothesis can also nicely explain the different responses between our experimental settings involving subjects acting as groups versus those where they act as an individual. We note the link to proximity here, with 'individuals' on average being more 'disconnected' in the ease with which channels of communication can arise.

Despite its clear contributions, this research should be seen as a starting point for future investigations. We propose that informational exchanges, boosted by proximity, are important for the diffusion of recycling. As these might intensified in a working environment, businesses can play a vital role in in tackling the long-standing issue of poor engagement with recycling practices. In addition, such environments can also stimulate competition (for us across WE floors) into who recycles the most. Contests typically create incentives for an overprovision of effort relative to the level which is deemed socially optimal. Such 'over-dissipation' (Konrad, 2009) is accentuated in applied settings and evidence shows the extent to which respondents engage in real contests consistently exceed the thresholds predicted by theory (Davis & Reilly, 1998). Therefore stimulating competitive engagement between employees could be a highly efficient complement to (domestic) policy in encouraging greater recycling uptake. Indeed, while recycling habits at home do not seem to translate into recycling in the workplace, there is evidence that suggests that the reverse might hold (see Berger & Kanetkar, 1995). To this end, we recognise the value of our work here in understanding the importance of exploring location for the uptake and diffusion of recycling. We believe our results, and our proposed explanations of these could be a crucial avenue of work for improving sustainable waste management practice.

References

Bandura, A. (1971). Vicarious and self-reinforcement processes. The nature of reinforcement, 228278.

Barr, S., Gilg, A. W., & Ford, N. J. (2001). A conceptual framework for understanding and analysing attitudes towards household-waste management. Environment and Planning A, 33(11), 2025-2048.

Barr, S., Shaw, G., Coles, T., & Prillwitz, J. (2010). ‘A holiday is a holiday’: Practicing sustainability, home and away. Journal of Transport Geography, 18(3), 474-481.

Bass, F. M. (1969). A new product growth for model consumer durables. Management science, 15(5), 215-227.

Berger, I. E., & Kanetkar, V. (1995). Increasing environmental sensitivity via workplace experiences. Journal of Public Policy & Marketing, 14(2), 205-215.

Berger, I. E. (1997). The demographics of recycling and the structure of environmental behavior. Environment and behavior, 29(4), 515-531.

Czajkowski, M., Hanley, N., & Nyborg, K. (2017). Social norms, morals and self-interest as determinants of pro-environment behaviours: the case of household recycling. Environmental and Resource Economics, 66(4), 647-670.

Davis, D. D., & Reilly, R. J. (1998) “Do too many cooks always spoil the stew? An experimental analysis of rent-seeking and the role of a strategic buyer.” Public Choice 95; 89-115

Derksen, L., & Gartrell, J. (1993). The social context of recycling. American sociological review, 434-442.

Diamond, W. D., & Loewy, B. Z. (1991). Effects of probabilistic rewards on recycling attitudes and behavior 1. Journal of Applied Social Psychology, 21(19), 1590-1607.

Folz, D. H. (1991). Recycling program design, management, and participation: a national survey of municipal experience. Public Administration Review, 222-231.

Fuller, D. A. (1978). Recycling consumer solid waste: a commentary on selected channel alternatives. Journal of Business Research, 6(1), 17-31.

Gamba, R. J., & Oskamp, S. (1994). Factors influencing community residents' participation in commingled curbside recycling programs. Environment and behavior, 26(5), 587-612.

Geller, E. S., Chaffee, J. L., & Ingram, R. E. (1975). Promoting paper recycling on a university campus. Journal of Environmental Systems, 5(1), 39-57.

Kashyap, R. K., & Iyer, E. S. (2001). Attitudes and behaviors of college students in regards to the environment and recycling. In Developments in Marketing Science (Vol. 24), Moore M, Moore R (eds). Academy of Marketing Science; 71–79

Konrad, K. A. (2009) “Strategy and Dynamics in Contests.” Oxford University Press

Knickmeyer, D. (2020). Social factors influencing household waste separation: A literature review on good practices to improve the recycling performance of urban areas. *Journal of cleaner production*, *245*, 118605.

Iyer, E. S., & Kashyap, R. K. (2007). Consumer recycling: Role of incentives, information, and social class. *Journal of Consumer Behaviour: An International Research Review*, *6*(1), 32-47.

Lee, Y. J., De Young, R., & Marans, R. W. (1995). Factors influencing individual recycling behavior in office settings: A study of office workers in Taiwan. Environment and behavior, 27(3), 380-403.

Luyben, P. D., & Bailey, J. S. (1979). Newspaper recycling: The effects of rewards and proximity of containers. *Environment and behavior*, *11*(4), 539-557.

Mahajan, V., Muller, E., & Bass, F. M. (1990). New product diffusion models in marketing: A review and directions for research. Journal of marketing, 54(1), 1-26.

Marans, R. W., & Lee, Y. J. (1993). Linking recycling behavior to waste management planning: A case study of office workers in Taiwan. Landscape and Urban Planning, 26(1-4), 203-214.

McCarty, J. A., & Shrum, L. J. (2001). The influence of individualism, collectivism, and locus of control on environmental beliefs and behavior. Journal of Public Policy & Marketing, 20(1), 93-104.

Meneses, G. D., & Palacio, A. B. (2005). Recycling behavior: A multidimensional approach. Environment and behavior, 37(6), 837-860.

Miafodzyeva, S., & Brandt, N. (2013). Recycling behaviour among householders: Synthesizing determinants via a meta-analysis. Waste and Biomass Valorization, 4(2), 221-235.

Oke, A. (2015). Workplace waste recycling behaviour: A meta-analytical review. Sustainability, 7(6), 7175-7194.

Scott, R. H. (2009). Sustainable curriculum, sustainable university. eCULTURE, 2(1), 15.

Shrum, L. J., Lowrey, T. M., & McCarty, J. A. (1994). Recycling as a marketing problem: A framework for strategy development. Psychology & Marketing, 11(4), 393-416.

Van den Bulte, C. (2002). Want to know how diffusion speed varies across countries and products? Try using a Bass model. PDMA visions, 26(4), 12-15.

Varotto, A., & Spagnolli, A. (2017). Psychological strategies to promote household recycling. A systematic review with meta-analysis of validated field interventions. *Journal of Environmental Psychology*, *51*, 168-188.

Witmer, J. F., & Geller, E. S. (1976). Facilitating Paper Recycling: Effects of Prompts, Raffles, and Contests 1. Journal of Applied Behavior Analysis, 9(3), 315-322.

Appendices

Appendix A: RE Instructions Monitoring Phase

University of East Anglia

NORWICH City Council

Norfolk County Council

CAN RECYCLING TRIAL

January 9, 2019

University of East Anglia
School of Economics
Earlham Road
Norwich, NR4 7TJ

Dear Resident,

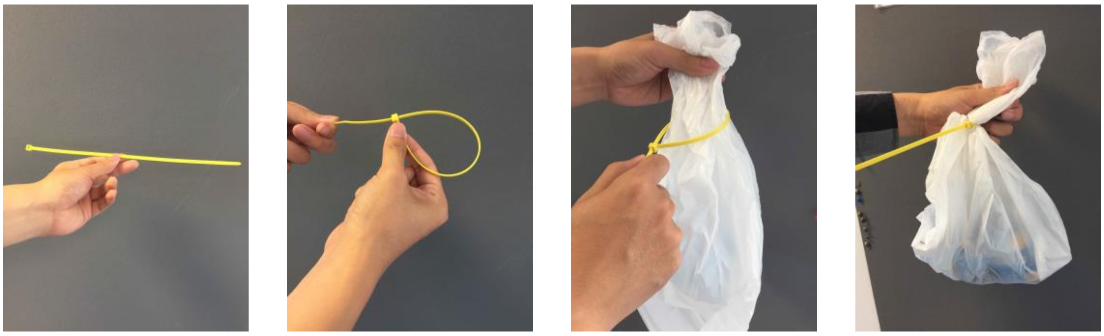
The University of East Anglia (UEA) and Norwich City Council are working together to trial **a new 'can recycling' scheme** from 21st January 2019 until early April 2019.
We will be collecting cans separately from other recycling and measuring the total numberof cans recycled each week per household. We would really appreciate your help with this trial, we are asking you to put all of your drinks cans in a separate bag and put the bagin the special bin provided.
We will not need any of your personal details - each property has been assigned a code, linked to coloured cable tie, so the information we collect is anonymous.

Every household will be given transparent plastic bags.

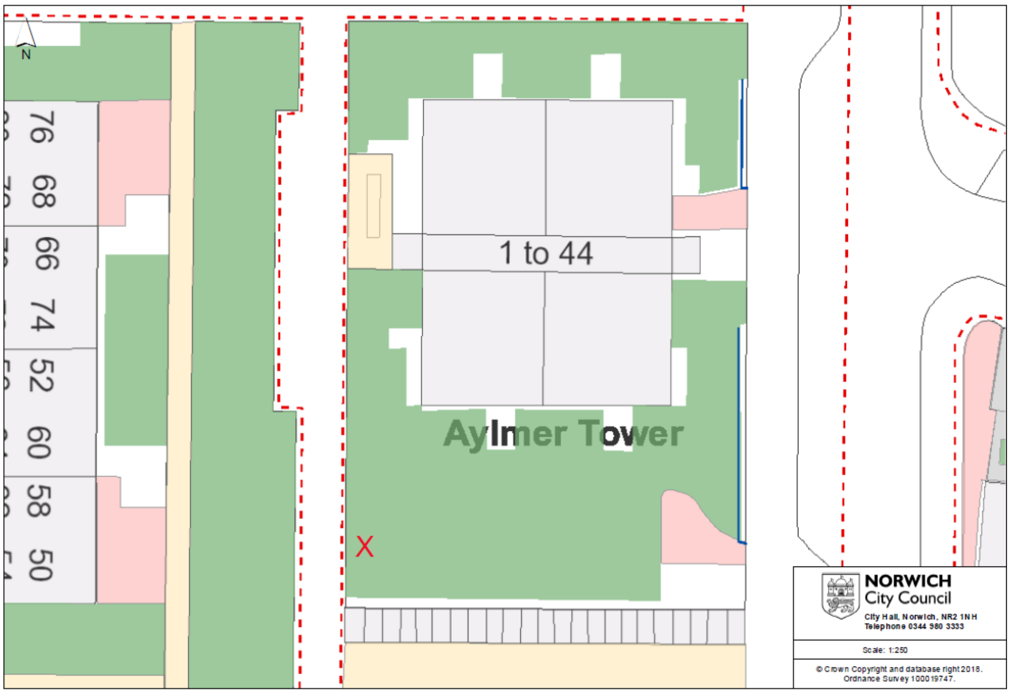
Each week:

- Please place all of your empty drinks cans in just one of the plastic bags provided.

- Seal the bag using a cable tie. Cable ties' colour and length are unique to your property, so please make sure you use the ones provided so that we can count how many cans each household recycles accurately.



- Place your single plastic bag of cans in the 'cans bin' in the area outside the building,identified in the map below with a red 'X'.



Cans will be collected by authorised personnel **every Monday** at some point between 8am-10pm.

If you have any questions concerning this project, please do not hesitate to contact ususing the details provided at the end of the letter.

We thank you in advance for your cooperation and participation in this project.Sincerely,

Mike Brock - T: 01603 597531
Stefania Sitzia - T: 01603 597189
Jiwei Zheng - T: 01603 593422
can.reclycing@uea.ac.uk

Appendix B: SE instructions Individual PPC

University of East Anglia

NORWICH City Council

Norfolk County Council

CAN RECYCLING TRIAL

January 9, 2019

University of East Anglia
School of Economics
Earlham Road
Norwich, NR4 7TJ

Dear Student,

This is to inform you of one important change in the 'can recycling' introduced in September 2018.

From January 14th 2019 until March 18th 2019 you will be paid **£0.10 for each can recycled**. Only cans sealed in the transparent plastic bags with the coloured ties you are given will be considered for payment. So please, do not put any loose cans in the communal cardboard bin if you want to be paid for what you recycle.

To keep track of how many cans you have recycled, you will be given one coloured ticket for each can you recycle. You will only be given tickets if your recycled cans are sealedin plastic transparent bags with the coloured tie you are given. Tickets will be sealed in envelopes and left in your flat every Monday after the can collection.

Remember that the ties' colour is unique to you, so to identify the envelope that contains your tickets, we will write on the envelope the colour of the tie assigned to you and the colour of your raffle tickets.

You will be able to check how many cans you have recycled by counting the number of tickets you have been given. Each student will be assigned tickets of the same colour with sequential numbering (starting from one). The largest number in the sequence represents the total number of cans you have recycled until then. The colour of the tickets, when possible, will be unique to you. However, when this is not possible, your tickets will still be uniquely identified by a code printed on them.

Payments will be made in cash and can be collected in the Accommodation Office on Wednesday 27th March 2019. Bring the tickets with you and you will be paid accordingly.

If you have any questions concerning this project, please do not hesitate to contact us using the details provided at the end of the letter.

We thank you in advance for your cooperation and participation in this project.

Sincerely,

Mike Brock - T: 01603 597531
Stefania Sitzia - T: 01603 597189
Jiwei Zheng - T: 01603 593422

Appendix C: The Bass Model and Its Parameters' Estimation

C.1 The math of the Bass Model

The Bass Model, firstly presented by Bass (1969) is a model that relies on the idea that there are two types of costumers: innovators and imitators. This costumers, or "potential adopters" are influenced by two different mean of communication – mass media, or information specifically related to the product (service) and word of mouth.

The Bass Model derives from the hazard function:

$$\frac{f(t)}{1-F(t)} = p + q\,F(t) \qquad (1)$$

Where:

F(t) is ratio of people (out of the total market volume M) that bought the product by the time and f(t) = ratio of people (out of the total market volume M) that bought the product at any time t. p is the parameter represents the innovators and q the imitators.

Hence, we have:

$$f(t) = F'(t) \qquad (2)$$

The hazard function expressed the idea that an adoption will occur at time t, given that has not yet adopted. Moreover, the basic premise states that the conditional probability of adoption at time t is increasing in the fraction of population that has already adopted.

We have an ordinary differential equation for F(t):

$$\frac{F'(t)}{1-F(t)} = p + q\,F(t), F(0) = 0, \qquad (3)$$

Which can be solved by the separation of variables:

$$\frac{dF}{(1-F)(p+qF)} = dt \;\rightarrow\; F(t) = \frac{1-e^{-(p+q)t}}{1+\frac{q}{p}e^{-(p+q)t}} \qquad (4)$$

Corresponding function f(t) = F'(t):

$$f(t) = \frac{\frac{(p+q)^2}{p} e^{-(p+q)t}}{\left[1 + \frac{q}{p} e^{-(p+q)t}\right]^2} \quad (5)$$

C.2 Estimating the Bass Parameters – Calibration[18]

To estimate the Bass parameters p and q, we can use the historical adoption data (quantity of product sold, sales, individual adopters' numbers) to fit the adoption curve and estimate the parameters. In this specific case to fit the adoption curves we have employed either the number of cans recycled (in the SE and WE) or the number of flats that have engaged with the service (in the SE and RE).

There are two main assumptions and the basis of these the estimation:

1) The number of adopters (or quantities of product adopted, or sales) in any period is equal to:

$$s(t) = m^* f(t) \quad (6)$$

   Therefore: equal to the market potential parameter (m) multiplied by the value of the diffusion function (defined in the previous subsection 8.1) at a specific time t.

2) The cumulative number of adopters (or quantities of product adopted, or sales) up to time a specific time t, can be defined as:

$$S(t)= mF(t) \quad (7)$$

If we substitute (6) and (7) in the Bass equation (1) we find:

$$\frac{\frac{s(t)}{m}}{\frac{1-S(t)}{m}} = p + q\,\frac{S(t)}{m} \quad (8)$$

[18] This section is based on the material of: https://srdas.github.io/MLBook/productForecastingBassModel.html, where additional computational and programming details can be found.

We may rewrite this as:

$$s(t)=[\, p+q\,\frac{S(t)}{m}\,]\,[\, m - S(t)\,] \qquad (9)$$

Therefore,

$$s(t)=\beta_0 + \beta_1\, S(t) + \beta_2\, S(t)^2 \qquad (10)$$

where:

$$\beta_0 = pm \qquad (11)$$
$$\beta_1 = q\text{-}p \qquad (12)$$
$$\beta_2 = -q/m \qquad (13)$$

Equation x may be estimated with an Ordinary Least Square (OLS) regression of the number of adopters (or number of products adopted) against the cumulative number of adopters (or number of product adopted).

Since:

$$\beta_1 = q\text{-}p = -m\,\beta_2 - (\beta_0/m) \qquad (14)$$

we obtain a quadratic equation in m:

$$\beta_2 m^2 + \beta_1 m + \beta_0 = 0 \qquad (15)$$

we solve equation (15) for m, and then we may use the value to solve for:

$$p= \beta_0/m \qquad (16)$$

$$q= -m\beta_2 \qquad (17)$$