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Are consumers concerned about plastic water bottles environmental impact?

C. Orset ; N. Barret ; A. Lemaire

UMR Economie Publique
Avenue Lucien Brétignières – 78850 Grignon
16 rue Cl. Bernard – 75005 Paris
Tel. +33 (0)1 30 81 53 30
Fax. +33 (0)1 30 81 53 68
http://www.grignon.inra.fr/economie-publique

Are consumers concerned about plastic water bottles environmental impact?

Caroline Orset* Nicolas Barret† Aurélien Lemaire‡

Abstract

Although plastic induces environmental damages, almost all water bottles are made from plastic. However, these damages are more or less significant according to the plastic used. This study evaluates the consumers' willingness to pay (WTP) for different plastics used for water packaging. Successive messages emphasizing the characteristics of plastic are delivered to participants allowing explaining information influence on the consumers' WTP. We find that information has a significant effect on WTP. The participants' WTP for plastic bottles tends to increase after information emphasizing that the related plastic bottles has no negative impact on the environment, and to decrease with information on its negative impact. Using a fixed effect panel model, we show that there is a significant premium for recycled plastic bottles except when biodegradable plastic bottles are present on the market. We compare the welfare effects of regulatory policies allowing reducing environmental damages of plastic water bottles. We get that information campaign on plastic bottles issues would be the best policy whether it would not be difficult to implement it in practice. Then we discuss about other environmental policies and tools which could be applied in order to reduce plastic water bottles negative impact on the environment.

Keywords: Biodegradable plastic bottles; Bioplastic bottles; Information campaign; Recycling plastic bottles; Regulatory instruments; Consumer's willingness to pay.

JEL Classification: C90, D12, L66, Q57, Q58 .

*UMR AgroParisTech-INRA Economie Publique, 16 rue Claude Bernard, 75005 Paris, France. Email: caroline.orset@agroparistech.fr

†Group MOM - Materne Mont Blanc.

‡CITEPA (Centre interprofessionnel technique d'études de la pollution atmosphérique).

1 Introduction

Plastic packaging is widely used everywhere in the world. This kind of packaging produces an important quantity of waste. One of the most common plastic used is Polyethylene terephthalate abbreviated PET. This plastic is strong and durable, chemically and thermally stable. It has low gas permeability and is easily processed and handled. This almost unique combination of properties makes PET a very desirable material for a wide range of applications including food and beverage packaging especially water bottles at a very cost effective price. Globally 389 billion of PET bottles had been produced in 2010, 46% of them for water packaging (ELIPSO, 2012). But this stability leads PET to be highly resistant to environmental biodegradation. Biodegradation of one PET bottle left in nature can last around 500 years. Thus, this causes many and varied environmental concerns for both terrestrial and marine areas. Its accumulation is particularly impressive in the world's oceans where ends around 10% of the global plastic production every year (Fitzgerald, 2011). A seafaring scientist named Captain Charles Moore discovered and confirmed the existence of the Great Pacific Garbage Patch in 1997. In 2010, another similar area had been discovered in the Atlantic Ocean: The North Atlantic Garbage Patch. Finally, in 2013, a French expedition named the 7^{th} Continent expedition studied the Great Pacific Garbage Patch (Bossy, 2013) and started a new expedition in May 2014 in the North Atlantic Ocean.[1] The vast majority of all those marine debris is plastic materials and many of them are made of PET. According to Azzarello and Van Vleet (1987), Derraik (2002), Moore (2008), Saido (2014), and Sazima et al. (2002) plastic debris create a direct threat to wildlife, with many and varied species documented as being negatively impacted by those small plastic items. The main danger for most marine species is ingestion. Juvenile animals often become entangled in plastic debris, which can result in serious injury as the animal grows. Plastic ingested by animals persists in the digestive system implying a decrease feeding stimuli, secretion of gastric enzymes and levels of steroid hormones, leading to reproduction problems.

As very often concerning highly complex topics, the range of possible solution for protecting the ecosystem of plastic pollution is wide. Recently on the 13^{th} of March 2014, San Francisco municipality has made a step with an ordinance to ban the sale of PET water bottles on city-owned property (Timm, 2014). On the 2^{nd} July 2014, the European Commission adopted the Packaging and Packaging Waste Directive 94/62/EC whose the objective is: *"to limit negative impacts on the environment, in particular in terms of littering, to encourage waste prevention and a more efficient use of resources, while limiting negative socio-economic impacts. More specifically, the proposal aims at reducing the consumption of plastic carrier bags with a thickness of below 50 microns (0.05 millimetres) in the European Union."*[2] Actually, this directive especially concerns plastic bags, and there is no legislation on plastic bottles yet. However, with plastic bags, plastic bottles are the most emblematic plastic wastes.

Suppliers are working on the reduction of plastic wastes. The significant environmental

[1] For more details see: *http://expedition-7eme-continent.e-monsite.com/en/pages/page.html*.

[2] From the Proposal for a directive of the European parliament and of the council amending Directive 94/62/EC on packaging and packaging waste to reduce the consumption of lightweight plastic carrier bags /* COM/2013/0761 final - 2013/0371 (COD) */

drawbacks of plastic disposal via both landfill and incineration are the driving force behind the development of plastic recycling processes (Paponga et al, 2014). PET is now recycled in many countries that are developing specific waste management policies. This recycled PET is named r-PET. In France, this solution has been used 20 years ago. In 2010, 310,000 tons of PET bottles have been collected in France: it represents a recycling rate of 51%. Around 30% of this collected PET can be used in order to produce food grade r-PET quality.[3] Another solution is the development of new plastics with less environmental impact like bio-based (plant-derivative) plastics. The two most known biopolymers are polyactic acid (PLA) and polyethylene-furanoate (PEF). They are derived from renewable biomass sources such as corn starch or vegetable oil. PLA is produced from glucose and it is biodegradable. La Mantia et al (2012) prove that there is a better impact on environment of PLA compared to PET. However, PLA production is still low because even if PLA is mentioned as biodegradable plastic its needs anaerobic conditions. Its degradation is a source of methane that is a very powerful greenhouse effect gas. In addition, PLA recycling processes are still in progress. Loopla[4] by Galatic uses PLA wastes in order to recycle them but their process does not lead to 100% recycling of PLA. In addition, since the introduction of PLA in PET process recycling can lead to problems concerning PET recycling quality, few recycling companies invest in PLA recycling. Hence, in our study, we do not consider the recyclable property of PLA. By contrast, PEF is fully recyclable like PET but it is poorly biodegradable. PEF is made by converting sugars from sugarcane into plastic. Nowadays more than 2.5 billion plastic bottles made of biopolymers are already in use around the world, but this only represents less than 1% of global production. One of the main limiting aspects is the cost. But the production would increase in the next years, especially if there is a consumer?s demand.

So do consumers care about plastic water bottles environmental impacts? Does information on these impacts change consumers' purchasing decisions? On the welfare point of view, which environmental policies could be optimal? To address these questions, we propose to study the consumers' perceptions through a willingness-to-pay (WTP) analysis. Indeed, consumers' perceptions are not only essential for packaging companies? choices but they are also for environmental policies.

Our approach relies on two building blocks. First, our paper is linked to the experimental works which deal with the WTP and the information. Food experiments constitute some (for instance, on palm oil, Disdier et al, 2013; on milk, Marette and Millet, 2014, and on organic apples, Marette et al, 2012). Our paper contributes to this literature by investigating the precise impact of information and environmental sensitivity on the WTP of the consumers for plastic water bottles. We believe to be the first study focusing on the consumer perception regarding plastic bottles. We conduct an analysis to elicit the WTP for different kinds of plastic bottles with increasing levels of information on the use of various plastic bottles, and their environmental impacts. We find that information matters in terms of WTP. The consumers' WTP for a plastic bottles tends to increase after information emphasizing that the related plastic bottles has no

[3]See ELIPSO (2012) for more details.

[4]See for more details: $http://www.loopla.org/cradle/cradle.htm$.

negative impact on the environment, and to decrease with information on its negative impact. The importance of predicted WTP is overlooked in the studies by Disdier et al. (2013), Huffman et al. (2007), Lusk et al. (2005), Lusk and Marette (2010), Roosen and Marette (2011), and Rousu et al. (2007). Experimental literature shows that a significant proportion of consumers are willing to pay substantial premiums for environmentally friendly products (Bernard and Bernard, 2009; Bougherara and Combris, 2009; Disdier et al., 2013, Marette et al, 2012; Marette and Millet, 2014; and Yue et al., 2009). We then analyse recycled, organic, biodegradable, and recycling plastic bottles consumption premiums.

Then, we contribute to the ecological economics literature on the reduction of pollution and waste on the environment by proposing environmental policies and instruments which could incentive consumers to purchase plastic bottles with a lower negative impact on the environment. A lot of works have been done on the producer side, essentially on the producer responsibility regulations based on the Extended Producer Responsibility principle to reduce waste and pollution in the environment (Da Cruz et al., 2012, 2014; Hage, 2007; Mayer, 2007; Numata, 2009; Palmer and Wall, 1997). But none of these works have studied this issue from the consumers' side. In this paper, from the consumers' revealed and estimated preferences on plastic used for water bottles packaging, we analyse the impact of environmental policies on the social welfare. We propose four policies: an information campaign on the advantages and the inconveniences of each plastic bottle on the environment, an organic policy favouring plastic bottles issued of renewable products, a biodegradable policy favouring biodegradable plastic bottles, and a recycling policy favouring recycling plastic bottles. This allows us both to identify the effects of each policy on the consumers' and producers' welfare, and to recommend the Pareto optimal environmental policy. We get that, on the welfare point of view, the best environmental policy for a regulator would be the information campaign. But a campaign with complete information is difficult to implement in practice. As second best alternatives, the regulator could propose a recycling policy with a non-recycling tax or a biodegradable policy with a biodegradable subsidy. However, these two policies do not support the production and consumption of the same plastic bottles. Regulator's choice would then depend on the regulator's ecological and financial priorities and lobbies' pressures.

The paper is organized as follows. Section 2 presents the study. Section 3 focuses on the results. From a welfare analysis, section 4 displays the regulator's choice between different environmental policies and tools. Finally, section 5 concludes.

2 The study

In 2011, French consumed around 5,5 billions of water bottles made of single use plastic: they are the third biggest water bottles consumer after Italian and American people. According to TNS Sofres 77% of the French citizen drink water bottles. We then propose to analyse the French consumers' perception on plastic water bottles.

2.1 Target respondents

During February 2014, we conducted the study through Marketest.[5] Marketest had selected French participants by using the quota method, i.e., the same proportions of sex, age and socio-economic status (occupation, income, education) criteria in the group of respondents as in the census report of French population by INSEE.[6] We had especially prepared the questionnaire to be posted online on the internet. The target respondents consists of 148 French people aged between 18 and 66.

Table 1 presents the socio-economic characteristics (gender, age, education, household composition, income, and occupation) of the participants. Differences between our panel and INSEE (which represents the general French population) are tested using the Pearson chi-squared test. A P-value (against the null hypothesis of no difference) of less than 5% is considered significant. The results in the last column of Table 1 suggest that the two groups are not significantly different.

Description	Study panel (%)	INSEE (%)	Chi2 test P-value
Gender			
Female	54.7	51.5	0.518
Male	45.3	48.5	
Age			
<20	14.9	25.0	0.063
[20-64]	65.5	57.0	
>64	19.6	18.0	
Education			
No baccalaureate (BAC)	45.9	59.0	0.062
BAC	21.0	16.0	
3 years after BAC	16.2	11.0	
More than 3 years after BAC	16.9	14.0	
People living in the household			
1 person	29.7	34.0	0.662
2 persons	27.7	26.0	
3 persons and more	42.6	40.0	

Notes : Baccalaureate is the French high school diploma.

Description	Study panel (%)	INSEE (%)	Chi2 test P-value
Monthly net income of the household (€)			
<1000	12.2	10.0	0.973
[1000-1500)	20.3	20.0	
[1500-2500)	20.3	20.0	
[2500-4000)	29.0	30.0	
[4000-6000)	10.1	10.0	
6000 ≤	8.1	10.0	
Socio-professional categories			
Farmers	0.0	1.0	0.987
Craftsman or trading	2.7	3.0	
Executives and professionals	9.5	9.6	
Freelance workerds	14.2	13.0	
Employees	16.9	17.0	
Workers	12.8	12.2	
Retired or looking for a job	27.7	26.5	
Without any professionnal activities	16.2	17.7	

Table 1: Socio-economic characteristics of participants.

Table 2 focuses on the plastic bottles consumption and the participants' preferences on the importance attached to the protection of environment, on the confidence to firm's communica-

[5]For more details on Marketest see: *http : //www.marketest.co.uk/*.

[6]INSEE (Institut national de la statistique et des études économiques) is the census bureau in France.

tion campaign and on the confidence on firm's environment friendly engagement.

Description	Study panel (%)
Plastic water 1.5L bottles consumption per week	
Never or less than one bottle	12.8
Between one and three bottles	31.8
More than three bottles	55.4
Plastic water and environment	
Plastic packaging are harmful to the environment	80.4
Plastic packaging are not harmful to the environment	19.6

Description	Importance attached to the protection of environment	Confidence to firm's communication campaign	Confidence on firm's environment friendly engagement
Does not know	0.7	34.5	43.9
No	1.4	43.2	12.8
Yes		22.3	43.3
Not too strong	33.8		
Strong enough	47.9		
Very strong	16.2		

Table 2: Plastic bottles consumption and participants' preferences of the study panel (%).

Close to 90% of the panel are heavy consumers of water plastic bottles. Only 19.6% of the participants think that plastic bottles uses do not create damages on the environment. More than 60% of our panel have an environmental conscious. 43.2% of the participants declare themselves not convinced by firm's communication campaign and 43.3% believe on firm's environment friendly engagement (label).

2.2 Products

Our study focuses on plastic water bottles. We consider a pack of six plastic water 1.5L bottles. Different kinds of plastic are proposed: PET, r-PET, PLA and PEF. PET is currently the most-widely used polyester in bottles. It is petroleum based and 100% recyclable but not biodegradable. r-PET is PET which has been recycled and is recycled. PLA is a biodegradable plastic. We do not mention its possible recyclable property in this work because since now only few recycling companies have invested in its recycling and the actual processes do not lead to 100% recycling of PLA.[7] It is derived from renewable resources. PLA is then considered as a bioplastic as well as PEF which is also made from renewable resources. PEF is 100% recyclable but not biodegradable. We have then decided to study these four kinds of plastic because they

[7]This allows us to separate biodegradable and recycling participants' interest.

allow us to compare the demand for bioplastics, recyclable and biodegradable plastics for water bottles packaging.

In average, the observed pack of six water 1.5L bottles price in Paris is at 3.6 Euros.[8] Participants are not influenced by trademark neither by mineral and spring water. We only focus on the kind of plastic used for water bottles packaging.

2.3 Experimental design and information revealed

In the questionnaire, successive messages emphasizing the plastic bottles characteristics and their environmental impacts are delivered to the survey participants. WTP is elicited after each message with the following question: *What is the maximum price you are willing to pay for a pack of six water 1.5L bottles with a packaging made of this plastic?* Only PET plastic bottles are presented in the three first rounds, then r-PET and biopolymer bottles are introduced in the fourth round and in the fifth round, respectively. Finally, the distinction between PLA and PEF bottles is offered from the sixth round. The experiment is divided into several stages as described in Figure 1.[9]

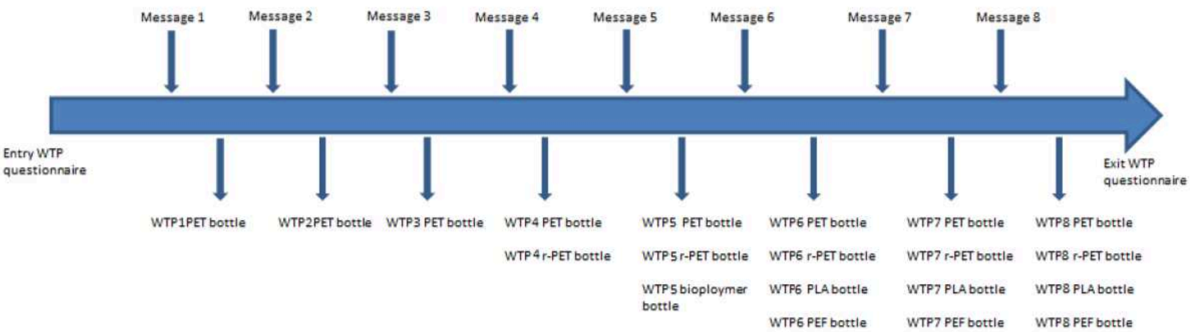


Figure 1: Questionnaire design.

[8]This price is estimated from our enquiry at Naturalia and Carrefour market, in November 2013, in Paris. According to INSEE data, the national price is around 3.03 Euros.

[9]Messages are given in Appendix.

The sequence of information revealed does no differ between the participants. As pre-tests have showed changing the order of the messages appear difficult to the participant's understanding. Marketest has its own panel of respondents and pays them for replying to questionnaire. The questionnaire is as follows: first, a text helps participants to understand the purpose of this study. No information is given about the different kinds of plastic bottles. Then, participants fill in an entry questionnaire on consumption behaviour and socio-demographic characteristics. Finally, based on different types of information revealed to participants, eight rounds of WTP elicitation are successively determined.

The observed retail price for a pack of six water 1.5L bottles, 3.6 Euros is revealed in message 1, before the first WTP elicitation, allowing us to control the anchorage effect for the first message.[10] Messages 2 and 3 reveal detailed information about the negative consequences of PET bottles on the environment (pollution and non-biodegradable). Messages 4 and 5 introduce the r-PET and biopolymers bottles, respectively. Then in message 6, biopolymers are divided in two categories of plastic, the biodegradable one, PLA, and the non-biodegradable one, PEF. Message 7 gives information on the negative impact of PLA bottles on the environment by clarifying that PLA bottles are polluting. Finally, message 8 informs the participants that PET, r-PET and PEF bottles have no negative impact on the environment thank to their recyclable property.[11]

3 Results

3.1 Descriptive analysis

Figure 2 presents the distributions of the WTP for a pack of six water 1.5L bottles according to the type of plastic and the amount of information provided. It shows that r-PET and PLA bottles attract the highest WTP for any level of information while PET bottles WTP is the lowest. We note that the reduction of WTPs for PET, PLA and PEF bottles following an information on the negative impact of these products is more important in absolute values than the increase of the WTPs for r-PET, PLA and PEF bottles when information specify that these products have no negative impact. In their prospect theory, Kahneman and Tversky (1979) observe that the impact of a loss on utility is twice higher than the impact of a symmetric gain on the utility. Our result presents this observation too. Indeed, after a message on the negative impact on the environment of PET bottles (messages 2 and 3), of PLA bottles (message 7) and of PEF bottles (message 6) the decrease in absolute value of the WTP for PET, PLA and PEF bottles is higher than the increase of the WTP for r-PET and PEF bottles after a message specifying that there is no negative impact on the environment of r-PET and PEF bottles (message 8) and of PLA bottles (message 6). In addition, we find that the average and median WTPs are lower than the reference price for a pack, that is 3.6 Euros, which is observed in Paris. Hence, at this price, the demand for a pack of plastic bottles of our panel, which represents French population, is low. Actually, this result is interesting and explains the

[10]See Drichoutis et al. (2008) for a discussion on the issue of provision of reference prices prior to the auctions.
[11]See messages in appendix.

national price of a pack of plastic bottles 3.03 Euros.

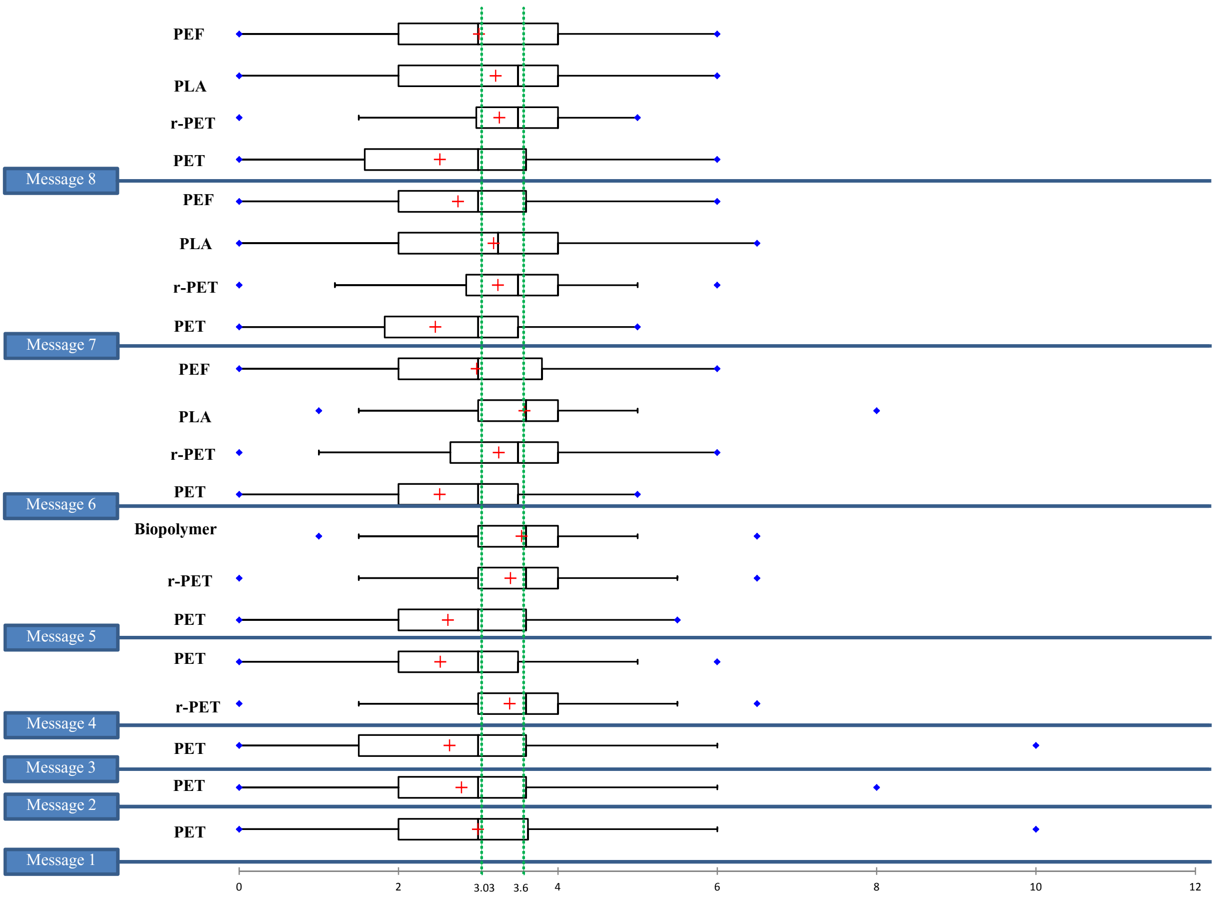


Figure 2: Distribution of the Willingness-To-Pay for a pack of six plastic water 1.5L bottles (in Euros).

In Figure 3, we present the average WTP in Euros for one pack of six water 1.5L bottles expressed by all participants i after each message j with $j = 1, 2, ..., 8$. The standard deviation is reported in parentheses. Analysed vertically, each column indicates the average WTP of participants for each pack (PET bottles in blue, r-PET bottles in red, Biopolymer bottles in green, PLA bottles in purple, and PEF bottles in orange), separately. We test for the significance of the WTP differences linked to the information revelation with the Wilcoxon test for paired samples. The test is made as follows: between messages j (between bars) for measuring the impact of information revelation on the average WTP for a given pack; For each specific message j for measuring the average WTP differences between two packs (between bars on a given column of two graphs).

We first note that information matters. Indeed, following the revelation of information, participants change their WTP. We observe that after each message on the negative impact on the environment of the plastic bottles (messages 2 and 3 for PET bottles, message 7 for PLA bottles, and message 6 for PEF bottles) the WTP for plastic bottles decreases while it increases after messages specifying that there is no negative impact of the plastic bottles on the environment (message 6 for PLA bottles, and message 8 for PET, r-PET and PEF bottles).

The introduction of PLA and PEF bottles, message 6, leads to a statistically significant decrease of the WTP expressed for PET and r-PET bottles. There is a substitution between PET and r-PET bottles , and bioplastics bottles. In particular, PLA bottles attract participants who previously purchased PET and r-PET bottles, while PEF bottles only attract the ones who consumed PET bottles. This difference is surely due to the non-biodegradability of PEF bottles. We observe that message 7, which gives an information on the negative impact of PLA bottles on the environment, leads to a statistically significant decrease of the WTP expressed for PLA and PEF bottles. Participants seem to associate both biopolymers. There is a problem of difference perception. Finally, message 8, which clarifies that PEF bottles have no negative impact on the environment, leads to a statistically significant increase of the WTP expressed for PEF bottles implying that participants are sensitive to recycling.

From message 4, which introduces r-PET bottles, we note that the WTP for PET bottles is always significantly lower than the WTPs for the other plastic bottles. Participants look like preferring recycled, biodegradable and organic plastic bottles. Furthermore, message 5, which introduces bioplastics bottles, has also a significant impact on the WTP for r-PET bottles. Actually, participants show with this message a clear preference for bioplastics. However, with message 6, which introduces PLA bottles (biodegradable) and PEF bottles (non-biodegradable), participants significantly confirm their preference between PLA bottles and r-PET bottles and reverse their preference between r-PET bottles and PEF bottles. Biodegradability looks like seducing participants. By the way, after message 7, which gives an information on the negative impact of PLA bottles on the environment, there is no more significant difference between the average WTPs for r-PET and PLA bottles. Finally, participants seem not favouring plastic bottles made of sugar or corn instead of petroleum. Actually, it is possible that participants be worried about using food for making plastic bottles which would lead to an intense production of sugar and corn, and so to reallocation of the land use with all the possible known negative impacts on the biodiversity. Moreover, some of the participants might also be confused by the trade-off between using food for making plastic bottles and producing food for human being consumption.

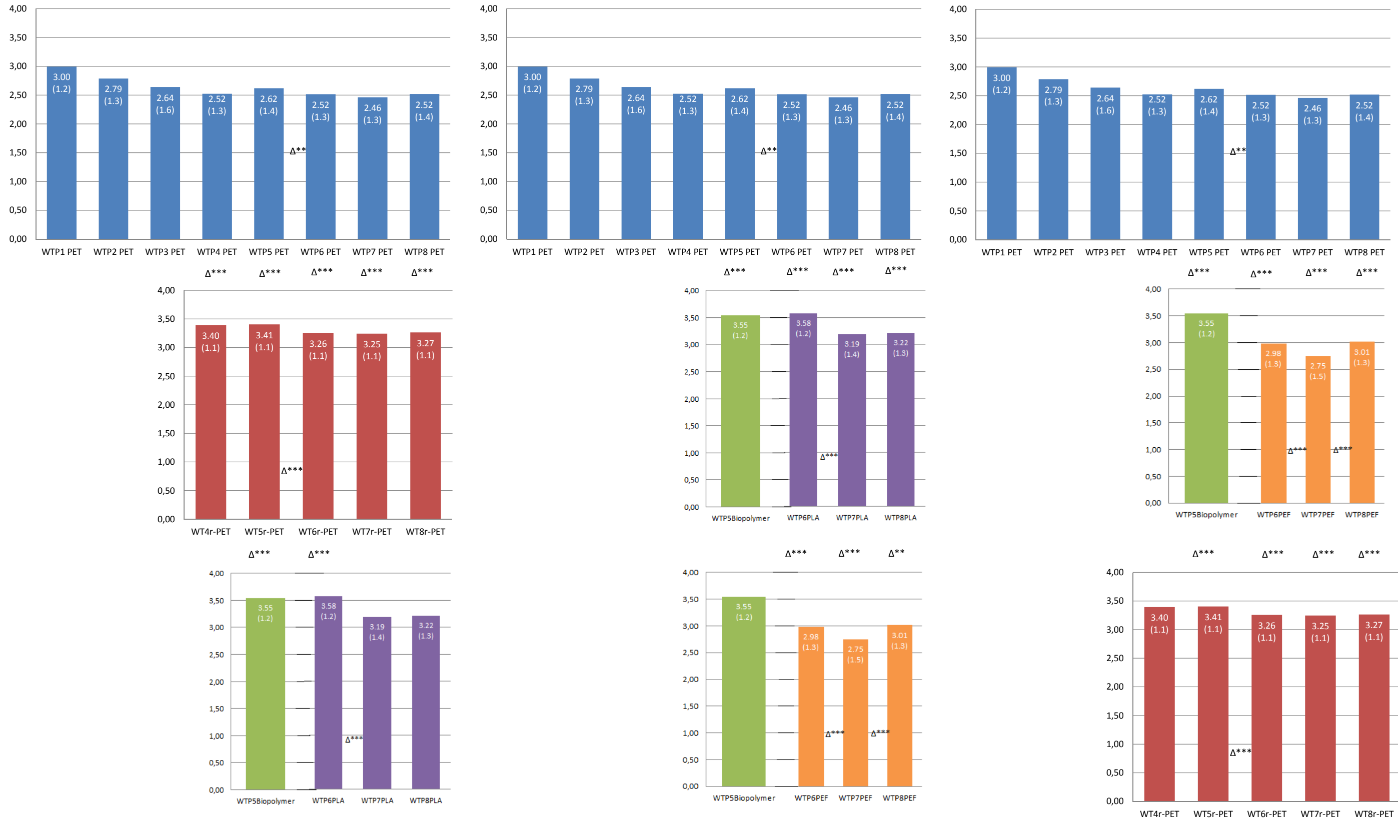


Figure 3: Average WTP for one pack of six water 1.5L bottles and variations after information revelation. Note: Average WTP (in Euros); Standard deviation in parentheses; Δ^{***} and Δ^{**} denote significant differences at the 1% and 5% levels, respectively, as tested by the Wilcoxon test.

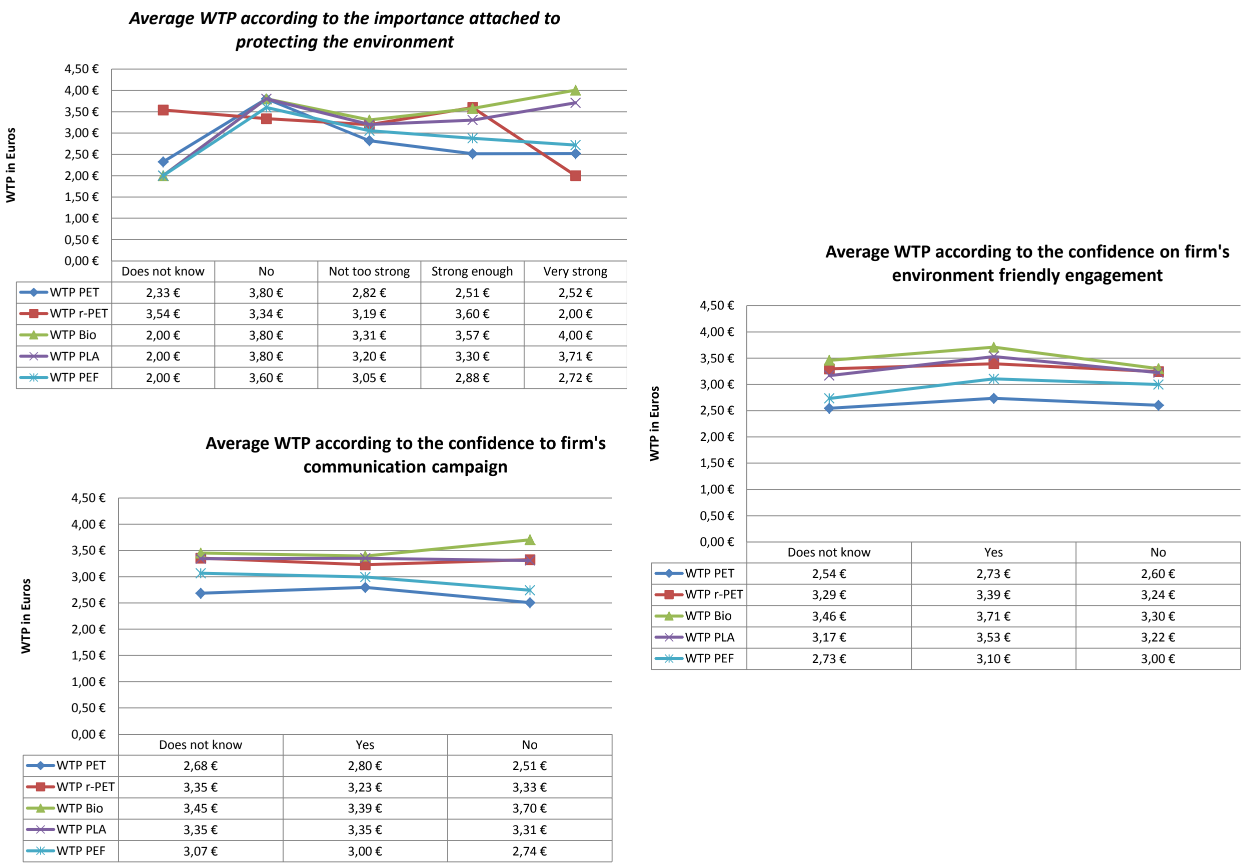
Table 3 shows that after all the messages some consumers are willing to boycott plastic bottles while they were buying them at the beginning of the study. Information are then really useful for their decision. Nevertheless, 27.7% of our participants does not seem affected by information because their WTP at the beginning and at the end of the study is identical. This percentage is lower to their declaration on their sensitivity to firm's communication campaign. Actually, 43.2% of the participants think that they are not affected by firm's communication campaign. It seems that the sender of messages (information) is important for participants.

	Number	%
Participants boycotting PET bottles		
Such that $WTP_1PET>0$ and $WTP_8PET=0$	14	9.5
Participants boycotting r-PET bottles		
Such that WTP_4 r-PET>0 and WTP_8 r-PET=0	2	1.4
Participants boycotting PLA bottles		
Such that $WTP_6PLA>0$ and $WTP_8PLA=0$	6	4.1
Participants boycotting PEF bottles		
Such that $WTP_6PEF>0$ and $WTP_8PEF=0$	4	2.7
Participants indifferent to messages		
Such that $WTP_1PET>0$ and $WTP_1PET=WTP_8PET$	41	27.7
Such that WTP_4 r-PET>0 and WTP_4 r-PET=WTP_8 r-PET		
Such that $WTP_6PLA>0$ and $WTP_6PLA=WTP_8PLA$		
Such that $WTP_6PEF>0$ and $WTP_6PEF=WTP_8PEF$		

Table 3: Distribution of participants.

Finally, from Figure 4, we first observe participants who are very strongly and strongly enough concerned by the protection of the environment are willing to pay more in average for bioplastics bottles (PLA and PEF) than for the other plastic bottles. However, the participants with a very strong interest are not willing to pay more than 2 Euros in average for r-PET bottles, lower than for PET bottles (2.52 Euros). Actually, they surely do not perceive the environmental benefit of consuming recycled plastic bottles and they have a higher valuation for water bottles packaging made with raw material (petroleum which is a polluting). In addition, participants who have no concern for the protection of the environment have the highest average WTP for plastic bottles.

Then, we note the confidence to firm's communication campaign and on firm's environment friendly engagement do not influence the participants? rank order list of plastic bottles. Whatever their believes, they make a ranking of plastic (from the most preferred plastic to least preferred): PLA $\geq$r-PET$>$ PEF $>$ PET. In addition, on average, participants who are confident to firm's engagement have a higher WTP than one who are confident to firm's communication campaign.



	Does not know	No	Not too strong	Strong enough	Very strong
WTP PET	2,33 €	3,80 €	2,82 €	2,51 €	2,52 €
WTP r-PET	3,54 €	3,34 €	3,19 €	3,60 €	2,00 €
WTP Bio	2,00 €	3,80 €	3,31 €	3,57 €	4,00 €
WTP PLA	2,00 €	3,80 €	3,20 €	3,30 €	3,71 €
WTP PEF	2,00 €	3,60 €	3,05 €	2,88 €	2,72 €

	Does not know	Yes	No
WTP PET	2,68 €	2,80 €	2,51 €
WTP r-PET	3,35 €	3,23 €	3,33 €
WTP Bio	3,45 €	3,39 €	3,70 €
WTP PLA	3,35 €	3,35 €	3,31 €
WTP PEF	3,07 €	3,00 €	2,74 €

	Does not know	Yes	No
WTP PET	2,54 €	2,73 €	2,60 €
WTP r-PET	3,29 €	3,39 €	3,24 €
WTP Bio	3,46 €	3,71 €	3,30 €
WTP PLA	3,17 €	3,53 €	3,22 €
WTP PEF	2,73 €	3,10 €	3,00 €

Figure 4: Average WTP (in Euros) according to participants' believes.

3.2 Econometric estimations

3.2.1 Willingness-To-Pay

We now investigate the determinants of WTP through estimations. Two general types of models (Ordinary Least Square regression (OLS) and Random effect panel regression) are estimated on pooled data (L = 2,960). They include dummies for the considered plastic bottles, PET bottles are the reference modality in all the models, and dummies for available information. All models also include six additional control variables: age, gender, income, individual attachment to the protection of the environment, the individual's confidence on firm's communication campaign, and the individual's confidence on firm's environment friendly engagement.[12]

Table 4 presents the estimations results. Results of the two models are very close. The sign of the coefficient are always identical only the intensity of the effect differs. All the coefficients are significant.

Endogenous variable : Pooled Willingness To Pay in €/pack of six water 1.5L bottles

	OLS	RANDOM-EFFECTS PANEL
	(1)	(2)
Constant	2.440***	2.511***
	(0.010)	(0.105)
r-PET (PET)	0.601***	0.579***
	(0.065)	(0.087)
Biopolymer (PET)	0.832***	0.805***
	(0.112)	(0.152)
PLA (PET)	0.867***	0.950***
	(0.112)	(0.152)
PEF (PET)	0.199***	0.174*
	(0.075)	(0.102)
Message 6 PET-0 (-1)	-0.214***	-0.230**
	(0.075)	(0.101)
Message 7 PLA-0 (-1)	-0.375***	-0.495***
	(0.126)	(0.170)
Observations	2,960	2,960
R^2	0.119	
Adjusted R^2	0.114	
Log-likelihood	-4846.462	−4851.617

*p<0.1; **p<0.05; ***p<0.01. Standard errors in parentheses.

Table 4: Results from regressions about pooled WTPs in levels.

We find that relatively to the PET bottles, the WTPs for the other kinds of plastic bottles are on average higher. The WTPs for PLA bottles and for r-PET bottles are the highest while the one for PEF bottles is the lowest. Biodegradability increases more the participant's WTP than organic and recycled properties.

[12]Bazoche et al (2013), Bernard and Bernard (2009), Crociata et al (2015), Hughnet et al (2007), Polyzou et al (2011) and Smed (2012) have showed the importance of control variables for studying good consumption behaviours, recycling behaviours, and WTP for environmental goods.

Looking at the information effect, we get that on average the WTP for PET bottles (non-biodegradable plastic bottles) before the introduction of the possibility of consuming biodegradable plastic bottles as PLA bottles (message 6) significantly decreases. Actually, there is a substitution between PET bottles and PLA bottles. However, on average the WTP for PLA bottles before the indication that the biodegradable plastic bottles may pollute (message 7) significantly decreases. Hence, knowing that PLA bottles, biodegradable plastic bottles, may finally create damages on the environment modifies the behaviour of participants who substitute the biodegradable plastic bottles (PLA) by the recycled plastic bottles (r-PET).

3.2.2 Premiums

We now analyse the difference in WTP between two kinds of plastic bottles. Hence, as we examine difference in WTP and not the WTP itself, some differences may be negative. We do not exclude them because a negative premium implies a preference for the individual for the non-reference plastic bottles. In addition, we do not consider the WTP expressed before message 4 since only PET bottles were available on the market. As our group of respondents includes 148 participants, the number of observations is either 444 (=148*3) or 740 (=148*5). The results are presented in Table 5.

We first consider the *Recycled Premium* which represents the premium for plastic bottles which are already recycled such as r-PET bottles. We find that participants prefer recycled plastic bottles except when biodegradable plastic bottles are present on the market. However, the difference between r-PET bottles and PLA bottles is really small, and is positive after message 7.

Then, we focus on *Organic Premium* which is characterized by the premium for plastic bottles produced from renewable resources which reduce the negative impact of plastic bottles on the environment such as PLA and PEF bottles. We observe that individuals have a higher demand for PLA bottles than for PEF bottles. The global premium is even negative when we compare r-PET bottles and PEF bottles.

Finally, we study *Biodegradable Premium* and *Recycling Premium* which are characterized by the premium for biodegradable plastic bottles such as PLA bottles, and for plastic bottles which are recyclable such as PET, r-PET and PEF bottles, respectively. The global biodegradable premium is always positive implying a strong demand for PLA bottles and so biodegradable plastic bottles. However, we may note that the biodegradable premium (recycling premium) becomes negative (positive) between PLA bottles and r-PET bottles after message 7. The difference is very small. It seems that the choice between PLA and r-PET bottles is difficult for participants.

Recycled Premium in €/ pack of six water 1.5L bottles

	Average premium for r-PET bottles instead of PET bottles	Average premium for r-PET bottles instead of PLA bottles	Average premium for r-PET bottles instead of PEF bottles
Message 4	0.87		
Message 5	0.79		
Message 6	0.74	-0.32	0.28
Message 7	0.78	0.05	0.50
Message 8	0.75	0,05	0.25
Global Mean	0.79	-0.07	0.34

Organic Premium in €/ pack of six water 1.5L bottles

	Average premium for PLA bottles instead of PET bottles	Average premium for PEF bottles instead of PET bottles	Average premium for PLA bottles instead of r-PET bottles	Average premium for PEF bottles instead of r-PET bottles
Message 6	1.06	0.46	0.32	-0.28
Message 7	0.73	0.28	-0.05	-0.50
Message 8	0.70	0.49	-0,05	-0.25
Global Mean	0.83	0.41	0.07	-0.34

Biodegradable Premium in €/ pack of six water 1.5L bottles

	Average premium for PLA bottles instead of PET bottles	Average premium for PLA bottles instead of r-PET bottles	Average premium for PLA bottles instead of PEF bottles
Message 6	1.06	0.32	0.60
Message 7	0.73	-0.05	0.45
Message 8	0.70	-0.05	0.21
Global Mean	0.83	0.07	0.42

Recycling Premium in €/ pack of six water 1.5L bottles

	Average premium for PET bottles instead of PLA bottles	Average premium for r-PET bottles instead of PLA bottles	Average premium for PEF bottles instead of PLA bottles
Message 6	-1.06	-0.32	-0.60
Message 7	-0.73	0.05	-0.45
Message 8	-0.70	0.05	-0.21
Global Mean	-0.83	-0.07	-0.42

Table 5: Pooled premiums.

We then analyse the determinants of these premiums through estimations, in particular the information effect. In Table 6, we present results. We use the fixed effect estimator on pooled data (L = 444 to 740), dummies for available information, and control variables: the participants' socio-economic characteristics (age, gender, income) and their initial perception about their attachment to the protection of the environment, their confidence on firm's communication campaign, and their confidence on firm's environment friendly engagement.

We first note that some estimated coefficients are not significant, suggesting that information does not affect the premium for PLA bottles instead of PET and r-PET instead of PET. However, messages 7 and 8 have an impact on other premiums.

The premium for PEF bottles instead of PET or r-PET bottles is negatively significantly affected by message 7 (message on the negative impact of PLA bottles on the environment) and positively by message 8 (which clarifies that PEF bottles have no negative impact on the environment). Actually, it seems that participants have associated the two biopolymers, information on the negative impact of one of them decrease the WTP of the other. The average WTP for PEF bottles is always higher (lower) than for PET bottles (for r-PET bottles), message 7 decreases this difference while message 8 increases it.

Afterwards, we get that the premium for PLA bottles instead of r-PET bottles is strongly negatively affected by message 7. This suggests that participants would have inclined to substitute PLA bottles by r-PET bottles when they are informed on the negative impact of biodegradable plastic bottles on the environment.

We point out that the premium for PLA bottles instead of PEF bottles is strongly negatively affected by messages 7 and 8. Hence, after message 7, participants still prefer on average consuming PLA bottles than PEF bottles, but this preference decreases after message 8.

Recycled Premium in €/ pack of six water 1.5L bottles

Model: FIXED-EFFECT PANEL

	Endogenous variable		
	Average premium for r-PET bottles instead of PET bottles	Average premium for r-PET bottles instead of PLA bottles	Average premium for r-PET bottles instead of PEF bottles
Const	0.872***	-0.323***	0.278***
	(0.051)	(0.065)	(0.071)
Message 5-0 (-1)	-0.086		
	(0.073)		
Message 6-0 (-1)	-0.045		
	(0.073)		
Message 7-0 (-1)	0.042	0.376***	0.222**
	(0.073)	(0.092)	(0.100)
Message 8-0 (-1)	-0.038	-0.007	-0.245**
	(0.073)	(0.092)	(0.100)
Observations	740	444	444
R^2	0.828	0.524	0.666
Adjusted R^2	0.007	0.069	0.024
Log-likelihood	-616.930	-435.074	-473.198

*p<0.1; **p<0.05; ***p<0.01. Standard errors in parentheses.

Organic Premium in €/ pack of six water 1.5L bottles

Model: FIXED-EFFECT PANEL

	Endogenous variable			
	Average premium for PLA bottles instead of PET bottles	Average premium for PEF bottles instead of PET bottles	Average premium for PLA bottles instead of r-PET bottles	Average premium for PEF bottles instead of r-PET bottles
Const	1.012	0.464***	0.323***	-0.278***
	(0.554)	(0.063)	(0.065)	(0.071)
Message 7-0 (-1)	-0.651	-0.180**	-0.376***	-0.222**
	(0.217)	(0.089)	(0.092)	(0.100)
Message 8-0 (-1)	0.759	0.207**	0.007	0.245**
	(0.220)	(0.089)	(0.092)	(0.100)
Observations	444	444	444	444
R^2	0.280	0.632	0.524	0.666
Adjusted R^2	0.081	0.021	0.069	0.024
Log-likelihood	-706.428	-420.573	-435.074	-473.198

*p<0.1; **p<0.05; ***p<0.01. Standard errors in parentheses.

Biodegradable Premium in €/ pack of six water 1.5L bottles

Model: FIXED-EFFECT PANEL

	Endogenous variable		
	Average premium for PLA bottles instead of PET bottles	Average premium for PLA bottles instead of r-PET bottles	Average premium for PLA bottles instead of PEF bottles
Const	1.012	0.323***	0.601***
	(0.554)	(0.065)	(0.089)
Message 7-0 (-1)	-0.651	-0.376***	-0.154
	(0.217)	(0.092)	(0.125)
Message 8-0 (-1)	0.759	0.007	-0.239*
	(0.220)	(0.092)	(0.125)
Observations	444	444	444
R^2	0.280	0.524	0.528
Adjusted R^2	0.081	0.069	0.033
Log-likelihood	-706.428	-435.074	-572.367

*p<0.1; **p<0.05; ***p<0.01. Standard errors in parentheses.

Recycling Premium in €/ pack of six water 1.5L bottles

Model: FIXED-EFFECT PANEL

	Endogenous variable		
	Average premium for PET bottles instead of PLA bottles	Average premium for r-PET bottles instead of PLA bottles	Average premium for PEF bottles instead of PLA bottles
Const	-1.012	-0,323***	-0,601***
	(0.554)	(0,065)	(0,089)
Message 7-0 (-1)	0.651	0,376***	0,154
	(0.217)	(0,092)	(0,125)
Message 8-0 (-1)	-0.759	-0,007	0,239*
	(0.220)	(0,092)	(0,125)
Observations	444	444	444
R^2	0.280	0,524	0,528
Adjusted R^2	0.081	0,069	0,033
Log-likelihood	-706.428	-435,074	-572,367

*p<0.1; **p<0.05; ***p<0.01. Standard errors in parentheses.

Table 6: Results from regressions about pooled premiums.

4 Consumer welfare and regulation

Contrary to questions about trade-off between regular and organic products in which regulator would choose to support organic products because they are more safety for health and their production reduces damages on the environment, the question of plastic bottles packaging is more technical and complex. Indeed, the regulator cannot support only one kind of plastic bottles because all of them present advantages and inconveniences for the environment.

First, the regulator may decide to make a policy of information which presents to people the different impacts of all kinds of plastic bottles on the environment. The goal of this campaign is to raise awareness among people to plastic bottles damages on the environment, and specifically among plastic bottles' consumers. In our panel, only 35% pretend not having or not having a strong attachment to the protection of environment. So, with this campaign, a large part of people will choose the plastic packaging for water bottles that they perceive as the less dangerous for the environment. We will call the policy the *'information policy'*.

The use of plant products from renewable sources is interesting because it helps limit resource depletion. An independent life-cycle-analysis studies by the Copernicus Institute at the University of Utrecht has demonstrated that the carbon footprint of PEF is $50\% - 70\%$ lower than PET. In addition, as PET and r-PET, PEF is 100% recyclable but it is superior gas barrier (10 times PET for O_2 and 5 times for CO_2).[13]From Alpha Packaging,[14] the carbon dioxide transmission rate[15] in cm3-mil/m2/24hr of PET is 540 while the one of PLA is 201. So, from these indicators, PLA and PEF look like less harmful to the environment than PET and r-PET. However, the environmental impact of organic plastics (bioplastics), PLA and PET, is often debated. Indeed, from Detzel et al (2013) PLA has advantages over the fossil polymers (PET, r-PET) with respect to climate change and resource consumption and disadvantages with respect to acidification and eutrophication as well as impact categories used to rate toxicity potentials. Moreover, PEF is not biodegradable and may create degradation to the nature if it is thrown. Hence, regulator may support an environmental policy favouring organic plastics bottles (PLA and PEF) if he wants to reduce gas barrier and to promote a production derived from renewable biomass sources. We call this policy the *'organic policy'*.

In addition, biodegradation property allows plastic (PLA) to be easily broken down by microorganisms and return to nature. Other environmental benefits are also identified: low toxicity to wildlife and flora and lower health risks, reduced use of protective equipment, no need specific storage. However, biodegradation of plastic is slowed down if the environment for microorganisms is not appropriate. For PLA, microorganisms need high oxygen conditions and require a high temperatures (more than $55°C$ ($131°F$) to degrade PLA plastic. In addition, methane might be released when there is degradation in an anaerobic landfill environment. So biodegradation may not always solve environmental problem. However, if the regulator wants

[13]See $http://www.packagingdigest.com/resins/pef-will-not-oust-pet-for-beverage-bottles-anytime-soon140724$.

[14]For more details see: $http://www.alphap.com/bottle-basics/plastics-comparison-chart.php$.

[15]Carbon dioxide transmission is the measurement of the amount of carbon dioxide gas measure that passes through a substance over a given period. The lower the readings, the more resistant the plastic is to letting gasses through.

to reduce toxicity to nature and to limit wastes, he may support the use of biodegradable plastic for water bottles packaging. We will call this policy the *'biodegradable policy'*.

Finally, recycling of plastic bottles (PET, r-PET and PEF) has environmental and economic advantages over the non-recyclable plastic bottles (PLA). These recyclable plastics reduce landfills and so the pollution that it causes. Increasing the recycling rate is an interesting way for reducing greenhouse gas emissions, limiting wastes, and so for preserving the environment as mentioned in Abbott et al (2011), Accuff And Kaffine (2013), Kinnaman et al (2014). Moreover, the recycling also contributes to the economic development of a country by creating new industries (new jobs and tax revenue).[16] However, there are some environmental downsides to recycling. Plastic recycling uses different processes and some of them employ caustic chemicals which create emissions and water pollution. So regulator wants to reduce landfill, he may support recycling plastics for water bottles packaging. We will name this policy the *'recycling policy'*.

In this section, based on elicited WTP and purchase decisions, we investigate the welfare impact of various environmental policies (information policy, organic policy, biodegradable policy and recycling policy). We assume that all kinds of plastic bottles are available on the market. We first present the demands for each kinds of plastic bottles.

4.1 Plastic bottles demand

To convert the WTP to demand curves, it is assumed that each participant would make a choice related to the largest difference between his WTP and the market price. This choice is inferred because the real choice is not observed in the study, which only elicits WTP. Despite this limitation, this methodology is useful for estimating ex ante consumers' reactions to regulatory instruments.

Figure 5 shows the ordered WTP for the four plastic bottles. The cumulative number of participants (equivalent to one purchased pack of six plastic water 1.5L bottles per participant) is represented on the X-axis and the ordered WTP (in Euros) corresponding to the cumulative number of participants is represented on the Y-axis in decreasing order. The black ordered curve is the elicited WTP directly observed from the panel study, the blue curve is the predicted WTP with the classical OLS estimation, and the red curve is the predicted WTP with the random effect panel estimation.[17]

The left sides (right sides) of each graphs in Figure 5 shows that, for relatively high-values (low-values) of WTP, the elicited WTPs directly observed from the panel study are significantly higher (lower) than the WTPs predicted. The differences between OLS and the random effects estimation are not significant.

[16] For more details on the economic development impacts see: *http://www.epa.gov/osw/conserve/tools/localgov/benefits/*.

[17] Note that the WTP in all the curves is ordered, which means that a given number on the X-axis indicates the ranking of WTP related to each curve and not a specific participant.

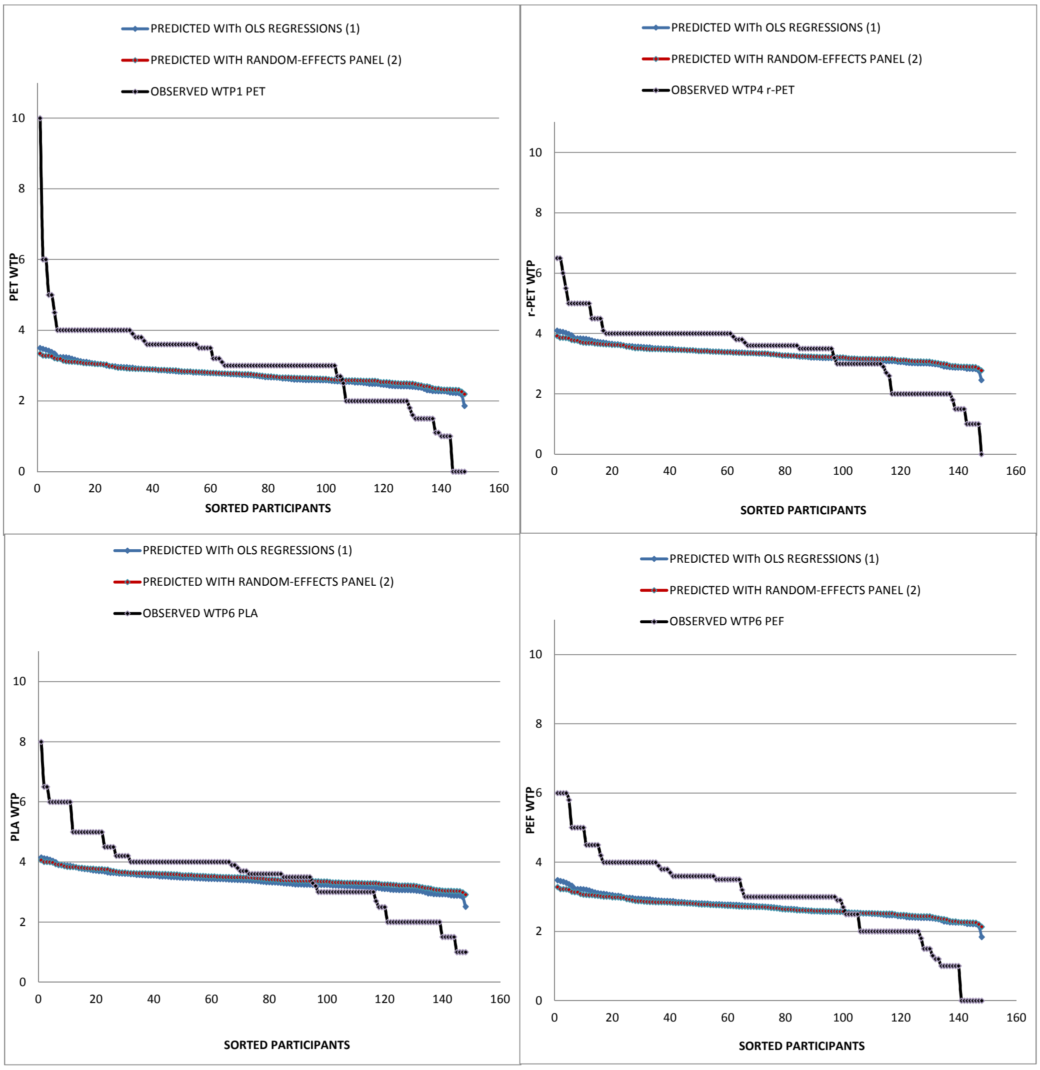


Figure 5: Observed and predicted demand functions for the four kinds of plastic bottles (in Euros).

4.2 Regulatory interventions

We now focus on the different tools for implementing the information policy, the organic policy, the biodegradable policy and the recycling policy.

4.2.1 Information campaign

For the information policy, the regulator may make a complete campaign of information on plastic bottles' impact on the environment. That is this public intervention consists in a very intense consumer information campaign, perfectly understood by consumers and revealing complete information on plastic bottles issues linked to the environment, which corresponds to the situation of round #8. Following this campaign, consumers are perfectly informed. Consumers directly internalize all information provided by the campaign. Consumer i can choose between five outcomes: one pack of six water 1.5L PET bottles at price P(PET) Euros, one pack of six water 1.5L r-PET bottles at price P(r-PET) Euros, one pack of six water 1.5L PLA bottles at price P(PLA) Euros, one pack of six water 1.5L PEF bottles at price P(PEF) Euros, or none of those. We consider that purchasing decisions are determined by the WTP for PET, r-PET, PLA and PEF bottles given by WTP_8 PET, WTP_8 r-PET, WTP_8 PLA and WTP_8 PEF, respectively. We assume that a consumer purchases one pack of six water plastic 1.5L bottles if his WTP is higher than the price observed for that pack in the supermarket. He chooses the option generating the highest utility (with a utility of non-purchase normalized to zero). Because complete information is perfectly internalized by consumers, no other tool can improve the welfare. The per-unit surplus and welfare for participant $i \in N$ is as follows:

$$W_i^L = max\{0, WTP_{i8}k - P(k); k \in \{PET, r-PET, PLA, PEF\}\}. \quad (1)$$

To implement the three other policies, the regulator may use three different tools. In configurations #1 to #3, we assume that consumers are imperfectly informed about plastic bottles issues. In configurations #1 and #2 the tools used consists in the adoption of a per-unit tax and a per-unit subsidy, respectively. In configuration #3, it consists of enforcement of a mandatory standard imposing a certain kind of plastic bottles on all producers.

4.2.2 Configuration #1: A per-unit tax

To simulate the tax scenario, we consider that consumers have no precise knowledge about the concerned plastic bottles, which corresponds to the situation of round #1 for PET bottles, the situation of round #4 for r-PET bottles, and the situation of round #6 for PLA and PEF bottles. The public intervention consists in configuration #1 in the adoption of a per-unit tax. WTP_{i1} PET, WTP_{i4} r-PET, WTP_{i6} PLA and WTP_{i6} PEF of consumer i are considered by the regulator in determining the welfare impact of the tax. Consumer i can choose between five outcomes: one pack of six water 1.5L PET bottles at price P^{τ}(PET) Euros, one pack of six water 1.5L r-PET bottles at price P^{τ}(r-PET) Euros, one pack of six water 1.5L of PLA bottles at price P^{τ}(PLA) Euros, one pack of PEF bottles at price P^{τ}(PEF) Euros, or neither. He makes his purchasing decision based on his surplus maximization, which is equal to:

$$CS_i^{\tau} = max\{0, WTP_{ij}k - P^{\tau}(k)\}. \tag{2}$$

where $i \in N$, $k \in \{PET, \text{r-PET}, PLA, PEF\}$, and $j = \begin{cases} 1, & \text{for k=PET;} \\ 4, & \text{for k=r-PET;} \\ 6, & \text{for k=PLA and k=PEF.} \end{cases}$.

The absence of complete information about the plastic bottles issues leads to a non-internalized damage or benefit and biases the purchasing decision. When complete information (round #8) is revealed, some consumers stop buying the product they previously bought. The non-internalized damage or benefit linked to the production of pack of six 1.5L plastic bottles is $\mathbb{1}[k, i] * (WTP_{i8}k - WTP_{ij}k)$ where $\mathbb{1}[k, i]$ is an indicator variable that takes the value 1 if the pack of plastic bottles k is purchased by the consumer i, namely if $WTP_{ij}k - P^{\tau}(k) > max\{0, WTP_{ij'}k' - P^{\tau}(k'); k \neq k'\}$. If the product is not purchased, $\mathbb{1}[k, i] = 0$.

By using (2), the complete surplus integrating the non-internalized damage or benefit is defined by:

$$C_i(\tau) = CS_i^{\tau} + \sum_k \mathbb{1}[k, i] * (WTP_{i8}k - WTP_{ij}k)\,. \tag{3}$$

where $i \in N$, $k \in \{PET, \text{r-PET}, PLA, PEF\}$, and $j = \begin{cases} 1, & \text{for k=PET;} \\ 4, & \text{for k=r-PET;} \\ 6, & \text{for k=PLA or k=PEF.} \end{cases}$.

This complete surplus integrates the non-internalized damage or benefit represented by WTP differences following the revealed messages. With this complete surplus, the regulator also considers the possible tax income coming from each participant. The tax is only paid by consumers purchasing one pack of six water 1.5L k bottles which does not correspond to the policy setting up by the regulator, with $k \in \{PET, \text{r-PET}, PLA, PEF\}$. So $\mathbb{1}[k, i] = 1$ leading to a possible income $\tau * \mathbb{1}[k, i]$ received by the regulator ($\mathbb{1}[k, i] = 0$ if the pack of six water 1.5L k bottles is not purchased). By taking into account the complete surplus integrating the non-internalized damage and the estimated tax income, the per-unit welfare related to a participant i is as follows:

$$W_i(\tau) = max\{0, WTP_{ij}k - P^{\tau}(k)\} + \sum_k \mathbb{1}[k, i] * (WTP_{i8}k - WTP_{ij}k) + \tau * \sum_k \mathbb{1}[k, i] \tag{4}$$

where $i \in N$, $k \in \{PET, \text{r-PET}, PLA, PEF\}\}$, and $j = \begin{cases} 1, & \text{for k=PET;} \\ 4, & \text{for k=r-PET;} \\ 6, & \text{for k=PLA or k=PEF.} \end{cases}$.

The optimal tax τ^* is given by tatonnement, maximizing the average welfare $\sum_i^N W_i(\tau)/N$ over the $N = 148$ participants.

4.2.3 Configuration #2: A per-unit subsidy

To simulate the subsidy scenario, we consider the same situation than for configuration #1, that is consumers have no precise knowledge about the concerned plastic bottles. The public intervention consists in the adoption of a per-unit subsidy. WTP_{i1}(PET), WTP_{i4}(r-PET),

WTP_{i6}(PLA) and WTP_{i6}(PEF) are considered by the regulator in determining the welfare impact of the subsidy. Consumer i can choose between five outcomes: one pack of six water 1.5L PET bottles at price P^s(PET) Euros, one pack of six water 1.5L r-PET bottles at price P^s(r-PET) Euros, one pack of six water 1.5L PLA bottles at price P^s(PLA) Euros, one pack of six water 1.5L PEF bottles at price P^s(PEF) Euros, or neither. He makes his purchasing decision based on his surplus maximization, which is equal to:

$$CS_i^s = max\{0, WTP_{ij}k - P^s(k)\}. \tag{5}$$

where $i \in N$, $k \in \{PET, \text{r-PET}, PLA, PEF\}$, and $j = \begin{cases} 1, & \text{for k=PET;} \\ 4, & \text{for k=r-PET;} \\ 6, & \text{for k=PLA and k=PEF.} \end{cases}$.

The absence of complete information about the plastic bottles issues leads to a non-internalized damage or benefit and biases the purchasing decision. As for the tax, when complete information (round #8) is revealed, some consumers stop buying the product they previously bought. The non-internalized damage or benefit linked to the production of pack of six 1.5L plastic bottles is $\mathbb{1}[k,i] * (WTP_{i8}k - WTP_{ij}k)$ where $\mathbb{1}[k,i]$ is an indicator variable that takes the value 1 if the pack of plastic bottles k is purchased by the consumer i, namely if $WTP_{ij}k - P^s(k) > max\{0, WTP_{ij'}k' - P^s(k'); k \neq k'\}$. If the product is not purchased, $\mathbb{1}[k,i] = 0$.

By using (5), the complete surplus integrating the non-internalized damage or benefit is defined by:

$$C_i(s) = CS_i^s + \sum_k \mathbb{1}[k,i] * (WTP_{i8}k - WTP_{ij}k) \tag{6}$$

where $i \in N$, $k \in \{PET, \text{r-PET}, PLA, PEF\}\}$ and $j = \begin{cases} 1, & \text{for k=PET;} \\ 4, & \text{for k=r-PET;} \\ 6, & \text{for k=PLA or k=PEF.} \end{cases}$.

This complete surplus integrates the non-internalized damage or benefit represented by WTP differences following the revealed messages. With this complete surplus, the regulator also considers the possible subsidy he has to give. The subsidy only reduced the price paid by consumers purchasing one pack of six water 1.5L k bottles corresponding to the policy setting up by the regulator, with $k \in \{PET, r-PET, PLA, PEF\}$. So $\mathbb{1}[k,i] = 1$ leading to a possible expense $s * \mathbb{1}[k,i]$ given by the regulator ($\mathbb{1}[k,i] = 0$ if the pack of six water 1.5L k bottles is not purchased). By taking into account the complete surplus integrating the non-internalized damage and the estimated subside expense, the per-unit welfare related to a participant i is as follows:

$$W_i(s) = max\{0, WTP_{ij}k - P^s(k)\} + \sum_k \mathbb{1}[k,i] * (WTP_{i8}k - WTP_{ij}k) - s * \sum_k \mathbb{1}[k,i]. \tag{7}$$

where $i \in N$, $k \in \{PET, \text{r-PET}, PLA, PEF\}$ and $j = \begin{cases} 1, & \text{for k=PET;} \\ 4, & \text{for k=r-PET;} \\ 6, & \text{for k=PLA or k=PEF.} \end{cases}$.

The optimal subsidy s^* is given by tatonnement, maximizing the average welfare $\sum_i^N W_i(s)/N$ over the $N = 148$ participants.

4.2.4 Configurations #3: A Standard

To simulate the standard scenario, we also consider that consumers have no precise knowledge about the concerned plastic bottles. Public intervention consists of constraining the purchase of one pack of six water 1.5L k bottles with k=PET, r-PET, PLA, and/or PEF. The consumer i's purchasing decision is based on her surplus maximization, which is equal to:

$$CS_i^S = max\{0, WTP_{ij}k - P(k)\} \tag{8}$$

where $i \in N$, and $j = \begin{cases} 1, & \text{for k=PET;} \\ 4, & \text{for k=r-PET;} \\ 6, & \text{for k=PLA and k=PEF.} \end{cases}$.

The non-internalized damage or benefit linked to the production of plastic bottles is $\mathbb{1}[k,i] * (WTP_{ij}k - WTP_{i1}k)$ where $\mathbb{1}[k,i]$ is an indicator variable that takes the value 1 if the pack of k bottles is purchased by the consumer i. If the product is not purchased, $\mathbb{1}[k,i] = 0$.

By using (8), the complete surplus integrating the non-internalized damage or benefit is defined by:

$$C_i^S \quad = \quad CS_i^S + \sum_k \mathbb{1}[k,i] * (WTP_{i8}k - WTP_{ij}k)\,. \tag{9}$$

where $i \in N$, and $j = \begin{cases} 1, & \text{for k=PET;} \\ 4, & \text{for k=r-PET;} \\ 6, & \text{for k=PLA or k=PEF.} \end{cases}$.

This complete surplus integrates the non-internalized damage or benefit represented by WTP differences following the revealed messages.

4.3 Welfare analysis

To perform the welfare analysis, we consider a baseline scenario in which the four packs of six plastic water 1.5L bottles are sold without any additional regulation. This baseline welfare is defined by (3) with $\tau = 0$. Policy simulations compare the welfare effects of regulatory instruments aimed at internalizing attributes valued by consumers after revelation of full information.

Tables 7 to 10 present the results of the welfare analysis for the four policies (information policy, organic policy, biodegradable policy and recycling policy): the sum of welfare variations with elicited and predicted values linking models (1) and (2) in Table 4. With a number $N = 148$, we detail the sum of welfare variations linked to one purchased pack of six water 1.5L bottles and we define the variation in consumer surplus, tax income and subsidy expense by $\Delta W_N^L = \sum_{i=1}^N \left[W_i^L - W_i(0)\right]/N$ for the information campaign. Then, for each configuration, we define the variation in consumer surplus, tax income and subsidy expense by $\Delta W_N(\tau^*) = \sum_{i=1}^N \left[W_i(\tau^*) - W_i(0)\right]/N$ for the tax τ^*, and $\Delta W_N(s^*) = \sum_{i=1}^N \left[W_i(s^*) - W_i(0)\right]/N$ for the subsidy s^*, and $\Delta C_N^S = \sum_{i=1}^N \left[C_i^S - W_i(0)\right]/N$ for the mandatory standard. The profit variation is defined by $P(k) * \left[\sum_{i=1}^N \left[\mathbb{1}[k,i,l] - \mathbb{1}[k,i,0]\right]/N\right]$ with $k \in \{PET, r-PET, PLA, PEF\}$ and l={ 0 for the Reference configuration in which $\tau = 0$; 1 for Configuration #1; 2 for Configuration #2; 3 for Configuration #3}. Then the tax income and the subsidy expense are $\tau^* * \left[\sum_{i=1}^N \mathbb{1}[k,i]/N\right]$ and $s^* * \left[\sum_{i=1}^N \mathbb{1}[k,i]/N\right]$, respectively. Finally, the welfare variation is the sum of the variation in consumer surplus, tax income and subsidy expense and the profit variation for all the plastic bottles' producers. Our calculations use the prices observed for the pack of six 1.5L plastic bottles, namely one pack of six water 1.5L PET bottles at price P(PET)=3.6 Euros, one pack of six water 1.5L r-PET bottles at price P(r-PET)=3.54 Euros, one pack of six water 1.5L PLA bottles at price P(PLA)=3.42 Euros, and one pack of six water 1.5L PEF bottles at price P(PEF)=3.3 Euros.[18]

4.3.1 Information policy

The first policy consists in an information campaign perfectly understood by consumers and revealing complete information about environmental impacts of all the plastic bottles, which corresponds to the situation of round #8. Each consumer can choose between five outcomes: one pack of six water 1.5L PET bottles at price P(PET) Euros, one pack of six water 1.5L r-PET bottles at price P(r-PET) Euros, one pack of six water 1.5L PLA bottles at price P(PLA) Euros, one pack of six water 1.5L PEF bottles at price P(PEF) Euros, or none of those. Table 7 presents the results of the welfare analysis under the information policy.

Information Policy

	Information Campaign
Elicited WTP	
Variation in consumer surplus, tax income and subsidy income	0.388
Profit variation for PET bottles' producers	-0.195
Profit variation for r-PET bottles' producers	3.325
Profit variation for PLA bottles' producers	-1.248
Profit variation for PEF bottles' producers	-0.803
Tax income/subsidy expense	0
Welfare variation	1.467
Predicted WTP with model OLS (1)	
Variation in consumer surplus, tax income and subsidy income	0.081
Profit variation for PET bottles' producers	0
Profit variation for r-PET bottles' producers	3.54
Profit variation for PLA bottles' producers	-1.502
Profit variation for PEF bottles' producers	0
Tax income/subsidy expense	0
Welfare variation	2.119
Predicted WTP with model RANDOM-EFFECTS PANEL (2)	
Variation in consumer surplus, tax income and subsidy income	0.145
Profit variation for PET bottles' producers	0
Profit variation for r-PET bottles' producers	3.54
Profit variation for PLA bottles' producers	-1.826
Profit variation for PEF bottles' producers	0
Tax income/subsidy expense	0
Welfare variation	1.859

Table 7: Surplus and profit variations over the 148 participants (in Euros) for the Information Policy.

Giving consumers full information via a campaign has a positive impact on the consumers' welfare and on the r-PET bottles' producers. However, for the producers of the other kinds of

[18]These prices are estimated from our enquiry at Naturalia and Carrefour market, in November 2013, in Paris. In our questionnaire, we have only given one reference price (3.6 Euros) for a pack of six water 1.5L plastic bottles based on the most used plastic, PET, in order not to make confused the participants.

plastic (PET, PLA and PEF) bottles, information campaign decreases or do not have an effect on their profits. From this result, the information policy looks like creating a higher demand for the r-PET bottles, the recycled plastic bottles. So it seems that for participants the plastic bottles with the highest environmental quality are the recycled plastic bottles.

4.3.2 Organic policy

In this part, the regulator supports an environmental policy favouring organic plastic bottles (PLA and PEF). His objective is the gas barrier reduction and a production derived from renewable biomass sources. To reach its goal, he proposes three different configurations, #1 to #3.

We assume that consumers are imperfectly informed about plastic bottles issues on the environment. In configurations #1 and #2 the public intervention consists in the adoption of a per-unit tax on pack of six water 1.5L non-organic plastic bottles (on PET and r-PET) and a per-unit subsidy on pack of six water 1.5L organic plastic bottles (on PLA and PEF), respectively. In configuration #3, public intervention consists of enforcement of a mandatory standard imposing organic plastic bottles on all bottles' producers (PLA and PEF).

Configuration #1: A per-unit tax on non-organic plastic bottles

Here, $\tau = \tau_{NO}$. Consumer i can choose between five outcomes: one pack of six water 1.5L PET bottles at price $P^{\tau_{NO}}(PET) = P(PET) + \tau_{NO}$ Euros, one pack of six water 1.5L r-PET bottles at price $P^{\tau_{NO}}$(r-PET)=P(r-PET)+τ_{NO} Euros, one pack of six water 1.5L of PLA bottles at price $P^{\tau_{NO}}(PLA) = P(PLA)$ Euros, one pack of PEF bottles at price $P^{\tau_{NO}}(PEF) = P(PEF)$ Euros, or neither. The tax is only paid by consumers purchasing non-organic plastic bottles with $\mathbb{1}[PET, i] = \mathbb{1}$[r-PET,i]= 1 leading to a $\tau_{NO} * \mathbb{1}[PET, i]$ and $\tau_{NO} * \mathbb{1}$[r-PET,i] received by the regulator ($\mathbb{1}[PET, i] = \mathbb{1}$[r-PET,$i$] = 0 if organic plastic bottles are purchased). The optimal tax τ^*_{NO} is given by tatonnement, maximizing the average welfare $\sum_i^N W_i(\tau^*_{NO})/N$ over the $N = 148$ participants.

Configuration #2: A per-unit subsidy on organic plastic bottles

Here, $s = s_O$. Consumer i can choose between five outcomes: one pack of six water 1.5L PET bottles at price $P^{s_O}(PET) = P(PET)$ Euros, one pack of six water 1.5L r-PET bottles at price P^{s_O}(r-PET)=P(r-PET) Euros, one pack of six water 1.5L PLA bottles at price $P^{s_O}(PLA) = P(PLA) - s_O)$ Euros, one pack of six water 1.5L PEF bottles at price $P^{s_O}(PEF) = P(PEF) - s_O$ Euros, or neither. The subside only reduced the price paid by consumers purchasing organic plastic bottles with $\mathbb{1}[PLA, i] = \mathbb{1}[PEF, i] = 1$ leading to a possible expense $s_O * \mathbb{1}[PLA, i]$ and $s_O * \mathbb{1}[PEF, i]$ paid by the regulator ($\mathbb{1}[PLA, i] = \mathbb{1}[PEF, i] = 0$ if non-organic plastic bottles are purchased). The optimal subsidy s^*_O is given by tatonnement, maximizing the average welfare $\sum_i^N W_i(s^*_O)/N$ over the $N = 148$ participants.

Configuration #3: A standard on organic plastic bottles

Here $S = S_O$. Consumer i can choose between three outcomes: one pack of six water 1.5L PLA bottles at price $P(PLA)$ Euros, one pack of six water 1.5L PEF bottles at price $P(PEF)$ Euros, or neither.

Results

Table 8 sums up the welfare analysis for organic policy.

	Organic Policy		
	Configuration # 1 Non Organic tax	Configuration # 2 Subsidy for Organic	Configuration # 3 Organic Standard
Elicited WTP	τ_{NO}*= 0.39	s_O*= 0.11	
Variation in consumer surplus, tax income and subsidy expense	0.024	0.015	0.002
Profit variation for PET bottles' producers	-0.146	-0.024	-0.195
Profit variation for r-PET bottles' producers	-0.072	0	-0.215
Profit variation for PLA bottles' producers	0.046	0	0.069
Profit variation for PEF bottles' producers	0.067	0.045	0.089
Tax income/subsidy expense	0.021	0.068	0
Welfare variation	-0.081	0.036	-0.250
Predicted WTP with model OLS (1)	τ_{NO}*= 0	s_O*= 0	
Variation in consumer surplus, tax income and subsidy expense	0	0	0
Profit variation for PET bottles' producers	0	0	0
Profit variation for r-PET bottles' producers	0	0	0
Profit variation for PLA bottles' producers	0	0	0
Profit variation for PEF bottles' producers	0	0	0
Tax income/subsidy expense	0	0	0
Welfare variation	0	0	0
Predicted WTP with model RANDOM-EFFECTS PANEL (2)	τ_{NO}*= 0	s_O*= 0	
Variation in consumer surplus, tax income and subsidy expense	0	0	0
Profit variation for PET bottles' producers	0	0	0
Profit variation for r-PET bottles' producers	0	0	0
Profit variation for PLA bottles' producers	0	0	0
Profit variation for PEF bottles' producers	0	0	0
Tax income/subsidy expense	0	0	0
Welfare variation	0	0	0

Table 8: Surplus and profit variations over the 148 participants (in Euros) for the Organic Policy.

We first note the two predicted models suggest that no proposed tool is useful for implementing organic policy. However, the elicited model shows that a tax on non-organic plastic bottles and an organic standard lead to a global negative welfare variation while an organic subsidy implies a positive welfare variation. The consumer surplus variation is the highest with the subsidy. With the standard, this surplus is negative. PEF bottles' producers have a positive variation of their profit while PET bottles' producers have a negative variation whatever the tools. PLA bottles' producers have a positive variation of their profit except with a subsidy where its variation welfare is equal to zero as the one of r-PET bottles' producers who have a negative variation of their profit for the other tools. So these tools looks like to be efficient to increase the global demand of organic plastic bottles. The best tool according to the consumer welfare analysis and the global welfare analysis is the subsidy for organic plastic bottles.

4.3.3 Biodegradable policy

The regulator supports an environmental policy favouring biodegradable plastic bottles (PLA). He incites the use of a plastic which can be easily broken down by microorganisms and return to nature. In addition, he wants to reduce the toxicity to wildlife and flora. To reach its goal, he proposes three configurations, #1 to #3. We assume that consumers are imperfectly informed about plastic bottles issues on the environment. In configurations #1 and #2 the public intervention consists in the adoption of a per-unit tax on the pack of six water 1.5L non-biodegradable plastic bottles (on PET, r-PET and PEF) and a per-unit subsidy on pack of six water 1.5L biodegradable plastic bottles (on PLA), respectively. In configuration #3, public intervention consists of enforcement of a mandatory standard imposing a biodegradable plastic bottles on all bottles' producers (PLA).

Configuration #1: A per-unit tax on non-biodegradable plastic bottles

Here, $\tau = \tau_{NB}$. Consumer i can choose between five outcomes: one pack of six water 1.5L PET bottles at price $P^{\tau_{NB}}(PET) = P(PET) + \tau_{NB}$ Euros, one pack of six water 1.5L r-PET bottles at price $P^{\tau_{NB}}$(r-PET)=P(r-PET)+τ_{NB} Euros, one pack of six water 1.5L of PLA bottles at price $P^{\tau_{NB}}(PLA) = P(PLA)$ Euros, one pack of PEF bottles at price $P^{\tau_{NB}}(PEF) = P(PEF) + \tau_{NB}$ Euros, or neither. The tax is only paid by consumers purchasing non-biodegradable plastic bottles with $\mathbb{1}[PET, i] = \mathbb{1}[\text{r-PET}, i] = \mathbb{1}[PEF, i] = 1$ leading to a $\tau_{NB} * \mathbb{1}[PET, i]$, $\tau_{NB} * \mathbb{1}[\text{r-PET}, i]$ and $\tau_{NB} * \mathbb{1}[PEF, i]$ received by the regulator ($\mathbb{1}[PET, i] = \mathbb{1}[\text{r-PET}, i] = \mathbb{1}[PEF, i] = 0$ if biodegradable plastic bottles are purchased). The optimal tax τ^*_{NB} is given by tatonnement, maximizing the average welfare $\sum_i^N W_i(\tau^*_{NB})/N$ over the $N = 148$ participants.

Configuration #2: A per-unit subsidy on biodegradable plastic bottles

Here, $s = s_B$. Consumer i can choose between five outcomes: one pack of six water 1.5L PET bottles at price $P^{s_B}(PET) = P(PET)$ Euros, one pack of six water 1.5L r-PET bottles at price P^{s_B}(r-PET)= P(r-PET) Euros, one pack of six water 1.5L PLA bottles at price $P^{s_B}(PLA) = P(PLA) - s_B$ Euros, one pack of six water 1.5L PEF bottles at price $P^{s_B}(PEF) = P(PEF)$ Euros, or neither. The subside only reduced the price paid by consumers purchasing biodegradable plastic bottles with $\mathbb{1}[PLA, i] = 1$ leading to a possible expense $s_B * \mathbb{1}[PLA, i]$ paid by the regulator ($\mathbb{1}[PLA, i] = 0$ if non-biodegradable plastic bottles are purchased). The optimal subsidy s^*_B is given by tatonnement, maximizing the average welfare $\sum_i^N W_i(s^*_B)/N$ over the $N = 148$ participants.

Configuration #3: A standard on biodegradable plastic bottles

Here $S = S_B$. Consumer i can choose between two outcomes: one pack of six water 1.5L PLA bottles at price $P(PLA)$ Euros, or neither.

Results

Table 9 sums up the welfare analysis for the biodegradable policy.

	Biodegradable Policy		
	Configuration # 1 Non Biodegradable tax	Configuration # 2 Subsidy for Biodegradable	Configuration # 3 Biodegradable Standard
Elicited WTP	τ_{NB}*= 0.39	s_B*=0.39	
Variation in consumer surplus, tax income and subsidy expense	0.011	0,008	-0.006
Profit variation for PET bottles' producers	-0.122	-0.024	-0.195
Profit variation for r-PET bottles' producers	-0.072	-0.072	-0.215
Profit variation for PLA bottles' producers	0.809	0.855	0.924
Profit variation for PEF bottles' producers	-0.691	-0.691	-0.803
Tax income/subsidy expense	0.037	0.240	0
Welfare variation	-0.065	0.076	-0.295
Predicted WTP with model OLS (1)	τ_{NB}*= 0	s_B*=0	
Variation in consumer surplus, tax income and subsidy expense	0	0	0
Profit variation for PET bottles' producers	0	0	0
Profit variation for r-PET bottles' producers	0	0	0
Profit variation for PLA bottles' producers	0	0	0
Profit variation for PEF bottles' producers	0	0	0
Tax income/subsidy expense	0	0	0
Welfare variation	0	0	0
Predicted WTP with model RANDOM-EFFECTS PANEL (2)	τ_{NB}*= 0	s_B*=0	
Variation in consumer surplus, tax income and subsidy expense	0	0	0
Profit variation for PET bottles' producers	0	0	0
Profit variation for r-PET bottles' producers	0	0	0
Profit variation for PLA bottles' producers	0	0	0
Profit variation for PEF bottles' producers	0	0	0
Tax income/subsidy expense	0	0	0
Welfare variation	0	0	0

Table 9: Surplus and profit variations over the 148 participants (in Euros) for the Biodegradable Policy.

We first note that for the two predicted models suggest that no tool is useful. However, the elicited model shows that only the subsidy for biodegradable plastic bottles leads to positive consumer surplus and global welfare variations. Moreover, this subsidy encourages the biodegradable plastic bottles (PLA) demand and discourages the non-biodegradable plastic (PET, r-PET and PEF) bottles demand. So from the elicited model and on the welfare point of view, the subsidy at 0.39 Euros per pack of six water 1.5L biodegradable plastic bottles would be an efficient tool for increasing the consumer's surplus, decreasing the non-biodegradable plastic bottles demand and increasing the biodegradable plastic bottles demand.

4.3.4 Recycling policy

Now, the regulator supports an environmental policy favouring recycling plastic (PET, r-PET and PEF) bottles. He wants to reduce landfills and so the pollution that it causes. To reach its goal, he proposes three different configurations, #1 to #3.

We assume that consumers are imperfectly informed about plastic bottles issues on the environment. In configurations #1 and #2 the public intervention consists in the adoption of a per-unit tax on pack of six water 1.5L non-recycling plastic bottles (on PLA) and a per-unit subsidy on pack of six water 1.5L recycling plastic bottles (on PET, r-PET and PEF), respectively. In configuration #3, public intervention consists of enforcement of a mandatory standard imposing recycling plastic bottles on all bottles' producers (PET, r-PET and PEF).

Configuration #1: A per-unit tax on non-recycling plastic bottles

Here, $\tau = \tau_{NR}$. Consumer i can choose between five outcomes: one pack of six water 1.5L PET bottles at price $P^{\tau_{NR}}(PET) = P(PET)$ Euros, one pack of six water 1.5L r-PET bottles at price $P^{\tau_{NR}}$(r-PET)=P(r-PET) Euros, one pack of six water 1.5L of PLA bottles at price $P^{\tau_{NR}}(PLA) = P(PLA)+\tau_{NR}$ Euros, one pack of PEF bottles at price $P^{\tau_{NR}}(PEF) = P(PEF)$ Euros, or neither. The tax is only paid by consumers purchasing non-recycling plastic bottles with $\mathbb{1}[PLA, i] = 1$ leading to a $\tau_{NR} * \mathbb{1}[PLA, i]$ received by the regulator ($\mathbb{1}[PLA, i] = 0$ if recycling plastic bottles are purchased). The optimal tax τ^*_{NR} is given by tatonnement, maximizing the average welfare $\sum_i^N W_i(\tau^*_{NR})/N$ over the $N = 148$ participants.

Configuration #2: A per-unit subsidy on recycling plastic bottles

Here, $s = s_R$. Consumer i can choose between five outcomes: one pack of six water 1.5L PET bottles at price $P^{s_R}(PET) = P(PET) - s_R$ Euros, one pack of six water 1.5L r-PET bottles at price P^{s_R}(r-PET)=P(r-PET)$-s_R$ Euros, one pack of six water 1.5L PLA bottles at price $P^{s_R}(PLA) = P(PLA)$ Euros, one pack of six water 1.5L PEF bottles at price $P^{s_R}(PEF) = P(PEF) - s_R$ Euros, or neither. The subside only reduced the price paid by consumers purchasing organic plastic bottles with $\mathbb{1}[PET, i] = \mathbb{1}[r - PET, i] = \mathbb{1}[PEF, i] = 1$ leading to a possible expense $s_R * \mathbb{1}[PET, i]$, $s_R * \mathbb{1}[\text{r-PET}, i]$ and $s_R * \mathbb{1}[PEF, i]$ paid by the regulator ($\mathbb{1}[PET, i] = \mathbb{1}[\text{r-PET}, i] = \mathbb{1}[PEF, i] = 0$ if non-recycling plastic bottles are purchased). The optimal subsidy s^*_R is given by tatonnement, maximizing the average welfare $\sum_i^N W_i(s^*_R)/N$ over the $N = 148$ participants.

Configuration #3: A standard on recycling plastic bottles

Here $S = S_R$. Consumer i can choose between four outcomes: one pack of six water 1.5L PET bottles at price $P(PET)$, one pack of six water 1.5L r-PET bottles at price P(r-PET) Euros, one pack of six water 1.5L PEF bottles at price $P(PEF)$ Euros, or neither.

Results

Table 10 shows the welfare analysis for recycling policy.

	Recycling Policy		
	Configuration # 1 Non Recycling tax	Configuration # 2 Subsidy for Recycling	Configuration # 3 Recycling Standard
Elicited WTP	τ_{NR}*= 0.08	s_R*= 0	
Variation in consumer surplus, tax income and subsidy expense	0.024	0	-0,025
Profit variation for PET bottles' producers	0	0	0.049
Profit variation for r-PET bottles' producers	0	0	0.765
Profit variation for PLA bottles' producers	0	0	-1.248
Profit variation for PEF bottles' producers	0.156	0	0.357
Tax income/subsidy expense	0.029	0	0
Welfare variation	0.018	0	-0.102
Predicted WTP with model OLS (1)	τ_{NR}*= 0.17	s_R*= 0	
Variation in consumer surplus, tax income and subsidy expense	0.451	0	-0.021
Profit variation for PET bottles' producers	0	0	0
Profit variation for r-PET bottles' producers	0.717	0	0.789
Profit variation for PLA bottles' producers	-1.086	0	-1.502
Profit variation for PEF bottles' producers	0	0	0
Tax income/subsidy expense	0.022	0	0
Welfare variation	0.082	0	-0.734
Predicted WTP with model RANDOM-EFFECTS PANEL (2)	τ_{NR}*= 0.24	s_R*= 0	
Variation in consumer surplus, tax income and subsidy expense	0.128	0	0.043
Profit variation for PET bottles' producers	0	0	0
Profit variation for r-PET bottles' producers	0	0	0.622
Profit variation for PLA bottles' producers	-1.202	0	-1.826
Profit variation for PEF bottles' producers	0	0	0
Tax income/subsidy expense	0.044	0	0
Welfare variation	-1.074	0	-1.161

Table 10: Surplus and profit variations over the 148 participants (in Euros) for the Recycling Policy.

We first note that for the elicited and the predicted models, the subsidy for recycling is not useful. Finally, we observe that all the models say that a recycling standard leads to a global negative welfare variation. Actually, in this situation the impact on the profit of the PLA bottles' producers, i.e., the non-recycling producers is so negatively high that it leads to a global negative welfare variation. However, the consumer's surplus variation and the recycling plastic (r-PET) bottles demand variation are positive while the non-recycling bottles (PLA) demand variation is negative with the random effect panel model. This model suggest that a recycling standard could be an efficient tool for increasing the consumer's surplus, for decreasing the non-recycling plastic bottles demand and increasing the recycling plastic bottles demand. Finally, the elicited model and the OLS model show that the global welfare variation is positive for the recycling tax while it is negative with the random effect panel model. In addition, we note that the consumer surplus variation is negative with the elicited model. So, only the OLS model suggests that a tax on non-recycling plastic bottles at 0.17 Euros per pack of six water 1.5L non-recycling plastic bottles would be an efficient tool for increasing the consumer's surplus, decreasing the non-recycling plastic bottles demand and increasing the recycling plastic bottles demand, in particular the r-PET bottles demand.

4.3.5 In summary

On the welfare point of view, the best policy would be the information campaign. Indeed, giving consumers full information via a campaign has the highest positive impact in terms of welfare. According to our panel, this policy would increase the consumer surplus and the r-PET bottles demand while it would decrease PET, PLA and PEF bottles demands. However, a campaign with complete information is difficult to implement in practice and in this work we do not consider the price of this information which would decrease the positive welfare variation. Due to the limitations linked to campaigns, the analysis suggests other policies.

From our panel, as second best policy, the recycling policy with a tax on non-recycling plastic bottles at 0.17 Euros per pack of six water 1.5L non-recycling plastic bottles is a good alternative in terms of welfare. This would imply an increase in the consumer surplus and in the r-PET bottles demand, and it would decrease the non-recycling plastic bottles (PLA) demand. However, we may note that a biodegradable policy with a subsidy for biodegradable plastic bottles at 0.39 Euros per pack of six water 1.5L biodegradable plastic bottles is also a good proposition in terms of welfare. Its effect would be an increase in the consumer surplus and in the PLA bottles demand, and it would decrease the non-biodegradable plastic (PET, r-PET and PEF) bottles demand. Hence, these two policies have opposite effects on plastic bottles demands. Featuring between biodegradable plastic bottles or recycling plastic bottles would then depend on regulator's priorities and lobbies' pressures.

5 Conclusion

This paper suggests that consumers are concerned by plastic water bottles environmental impacts. Our panel of 148 participants is a representative sample of the French population. So its plastic bottles environmental impacts perception may then be useful as well for plastic bottles companies decisions (on production, research and development) as for public authorities choices (environmental policies).

Revealed information mainly affects the WTP expressed for the different kinds of plastic bottles. The participants' WTP for a plastic bottles tends to increase after information emphasizing that the related plastic bottles has no negative impact on the environment, and to decrease with information on its negative impact. Indeed, there is a significant difference between the WTP for PET bottles when participants have no information on the PET bottles environmental impact (3 Euros in average) and the WTP after messages 2 and 3 putting into evidence the negative impacts of PET bottles on environment (2.64 Euros in average). We also observe this information effect on the WTP for PLA bottles which goes from 3.58 Euros in average to 3.19 Euros in average with the revelation on PLA bottles negative impacts on the environment (message 7). Moreover, the WTP for PEF bottles is also affected by message 8, on the recyclable property of PEF bottles, going from 2.75 Euros in average to 3.01 Euros in average. Looking at the effect of information on plastic bottles demand, we get that with message 6 the WTPs for PET bottles and for r-PET bottles are on average lower than the ones for the two other plastic bottles. Participants look like concerned by the use of organic plastics (biopolymers) for producing water bottle and substitute regular plastic bottles (PET and r-PET) to organic plastic bottles (PLA and PEF). So communicating only on the fact that the bottles are made of bioplastic (like manufacturers are currently doing so)[19] vehicles a very positive image for consumers who significantly accept to pay more. However, message 7 neutralizes this substitution effect. Knowing that PLA bottles, biodegradable plastic bottles, may create damages on the environment modifies the participants' WTP for PLA bottles by decreasing it and by strongly increasing the one for r-PET bottles. This information effect is so important that it reverses the substitution between biodegradable and recyclable plastic bottles (PLA and r-PET).[20]

This paper also shows that our study may help compare various regulatory scenarios. We have analysed the effect of possible regulation by estimating the welfare impact of four different environmental policies: information policy, organic policy, biodegradable policy and recycling policy. Our welfare estimate for defining a regulatory policy show that information policy is socially optimal. According to our panel, this policy would increase r-PET bottles demand and decrease PET, PLA and PEF bottles demands. However, an information campaign with complete information is difficult to implement in practice. A recycling policy with a tax on non-recycling plastic bottles and a biodegradable policy with a subsidy for biodegradable plastic bottles might be second best solutions on the welfare point of view. But these two policies have opposite effects on plastic bottles demands. On the ecological point of view, it would be difficult for a regulator to support its choice between the biodegradable policy and recycling policy. The two policies present advantages and inconveniences for the environment. Nevertheless, a regulator might prefer imposing a tax than a subsidy for reducing public expenses. Lobby's pressure may also influence its choices.

Our work presents some limitations. First, as in all WTP approaches, there might be a hypothetical bias in our study. As suggested by Lusk (2003) we have tried to reduce this bias with a cheap talk explaining to participants that they should reply as if they would pay for the pack of six 1.5L plastic bottles. Second, we did not consider controversies or incorrect messages leading to participants' confusion or misunderstanding. To correct this, we would introduce a probability of being wrongly informed δ, namely a probability of having participants with misunderstanding regarding linseed, such that the variation in consumer surplus, tax income and subsidy income for the information campaign would become $\Delta W_N^L = \sum_{i=1}^{N} \left[(1-\delta)W_i^L - \delta W_i(0)\right]/N$. This assumption would decrease the social benefit of using advertising campaigns. Third, the way to collect data might be discussed. We have used an online study. Cobanoglu et al (2001), Couper (2000), and McDonald and Adam (2003) highlight that online studies allow to save time

[19]For instance, see Volvic logo: *http : //naturalplasticstests.blogspot.fr/*2011/01/*volvic − sugar − based − pet − bottle − hits − uk.html*.

[20]Remember that in our study, we have considered that PLA bottles are not recyclable due to the low level of recycled PLA today. This has allowed us to evaluate the interest of participants for recycled, organic, recycling and biodegradable plastic bottles, respectively.

and efforts in collecting data. Moreover, Fricker et al (2005), Kreuter et al (2008) and Heerwegh and Loosveld (2008) show that online studies make it possible to get higher quality answers with less 'I do not know' and less unanswered than telephone survey and personal interview survey. So on the quality data collection, online studies do not look to present more disadvantage than other kinds of surveys. Finally, we have considered that producers' cost was always the same whatever the level of production. We have done this simplification because there is no cost data access for plastic bottles production. Introducing variable costs would decrease the producer's benefit variation when its demand increases with the policy while when its demand decreases it would increase its profit variation.

Finally, as we have seen in this study, all the actual kinds of plastic bottles present advantages and inconveniences on the environment. It is still difficult to perfectly rank them according to environmental indicators. In this work, we have proposed different policies linked to the actual possibilities of plastic bottles. Ferrara and Plourdes have discussed about plastic substitution, for instance by using glass. However, glass has also bad effects on the environment and it is not clear that its use is beneficial in comparison to plastic. So we have another possibility, increasing the environmental interest of bottles companies for innovating in a plastic with a better environmental quality (with biodegradability, recycling, and organic properties). A way to motivate innovation is creating a demand from consumers and from water companies. By analysing the WTP to participants we have showed their preferences, and so their demands for the different plastic bottles. Participants really hesitate between r-PET bottles and PLA bottles, so it is clear that if a plastic bottle could be a mix of these two plastic bottles, we would have a consumer demand which would increase water companies demand for these kinds of plastic bottles.[21]

Appendix

Message 1: *The average price for a pack of six water 1.5L bottles is 3,60 Euros.*

Message 2: *PET plastic used for water bottle is 100% petroleum derived. The average weight of a 1.5L empty bottle is 32 grams : it needs 64 ml of petroleum to produce it (13 coffee spoon).*

Message 3: *Those bottles made with PET needs 500 years to be completely degraded in the nature.*

Message 4: *It is now technologically possible to produce bottles made of 100% of recycled PET, r-PET.*

Message 5: *It is now technologically possible to produce bottles made of 100% of biopolymers (derived from sugar or corn, renewable resources, and not from petroleum, fossil resource).*

[21]This study could then motivate more bottles companies to develop the recycling property and process for PLA.

Message 6: *There are two kinds of biopolymers. The first one, PEF, is not presenting a better biodegradability and has the same negative impact on the environment than PET or r-PET if it is not recycled. The second one, PLA, is biodegradable and can be composted.*

Message 7: *The biodegradable biopolymer, PLA, is a source of methane (powerful greenhouse effect gas).*

Message 8: *As for the non-biodegradable biopolymer, PEF, it is recyclable like the classical polymer. It can be reused without negative impact on the environment.*

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References

1. Abbott, A., Nandeibam, S., and O'Shea, L. (2011), "Explaining the variation in household recycling rates across the UK", *Ecological Economics*, Vol. 70, 2214-2223.

2. Acuff, K., and Kaffine, D.T. (2013), "Greenhouse gas emissions, waste and recycling policy", *Journal of Environmental Economics and Management*, Vol. 65, 74-86.

3. Azzarello, M.Y. and Van Vleet, E.S (1987), "Marine birds and plastic pollution", *Marine Ecology*, Vol. 37, 295-303.

4. Bazoche, P., Combris, P., Giraud-Hraud, E., Pinto, A. S., Bunte, F. and Tsakiridou, E. (2013), "Willingness-to-pay for pesticide reduction in the EU: Nothing but organic?", *European Review of Agricultural Economics.*

5. Bernard, J. C. and Bernard, D. J. (2009), "What is it about organic milk? An experimental analysis", *American Journal of Agricultural Economics*, Vol. 91, 826-836.

6. Bougherara, D., and Combris, P. (2009), "Eco-labelled food products: what are consumers paying for?", *European Review of Agricultural Economics*, Vol. 36, Issue 3, 321-341.

7. Bossy, D. (2013), "L'expédition 7e continent confirme : l'océan est une soupe de plastique", *Futura-Sciences.*

8. Cobanoglu C., Warde B. et Moreo P. (2001), "A comparison of mail, fax, and Web-based survey methods", *International Journal of Market Research*, Vol. 43, Issue 4, 405-410.

9. Couper, M.P. (2000), "Web surveys: A review of issues and approaches", *The Public Opinion Quarterly*, Vol. 64, Issue 4, 464-494.

10. Crociata, A., Massimiliano, A. and Sacco, P.L. (2015), "Recycling waste: Does culture matter?", *Journal of Behavioral and Experimental Economics*, Vol. 55, 40-47.

11. Da Cruz, N.F., Simoes, P., Marques, R.C. (2012), "Economic cost recovery in the recycling of packaging waste: the case of Portugal", *Journal of Cleaner Production*, Vol. 37, 8-18.

12. Da Cruz, N.F., Ferreira, S., Cabral, M., Simoes, P., Marques, R.C. (2014), "Packaging waste recycling in Europe: Is the industry paying for it?", *Waste Management*, Vol. 34, Issue 2, 298-308.

13. Derraik, J.G.B. (2002), "The pollution of the marine environment by plastic debris: A review", *Marine Pollution Bulletin*, Vol. 44, Issue 9, 842-852.

14. Detzel, A., Kauertz, B. and Derreza-Greeven, C. (2013), "Study of the Environmental Impacts of Packagings Made of Biodegradable Plastics", Federal Environment Agency in Germany.

15. Disdier, A-C., Marette, S., Millet, G. (2013), "Are consumers concerned about palm oil? Evidence from a lab experiment", *Food Policy*, Vol. 43, 180-189.

16. ELIPSO (2012), "Plastic and flexible packaging", No.14.

17. Fitzgerald, E. (2011), "Pacific Ocean Plastic Waste Dump".

18. Fricker S., Galesic M., Tourangeau R. et Yan T. (2005), "An experimental comparison of Web and telephone surveys", *The Public Opinion Quarterly*, Vol. 69, Issue 3, 370-392.

19. Hage, O. (2007), "The Swedish producer responsibility for paper packaging: an effective waste management policy?", *Resources, Conservation and Recycling*, Vol. 51, Issue 2, 314-344.

20. Heerwegh D. and Loosveldt G. (2008), "Face-to-face versus Web surveying in a high-Internet coverage population: differences in response quality", *The Public Opinion Quarterly*, Vol. 72, Issue 5, 836-846.

21. Huffman, W. E., Rousu, M., Shogren, J. F. and Tegene, A. (2007), "The effects of prior beliefs and learning on consumers? acceptance of genetically modified foods", *Journal of Economic Behavior and Organization*, Vol. 63, 193-206.

22. Hughner, R. S., McDonagh, P., Prothero, A., Shultz, C. J. and Stanton, J. (2007), "Who are organic food consumers? a compilation and review of why people purchase organic food", *Journal of Consumer Behaviour*, Vol. 6, 94-110.

23. Kahneman, D. and Tversky, A. (1979), "Prospect theory: An analysis of decision under risk", *Econometrica*, Vol. 47, 263?292.

24. Kinnaman, T.C., Shinkuma, T., and Yamamoto, M. (2014), "The socially optimal recycling rate: Evidence from Japan", *Journal of Environmental Economics and Management*, Vol. 68, 54-70.

25. Kreuter F., Presser S. et Tourangeau R. (2008), "Social desirability bias in CATI, IVR, and Web surveys: The effects of mode and question sensitivity", *The Public Opinion Quarterly*, Vol. 72, Issue 5, 847-865.

26. La Mantia, F.P., Botta, L., Morreale, M., Scaffaro, R. (2012), "Effect of small amounts of poly(lactic acid) on the recycling of poly(ethylene terephthalate) bottles", *Polymer Degradation and Stability*, Vol. 97, Issue 1, 21-24.

27. Lusk, J.L. (2003), "Effects of cheap talk on consumer willingness to pay for golden rice", *American Journal of Agricultural Economics*, Vol. 85, No. 4, 840-856.

28. Lusk, J. L., House, L. O., Valli, C., Jaeger, S. R., Moore, M., Morrow, B. and Traill ,W. B. (2005), "Consumer welfare effects of introducing and labeling genetically modified food", *Economics Letters*, Vol. 88, 382-388.

29. Lusk, J.L., Marette, S. (2010), "Welfare effects of food labels and bans with alternative willingness to pay measures", *Applied Economic Perspectives and Policy*, Vol. 32, 319-337.

30. Marette, S., Messan, A., Millet, G. (2012), "Consumers' willingness to pay for eco-friendly apples under different labels: Evidences from a lab experiment", *Food Policy*, Vol. 37, 151-161.

31. Marette, S., and Millet, G. (2012), "Economic benefits from promoting linseed in the diet of dairy cows for reducing methane emissions and improving milk quality", *Food Policy*, Vol. 46, 140-149.

32. Mayers, C.K. (2007), "Strategic, financial, and design implications of extended producer responsibility in Europe? A producer case study", *Journal of Industrial Ecology*, Vol. 11, Issue 3, 113-131.

33. McDonald H. et Adam S. (2003), "A comparison of online and postal data collection methods in marketing research", *Marketing Intelligence and Planning*, Vol. 21, Issue 2, 85-95.

34. Moore, C. J. (2008), "Synthetic polymers in the marine environment: A rapidly increasing, long-term threat", *Environmental Research*, Vol. 108, Issue 2, 131-139.

35. Numata, D. (2009), "Economic analysis of deposit-refund systems with measures for mitigating negative impacts on suppliers", *Resources, Conservation and Recycling*, Vol. 53, Issue 4, 199?207.

36. Paponga, S., Malakula, P., Trungkavashirakuna, R., Wenununa, P., Chom-ina, T., Nithitanakulb, M., Sarobolc, E. (2014), "Comparative assessment of the environmental profile

of PLA and PET drinking water bottles from a life cycle perspective", *Journal of Cleaner Production*, Vol. 65, 539-550.

37. Palmer, K., and Walls, M. (1997), "Optimal policies for solid waste disposal taxes, subsidies, and standards", *Journal of Public Economics*, Vol. 65, Issue 2, 193?205.

38. Polyzou, E., Jones, N., Evangelinos, K.I., Halvadakis, C.P. (2011), "Willingness to pay for drinking water quality improvement and the influence of social capital", *Journal of Socio-Economics*, Vol. 40, 74-80.

39. Roosen, J. and Marette, S. (2011), "Making the ?right? choice based on experiments: Regulatory decisions for food and health", *European Review of Agricultural Economics*, Vol. 38, 361-381.

40. Rousu, M., Huffman, W., Shogren, J. and Tegene, A. (2007), "Effects and value of verifiable information in a controversial market: Evidence from lab auctions of genetically modified food", *Economic Inquiry*, Vol. 45, 409-432.

41. Saido, K. (2014), "Ocean Contamination Generated from Plastics", *Reference Module in Earth Systems and Environmental Sciences, Comprehensive Water Quality and Purification*, Vol. 1, 86-97.

42. Sazima, I., Gadig, O.B., Namora, R.C., Motta, F.S. (2002), "Plastic debris collars on juvenile carcharhinid sharks (Rhizoprionodon lalandii) in southwest Atlantic", *Marine Pollution Bulletin*, Vol. 44, Issue 10, 1149-51.

43. Smed, S. (2012), "Information and consumer perception of the ?organic? attribute in fresh fruits and vegetables", *Agricultural Economics*, Vol. 43, 33?48.

44. Timm, J. C. (2014), "San Francisco bans sale of plastic water bottles on city property", MSNBC.

45. Yue, C., Alfnes, F., Jensen, H.H. (2009), "Discounting spotted apples: investigating consumers? willingness to accept cosmetic damage in an organic product", *Journal of Agricultural and Applied Economics*, Vol. 41, 29-46.