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Nudges to increase recycling and reduce waste

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Abstract

Increasing amounts of waste produced by households create serious environmental problems, which may be counteracted with strategies for waste reduction and increased recycling. In this study we look at the potential for changing household behaviour through the provision of personalized information about own recycling and waste habits over time, compared with averages for other households in the same district or municipality. Our randomized field experiment includes about nine thousand households in Kristiansand, Norway. The results show that, compared to the control group, households who received letters with information on recycling behaviour increased their share of recycled waste by on average 2 percentage points over the first 7 months after the letter was received. Providing advice on recycling increased the effect of the letter. Also households who were above median recyclers prior to the treatment increased their recycling after receiving the letter. Households who received the letter promoting waste reduction were also seen to increase their recycling, but it is unclear to what extent they were also inspired to reduce their total quantity of waste produced.

1 Introduction

The amount of waste generated by Norwegian households was 430 kg per inhabitant in 2012, twice as much as 20 years before (SSB 2014). After a reduction due to the financial crisis in 2007-2009, the waste per capita has from 2010 increased at what seems like an accelerating pace. Waste has environmental costs in terms of for instance water pollution and methane emissions from landfills, as well as air pollution from incineration plants. Recycling waste material reduces these costs, both because less pollution is generated, and because it reduces the demand for new material such as wood to make paper, petrol to make plastic and so on (EPA 2009). The share of the waste material that goes to recycling has increased considerably over the last years. In 2012 43% of the Norwegian waste was recycled as material for new products and 40% was recycled as energy production from incineration plants, meaning burning of unsorted waste (SSB 2014). This means that there is still a large potential for Norwegian households to increase their recycling of material such as plastic, paper, glass and metal, which is more environmentally beneficial than burning for energy production. However, from an environmental point of view, recycling is always inferior to reducing the amount of waste. This is because the negative external effects from producing the wasted products are considerably higher than what can be gained from recycling (EPA 2009, Hansen 2010).

Thus, both increased recycling and reduced waste are important environmental policy aims. Recycling has been promoted since the 80s. Over the last years also waste prevention has increasingly become a priority in many national policies worldwide (Zorpas 2013), and there has been a particular focus on food waste (Buzby and Hyman 2012).

In this paper we look at recycling and waste quantities at the household level. Our aim is to find out if it is possible to influence household behaviour into increasing the amount of waste that goes to recycling, and reducing the overall amount of waste it generates. The method we have used is a randomized field experiment, where we provide information to two different treatment groups which is either meant to increase their level of recycling, or reduce their quantity of waste. The effect of this information on their recycling and waste levels are measured against a control group.

Recycling and waste reduction are two concepts that are closely related, yet on some aspects fundamentally different. While recycling basically is about sorting your waste into different containers, waste reduction is far more complex, and includes various different acts such as to avoid junk mail and use your own shopping bag, or a range of different behaviours to reduce food waste (Cox et al 2010). Studies which have looked at recycling and waste prevention behaviour together, have found that the two are not correlated, meaning that those who recycle a lot not necessarily also do waste prevention activities (Ebreo and Vining 2001, Tucker and Douglas 2007). Some studies have found that waste prevention appears to be a poorly understood concept, while the recycling norm has become so strong that this is generally people's understanding when they are asked to 'reduce waste' (Cox et al 2010). Research also suggests that recycling may become a reason for not doing more to reduce waste (ibid).

Numerous previous studies have looked at recycling at household levels, and tried to identify the drivers for increased recycling. Studies on socio-demographic variables influencing recycling have found that it increases with higher income and larger households (Jenkins 2003), higher education levels (Reschovsky 1994) , and that women recycle more than men (Iyer and Kashyap 2011). It has also been found that the presence of a kerbside collection system have a strong impact on recycling (Kneip and Best 2011). Kerbside collection of recycled material is now common in most of Norway, particularly for paper (Kippenberg 2007). This means that although access to recycling facilities is still important, it is no longer the only key inhibitor to participation in recycling, and that other aspects need to be investigated (Iyer and Kashyap 2011).

According to Tucker and Douglas (2007) many people who carry out waste reduction behaviours do it as a normal part of their everyday life, and not for reasons related to waste reduction. Studies looking at waste prevention behaviours have found that they are more prevalent among individuals who are older, with middle to high income, female, living in detached properties and not living with

children at home (Cox et al. 2010). In general it is difficult to explain waste prevention behavior, which could be related to the fact that it is not just one single behaviour, but many (ibid).

A key to increasing recycling and waste prevention is not only to understand what the drivers are behind these actions, but also what policies may promote them. Previous studies have found that disseminating information that increases consumers' knowledge has a more lasting effect on recycling than offering incentives (Iyer and Kashyap 2011). Osbaldiston (2011) found that feedback on performance of recycling is an efficient way of promoting it, although not as efficient as others, such as goal-setting. Interventions to induce waste prevention behaviour among households are still a relatively new area for authorities, but some examples which have been tried are doorstepping campaigns with information packs and advice (Dorset County Counsel 2008), and campaigns where individuals sign up to be part of a group receiving a package of advice, challenge activities and hands on support (Waste Watch 2006).

When confronted with an ambiguous situation, people look to others for cues about how to behave, a concept known as 'social proof' (Moseley 2013). In a study of recycling and attitudes in Norway, Brekke et al. (2010) found that people's propensity to ascribe responsibility was increasing in how common they think recycling is in their social group. They also found that the more common people believe recycling to be among their peers, the more they are likely to be recycling themselves. Thus, one important element to increase pro-environmental behaviour such as recycling and waste reduction is the development of a social norm. Also other previous studies have found that societal norms and peer or community pressure increase an individual's motivation to recycle (Iyer and Kashyap 2011). Knowing or seeing that others are taking action can create a sense that individual contributions are worth the effort (Tucker and Douglas 2007). But according to Cox et al (2010), waste prevention behaviour, unlike recycling, tends to be private and invisible, so there is much less likelihood of a social norm developing.

Hence, what seems to be important is, on the one hand, to provide information about recycling and waste prevention (Iyer and Kashyap 2011), and on the other hand, to develop a norm in society, where recycling and waste prevention is considered pro-social behaviour (Nomura 2011). Providing feedback on an individual's own performance related to the rest of the society can serve to activate specific norms in that individual's mind, and the information can serve as a guideline to what is the appropriate course of action (ibid).

Social comparative feedback has been used in several previous studies related to electricity use. But where some studies have found a positive effect of providing information about own compared to neighbours' performance (Schultz et al. 2007), others find no such effect (Fischer 2008, Sælen et al. 2013). An important difference between electricity and recycling is that electricity use is invisible, while it is relatively more easy to see how much one recycles. Hence while feedback on own electricity consumption may have an effect, for recycling it may also be necessary to give comparative feedback, that is, own recycling compared to others, in order to change behaviour. Studies of the effect of social comparative feedback has also been conducted in relation to recycling. In a study from England by Nomura et al. (2011) feedback was given on the recycling performance of entire streets, not on each individual households. It was found that the feedback increased the likelihood of more households participating in the food recycling scheme by 2.8%, and that the effect was strongest after the second letter with feedback was sent (Nomura et al. 2011). An example of a study on how it is possible to create incentives to reduce food waste is the study by Kallbekken and Sælen (2013). In their experiment the plate sizes at hotel buffets were reduced, and social cues were given to the hotel guests. This "nudge" reduced the amount of food wasted by around 20%.

In this study we are using both social comparative feedback, feedback on own performance, and information and advices related to both recycling and waste reduction. An experiment was carried out in the city of Kristiansand in southern Norway, where this type of information was provided to 6000 households. Waste statistics from these households, and 3000 more in a control group, was provided by the waste management agency in the area. The aim was to find out to what extent the letters have had an effect on household recycling and waste reduction. The structure of the paper is as follows: The first part describes the experiment and how it was run. In the following section we look at the results using the waste statistics from these households. In the next part we analyse some of the results of a survey carried out during the project. The last part concludes.

2 Experimental design

This study uses data from a natural field experiment on household waste in Kristiansand, which is the fifth largest municipality in Norway (about 85,000 inhabitants). The experiment was carried out in 2014 in collaboration with Avfall Sør, which is a publicly owned company responsible for waste management and collection in the Kristiansand region (Kristiansand and three surrounding municipalities). The waste collection system in this region is described below. Next we present the experimental design and the data used in this study.

2.1 Waste collection system in the Kristiansand region

The household waste system in the Kristiansand region consists of a kerbside collection scheme, about sixty local collection points (for glass, metal, plastic and textiles), and four larger recycling stations (all types of waste including hazardous waste). In the kerbside collection scheme, each household has three types of waste bins: a paper waste bin; an organic waste bin (food waste, garden waste, etc.); and a residual waste bin for unsorted waste.

The paper waste bin is picked up every fourth week, while the other two waste bins are picked up once per week. Each waste bin has attached a radio frequency identification (RFID) tag that transmits relevant data to a corresponding reader on each recycling truck. These data – a binary indicator that waste bin x has been picked up at date y and, conditional on being picked up, the weight of that waste bin – are in turn passed on to a central computer database. Thus, the kerbside collection scheme in Kristiansand is relatively unique in that detailed waste data, including total weights and degree of recycling, are available at the household level.

Today, these data are mainly used to calculate a partly variable household waste collection fee; the households pay a fixed fee based on the size of each of the three waste bins (size chosen by the household, varies from 120 to 660 litres, the large majority has 120 litre bins), and a variable fee based on the number of times the organic waste and the residual waste bins have been picked up by the recycling trucks in a given year[4]. The fee is not related to the amount of kilos in the bin being emptied. The households decide themselves whether or not to put the waste bin at the collection point, where it will be emptied regardless of how full it is.

2.2 Outline of experiment

The field experiment in this study uses personal information and social comparative feedback as a means to motivate households to reduce total waste and increase their degree of recycling. The treatment consist of personal letters to households in Kristiansand with information about own waste data and corresponding waste data in a comparison group. The experiment has one control group and two main treatment groups. The first treatment group (quantity group) focuses on total household waste, while the second treatment group (recycle group) focuses on degree of waste sorting. An overview of the experiment is provided in Table 1. The different elements in the experiment are discussed in more detail below.

[4] The fee for 2014 was 40 NOK for a 120 liter bin of residual waste and 33 NOK for a 120 liter bin of organic waste

Table 1. Overview of field experiment on household waste in Kristiansand

Timeline	Recycle group: Degree of waste sorting (2,994 households)	Quantity group: Total household waste (3002 households)	Control group (2983 households)
Jan 1, 13-Aug 15, 14	Record number of times waste collected and weight (kg) for each emptied waste bin (paper, organic and residual waste bins) for each household through the RFID tag system.		
Jan 10, 14	First letter: Recycle group 1 and 2: Information on own waste sorting in 2012/13 and corresponding average for households in same district in 2013. Motivational cue for increased degree of waste sorting in 2014. Recycle group 2 (1,970 of 2,994 households): Additional page with advices on how to improve waste sorting and examples of recycling benefits.	First letter: Quantity group 1 and 2: Information on own total waste (kg) in 2012/13 and corresponding average for households of different sizes in Kristiansand in 2013. Motivational cue for reducing waste in 2014. Quantity group 2 (2,014 of 3,002 households): Additional page with advices on how to reduce waste and examples of benefits from reducing waste.	
Sept 15, 14	Second letter: Information on own change in waste sorting from Jan-Jun 2013 to Jan-Jun 2014 and corresponding average change for households in same district. Invitation to online survey.	Second letter: Information on change in own total waste (kg) from Jan-Jun 2013 to Jan-Jun 2014 and corresponding average changes for households of different sizes in Kristiansand. Invitation to online survey.	First letter: Invitation to online survey.

2.2.1 First round of letters

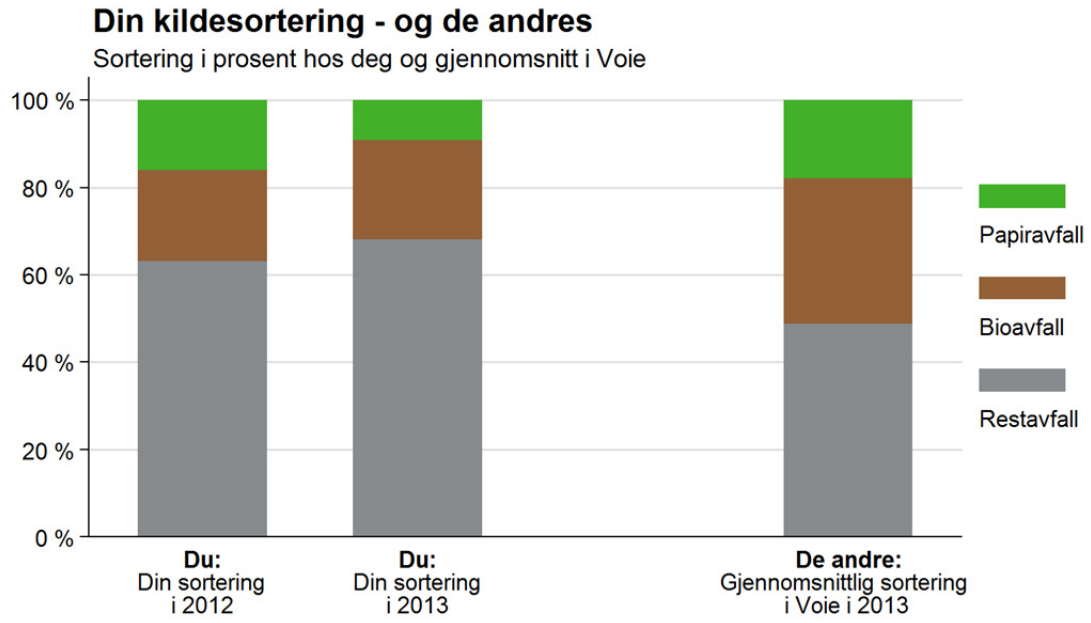
The first round of letters in the experiment was mailed by Avfall Sør on January 10, 2014. A total of 6,006 households received one out of four types of letters, while the control group of 2,983 households did not receive any letter. To be included in one of the treatment groups or the control group, the households needed to pass the following inclusion criteria; (i) the household does not share waste bins with other households (e.g., cooperatives); (ii) the household has not signed up for home composting; (iii) more than 50 kg and less than 2,500 kg waste was collected from the household in both 2012 and 2013; and (iv) waste was collected from the household at least once during the first quarter of 2012, and at least once during the last quarter of 2013.[5] There were no statistically significant differences between the two treatment groups and the control group with respect to mean household waste (kg) and degree of waste sorting in 2012 and 2013.

The households in the recycle group (2,996 households) received letters with information about own degree of recycling in 2012 and 2013 and the corresponding average for households residing in the same district in 2013. As a motivational cue for increased degree of recycling in 2014, the letter finishes by saying that another letter with updated information will be sent out in six months, and then encourages the reader to try to improve their recycling and become better than others in the district. About two-thirds of the households also received an additional page with general information about recommendations on how to improve their own waste sorting, and some examples on how recycling benefits society (Appendix, in Norwegian). An extract of the first page of the recycling letter, which was sent to all households in the recycle group is provided in Figure 1.

[5] There were also some additional, more technical inclusion criteria that are not detailed here.

Are you better at waste sorting than other households at Andøya?

[…] In 2013, we picked up a total of 1,042 kg waste from your household. […] The figure below shows how your waste was distributed between the three different types of waste bins in 2012 and 2013. To the right you see the corresponding average for other households at Andøya in 2013. **Low share of residual waste** (grey) means **high degree of waste sorting**. Was your household better at waste sorting in 2013 than in 2012? And were you better than other households at Andøya in 2013?



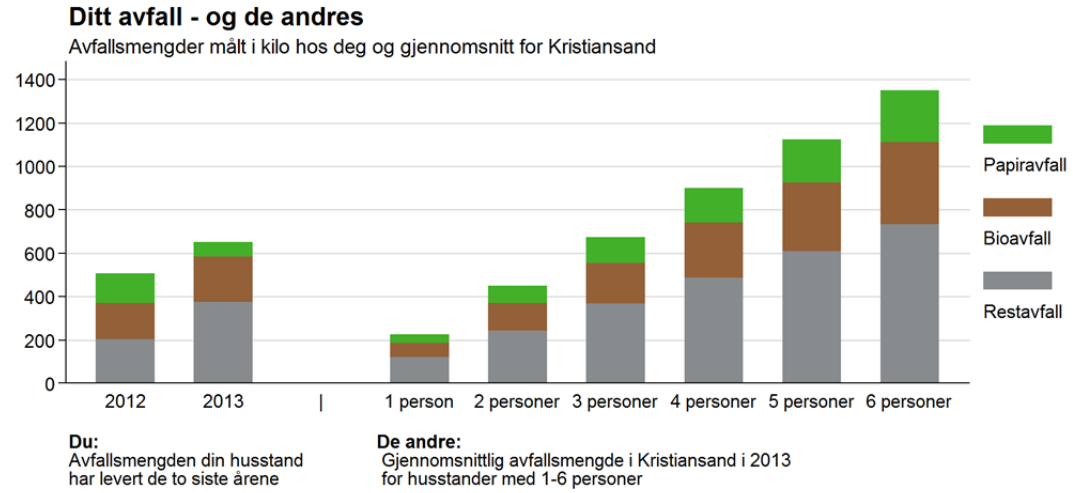
Monitor your waste sorting in 2014: Later this year, you will receive information about your waste sorting this year compared against last year. Can you increase your degree of waste sorting this year compared against last year? And will you be better at waste sorting than other households at Andøya? […]

Figure 1. Extract of the first letter to the recycle group with information about degree of recycling

The households in the quantity group (3,002 households) received letters with information about own total waste volume (kg) in 2012 and 2013, the corresponding averages for households of different sizes in Kristiansand in 2013, and a motivational cue for reducing waste in 2014. About two-thirds of the households also received an additional page with advices on how to reduce waste as well as some examples of individual and environmental benefits from reducing waste (Appendix, in Norwegian). This allows for assessing whether such general information has an additional effect on reducing household waste. An extract of the first page of the total household waste letter, which was sent to all households in the quantity group, is provided in Figure 2.

Do you throw less waste than other households in Kristiansand?

[…] The figure below shows how much waste we picked up from your household in 2012 and 2013, split by type of waste. […] To the right you see average waste volumes for all households in Kristiansand in 2013, split by number of persons living in the household. Did you throw away less waste in 2013 than in 2012? And did you throw away less waste than other households of your size in 2013?



Monitor your waste in 2014: Later this year, you will receive information about how much waste we pick up this year compared to last year. Can you throw away less waste this year compared to last year? And can you throw away less waste than other households in Kristiansand? […]

Figure 2. Extract of the first letter to quantity group with information about total household waste

The letters to the two treatment groups focus on two different aspects of household waste, but are otherwise very similar in design. The main difference is related to the size of the comparison groups. In the recycle group, the comparison group is all households residing in the same district as the household itself. The districts in the recycle group vary in size from 63 households in the smallest district, to 885 households in the largest district. Unlike degree of waste sorting, total waste volume is sensitive to household size. We do not have access to data on household size or the number of inhabitants at the district level. Therefore, in the quantity group, all households in Kristiansand constitute the comparison group. For simplicity, we assume a linear relationship between household size and total waste volume, and as shown in Figure 2, we asked each household to compare themselves against households of their own size. The information in this letter is therefore a bit more complicated to read than the information in the recycle letter.

2.2.2 Second round of letters

The second round of letters was mailed on September 15th, 2014. This letter had two main purposes. First, the households in the two treatment groups received information about changes in own total waste volume and degree of waste sorting, respectively, from Jan-Jun 2013 to Jan-Jun 2014, and corresponding average changes in the respective comparison groups. Second, the letter included an invitation to participate in an internet survey focusing on household waste and socio-demographic characteristics. Also the households in the control group (2983 households) received letters with invitation to participate in the internet survey.

3 Data and methods

3.1 Summary statistics pre-treatment data

Table 2 and 3 below shows average waste quantities and degree of recycling in 2012 and 2013, for each of the three groups in the experiment, measured in terms of weight (kg) and number of times waste bins were collected, respectively.

Table 2. Waste quantity and degree of recycling before experiment, measured by weight

	Variable	Recycle group	Quantity group	Control group
2012	**Total weight**	723 kg	726 kg	720 kg
	% residual	45%	47%	47%
	% organic	33%	32%	32%
	% paper	22%	20%	21%
	Residual	326 kg	341 kg	335 kg
	Organic	239 kg	238 kg	230 kg
	Paper	158 kg	146 kg	155 kg
2013	**Total weight**	769 kg	765 kg	784 kg
	% residual	49%	50%	50%
	% organic	33%	33%	32%
	% paper	18%	16%	18%
	Residual	377 kg	387 kg	392 kg
	Organic	254 kg	253 kg	247 kg
	Paper	137 kg	126 kg	145 kg

Table 3. Waste quantity and degree of recycling before experiment, measured by number of times bins collected

	Variable	Recycle group	Quantity group	Control group
2012	**Total times collected**	55.9	57.1	54.9
	% unsorted	53%	54%	53%
	% organic	30%	29%	29%
	% paper	18%	17%	18%
	Unsorted	29.6	30.8	29.3
	Organic	16.5	16.8	15.8
	Paper	9.8	9.5	9.8
2013	**Total times collected**	56.8	57.7	56.2
	% unsorted	54%	54%	54%
	% organic	29%	29%	29%
	% paper	18%	16%	17%
	Unsorted	30.7	31.4	30.3
	Organic	16.8	17.0	16.2
	Paper	9.3	9.2	9.7

We observe that the means of the three groups are similar, for all the different categories, in the two years before the experiment. There are no statistically significant differences between the means. We also observe that from 2012 to 2013 there has been an increase in the total amount of waste produced on average by each household. The amount of residual and organic waste has increased, while the amount of paper has decreased, this is particularly visible when using weight in kg as measure (Table 2). That paper waste has decreased is possibly a consequence of the digitalization of information. The percentage of residual waste, measured in kg (Table 2) increased by approximately 4 percentage points from 2012 to 2013, hence the share recycled went down.

The percentages obtained by the two measures vary slightly. In 2013 the percentage unsorted waste was 49% in terms of weight, but 54% in terms of number of times bins collected. This can be explained by the fact that organic and paper waste often will have a higher weight than unsorted waste, which often contains plastic. Plastic containers and bags often take up a lot of volume, but have a low weight.

In the following we will use both weight and number of times bins collected as measures. Although weight is probably a more accurate measure than number of times waste collected, the two complement each other in that one of them measures weight, and the other volume. We are also aware that the weights on the waste collecting cars sometimes get damaged[6], and therefore report incorrect weights. When the weight difference is big the error is easily detected, but when it is small this is more difficult, and there is a possibility that cars for several weeks may have given incorrect weights in certain districts. For this reason as well we have chosen to sometimes present both set of numbers.

[6] Weights are calibrated when there is suspicion of damage, this happens on average twice a year per car.

3.2 Post treatment data analysis

As described in Section 2.2, the recycle group and the quantity group received letters promoting recycling and waste reduction, respectively. However, these two aspects are strongly related, and we will therefore measure the effect of the two different letters on both recycling and waste quantities, for both our treatment groups.

3.2.1 Average recycling levels pre and post treatment

The data that will be analysed in this section are from the period January 2012 until August 15th 2014. If we first consider the effect of the letters for the whole post treatment period, we can look at the simple averages for the recycle, quantity and control groups, for the post treatment period, and the same period the previous year (Feb-Aug 2013). The figure below show the weight of the recycled waste (paper and organic) as a percentage share of total waste.

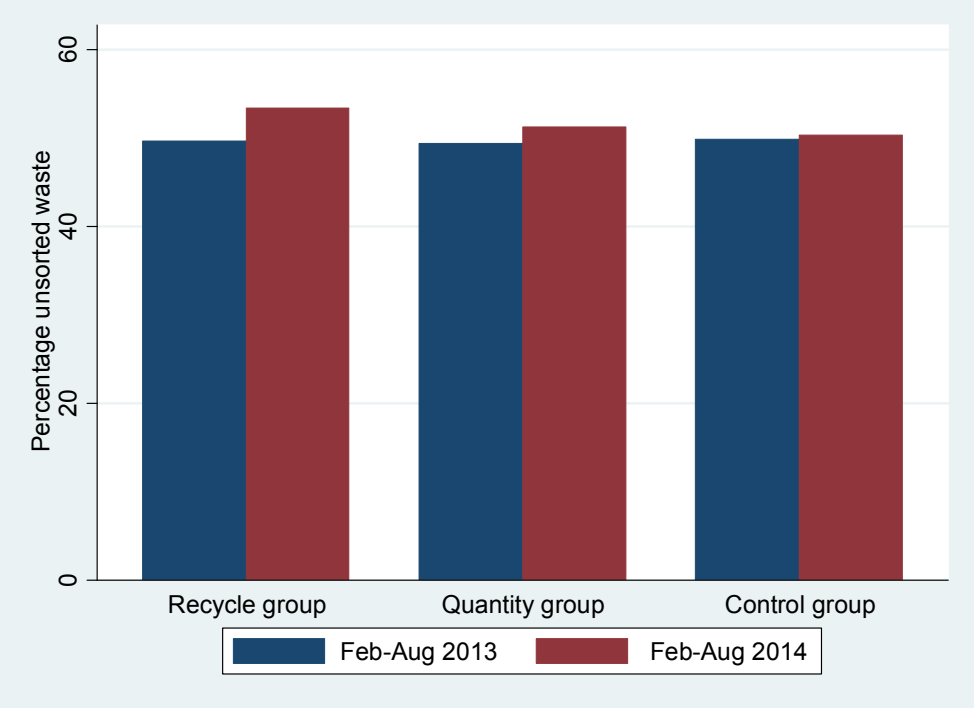


Figure 3. Average recycling level before and after nudge, measured in kg

The difference between the recycling level in 2013 and 2014 is larger in the recycle group and the quantity group, compared to the control group, and the difference is statistically significant. The average recycling level increased by 3.4 percentage points for the recycle group, by 1.6 for the quantity group and by 0.1 for the control group.

In order to get panel data properties, the data can be divided into different periods, where each period should contain at least one round of collecting paper bins, which happens once every 4 weeks. One observation per 4-week period is thus one possible measure. Another possibility is to put 3 following 4 week periods together, and get one observation per 12 week period. This creates more stability in the observations, but less observations. The figure below shows the average percentage of unsorted, residual waste per 12 week cycle, for the households who received the recycle letter, and for the control group.

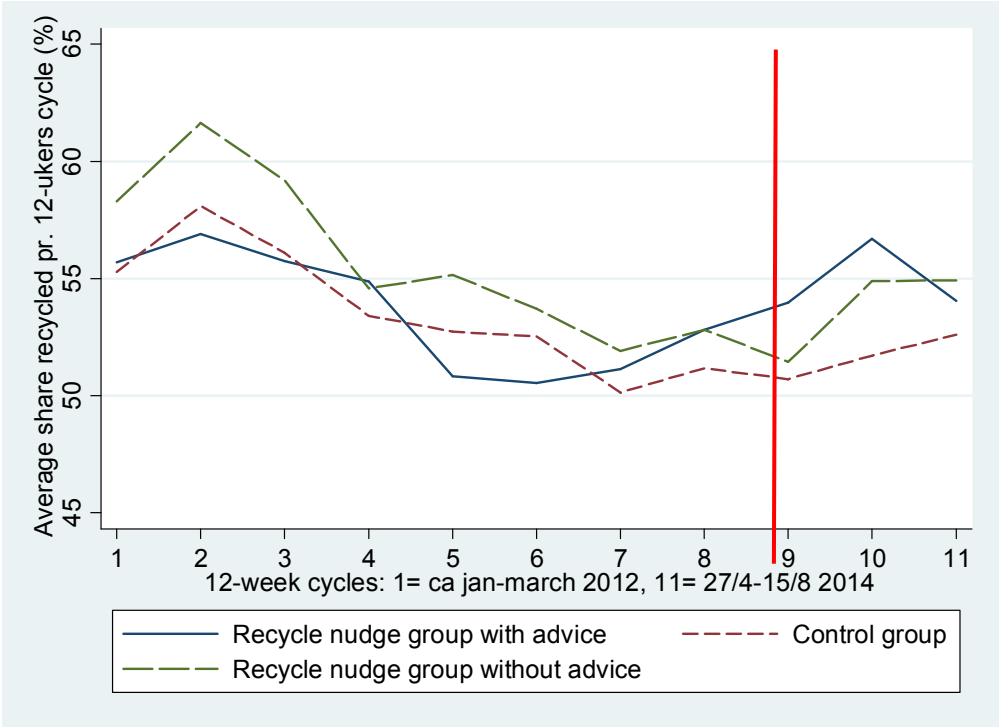


Figure 4. Periodic development in recycling 2012-2014, average per 12 week period

We see that on average, all groups increase their recycling from approximately cycle 7, which is the period 27/5-18/8 2013. The letter was received during cycle 9 (indicated by the red line), and the largest difference in average between the groups is observed in cycle 10. Thereafter the recycle group decreases its percentage recycled waste, while the control group continues to increase it. However, cycle 11 contains the two summer months July and August, where waste patterns are more unpredictable due to holidays and people either going away for longer periods, or receiving visitors at their house. Hence data from these two months should be looked at cautiously.

3.2.2 Average waste quantities before and after nudge: Periodic development

Figure 5 shows the periodic development in waste quantities for the group who received the letter promoting reduced waste quantities, and the control group. We see that the three curves follow each other closely, and there is little change after the nudge takes place in period 9. If anything, it looks as though the quantity group at first decreases its average amount of waste, and thereafter increases it compared to the control group.

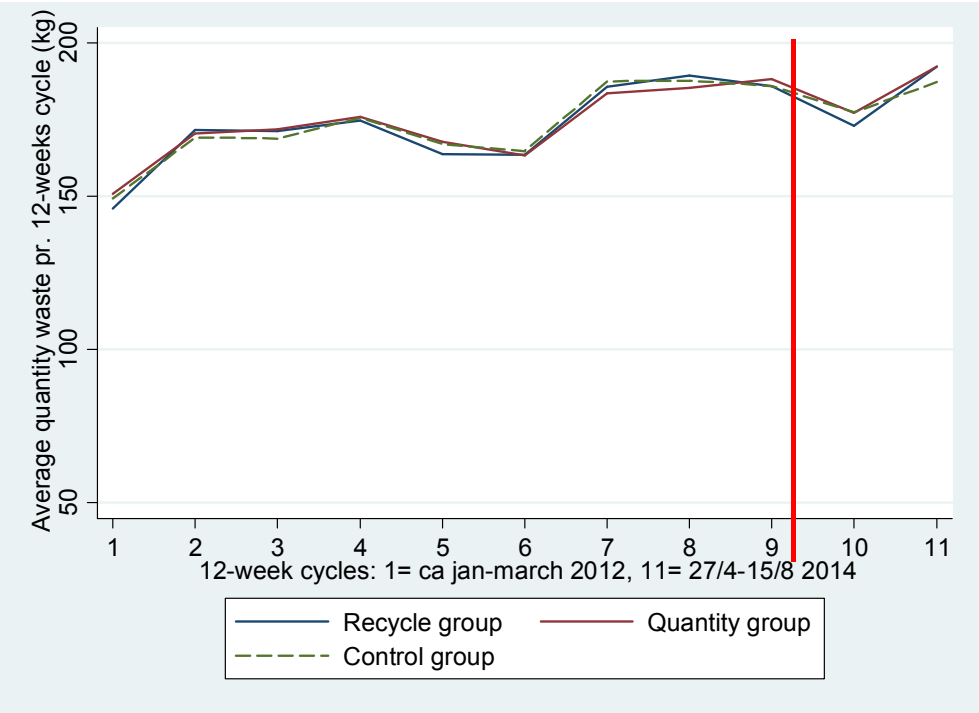


Figure 5. Periodic development in waste quantity 2012-2014, average per 12 week period

3.3 Econometric analysis

In order to estimate the effect of the letters, we need to control for the waste habits of each household before the letter was received. There are several possible methods to use in this case, which caractarizes as a randomized field experiment. Some of these methods are described in for instance Angrist and Pische (2009). Given that we have a panel data set with approximately monthly observations, we estimate a fixed effects panel regression model. The method will give the same results as a difference in difference method (Card and Krueger 1994).

$$Y_{it} = \mu_t + \mu_t \cdot D_{it} + \ \propto_i$$

Y_{it} is either the percentage recycled of total waste, or quantity waste, for houshold i in period t, μ_t is the period after treatment, D_{it} is the treatment group dummy (recycle or quantity group), and $\propto_i$ is the household fixed effects. The regression is clustered on households.

4 Results

4.1 Results recycling

When analysing the effect on recycling, we use waste data from the period January 2012-August 2014, with one observation per household per 4 week period. In addition to the main specification described above, we have made 3 more specifications. In specification 2 we check if the effect of the treatment is wearing off after some time. This is done by including an interaction between period after treatment, the dummy for the recycle group and if the waste cycle is later than April 2014. In specification 3 we check if the recycle advices given to two thirds of the households have an additional effect, and in specification 4 we check if households who had a level of recycling above the median in 2013 become worse at recycling after receiving the letter, the so-called "boomerang-effect" (Schultz et al 2007). Likewise, we also check if the effect is stronger on households who decreased their recycling from 2012 to 2013 (approximately 2/3 of the households) than on those who did not.

The results of the regression analysis are seen in Table 4 below.

Table 4. Regression results. Dependent variable is percentage recycled waste of total waste, measured by weight

	Spes 1	**Spes 2**	**Spes 3**	**Spes 4**	**Spes 5**
Period after treatment	1.3***	1.3***	1.3***	1.3***	1.3***
	(0.2)	(0.2)	(0.2)	(0.2	(0.2
Period after treatment*recycle nudge	2***	3***	0.8**	1.1**	4.9***
	(0.3)	(0.3)	(0.4)	(0.3)	(0.4)
Period after treatment*quantity nudge	1.5***	0.9**	1.5***	1.5***	5.2***
	(0.3)	(0.3)	(0.3)	(0.3)	(0.4)
Treatment*recycle nudge*last cycles		-1.7***			
		(0.3)			
Treatment*quantity nudge*last cycles		1***			
		(0.3)			
Treatment*recycle nudge*advice			1.9***		
			(0.4)		
Treatment*recycle nudge*below median recycling 2013				2.2***	
				(0.4)	
Treatment*recycle nudge*decreased recycling from 2012 to 2013					-4.3***
					(0.4)
Treatment*quantity nudge*decreased recycling from 2012 to 2013					-5.6***
					(0.4)
Household fixed effects	Yes	Yes	Yes	Yes	Yes
Number of households	8979	8979	8979	8979	8979
Observations	297298	297298	297298	297298	297298

Note: For all specifications, dependent variable is share recycled, data period is January 2012-August 2014, observations are at 4 week periods, and we have used a fixed effects model.

We observe that the share of recycled waste increases by 2 percentage points more in the recycle group, and by 1.5 percentage points more in the quantity group, than in the control group. With the specification checking for declining effect over time (Spes 2), we find that the effect decreases after April 2014, but the total effect is still positive (3.03-1.7=1.33).[7] For the quantity group we do not find the same reduction in recycling in time. We also find that giving advices (Spes 3) increases the effect on the recycling level (2.7 percentage points, compared to 0.8 for those who did not receive any advice). Furthermore, we see that those in the recycle group who had a recycling share below the

[7] When we do the same regression without the two summer months July and August, which have some uncertainty due to holidays, we do not find a declining effect over time.

median in 2013, increase their recycling by 3.4 percentage points more than the control group (Spes 4).Households who had a recycling share above the median in 2013 increased their recycling share by 1.1 percentage points more than the control group, hence we do not see any tendency of a "boomerang effect" (Schultz et al. 2007).

Finally, we see that the effect of the letter is stronger among households who had increased their recycling share from 2012 to 2013, than among households who had decreased it (Spes 5). For the quantity group the effect is even negative for those who had decreased their recycling level, but this is not significant. An explanation to this could be that it is more difficult to change the behaviour of those who are on a track of recycling less than to further improve the behaviour of those who are on a track of recycling more. It could also be the case that these numbers have a discouraging effect rather than creating incentives to improve. It is somewhat surprising to find this effect of the own-comparison feedback, while the social comparative feedback had a higher effect on households who were not good at recycling before the treatment.

A sensitivity analysis with data using household observations per 12 week period is shown in appendix 2. The results are very similarto the ones where observations per 4 week period are used. We have also performed the analysis using number of times bins collected instead of weight as measures, this also gives very similar results.

4.2 Results waste quantities

When analysing the effect of the letters on waste quantities, we use the same fixed effects model as for the recycle case, but this time with waste quantity as the dependent variable. We also use the same data period (January 2012-August 2014) and observation level (one observation per household per 4 week period). We look at the effect of the letters both on total waste quantity and on the quantity in each bin separately.

Table 5. Regression results quantity measured by weight, fixed effects

	Tot kg	Residual kg	Organic kg	Paper kg
Period after treatment	2.6***	2.3***	1.3***	-1.03***
	(0.3)	(0.2)	(0.2)	(0.08
Period after treatment*quantity group	0.8**	-0.6**	0.2	1.1***
	(0.4)	(0.3)	(0.2)	(0.1)
Period after treatment*recycle group	0.1	-1.1***	1***	0.3**
	(0.4)	(0.3)	(0.2)	(0.1)
Fixed effects	Yes	Yes	Yes	Yes
Number of households	8979	8979	8979	8979
Observations	297858	297858	297858	297858

The result of this fixed effects regression analysis is somewhat surprising. In the specification where total waste quantity is the dependent variable, the dummy variable for the quantity group is positive and significant at the 5% level. Looking at the specifications where the residual waste, the organic waste and the paper waste are the dependent variables, we see that while the effect of the letter on the residual waste is negative both for the quantity and the recycle group, the effect on the paper waste is strongly positive for the quantity group, and much stronger than for the recycle group (1.1 kg increase in paper waste per 4 week cycle, versus 0.3 kg for the recycle group). There is no significant effect on the organic waste for the quantity group, and a significantly positive effect on the organic waste for the recycle group.

When we do the same regression with number of times collected instead of weight as the dependent variable, we get rather different results.

Table 6. Regression results quantity measured by times waste collected, fixed effects

	Total Q	Residual Q	Organic Q	Paper Q
Period after treatment	0.2***	0.08***	0.1***	0.006**
	(0.02)	(0.01)	(0.01)	(0.003)
Period after treatment*quantity group	-0.1***	-0.09***	-0.03**	0.01**
	(0.02)	(0.01)	(0.01)	(0.005)
Period after treatment*recycle group	-0.02	-0.08***	0.03**	0.03**
	(0.02)	(0.01)	(0.01)	(0.005)
Household fixed effects	Yes	Yes	Yes	Yes
Number of households	8979	8979	8979	8979
Observations	297858	297858	297858	297858

The results on total waste are now the opposite of the ones obtained with kilos. Now the effect of the letter on the total amount of waste is significantly negative for the quantity group, and this is also the case for both the residual waste and the organic waste. The effect on the paper waste is positive and significant at the 5% level, but the effect is weaker than the effect found for the recycle group. The results derived with the data on number of times waste was collected seem more plausible than the ones derived from the weight data. These results indicate an increase in the amount of paper wasted by the quantity group, which could be due to the fact that the quantity letter also motivates to more recycling. But the paper increases less for the quantity group than for the recycle group. It is difficult to find a logical explanation to why the paper waste measured in terms of weight should increase a lot more in the group which received the quantity letter, than in both the control group and the recycle group. The divergence between the results derived from number of bins collected (Table 6) and the results derived from using weight data (Table 5) might indicate that a paper collecting car has had a problem with its scale in one of the districts of the quantity group, and that the weights obtained on paper for the quantity group are higher than what they actually should have been.

The quantity letter leads to a decrease in residual waste, this is the case both when measured by weight, and by number of times waste collected. The organic waste is found to decrease when number of times waste collected is used as a measure, while there is no significant effect on weight. This could be because the organic waste, on the one hand, decreases because the nudge inspires to less food waste, while on the other hand it may increase because the nudge also inspires to more recycling. When using number of times waste collected as a measure, the reduced waste effect seems to dominate the increased recycling effect.

A sensitivity analysis is found in the appendix, where we use observations per 12 week cycles. We find the same pattern and differences between analysis with weight and number of times waste collected. One difference is that the effect of the quantity letter on the organic waste is not significant, neither when using weight nor times collected as measure.

5 Results survey

In September a second letter was sent to the households participating in the experiment. In this letter, households belonging to the quantity and recycle group received updated information about their waste performance, both relative to their own previous performance, and relative to the average in their district (in the case of the recycle group) or municipality (in the case of the quantity group). The same letter contained an invitation to participate in an online survey. The invitation to the online survey was also sent to the households in the control group. Altogether 1409 people participated in the survey, although they did not all complete all the questions. Among the answers there were 473 people from the recycle group, 453 people from the quantity group and 483 people from the control group. On average, the households who responded to the survey have a higher level of recycling (61%) than the average for the whole experiment (50%). This selection bias is something that should be remembered when analysing these results.

5.1 Perception of letters

The survey contains a range of questions, but we will here only describe the results that are most relevant to the experiment. The respondents were asked how easy it was to understand the information in the letter they had just received. Approximately 84% found the information in the letter "easy to understand", and there was no difference between those who received the recycle letter and those who received the quantity letter. 10% thought the information was a bit or very difficult to understand, while 6% had not read the letter very well.

The respondents were then asked what they thought about the content of the letter. The table below summarizes their responses.

Table 7. Responses to information in letters

	Recycle group	Quantity group
Useful information	71%	73%
Useless information	6%	4%
I was surprised that my household do not recycle more	6%	5%
I was surprised that my household recycle that much	14%	16%
I think it will influence me to waste more	0.65%	0.67%
I think it will influence me to waste less	9%	16%
I think it will influence me to recycle more	27%	20%

As we can see, the two groups respond in a very similar way. The only difference is that there are more people in the quantity group than in the recycle group who believe they will be influenced to waste less (16 against 9%), while there are more people in the recycle group than in the quantity group who believe they will be influenced to recycle more (27 against 20%). In both cases people are more inspired to recycle more than to reduce waste, also in the quantity group.

Regarding the question whether they remembered receiving a similar letter in January the same year, 60% in the quantity group and 71% in the recycle group answered "yes". There are also far more people in the quantity group than in the recycle group who answered "no" to this question (33 against 16%). The rest are uncertain. It is difficult to find any socio-demographic explanation to this difference, as age, education and income level and household sizes are very similar in the two groups. It seems therefore that the recycle letter has left a more lasting impression on the respondents than the quantity letter.

Table 8. Answers to the question: "Do you remember receiving a similar letter dated January 10th 2014?"

	Recycle group	Quantity Group
Yes	71%	60%
No	16%	33%
Do not know	13%	7%

Among those who received supporting advices with the January letters, only 15% in the recycle group and 13% in the quantity group answered "yes" to the question if they received advices with the letter. 15% in the recycle group and 12% in the quantity group answered "no", while the rest are not sure.

Table 9 below shows how people answered the question "Do you think the information in the letter received in January has influenced your households waste habits?" This question is similar to the one asked about the September letter, only now the respondents were asked to look back at the effect that there might have been. There were far more people in the recycle group who thought it had made them recycle more (31%), than there were in the quantity group who thought it had made them reduce their waste (12%). There were also more people in the quantity group thought the letter had made them recycle more (17%). There was no significant difference in the answer to this question, between those who had received the advices and those who had not. But among those who remembered receiving the advices, there was a higher percentage who thought it had made them recycle more, and in the quantity group more people thought it had made them reduce their waste. It should however be noted that in these subgroups there are sometimes very few respondents.

Table 9. Answer to the question: "Do you think the information in the letter received in January influenced your households waste habits?"

	Recycle group			Quantity group		
	All	With advice	Remember advice	All	With advice	Remember advice
Has made me recycle more	31%	29%	49%	17%	18%	30%
Has made me waste less				11.7%	11.3%	23%
No influence	46%	47%	38%	47%	47%	45%

5.2 Other findings

In the survey we also tried to identify factors influencing people's waste habits. One of these questions were: «Which of the following statements do you consider the most correct concerning what happens to the sorted waste delivered to Avfall Sør?". The alternative answers where: 1) All of it is recycled and will become raw material for new products 2) All of it will be burnt with the unsorted waste, and 3) Some of the sorted material will be recycled, but a lot of it will also be burnt.

The true answer to this is that all of the sorted material goes to recycling, and it is therefore surprising that as many as 62% of the respondents believe a lot of it is being burnt with the unsorted waste, and 3% believe it all goes to combustion. A simple summary statistics also shows that this attitude has an effect on recycling levels, and also on waste levels. The table below shows the quantity of waste and the recycling levels of households, according to what they believe happen to the sorted waste.

Table 10. Average waste habits according to beliefs about what happens to sorted waste

	Quantity waste per person	% recycled
All of it is recycled	357	64%
A lot of it is burnt	366	61%
All of it is burnt	422	55%

We observe that it is particularly those who believe that all the sorted material goes to combustion, who have not only a lower degree of recycling, but also a higher total quantity of waste. This is probably due to the fact that they to a lower degree recycle plastic, metal or glass, which also will affect the total waste quantity, since this has to be delivered at special returning points.

6 Discussion

In this study households received information on their waste habits: their own performance over time and their performance compared to their neighbourhood. The aim was to see if this information had any impact on the households' waste behaviour. We found that when the information focused on degree of recycling, there was a significant impact on the households' recycling behaviour; the recycling share increased by 2 percentage points more among households that received the information than among households in the control group. The effect was strongest on households with a lower than median recycling prior to receiving the letter, but also households that were above the median increased their recycling. The effect of the letter was stronger on households who had increased their recycling from the previous year than on households who had decreased it. Giving practical advices on recycling together with the comparative feedback increased the effect of the letter. The effect seem to wear off some months after receiving the letter with the information, but as the last two months are the two summer months, July and August, which are unstable concerning waste behaviour. When these two months are taken out of the data set, there is no declining effect of the treatment. This means that there is no sign of the effect wearing off after 5 months, but we cannot say for sure what the effect is after seven months.

When the information in the letter was focused on waste reduction, the effect was less clear. In the group that received information on their waste quantities, the amount of unsorted, residual waste decreased, while there was no significant effect on organic waste, and paper waste increased. What seems to be the case is that the waste quantity letter created incentives to recycle more. This is confirmed in the survey performed, where 17% of the respondents who received the quantity letter answered that they believed it had made them recycle more, while only 12% believed it had made them waste less. This confirms findings from previous research, that the two concepts, recycling and waste reduction, are easily confounded (Cox et al. 2010). We can hypothesize if the fact that the organic waste did not increase in the quantity group, as it did for the recycle group, is an indication that two forces were at work at the same time: on the one hand people were inspired to reduce their organic waste, on the other hand they were inspired to recycle more, which meant to move waste from the residual bin to the bin for organic waste. The effect on total waste quantity is unclear, and results differ when using waste weights and number of times waste bins collected as measures. Further analysis would perhaps generate more clarity in our results, but it is unlikely to find anything but a weak effect on the total amount of waste, as is also indicated by the survey results. Getting people to reduce their amount of waste through information and social comparative feedback thus seems more difficult than to get them to increase their recycling. However, there is a possibility that part of the explanation to the weaker effect of the quantity letter, is that the comparison was made with the whole city of Kristiansand, and not only with the district that the household belonged to. As we did not know the number of household members, the graphical representation of the comparison was also less clear than in the recycling letter.

The study showed that, for the households which received the recycle letter, the amount of residual waste decreased by 1.1 kg per month per household, which corresponds to 8.5 kg for the seven first months of the experiment. For the whole recycle group of 2996 households, the amount of residual waste reduced is then almost 25.5 tonnes. If the letter had been sent to the whole experimental population (9000 households), the reduction would have been 76.5 tonnes. According to the WARM calculator, letting 76 tonnes recyclables go from combustion to recycling, saves the environment of 213 tonnes CO2-emissions (WARM 2014). This is only for the first seven months after the letter. What the long term effect is, in more uncertain. The long term effect, and the effect of the second letter sent after seven months, is necessary to estimate in a follow-up study.

Another interesting insight from the study, is to what extent there is a lack of trust in the recycling system among the inhabitants of Kristiansand, and how, not surprisingly, this affects the amount they deliver as sorted waste material. Hence, apart from sending letters to people with social comparison feedback, what can be done to increase recycling is to convince more people that their sorted material do indeed get recycled into new material, and not burnt.

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8 Appendix

Table 1. Fixed effects regression analysis with percentage recycled as dependent variable, 12 week period

	Spes 1	**Spes 2**	**Spes 3**	**Spes4**	**Spes 5**
Period after treatment	-0.7***	-0.7***	-0.7***	-0.7***	-0.7***
	(0.2)	(0.2)	(0.2)	(0.2)	(0.2
Period after treatment*recycle nudge	2***	3.2***	0.5	1***	4.6***
	(0.3)	(0.3)	(0.4)	(0.3)	(0.4)
Period after treatment*quantity nudge	1.2***	1.9***	1.2***	1.2***	4.8***
	(0.3)	(0.3)	(0.3)	(0.3)	(0.4)
Treatment*recycle nudge*last cycles		-2.9***			
		(0.3)			
Treatment*quantity nudge*last cycles		-1.7***			
		(0.3)			
Treatment*recycle nudge*advice			2.3***		
			(0.4)		
Treatment*recycle nudge*below median recycling 2013				2.1***	
				(0.4)	
Treatment*recycle nudge*decreased recycling from 2012 to 2013					-3.8***
					(0.4)
Treatment*quantity nudge* decreased recycling from 2012 to 2013					-5.4***
					(0.4)
Household fixed effects	Yes	Yes	Yes	Yes	Yes
Number of households	5977	5977	5977	5977	5977
Observations	197808	197808	197808	197808	197808

Table 2. Regression results quantity measured by weight, fixed effects, 12 week cycles

	Tot kg	Residual kg	Organic kg	Paper kg
Period after treatment	20.8***	12.4***	8.2***	0.3***
	(0.3)	(0.3)	(0.3)	(0.3
Period after treatment*quantity group	2.5**	-1.2	0.5	3.05***
	(1.2)	(0.9)	(0.6)	(0.3)
Period after treatment*recycle group	0.8	-3.3***	3.4***	0.8**
	(1.2)	(0.9)	(0.7)	(0.3)
Fixed effects	Yes	Yes	Yes	Yes
Number of households	8979	8979	8979	8979
Observations	107185	107185	107185	107185

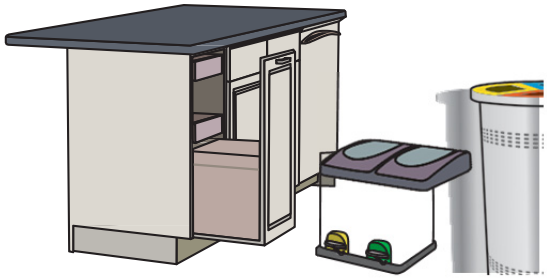
Table 3. Regression results quantity measured by times waste collected, fixed effects, 12 week cycles

	Total Q	**Residual Q**	**Organic Q**	**Paper Q**
Period after treatment	1.3***	0.7***	0.5***	0.2***
	(0.02)	(0.02)	(0.02)	(0.02)
Period after treatment*quantity group	-0.2***	-0.2***	-0.05	0.04**
	(0.07)	(0.04)	(0.04)	(0.01)
Period after treatment*recycle group	-0.04	-0.2***	0.1**	0.08***
	(0.07)	(0.04)	(0.04)	(0.01)
Household fixed effects	Yes	Yes	Yes	Yes
Number of households	8979	8979	8979	8979
Observations	107185	107185	107185	107185

Figure 1. List of advices on how to increase recycling and reduce waste

Tips til økt kildesortering

SORTER AVFALL HJEMME: Det er enkelt å kildesortere når du har lagt til rette for det. Avfall Sør har forsynt alle husstander med *matavfallskurv og bioposer, grønn kasse til papp og papir, samt rød kasse til farlig avfall og e-avfall.* I tillegg er det lurt å ha egne kasser eller poser for oppsamling av glass-, metall- og plast-emballasje. Kjøkkenleverandører har også gode løsninger for kildesortering.



BRUN DUNK - BIOAVFALL: Matavfall, hageavfall og annet biologisk nedbrytbart avfall egnet for kompostering.

GRØNN DUNK - PAPP OG PAPIR: Lesestoff, reklame, kopipapir. Papp og kartong. Skylte og tørre drikkekartonger.

GRÅ DUNK - RESTAVFALL: Det som blir igjen etter at du har sortert.

AVFALL TIL RETURPUNKTER I NÆROMRÅDET: Ren og tørr glass-, metall- og plastemballasje, samt tekstiler og sko. Kart over Kristiansands omlag 60 returpunkter finner du på: **www.sortere.no**

DETTE BRINGER DU TIL GJENVINNINGSSTASJONEN: Alle avfallstyper *unntatt matavfall* – også farlig avfall som maling, sterke rengjøringsmidler, batterier, elektriske og elektroniske artikler og lyspærer. Lyspærer, batterier og elektriske/elektroniske artikler kan også leveres i butikker der disse selges. *Husholdninger leverer gratis på gjenvinningsstasjonene. Gjenvinningen blir mer nøyaktig og du sparer tid dersom du har sortert avfallet på forhånd.*

VISSTE DU AT: Mengden metallemballasje i Norge er nok til å lage *300 000 sykler!*
Gjenvinning av *100 pizzaesker* gir en energigevinst som tilsvarer *12 timers bruk av tørketrommel!*
Mer informasjon og åpningstider for Avfall Sørs fire gjenvinningsstasjoner finner du på: **avfallsor.no**
Full sorteringsguide finner du hos: **avfallsor.no** eller: **sortere.no**

Tips til redusert avfallsmengde

1 Sorter ut emballasje av plast, glass og metall – i stedet for å kaste det som restavfall i grå dunk. *Rengjort emballasje bringes til et returpunkt*. Du finner kart over disse på www.sortere.no

2 Lag *ukeplan for middager* og bruk handleliste i butikken.

3 Bruk mat som snart går ut på dato før du kjøper nytt, eller frys det ned. Mat som er merket «best før» kan ofte spises lenge etter den oppgitte datoen.

4 Rester kan bli alternativ matpakke eller nytt middagsmåltid.

5 *Reparer, selg eller gi bort* brukbare ting i stedet for å kaste dem. Lever til for eksempel loppemarked og brukt butikk, eller annonser på finn.no. Klær, sko og tekstiler kan legges i tøycontainere som står utplassert på de fleste retur-punktene.

6 Stopp uønsket, uadressert reklame ved å sette klistre-merke på postkassen. Klistremerke får du blant andre hos Posten.

7 *Unngå engangsprodukter* (bæreposer, papptallerkener, plast-krus, engangsgriller osv.)

8 Kjøp kvalitet framfor ting som går lett i stykker.

Visste du at en fjerdedel av all mat vi kjøper, havner rett i søppelbøtta.
En husholdning på fire personer kaster mat for 10 000 kroner hvert år. *Kaster du mindre mat sparer du mange penger!*

Visste du at til sammen kaster nord- menn 377 000 tonn spiselig matavfall i året. Hvis vi sluttet å kaste denne maten, ville det redusere CO2-utslipp med cirka 716 300 tonn. Det tilsvarer effekten av å fjerne 1 av 7 personbiler fra veiene.