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On the perils of environmentally friendly alternatives

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ABSTRACT

Environmentally friendly alternatives (EFA) are touted as a key component of a transition towards lowering the impact of human activity on the environment. Still, the environmental costs of these technologies are seldom null; they are simply less environmentally damaging than existing options. In this paper, we investigate consumer behavior when an EFA is introduced. Using a carefully constructed field experimental design, we look at plastic bags vis-a-vis biodegradable (bio) bags, when the latter are offered for free versus at a price. Moreover, we explore offering costly biodegradable bags as part of the default choice. We find that giving away the bio bags for free results in a large behavioral rebound effect, resulting in a substantial increase in the total number of bags. Setting a small, rather symbolic price offsets this rebound effect completely. Interestingly, when the bio bag is offered as a default, the behavioral rebound remains. Our results lead us to conclude against providing these EFA for free and to caution against the use of subsidies to promote their uptake.

1. Introduction

In an attempt to reduce the environmental footprint on the planet's carrying capacity, consumers are substituting away from goods and services with high environmental impact, to alternatives touted to have a lower impact on the environment (Jones et al., 2020; Latvala et al., 2012; Tobler et al. 2011). Environmentally friendly alternatives are increasingly becoming a frequent sight in the consumption basket of households. This is happening in several areas of consumption, from plug-in hybrid vehicles instead of gasoline cars (Jenn 2020), solar instead of coal or gas to warm our homes (Wilson and Staffell 2018), bags and cutlery that are biodegradable instead of plastic (Song et al., 2009), meat substitutes instead of animal proteins (Reijnders and Sam Soret, 2003), and recycled fabrics instead of cotton or wool (Niinimäki et al., 2020).

The popularity of environmentally friendly alternatives should not be surprising, because they allow us to continue our daily lives in, or very near, a business-as-usual scenario, i.e., without really restricting our behavior for the environment's sake. For example, instead of opting for public transportation or reducing our travel, plug-in hybrid vehicles allow us to travel as usual with a lower impact on the environment. Undeniably, the key characteristic of environmentally friendly alternatives is their lower environmental footprint. Still, their environmental footprint is not zero. Most of these technologies require substantial resources for their production, and their increased use might still generate environmental impacts (Luderer et al., 2019; Baroni et al., 2007; Rosi et al., 2017; Larcher and Tarascon 2015). The result of the introduction of an environmentally friendly alternative is therefore not zero environmental impact,

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even if the old polluting alternative is completely phased out.

In this paper we investigate, using a field experiment, the effect on consumer behavior of introducing an environmentally friendly alternative. The environmentally friendly alternative we use is biodegradable (bio) plastic bags as an alternative to plastic bags.[1]

If consumers care about the environmental impact of their consumption, the availability of bio bags should result in a substitution from plastic to bio bags. In addition, the introduction of the more environmentally friendly alternative could convey passive information on the environmental consequences of our actions (i.e., priming of environmental concerns). This information in itself could affect behavior as well (Johe and Bhullar 2016; Jessoe and Rapson 2014; Cohn and Michel André, 2016). In particular, it could also mean that the total use of bags (i.e., of plastic and biodegradable bags) decreases beyond the mere substitution effect if users indeed note that the environmental impact of the new alternative is not zero.

In addition, there has been considerable attention to the so-called rebound effects of new technologies in areas such as energy efficiency (Gillingham et al. 2016) and fuel efficiency (Linn 2016). In this context, a conventional rebound effect would occur if, for example, the adoption of an improved energy efficiency technology would increase energy use because of the lower effective price per hour of light or heating. Although the extent of this rebound effect varies considerably across studies (see, e.g., Allcott 2011; Frondel and Vance 2013; Jessoe and Rapson 2014), there is no doubt that it can have a dampening impact on the effect of technological innovation on environmental quality.

In addition to the standard economic rebound effect, there could be a behavioral rebound effect (Dorner 2019).[2] This effect builds on the assumption that individuals care about the environmental impact of their behavior. There could, for example, be a direct altruistic concern, where the consumer cares about the environmental impact of their own consumption on others (Andreoni 1990; Kotchen and Moore 2008), or status concerns to signal pro-environmental behavior (Sexton and Sexton 2014). This concern implies that consumers are potentially willing to make choices to reduce the environmental impact of their behavior (e.g., carrying a reusable bag around in case one visits the supermarket). When the concern is removed because the good is perceived to be environmentally friendly, a non-conventional rebound effect could take place (Dorner 2019). The intuition behind the mechanism is as follows. Suppose a consumer cares about the marginal damage of her consumption and considers this effect when making consumption choices. Now, if the marginal damage for a good is reduced - it could be that a more environmentally friendly bag is introduced or that biofuel is made available for cars – then consumption choices will change as well. In particular, because of this change in marginal damage, consumption of the good will increase. This is what we denote as a behavioral rebound effect.

The total effect of a more environmentally friendly alternative on the environment is then unclear and would depend on two effects: a direct effect resulting from the substitution of the old technology for one with a lower marginal environmental damage, and an indirect effect associated with the standard economic and the behavioral rebound effects.

In this paper, we explore the substitution and rebound effects of providing an environmentally friendly alternative (i) at no cost, (ii) at a price, or (iii) at a price and offered as the default alternative. By providing the alternative at no cost, we can isolate a behavioral rebound effect since, as we will explain, the current good is typically also provided for free. This also means that our second treatment allows us to investigate a standard price effect on the use of an environmentally friendly alternative, and how that can counteract a behavioral rebound effect. Finally, in the third treatment, we investigate if providing the environmentally friendly alternative as a default affects behavior. Defaults have had very strong impacts on behavior in settings such as choice of energy contract (Pichert and Katsikopoulos 2008), and savings decision (Cronqvist et al. 2018). In our setting, we implement this in a situation where people make frequent decisions and where the decision is rather simple.

We investigate this in a field experimental setting using biodegradable bags as an alternative to plastic bags. Biodegradable bags are frequently regarded as a more environmentally friendly alternative to plastic bags, but their environmental impact is far from negligible, and their degradation requires very special conditions. In this paper, we abstain from discussing the biophysical and chemical properties of biodegradable versus plastic bags. Instead, we depart from the observation that biodegradable bags are regarded by consumers in our study site as a “greener” option to plastic bags; more than that, they are part of the Costa Rican National Strategy to Substitute Single Use Plastics. We then focus on behavioral changes resulting from making them available to consumers as part of their grocery shopping routine.[3] We find that the response to providing an environmentally friendly alternative for free is characterized by a strong behavioral rebound effect, which disappears when the bio bags are priced. Interestingly, when the bio bag is

[1] There are numerous policies world-wide that attempt to reduce the use and disposal of plastic items (Alpizar et al., 2020; Homonoff et al., 2021; Xanthos and Walker, 2017), including pricing of plastic bags (Convery et al., 2017; Rivers et al., 2017), deposit-refund schemes (Viscusi et al., 2011) and bans on single-use plastics and/or plastic bags (He, 2012; Homonoff et al., 2022).

[2] Other types of indirect rebound effects have also been discussed in the literature; primarily focusing on effects on behavior in other domains. The primary indirect effect is perhaps that money saved through say increased fuel efficiency can be spent on other products, and this will have an environmental effect (Gillingham et al., 2013; Dreijerink et al., 2023). Another indirect rebound effect could occur due to so-called moral licensing (Monin and Miller, 2001), where people act as if they have a license to behave selfishly in one setting/domain by acting environmentally friendly in another setting/domain. Tiefenbeck et al. (2013) found that information to households about their water use lowered water use, but increase electricity use, and Mazar and Zhong (2010) found that people were less altruistic after purchasing environmentally friendly product than after purchasing conventional products. However, it should be noted that several studies have found a positive spillover between domains/settings (see e.g. Jessoe et al., 2021; Carlsson et al., 2021a,b).

[3] For the sake of completeness, we would like to add that in this paper we do not endorse bio bags as an environmentally friendly alternative. Bio bags are not only costly to produce from an environmental perspective, but they also require to be disposed in a suitable manner if they are going to decompose as expected. Notably, Costa Rica does not have a separated organic waste collection system capable of degrading plastic bags, which again goes against the potential environmental benefits of bio bags.

offered as a default, the behavioral rebound remains.

We caution against the use of subsidies in the promotion of environmentally friendly alternatives. Although our experiment is not designed to identify optimal policies, our results provide a cautionary tale against providing environmentally friendly alternatives for free or at a subsidized price given the risk of a behavioral rebound effect.

The rest of the paper is organized as follows. In section 2 we describe the environmentally friendly alternative, detail the design of the experiment, provide the hypotheses we test with the experiment, and present how the experiment was implemented. In section 3 we outline our empirical approach. Section 4 reports the results, and in section 5 we discuss our findings.

2. Experimental design and procedure

2.1. Biodegradable plastic bags

Biodegradable plastics are materials degraded by the actions of microorganisms in the environment that are finally converted into inorganic substances; that is, the plastic goes through a complete breakdown into CO_2, H_2O and biomass in aerobic settings, and CO_2, CH_4 and biomass in anaerobic settings (Amaral-Zettler et al. 2020; Suzuki et al. 2020; Narancic and O'Connor, 2019). In our case, biodegradable light plastic bags are ASTM D6954,[4]-certified (ASTM 2013), which means they contain a pro-oxidant additive that promotes their abiotic degradation by the effect of intense sunlight and sustained thermal aging at moderate temperature (Quecholac-Piña et al., 2017). The biodegradable bags used in this experiment comply with the Costa Rican National Strategy to Substitute Single Use Plastic 2017–2021.

In this experiment, we focus on the two most commonly used plastic bag sizes (9x14 and 10 × 16 inches). These are small, transparent bags used to organize produce while shopping and their use is ubiquitous in farmer's markets in Costa Rica. Even though shoppers typically use baskets or sturdy reusable carryout bags while visiting the market, they would still use these plastic bags to package and organize their groceries neatly in the carryout bag.

Importantly, the existing plastic produce bags and the biodegradable options are equal in terms of strength and capacity, and as such are, from a manufacturer's point of view, as perfect substitutes as possible. Obviously, customers might have a prior, subjective opinion about the strength of biodegradable bags, and might request extra bags if they feel the bags might tear when exposed to sharp objects or heavy loads. The implication of this will be factored into our discussion.

2.2. Experimental design and decision environment[5]

The setting of our experiment is farmers markets in Costa Rica. At these markets, vendors sell a variety of fruits and vegetables on Saturdays throughout the year. There is a widespread use of plastic bags in these markets, not the least because customers buy a variety of goods from different vendors. As part of each purchase, vendors would place the items in a small plastic bag and hand the bag to the customer. Importantly, the bags are handled by vendors at all times. Similarly, neither the plastic nor the bio bags were offered to customers so that they could be used to pack produce from other vendors.

The number of bags per transaction is always determined by the buyer in interaction with the vendors. In some cases, the buyer might request a specific distribution of produce in several plastic bags (e.g. 1 kg of tomatoes split into two bags), as this will better protect the fruit, ensure that the bags will resist the weight of the fruit and even allow for the more orderly storage of the produce in the buyer's refrigerator. On the other hand, there are several ways to avoid the use of bags. Foremost, a customer might simply reduce the number of bags by rejecting the plastic or biobased bags offered to them, and instead place their purchased goods directly in a carryout bag or a trolley. This comes potentially at the cost of some damage to delicate fruits and vegetables. Another option is to use a biodegradable bag as a substitute to plastic bags.

We made sure that no substitute to plastic bags was provided by the vendors in the control group. In this treatment arm, everything was business as usual: vendors would pack the produce in one or several small plastic bags as requested by the buyer unless the buyer requested that the produce be placed directly on the trolley or tote bag. The vendors did not provide any further information.

In Treatment 1, a bio-bag was provided for free. Again, the total number of bags is determined by the interaction of vendors and buyers. In this case, the vendor offers a choice of plastic or bio bag and reads/says the following script: "*Would you like to reduce pollution in the oceans by using a biodegradable plastic bag for your [name of the fruit/vegetable] instead of a plastic bag?*"[6] We decided to frame the substitution away from plastic bags in the context of reducing the pollution in the oceans for two reasons. First, we wanted to give bio bags their best shot by prompting pro-environmental concerns. Secondly, we wanted to increase the realism of the decision: single use plastics and their effect on the environment were featured prominently in the public debate, given Costa Rica's newly minted strategy to reduce single use plastics. The decision on the total number of bags is then made by the buyer, who can request a specific distribution of produce in plastic bags, biodegradable bags, or both, or could decide to volunteer their own trolley or tote bag to avoid any bag at all.

[4] The ASTM D6954 is the Standard Guide for Exposing and Testing Plastics that Degrade in the Environment by a Combination of Oxidation and Biodegradation.

[5] See XXXXXXXXXXXXXXXXXXXXXXXXXXXX for preregistered experimental design.

[6] Literal translation from original in Spanish.

In Treatment 2, the bio bag was also introduced, but with a price per bag of 25 colones.[7] Vendors were instructed to say the following to customers: "*Would you like to reduce pollution in the oceans by using a biodegradable plastic bag for your [name of the fruit/vegetable] instead of a plastic bag? It will cost you 25 colones* per *bag?*" Except for the rather symbolic additional price, the buyer's decision is identical to treatment 1 and the control. The total number of bags is determined by the buyer's instruction to the vendor.

In Treatment 3, we simply changed the default situation. Instead of offering a choice between bags before packaging the produce, vendors packed the fruits in a bio bag and then read the same text as in Treatment 2, including mention of the price per bag. We are aware that this is a rather strong default setting, given that opting for the plastic bag would require unpacking the produce, possibly with people around you. The buyer in this case first has to accept or reject the bio bag. She could also request the produce to be packaged in additional plastic bags for free or biobags at a cost. Alternatively, she can reject the bio bag and volunteer the trolley or tote bag.

For all four groups we observe the number of plastic bags and bio bags consumed before (2 weekends) and after (2 weekends) the introduction of the bio bags.

2.3. Hypotheses

A consumer willing to reduce the environmental impact of her consumption can, simply put, take two, non-mutually exclusive actions: i. consume less, e.g., use fewer or no bags and carry other means of transporting and separating purchased goods; ii. opt for a more environmentally friendly alternative if it exists.

Table 1 describes the potential outcomes of introducing an environmentally friendlier alternative to plastic bags. All our treatments offer the opportunity to substitute away from plastic bags by using a bio bag. This allows for a one-to-one substitution between plastic and bio bags. However, the offer of the bio bag and the content of the message might induce subjects to reduce the use of any kind of bag, resulting in a substitution of one plastic bag by less than one bio bag. Finally, since bio bags are touted to be more environmentally friendly, subjects might be tempted to use even more bio bags than plastic bags.

In all treatments, we thus hypothesize a reduction in the use of plastic bags, compared to the control where bio bags are not available, based on the assumption that a non-negligible fraction of the consumers care about the environmental impact of their behavior (Andreoni 1990; Kotchen and Moore 2008). The effect on the total number of bags will ultimately depend on the size of the substitution effects and the behavioral rebound effect on bio bags. In Treatment 1, the risk of a behavioral rebound effect is largest, since the bio bags are provided for free. In Treatments 2 and 3, the introduction of a price per bio bag should reduce the behavioral rebound effect. In Treatment 3, the bio bag is offered as a default. Given that the price is rather symbolic, we hypothesize that people will stick to the default alternative leading to a one-to-one substitution of plastic bags.

2.4. Experimental procedure

The experiment follows a between-subject design in a clustered randomized setting. We implemented a cluster sampling, where each farmers market was considered a cluster. In total, we worked with 12 clusters, distributed in the two central provinces of Costa Rica which are closest in terms of socioeconomic characteristics. As can be seen in Fig. 1, the number of vendors differs between markets, with larger markets (e.g. Santo Domingo) having large numbers of vendors. Having said that, vendors are typically similar irrespective of the size of the market itself, although the artisanal nature of most vendors inhibits a more formal comparison between them. A total of 15 vendors were selected randomly from a list provided by the board administering the market. The selection was made from fruit and vegetable vendors, which consume the highest volume of ultra-thin plastic bags with very small micron sizes. Vendors of specific products such as processed food (cheese, juices, etc.) were excluded from the experiment as those products can hardly be sold without a plastic bag. We initially worked with three clusters per treatment (plus a control of three clusters) and 15 vendors per cluster, with a power of 89% anticipating a reduction in the number of plastic bags consumed by 35%. The 35% is conservative considering that the literature reports a reduction of well above 50% when pricing is introduced (see for example Cabrera, Caffera, and Cid 2021; Convery et al. 2007). However, at a later stage, we increased the number of vendors to 16 per cluster to adjust for attrition.

The field experiment lasted four weeks, two weeks pre-treatment and two weeks post-treatment.

For all treatment groups, each vendor received two 1-kg packages: one of the plastic bags and one of the bio bags at no cost; if the vendor required more plastic or bio bags during the day, the researcher provided additional weighed packages. Research assistants delivered the bags every Saturday before the retail market opened (4:00 a.m.) and collected the unused plastic and bio bag packages by the close of business (1:00 p.m.). After collection, the assistants weighed unused plastic and bio-bag packages as a direct measure of consumption. The number of bags consumed was calculated by subtracting the final weight from the initial weight of each package, plastic, and bio, separately; the total grams consumed were then divided by the individual weight of a bag, which is 4 g for a bag 9×16 inches, and 5 g for a bag of 10x16 inches. Plastic and bio bags have the same density and, therefore, each bag of the same size has the same weight. For the control group, vendors received only plastic bags at no cost; measurement followed the same procedure as in the treatments. The accuracy of the scale was tested before every measurement to ensure precision and correct conversion to the number of bags. Furthermore, for each kilogram of bags, 100 bags were picked randomly and were weighted individually to verify precision. At

[7] At the time of the survey 1USD = 596 colones, or one bag for about $0.04.

Table 1
Potential effects of introducing an environmentally friendlier alternative.[1]

Motivation	Action: Substitution of …	The outcome of our experiment	Environmental outcome
Substitution of polluting technology by a cleaner one	One plastic bag by one bio bag	-**Reduction** in the number of plastic bags -**Unchanged** total number of bags	Reduced environmental impact due to lower impact of bio bags
Priming of environmental concerns	One plastic bag by **less** than one bio bag	-**Reduction** in the number of plastic bags -**Reduction** in the total number of bags	Reduced environmental impact due to lower impact of bio bags and reduced total number of bags
Behavioral Rebound effect due to reduced environmental concerns of bio-bags	One plastic bag by **more** than one bio bag	-**Reduction** in the number of plastic bags -**Increase** in the total number of bags	Uncertain environmental impact[8]

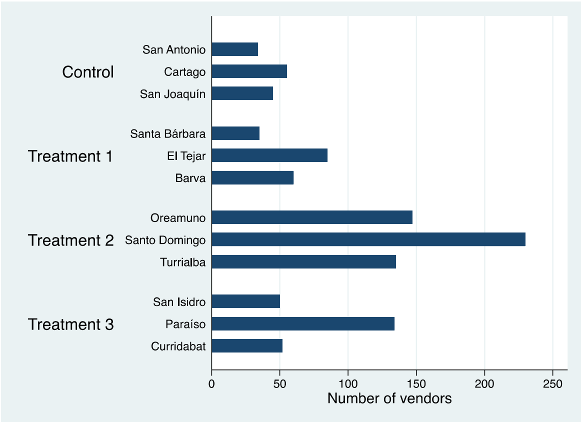

Fig. 1. Total number of vendors per location of farmer's market under study, and treatment assignment. A total of 16 vendors per market were randomly allocated to our treatments.

the end of the two-week treatment period, we applied a survey to the vendors.

Signs about biodegradable bags were located at the entrance of each market for all treatments. In addition, we had set a list of observation criteria that the research assistants had to pay attention to every day of the market to control for other external factors, such as weather, any municipal activity in the district, schools' activities, or fairs; see Appendix 2.

3. Empirical strategy

As mentioned above, there are two primary outcome variables of interest. The first is the number of plastic bags sold per week and vendor, and the second is the total number of bags (plastic and bio bags) sold per week and vendor. For both of these outcomes, we estimate the average treatment effect. Although the markets were randomized into treatment and control, there were few markets and as such there could be pre-treatment differences in the number of plastic bags per vendor. To take this into consideration we estimate a three-level random effects model. Following the model specification of Baltagi et al., 2001, standard errors are clustered at the market level; thus the model is organized as a series of *M* independent groups or clusters, at the farmers market.

$$\boldsymbol{y_{ijt}} = \boldsymbol{\beta_{1T} Treat_T} + \boldsymbol{\beta_2 After} + \boldsymbol{\beta_{3T}(Treat_T \text{After})} + \boldsymbol{u_{ijt}},$$

where y_{ijt} denotes the number of plastic bags (or total bags) of the *i*th vendor in the *j*th farmers market in weekend *t*. *After* is a dummy variable equal to 1 for the two weeks after the treatments were implemented. $Treat_T$ is a vector of dummy variables that indicates if a farmers market was assigned to a particular treatment group [T = 1, 2, 3]. The disturbance term is specified as

$$\boldsymbol{u_{ijt}} = \boldsymbol{u_j} + \boldsymbol{v_{ij}} + \boldsymbol{\varepsilon_{ijt}}$$

where u_j denotes the *j*th unobservable market effect, which is assumed to be i.i.d. $(0, {\sigma_\mu}^2)$, v_{ij} denotes the nested effect of the *ith* vendor within the *j*th market which is assumed to be i.i.d. $(0, {\sigma_v}^2)$, and i.i.d. ε_{ijt} denotes the reminder disturbance which is also assumed to be i.i.d. $(0, {\sigma_\varepsilon}^2)$. The $u_i' s, v_{ij}' s,$ and ε_{ijt} 's are independent of each other and among themselves.

Our coefficients of interest are $\beta_{3\mathrm{T}}$. Since there are three treatment groups, we estimate three treatment effects, relying on regressions where we pool all treatments and the control group. This model is estimated with a mixed effects maximum likelihood regression in Stata. As a robustness check, we also estimate a model with vendor fixed effects instead.

4. Results

4.1. Descriptive results

We begin by presenting the average number of plastic bags and the total average number of bags sold before and after the treatment in the four groups in Fig. 2; the actual numbers are reported inTable A1 in Appendix 1. Note that we do not have a balanced panel, primarily because of some attrition during the experiment. In the end, we have in total 729 observations from 189 vendors.

4.2. Regression results

Our main specification is a three-level random effects model, where we estimate treatment effects for plastic bags and for the total number of bags. Full results are reported in Table A2 in Appendix 1; below in Fig. 3, we report coefficient plots for the treatment effects.[9]

As expected, all three treatments have a sizeable and statistically significant negative effect on the number of plastic bags. In Treatment 1, the average number of plastic bags is reduced by 64% (from 130 to 83) bags per vendor and week. This is a sizeable effect. The estimated effect in Treatment 2 is somewhat smaller, and the difference between the two treatments is statistically significant; tests of difference in treatment effects are reported in Table 2. Thus, setting a small price on the bio bag partially offsets the reduction of plastic bags. There is a sizeable treatment effect on the number of plastic bags in Treatment 3 as well, but it is considerably lower than in the two other treatments, and the differences in treatment effects compared with Treatments 1 and 2 are statistically significant. Consequently, the reduction in plastic bag use is considerably smaller if a bio bag is given as a default but at a price.

We next turn to the total number of bags. In Treatment 1 where the bio bag is provided for free, there is a substantial increase in the total number of bags compared with the control group. Thus, despite a sizeable reduction in the number of plastic bags, the increase in demand for bio bags is so large that it more than offsets the reduction in plastic bags. Note that, in both Treatment 1 and the control group, all bags are provided for free. This suggests that there is a behavioral rebound effect for the total number of bags by the introduction of a more environmentally friendly alternative. We will return to the environmental implications of this later. For Treatment 2, there is no statistically significant treatment effect on the total number of bags. Thus, the rebound effect we observed in Treatment 1 disappears completely if the bio bag is sold at a small price. In Treatment 3, there is also a sizeable increase in the total number of bags. Thus, despite a smaller reduction in the number of plastic bags, there is still an offsetting rebound effect.

4.3. The required environmental improvement of bio bags

Establishing the exact environmental impact of a bio bag in comparison to a plastic bag is not easy and lies outside the focus of this paper and our expertise. Still, we can use our results to calculate the required difference in environmental impact between a plastic bag and a bio bag, such that the provision of this environmentally friendly alternative results in positive overall outcomes, given the results of the different treatments. Results are presented in Table 3[10].

Let us begin with Treatment 2, where the number of plastic bags is reduced, and the total number of bags remains unchanged. In this case, one plastic bag is substituted for one bio bag. As a result, even a slightly smaller environmental impact of bio bags compared with plastic bags would result in an improved environmental outcome.

When bio bags are introduced for free (Treatment 1), we observe a strong behavioral rebound effect. Each reduced plastic bag is substituted by 1.49 biodegradable bags. For this to result in an environmentally positive outcome, the impact on the environment of each biodegradable bag should at most be 67% that of a regular plastic bag.

The situation is more extreme in Treatment 3, where providing the bio bag as a default alternative backfires. Each reduced plastic bag is substituted by 2.29 bio bags. This result is driven by the rather small reduction in plastic bags. Again, the environmental impact of bio bags would have to be 43% that of a regular plastic bag for this pattern to result in positive environmental outcomes.

5. Discussion

As Table 1 shows, the overall effect on the total number of bags will depend on which of the following three effects will prevail: i. a substitution effect that leads to one-to-one substitution, leaving the total number of bags unaltered; ii. a priming effect in which the total number of bags is expected to be lower, or iii. a behavioral rebound effect, observable as an increase in the total number of bags.

[8] As pointed by a reviewer, if the inputs and costs associated to the production of one bio bag are lower than for a plastic bag, then there is room for increasing the use of biobags and still generate an environmental improvement, hence the uncertain environmental impact.

[9] Results from the corresponding fixed-effects model with vendor fixed effects is presented in Table A3 in Appendix 1. Estimated treatment effects are similar. Using a Hausman test we cannot reject a random effects model for plastic bags (p-value = 0.075) or the total number of bags (p-value = 0.302).

[10] By environmental impact here we mean the environmental costs of both producing and also of disposing of these bags.

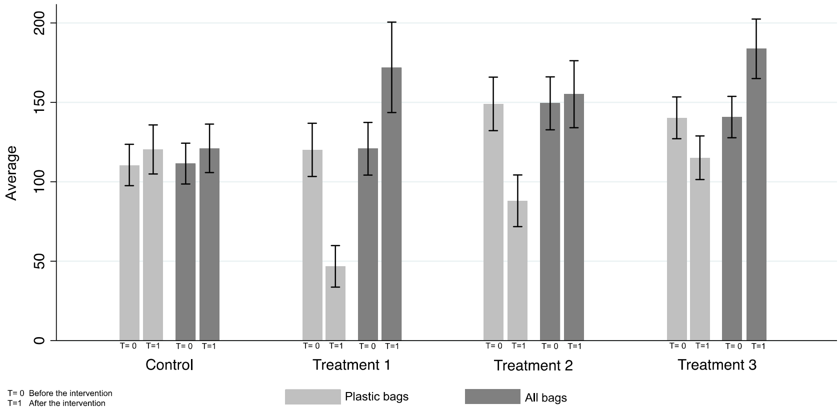

Fig. 2. Average number of bags sold before and after the intervention in each of the four treatment arms. T = 0 refers to the two weeks before treatment, and T = 1 to the two weeks of treatment. The "all bags" bars are the sum of plastic and bio bags. The height of the bar refers to the average use of bags per vendor within a given treatment arm, and 95% confidence intervals are shown. Note that there are differences in the number of bags sold in the pre-treatment weeks among the four groups. The average number of bags among vendors in Treatment 2 is almost 150 bags per week, while the average number of bags among vendors in the Control group is 111 bags. More important, though, is the observation that, while the number of plastic bags is roughly the same before and after in the Control group, they are considerably lower in Treatments 1 and 2. There is also a drop in the number of plastic bags among vendors in Treatment 3, but not as sizeable as in the other treatments. Thus, the descriptive statistics suggest that the treatments did, as intended, result in a decrease in the number of plastic bags. If we then look at the total number of bags sold, we observe that there is a sizeable increase in the total number of bags in Treatments 1 and Treatment 3, while it is roughly unchanged in the Control group and in Treatment 2. Thus, there is, first of all, evidence of a behavioral rebound effect. Second, in Treatment 2, where there is a price for the bio bag, the behavioral rebound effect observed is offset. As a next step, we estimate treatment effects using a regression model to control for vendor and market characteristics.

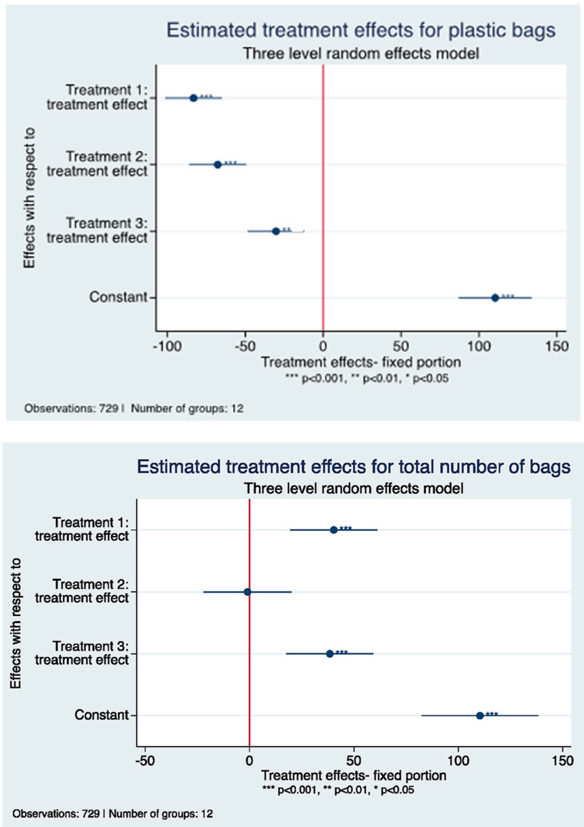

Fig. 3. Estimated treatment effects for plastic bags and total number of bags. All p-values for treatment effects account for multiple hypothesis testing using Bonferroni correction with three hypotheses.

Table 2
Test of difference in treatment effects.

	T1-T2	T2-T3	T1-T3
Reduction of plastic bags	15.55* (9.33)	37.38*** (9.28)	52.94*** (9.22)
Increase in the total number of bags	41.36*** (10.80)	−39.47*** (10.74)	1.88 (10.68)

Note: Standard errors are in parentheses. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

Table 3
Required environmental impact of bio bags in order for treatment to have a positive environmental impact (based on results in Table A2).

	Treatment 1	Treatment 2	Treatment 3
Reduction of plastic bags	75%	61%	27%
Increase in the total number of bags	37%	0%	35%
Required relative environmental impact of bio bags	<0.67	<1	<0.43

Our results show no evidence of a reduction in the total number of bags, despite the strong reduction of plastic bags in all three treatments. Reducing the total number of bags is as simple as carefully placing fruits and vegetables in a tote bag, yet we do not see that happening in our experiment. The results from Treatment 1 are quite extreme. Despite the strong reduction in the use of plastic bags, each of those bags is substituted by much more than one bio bag, an extreme example of a rebound effect. We call this a behavioral rebound effect because the effective price of packing produce remains at zero with plastic and biodegradable bags. Even more interestingly, we find that charging a small, rather symbolic price for the more environmentally friendly alternative (Treatment 2) completely takes away the behavioral rebound effect, and we observe a one-to-one substitution. Under this scenario, even slightly better biodegradable bags would render positive environmental outcomes.

In section 2.1 we argue that the plastic and biobags are, from a manufacturer's point of view, equally strong, but we do recognize that buyers might not perceive them as such. Given the randomization in our experimental design, there is a priori no reason to believe that buyers distrusted the bio bags more in T1 than in T2, so the behavioral rebound effect cannot be explained by this subjective assessment of the bags.

It is interesting to compare our results with a similar experiment on plastic bags designed and conducted after our experiment (Antinyan, 2021). In their experiment, customers faced either a financial incentive to reduce the use of plastic bags or information about the harms of plastic bags. In addition, both these treatments were implemented with and without free provision of one tote bag, sent to the customers, made of polypropylene that is reusable and washable. In their setting, the amount of the environmentally friendly alternative is thus fixed. The provision of the environmentally friendly substitute does not really have an impact on the use of plastic bags when coupled with the information provision only (3% reduction compared with no free reusable bag). However, when coupled with the financial incentive, the effect on the use of plastic bags is sizeable (18% reduction compared with no-fee reusable bags). Thus, also in their setting does the role of the environmentally friendly alternative depend on the informational setting and financial incentives.

In Treatment 3, we provided the bio bags as the default alternative, albeit still at a symbolic price. We expected that providing the bio bag as a default would serve as a signal of the appropriate behavior, and it would result in increased moral costs of switching back from the default bio-bag to a plastic bag. In essence, we are making the pro-environmental behavior easier. We expected that the strength of the default option would prevail over the rather symbolic price signal. Our result is not in line with what we expected. Although the average use of biobags per vendor is essentially equal in T2 ($n = 66$) and T3 ($n = 68$), the number of plastic bags in T3 is reduced only slightly. This result is similar to Dorner's (2019) laboratory results, who find that pro-environmental effort does not increase when it becomes more effective, and hence somehow easier.

We believe that the provision of a costly bio bag by default seems to create either a sense of entitlement (since I am paying, I can request more bags) and/or unhappiness. As a result, the default substitution of plastic for biobags is met with some buyers requesting their produce to be repackaged into a plastic bag, and some others requesting additional plastic bags to further separate their fruits and vegetables. The number of plastic bags remains therefore high, so much so that the environmental impact of a bio bag should be less than half that of a plastic bag for this treatment to result in positive environmental outcomes.

Previous experience does reveal a considerable variation in the size of the default effect. In a meta-analysis, Jachimowicz et al. (2019) identify two important factors that account for the variability in defaults' effectiveness. The first is that defaults tend to be more effective in the consumer domain than in the environmental domain. The second is that defaults are more effective when they are seen as endorsing the appropriate behavior. The default in our case is endorsing the appropriate behavior in the environmental domain. What could explain our result is the interaction between the environmental domain and the role of endorsement. Environmentally friendly behavior is probably explained by both direct concerns for the environment, but also self-image and signaling concerns (Bénabou and Jean, 2006; Venhoeven et al. 2016). The self-image concern could be negatively affected or eliminated if, as in our case, the environmentally friendly behavior is to some extent provided as a default (Venhoeven et al. 2016).

Finally, it is important to note that what we study in this paper is a short-run effect, and we know little about the long-run effects. There is evidence, for example, that the effect of pro-environmental nudges on behavior is reduced over time (Carlsson et al., 2021a,b). It is certainly of interest to investigate the long-run effects of the introduction of environmentally friendly alternatives, and to what extent a behavioral rebound effect persists over time.

6. Conclusion

In this paper, we have explored the consequences of introducing an environmentally friendly alternative that in principle allows consumers to continue their business as usual by substituting away from the more polluting base option. To reduce the environmental impact of their actions, consumers could opt for environmentally friendlier options or simply reduce consumption. In our experiment, these actions entail opting for biodegradable bags or simply rejecting the use of plastic bags in favor of tote bags.

We do not find any indication of subjects' willingness to reduce the use of bags, not even when primed by the setting of our experiment, in which plastic bags were mentioned in the context of ocean pollution. Although the number of plastic bags decreases significantly in all treatments, there is, at best, a one-to-one substitution towards bio bags, leaving the total number of bags unaltered.

Importantly, when the bio bags are provided for free, we observe a strong behavioral rebound effect. We caution against the use of subsidies in the promotion of environmentally friendly alternatives. Although our experiment is not designed to identify optimal policies, our results provide a cautionary tale against providing environmentally friendly alternatives for free or at a subsidized price given the risk of a behavioral rebound effect.

Finally, we find puzzling results from our treatment in which the bio bags were provided as the default alternative, albeit at a price. Our results seem to indicate that some subjects reacted negatively to the costly default, and requested either additional plastic bags for free or a repackaging of their produce. Further research is needed to understand the effect of implementing a costlier default alternative when compared to a standard no-cost default, and what implications can that have on subjects' overall behavior and environmental impact

CRediT authorship contribution statement

Francisco Alpizar: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Fredrik Carlsson:** Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Gracia Lanza:** Conceptualization, Data curation, Formal analysis, Writing – original draft.

Declaration of competing interest

The authors declare no material or financial interest that relate to the research described in the paper.

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Appendix 1

Table A1
Average number of bags used per week and vendor, before and after the intervention. Standard deviations in parentheses.

	Plastic bags		All bags	
	Before	*After*	*Before*	*After*
Control	111 (63)	121 (74)	111 (63)	121 (74)
Treatment 1	121 (81)	48 (62)	121 (81)	172 (137)
Treatment 2	149 (80)	89 (77)	149 (80)	155 (101)
Treatment 3	141 (64)	116 (66)	141 (65)	184 (91)

Table A2
Estimated treatment effects, random effects regression

	(1)	(2)
	Plastic bags	Total number of bags
Treatment 1: treatment effect	−83.23***	40.38***
	(9.21)	(10.67)
Treatment 2: treatment effect	−67.67***	−0.98

(*continued on next page*)

Table A2 (*continued*)

	(1)	(2)
	Plastic bags	Total number of bags
	(9.27)	(10.73)
Treatment 3: treatment effect	−30.28**	38.49***
	(9.16)	(10.61)
Post-treatment	8.47	8.43
	(6.47)	(7.49)
Treatment 1: pre-treatment	9.10	8.84
	(16.77)	(20.13)
Treatment 2: pre-treatment	39.36*	38.32
	(16.80)	(20.16)
Treatment 3: pre-treatment	29.63	29.31
	(16.71)	(20.05)
Constant	110.42***	110.42***
	(11.85)	(14.23)
Observations	729	729
Number of markets	12	12
Number of vendors	189	189

Standard errors in parentheses. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$ P-values for treatment effects account for multiple hypothesis testing using Bonferroni correction with three hypotheses.

Table A3
Fixed effects regression

	(1)	(2)
	Plastic bags	Total number of bags
Treatment 1: treatment effect	−83.76***	39.91***
	(9.25)	(10.72)
Treatment 2: treatment effect	−67.15***	−0.40
	(9.30)	(10.78)
Treatment 3: treatment effect	−29.20**	39.49***
	(9.20)	(10.66)
Post-treatment	8.25	8.25
	(6.49)	(7.51)
Constant	130.40***	130.20***
	(2.30)	(2.66)
Observations	729	729
R-squared	0.292	0.133
Number of groups (vendors)	189	189

Standard errors in parentheses. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

Appendix 2. Observation Criteria – Farmers market

1. Location of the farmer's fair:

   Dropdown menu with the list of farmers markets - (Select your answer)

2. Name of Collaborator (a):

   (Select your answer)

3. General Observation Criteria
   3.1 According to what has been observed, considering the period between the fair's start time and 8:00 a.m., what type of population, according to age range, predominates among the fair's clients?
   o Young people
   o Adults
   o Seniors

   Other observations: ___________________________________

   3.2 According to what has been observed, considering the period between 8:00 a.m. and 10:00 a.m., what type of population, according to age range, predominates among the fair's customers?
   o Young people
   o Adults

o Seniors

Other observations: ______________________________________

3.3 According to what has been observed, considering the period between 10:00 a.m. and 12:00 a.m., what type of population, according to age range, predominates among the fair's customers?
o Young people
o Adults
o Seniors

Other observations: ______________________________________

3.4 The prevailing weather condition during the day of the fair is:
o Sunny
o Cloudy
o Rainy

Other observations: ______________________________________

3.5 Is there any eventuality or activity that modifies the usual dynamics of the farmer's fair?
o YES
o NO

Please specify: _______________________________________

3.6 Do most of the clients of the farmer's fair carry shopping carts, reusable bags, or other means of storing the products purchased?
o Always
o Almost always
o Sometimes
o Almost never
o Never

3.7 According to what you observed, do most of the fair's customers use plastic bags even if they carry shopping carts, reusable bags, or other means to store the products purchased?
o YES
o NO

3.8 Do vendors generally give plastic bags to customers, even if they do not ask for them?
o YES
o NO

3.9 According to your perception, does the vendor influence the consumption of plastic bags by customers?
o YES
o NO

3.10 Including the registered producer, for the most part, what is the average number of people counted working in the stalls? ______________

3.11 If necessary, please note any additional observations or comments.

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