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Abstract

The rebound effect occurs when improvements in energy efficiency result in lower energy savings than expected due to changes in behavior. These behavioral changes can be caused by an economic compensation and a moral compensation. For moral compensation, we consider moral licensing effect, but also the case of moral cleansing effect. The objective of our paper is to distinguish the economic and moral compensation in the rebound effect. To do so, we propose a theoretical model and an online experiment with 1622 subjects. Our experimental results show that an improvement in energy efficiency leads to a rebound effect through economic compensation. Concerning moral compensation, we do not observe any moral licensing but rather consistent behavior among participants with strong environmental attitudes. Finally, we find evidence for moral cleansing, which reduces the magnitude of the rebound effect.

Keywords: Rebound effect, economic compensation, moral compensation, moral licensing effect, moral cleansing effect, online experiment

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1. Introduction

The rebound effect occurs when the improved efficiency of an energy service leads to lower energy savings than expected (Greening et al., 2000). This effect is usually expressed as the relative difference between the potential energy savings afforded by the improved efficiency and the actual energy savings. Gillingham et al. (2016) offer a simple illustration of this phenomenon: "Buy a more fuel-efficient car, drive more". The "drive more" part of the illustration represents the behavioral change that causes the gap between potential and actual energy savings. This behavioral change may be driven by two types of mechanisms: an economic compensation mechanism caused as an individual uses "a more fuel-efficient car" and a moral compensation mechanism linked to a previous virtuous act such as the "purchase" of a more ecological car.

Economic compensation occurs when an improvement in energy efficiency makes an energy service cheaper, which leads people to use it more (Sorrell et al., 2009). People can us more of this service (direct rebound effect) and/or other energy services (indirect rebound effect[1]). The majority of the literature on the rebound effect focuses on this economic compensation (see Greening et al. (2000) for a literature review) and often ignores a possible moral compensation effect.

The integration of moral compensation as another cause of the rebound effect is part of a recent research approach in behavioral economics (Dütschke et al., 2018; Sorrell et al., 2020; Reimers et al., 2021). Unlike economic compensation, moral compensation generates a change in energy consumption through a modification in preferences for the use of the energy service that has had an efficiency improvement (Santarius and Soland, 2018; Sorrell et al., 2020). A distinction is made in moral compensation between the moral licensing effect and the moral cleaning effect. The moral licensing effect occurs when the performance of a virtuous act (e.g., buying a more efficient car) gives an individual a sense of license to perform a less virtuous act later on (e.g., driving the more fuel-efficient might lead to consuming more energy) (Monin and Miller, 2001). The moral cleansing effect describes the opposite behavior, where an individual performs a virtuous act in order to compensate for a previous less virtuous act (Sachdeva et al., 2009). In this paper, we also consider the moral cleansing effect in the analysis of the rebound effect, since, like the moral

[1]For example, this is referred to as an indirect rebound effect when the savings from using a more efficient car are re-spent on heating more.

licensing effect, it can have an impact on energy consumption behaviors.

The main objective of our paper is to distinguish the economic and moral compensation present in the rebound effect. To the best of our knowledge, no empirical estimate has clearly identified which part of the rebound effect is caused by economic compensation and which is caused by moral compensation. The effectiveness of energy efficiency policies is directly proportional to our understanding of the rebound effect. Knowing more about the factors that explain it can help policymakers and researchers find more effective ways to reduce it.

In this paper, we first propose a theoretical model that takes into account both economic and moral compensation. Next, we design and run an online experiment that allows us to distinguish the two types of compensation. Our results show that improvement in energy efficiency leads to a rebound effect through economic compensation. In terms of moral compensation, we do not observe a moral licensing effect, but we find evidence of a moral cleansing effect, especially in individuals with strong environmental attitutes. This effect has the opposite impact of that of economic compensation, which would indicate that it could be used as an instrument to mitigate the rebound effect.

This paper is organized as follows. The following section provides an overview of the literature related to economic and moral compensation. In Section 3, we detail our theoretical model and the hypotheses we propose to test. The experimental design is outlined in Section 4 and the results of the experiment are presented in Section 5. Finally, Section 6 concludes.

2. Related literature on economic and moral compensation

Since Jevons and his famous paradox[2], the analysis of the rebound effect has mainly been conducted through the prism of economics (Greening et al., 2000;

[2]In *The Coal Question* (1865), Jevons indicates that an improvement in energy efficiency could paradoxically result in a "backfire" situation where overall energy consumption would increase rather than decrease (Alcott, 2005).

Gillingham et al., 2016). This is because the main impact of an energy efficiency improvement is the change in the cost of an energy service. When a price changes, it is then possible to explain changes in consumption behaviors by the mechanisms of the standard microeconomic framework of consumer theory, namely, the substitution effect and the income effect (Sorrell and Dimitropoulos, 2008; Borenstein, 2014). This simple analysis framework makes it possible to quantify the magnitude of the rebound effect by estimating the price elasticity of the demand for the energy service in question (Sorrell et al., 2009). This method reveals that all energy services are subject to a rebound effect when they become more energy efficient. This has been shown for the sector of road transport (Dimitropoulos et al., 2018; Frondel et al., 2012), space heating (Haas and Biermayr, 2000; Madlener and Hauertmann, 2011), space cooling (Dubin et al., 1986; Hausman, 1979), water heating (Guertin et al., 2003), residential lighting (Schleich et al., 2014) and for all energy services using electricity (Freire González, 2010). In this sector, the majority of studies estimate a "positive" rebound effect. This means that the increase in energy efficiency has resulted in energy savings, but less than initially expected. Finally, estimates of the rebound effect from an economic perspective make it possible to highlight some factors that impact its magnitude. The rebound effect appears to be greater (i.e., energy savings are lower than expected) in the long term rather than in the short term, (Hausman, 1979; Douthitt, 1986; Dimitropoulos et al., 2018). It appears to decrease as the income of individuals increases (Madlener and Hauertmann, 2011; Sorrell et al., 2009) and, in the case of space heating, is not proportionally related to the level of energy efficiency (Hediger et al., 2018).

Compared to research on economic compensation, research on moral compensation is much more recent, and therefore less mature. In 2015, the meta-analysis of Blanken et al. (2015) regrouped the results of 91 studies that used experimental methodology to analyze the moral licensing effect in general. Their analysis concludes that the moral licensing effect is small to medium in effect size (Cohen's d of

0.31) and slightly overestimated by a publication bias. The moral licensing effect has also been observed in pro-environmental behaviors. This showed that recycling (Catlin and Wang, 2013; Truelove et al., 2016; Ma et al., 2019), purchasing environmentally friendly products (Mazar and Zhong, 2010; Panzone et al., 2012; Meijers et al., 2015; Geng et al., 2016; Garvey and Bolton, 2017), donating to environmental associations (Meijers et al., 2015; Stikvoort et al., 2016; Clot et al., 2018), engaging in pro-environmental activities (Clot et al., 2013, 2016) and recalling past pro-environmental actions (Gholamzadehmir et al., 2019; Lalot et al., 2022) could potentially have a negative impact on other behaviors because of the moral licensing effect. We observe a lower number of studies on the moral cleansing effect, probably because this effect is not problematic as it leads to more pro-social behavior. Nevertheless, the study by Gholamzadehmir et al. (2019) shows that highlighting a lack of pro-environmental action can subsequently lead to more pro-environmental efforts. Finally, on factors that impact the moral compensation for pro-environmental behaviors, an important question is whether moral compensation is lower or higher in relationship to the environmental attitudes of individuals. The answer to this question is still a matter of debate; some studies find that the moral licensing effect is amplified in individuals with strong environmental attitudes (Truelove et al., 2014; Dorner, 2019), while other studies find the opposite (Clot et al., 2016; Garvey and Bolton, 2017).

In terms of energy-consumption behaviors, a small number of studies have started to include the moral licensing effect as a cause of the rebound effect. Some of these studies are theoretical papers or literature reviews (Dütschke et al., 2018; Sorrell et al., 2020; Reimers et al., 2021), but we also have some empirical evidence of the moral licensing effect occurring in an energy context. Perhaps the most famous example is the field experiment by Tiefenbeck et al. (2013), which shows that a nudge on water conservation has the unintended effect of increasing electricity consumption (which is similar to an indirect rebound effect). Günther et al. (2020) reveal the negative impact that the presence of a carbon offset program can have on the frequency of an individual's engaging in a CO_2-intensive everyday activity like showering. Engaging in green electricity programs can also generate a moral licensing effect and increase electricity consumption by 1-3% (Jacobsen et al., 2012; Harding and Rapson, 2019). Finally, two papers seek to study the effect of moral licensing as a cause of the rebound effect in a laboratory experiment. Firstly, Eberling et al. (2019) analyze consumers choices on whether to purchase more energy-efficient lightbulbs and find a small rebound effect, not intensified by a moral licensing effect. Secondly, Dorner (2019), with a theoretical model and a real-effort laboratory experiment in a decontextualized environment, shows how a technological improvement can reduce pro-environmental efforts and generate a rebound effect through both economic and moral compensation. This last paper is the closest to ours, except that we integrate moral compensation into our theoretical model, and our experimental design allows us to clearly distinguish the part of each type of compensation that contributes to the rebound effect.

3. Theoretical model

The theoretical model is based on the theory of environmental offsetting used to analyze how an energy efficiency improvement impacts consumption behaviors and generates a rebound effect. The theory of environmental offsetting explains the voluntary contribution to the public good as a way to compensate for activities that negatively impact the public good (Kotchen, 2009; Lange et al., 2017; Dorner, 2019).

For example, Kotchen (2009) proposes a model in which the consumption of a private good generates a negative externality (i.e., pollution) on the public good (i.e., the level of air quality). The individual has the opportunity to compensate for his negative externality by voluntarily contributing to the public good. Kotchen's model reveals the paradoxical result that a technological improvement that makes a private good less polluting may result in a decrease in contributions to the public good, which can qualify as a rebound effect. The explanation for this effect is that, by becoming less polluting, the demand for the private good slightly increases, which has the effect of reducing contributions to the public good.

In their model, Lange and Ziegler (2017) consider that, in addition to the level of the public good, the individual also takes into account the damage he personally causes to the public good through his private consumption. More precisely, the authors consider that individuals have environmental responsibility preferences and experience disutility when they pollute. This parameter of environmental responsibility is analogous to Andreoni's idea of warm glow (Andreoni, 1989, 1990), with the difference that the individual does not feel satisfaction in having contributed positively to the environment, but rather dissatisfaction in causing pollution. In addition to being able to voluntarily reduce one's pollution by purchasing offsets, an individual can also make a mitigation effort by consuming a non-polluting private good. With their model, Lange and Ziegler (2017) show that having the possibility to offset one's pollution does not necessarily reduce an individual's incentive to make a mitigation effort and allows for an overall reduction in environmental pollution levels.

Compared to these studies, we integrate into our model the idea that moral compensation impacts individual preferences. We assume that the perception of the environmental responsibility parameter is not fixed but rather depends on the nature of a previous act, in accordance with moral compensation theory. With this approach, we combine two fields of the literature, namely, the theory of environmental offsetting (Kotchen, 2009; Lange and Ziegler, 2017) and the modeling of moral compensation (Brañas-Garza et al., 2013; Gneezy et al., 2014).

3.1. General framework

We consider an individual whose utility function (U) depends on the consumption of a private good $x \geq 0$, an environmental public good $G \geq 0$ and a variable g that represents the individual's net impact on the public good. G can be interpreted as environmental quality. We assume that the consumption of x generates a negative externality and decreases G by a coefficient δ (with $\delta \geq 0$). The net impact of the individual on the public good is determined by:

$$g = y - \delta x \tag{1}$$

The term y (with $y \geq 0$) is the individual voluntary contribution to the public good (i.e., a pro-environmental effort). In our model, the individual's net impact on the public good can be positive (if $y > \delta x$) or negative (if $y < \delta x$). This differs from Andreoni (1990), who considers only a positive impact, and from Lange and Ziegler (2017), for whom the impact is negative or null. The final level of the public good is the sum of the initial level of the public good $\overline{G} > 0$ and the individual impact:

$$G = \overline{G} + g \tag{2}$$

The initial level of the public good can be seen as the current quality of the environment, which is an exogenous parameter to our model.

Preferences of an individual are represented by the following additive utility function:

$$U(x, G, g) = u_1(x) + u_2(G) + \lambda u_3(g) \tag{3}$$

where u_1 represents the utility associated with the consumption of the private good (with $u_1' > 0$ and $u_1'' \leq 0$), u_2 the utility associated with the quantity of the public good (with $u_2' > 0$ and $u_2'' \leq 0$) and u_3 the utility associated with the individual's net impact on the public good (with $u_3' > 0$ and $u_3'' \leq 0$). We associate to u_3 a moral appreciation parameter λ, which is fixed to 1 for the moment. Like Andreoni (1990), we assume that g has properties of a private good, independent of its properties of a public good and that g therefore enters the utility function twice.

The individual's choices are limited by a budget constraint:

$$w = x + y \tag{4}$$

with w being the level of exogenous wealth of the individual that can be allocated either in the consumption of the private good or in the contribution to the public good. Prices of both goods are normalized to 1 as is common in environmental offsetting models (Kotchen, 2009; Lange and Ziegler, 2017).

Substituting (1), (2), (4), into (3), the optimization problem to be solved can be written as:

$$\max_{y} \quad U(y) = u_1(w - y) + u_2(\overline{G} + y(1+\delta) - \delta w) + \lambda u_3(y(1+\delta) - \delta w) \tag{5}$$

From this, the optimal level of contribution to the public good y^* is given by the first order condition:

$$\begin{aligned} U'(y) = 0 \Longleftrightarrow & - u_1'(w - y) \\ & + (1+\delta) u_2'(\overline{G} + y(1+\delta) - \delta w) \\ & + (1+\delta)\lambda u_3'(y(1+\delta) - \delta w) = 0 \end{aligned} \tag{6}$$

3.2. Economic compensation

In our model, an energy efficiency improvement is translated by a decrease in the parameter δ, i.e., the negative externality generated by private consumption x. To study how this improvement impacts the optimal consumption level (x^*, y^*) and generates a rebound effect, we derive the equation (6) with respect to δ. This gives:

$$\frac{dU'(y^*(\delta), \delta)}{d\delta} = 0 \Leftrightarrow \frac{dy^*}{d\delta} = \frac{\frac{-\partial U'(y^*(\delta),\delta)}{\partial \delta}}{\frac{\partial U'(y^*(\delta),\delta)}{\partial y^*}} \tag{7}$$

where:

$$\frac{\partial U'(y^*(\delta),\delta)}{\partial \delta} = \underbrace{[u_2'(.) + \lambda u_3'(.)]}_{>0} + \underbrace{[u_2''(.) + \lambda u_3''(.)][(y-w)(1+\delta)]}_{>0} > 0 \tag{8}$$

and:

$$\frac{\partial U'(y^*(\delta),\delta)}{\partial y^*} = \underbrace{u_1''(.)}_{<0} + \underbrace{(1+\delta)^2[u_2''(.) + \lambda u_3''(.)]}_{<0} < 0 \tag{9}$$

From this, we can easily show[3] that $\frac{dy^*}{d\delta} > 0$. This means that the lower the externality generated by private consumption, the less the individual voluntarily contributes to the public good. In other words, an energy efficiency improvement ($\delta \searrow$) decreases the voluntary contribution to the public good ($y* \searrow$) and thus increases the private consumption ($x* \nearrow$), which reflects economic compensation. This result allows us to formalize the following hypothesis:

H1. Economic compensation: An exogenous decrease in the marginal damage of the private good generates a decrease in the voluntary contribution to the public good.

3.3. Moral compensation

In line with moral compensation principles, the adoption of a more energy efficient technology may influence an individual's perception of their environmental responsibilities and may indirectly affect how they evaluate the environmental impact of their private decisions. We choose to represent the effect of moral compensation in accordance with the theory of moral credential[4]. This theory explains the

[3]The proof of the hypothesis can be found in Appendix A.

[4]Another theory to explain moral compensation is the moral credits theory (Effron and Monin, 2010; Miller and Effron, 2010), which assumes that individuals have a moral bank account that can be credited with positive behavior and debited with negative behavior. The main difference between these two theories is that the moral credits theory assumes that negative behavior is always (unconsciously) perceived as such, but that it is legitimized by initial positive behavior, whereas, the moral credentials theory assumes that the initial positive behavior has mitigated the moral value of the negative behavior.

psychological mechanisms underlying moral compensation effects through a change in the moral value of one act caused by a previous act (Monin and Miller, 2001). In our model, the parameter λ represents the perceived value of the individual's net impact on the public good. We assume that this perceived value depends on the nature of an environmental deed, which takes place before the consumption phase. If an individual performs a virtuous act (e.g., reduces his carbon footprint or buys a more ecological car), we assume that the value of λ decreases (with a restriction of non-negativity of λ). Conversely, we assume that the value of λ increases when the individual performs a less virtuous act (e.g., increases his carbon footprint).

Previously set to 1, we now show how a variation of λ can influence the level of optimal consumption (x^*, y^*). To do so, we derive the equation (6), with respect to λ:

$$\frac{dU'(y^*(\lambda),\lambda)}{d\lambda} = 0 \Leftrightarrow \frac{dy^*}{d\lambda} = \frac{\frac{-\partial U'(y^*(\lambda),\lambda)}{\partial\lambda}}{\frac{\partial U'(y^*(\lambda),\lambda)}{\partial y^*}} \tag{10}$$

With :

$$\frac{\partial U'(y^*(\lambda),\lambda)}{\partial\lambda} = \underbrace{(1+\delta)u_3'(.)}_{>0} > 0 \tag{11}$$

$$\frac{\partial U'(y^*(\lambda),\lambda)}{\partial y^*} = \underbrace{u_1''(.)}_{<0} + \underbrace{(1+\delta)^2[u_2''(.)+u_3''(.)]}_{<0} < 0 \tag{12}$$

We can show that $\frac{dy^*}{d\lambda} > 0$[5]. This means that the more the individual values his individual net impact on the public good, the more he voluntarily contributes to that good. In other words, when the perceived value of the individual's net impact

[5]The proof of the hypothesis can be found in Appendix B.

on the public good decreases (respectively increases), the voluntary contribution to the public good also decreases (increases) and the consumption of the private good increases (decreases), which reflects a moral licensing effect (moral cleansing effect). This result allows us to formulate the following two hypotheses:

H2a. Moral licensing effect: A decrease in the perception of environmental responsibility caused by a previous virtuous act reduces voluntary contribution to the public good.

H2a. Moral cleansing effect: An increase in the perception of environmental responsibility caused by a previous less virtuous act increases voluntary contributions to the public good.

4. Experimental design

4.1. Experimental framework

The experiment based on the theoretical model is designed as follows: each participant must allocate his endowment (w) between private consumption (x) and the public good (y), given that the consumption of a unit of private good causes damage to the public good (δ). Our experiment is similar to a charity game in which a subject receives an endowment that he must allocate between himself and an Environmental Non-Gouvernmental Organization (ENGO) (Eckel and Grossman, 1996; Clot et al., 2016). In our experiment, each subject's endowment is 10 tokens ($w = 10$) and the ENGO is a carbon offset organization called South Pole[6] (SP). The particularity of the experimental set-up, which differs from a charity game, is that when a participant keeps a token for himself, he generates a negative externality on SP by decreasing the amount of donation by one token ($\delta = 1$). This particularity

[6]South Pole proposes to financially supports worldwide CO_2 reduction projects to offset its own emissions. For this experiment, we have chosen the Siam Cement Group Biomass to Energy, Thailand project: https://market.southpole.com/home/offset-emissions/project-details/45). To limit perception biases, the name of this project is not provided to participants.

represents the use of a technology that provides private benefits, while generating collective damage, which is true of every good that consumes energy to provide a service to its user (e.g., car, heating, computer, etc.). Each token kept for oneself is equal to 1€, and each token allocated to SP is also converted into 1€. Table 1 details the impact of the 11 possible choices on all the parameters of our experiment.

Table 1: The detailed impact of the 11 possible choices for $\delta = 1$

Tokens kept by the subject	**Damages to SP by tokens kept**	**Tokens directly donated to SP**	**Global impact on donation to SP**
x	$-\delta x$	y	$g = y - \delta x$
0	0	10	+10
1	-1	9	+8
2	-2	8	+6
3	-3	7	+4
4	-4	6	+2
5	-5	5	0
6	-6	4	-2
7	-7	3	-4
8	-8	2	-6
9	-9	1	-8
10	-10	0	-10

In the experiment, the impact of the subject's choice on the donation to SP can be positive or negative (as in a giving/taking game (Bardsley, 2008)). In order to ensure a positive level of donations to SP, the subject is informed that a donation is made by the experimenter. The initial amount of this donation is not disclosed to the subject[7]. The subject only knows that his decision directly impacts donations to SP. To reinforce the impact of this choice, the subject is informed that reducing donation by 1€ corresponds to an increase of 98.04 kg of CO_2 emissions into the

[7]We chose not to communicate this element to the subject so as not to diminish the perception of his impact on the donation to SP.

atmosphere, which is equivalent to a 462.4 km trip in a diesel car[8].

Only the first and the last columns of Table 1 are presented to subjects in order to avoid mental overload[9] (see Appendix E for the experimental instructions). Subjects are asked to pick one line, and thus a pair: private gain and impact on SP (to simplify, each amount is directly converted into euros). We believe that presenting the game in this way simplifies the subjects' choices, particularly in an online experiment. Therefore, we reveal only the most important elements, i.e., how much subjects can earn and what impact this choice has on the donation to SP.

4.2. Treatments

Our experiment is a 2 × 3 between-subject design[10]. Each subject is randomly assigned to one of the six treatments at the start of the experiment. The treatments are shown in Table 2. The differences between treatments relate to two elements: the impact of private consumption on the donation (i.e., value of parameter δ) and hypothetical previous efforts towards the environment (i.e., text reading in a previous stage). The first element refers to columns *High impact* and *Low impact* and the second element refers to lines *Control*, *Positive text* and *Negative text*. We detail these two elements in the following sections.

4.2.1. High vs Low impact

The difference between the *High impact* treatments (T_{High}) and the *Low impact* treatments (T_{Low}) comes from a change in δ, i.e., the damage caused by keeping one euro for oneself. In T_{High} keeping one euro has the negative impact of decreasing the

[8]These figures are calculated with the figures given by SP on the impact of the Siam Cement Group project (https://market.southpole.com/home/offset-emissions/project-details/45) and with the figures from the ADEME carbon base (https://bilans-ges.ademe.fr/fr/basecarbone/donnees-consulter/liste-element/categorie/151).

[9]Studies have shown that too much information can affect the behavior of individuals (Deck and Jahedi, 2015; Allred et al., 2016).

[10]We did not choose a within-subject design, even though it would have been more realistic regarding the rebound effect since the subject would have gone from a high-impact technology (T_{High}) to a low-impact technology (T_{Low}). The reason for this is that with within-subject, we cannot control that the first choice in T_{High} does not generate a moral compensation effect on the second choice in T_{Low}. So we would not have been able to distinguish the two compensations.

Table 2: Experimental design

	High impact (T_{High})	Low impact (T_{Low})
Control (T_C)	T_{CH}	T_{CL}
Positive text (T_{Pos})	T_{PH}	T_{PL}
Negative text (T_{Neg})	T_{NH}	T_{NL}

donation to SP by one euro ($\delta = 1$) and in T_{Low} the decrease is 0.5 euro ($\delta = 0.5$). In other words, each euro kept for oneself generates half as much damage to the SP donation in T_{Low} as it does in T_{High}. The rationale of our experimental set-up is to transcribe a switch towards a more energy-efficient technology, one that offers the same level of energy service but with less environmental impact, for example, when an individual switches from a "conventional vehicle" to an electric vehicle. According to hypothesis H1, it is expected that this efficiency improvement has the perverse effect of reducing the subject's pro-environmental efforts. In concrete terms this would mean that subjects in T_{Low} give fewer euros to SP than do those in T_{High} (i.e., $y_{T_{Low}} < y_{T_{High}}$).

4.2.2. Positive vs Negative texts

To analyze the impact of moral compensation on pro-environmental behaviors, we implement two types of treatments. Before the donation decision, the subject is asked to read a short text. The texts of each treatment are different (complete texts are in Appendix E). In the *Positive text* treatments (T_{Pos}), the subject is asked to imagine[11] that he has made a pro-environmental effort which has reduced his carbon footprint. We expect this positive text to decrease his moral perception

[11]The majority of studies in psychology that investigate moral compensation also use hypothetical behavior. The meta-analysis of Blanken et al. (2015) reveals that the moral licensing effect is not greater in the case where the behavior is actual and not hypothetical.

parameter λ. Inversely, in the *Negative text* treatments (T_{Neg}), the subject is asked to imagine that he has not made enough pro-environmental efforts and that his carbon footprint has continued to increase. We expect this negative text to increase his moral perception parameter λ. The objective of these two texts is to modify the emotional state of the subject, and more precisely to modify his (unobserved) moral perception parameter in order to test whether this affects his behavior in the experiment in accordance with our hypotheses of moral compensation. We assume that the positive text should induce a feeling of pride and thus generate a moral licensing effect (H2a). In contrast, the negative text should induce guilt in the subject and generate a moral cleansing effect (H2b). After reading the text (positive or negative), the subject answers two comprehension questions that reinforce the feeling of having made a positive or negative impact on the environment. Finally, we control for the emotional state of subjects after the text reading using a valence scale[12] (Betella and Verschure, 2016). With this manipulation check, it is expected that, on average, subjects in T_{Pos} (respectively T_{Neg}) will report feeling better (resp. worse) than subjects in the control group, who have read a neutral text.

4.2.3. Control treatments

To compare *Positive text* and *Negative text* treatments, we initially implement two control treatments. A first control treatment without any text reading, and a second control treatment where subjects read a neutral text, explaining the meaning of the carbon footprint. The difference between these two control group types is that the subjects in the second control group have to read a neutral text related to the environment (i.e., the definition of the carbon footprint) before the game, whereas the subjects in the first control group have only played the game and have not read a text. We chose to have two different types of control groups to analyze whether moral compensation effects are observable in comparison with a filler task

[12] The scale goes from 0 to 100, but is hidden from the subject; he can only see a sad and happy emoticon at opposite ends of the scale.

(i.e., reading a neutral text) or without one.

The meta-analysis by Blanken et al. (2015) looks at whether the moral licensing effect is higher if the control condition is neutral or negative[13], but does not distinguish in the neutral condition between experiments that use a neutral task and experiments that have no prior task. In our experiment, we observe no significant difference between the two control group types, either for *High impact* treatments (two-tailed Mann-Whitney U test, $p = 0.762$) or for *Low impact* treatments (two-tailed Mann-Whitney U test, $p = 0.355$). We conclude that reading an environmentally-neutral text does not significantly influence a subject's donation behavior. Consequently, we chose to merge the two types of control treatments together for the analysis of the results. This allows us to have a relatively similar number of subjects in all of the treatments in the study (see Table C.9).

4.3. Experimental protocol

The experiment was conducted online between April and May 2022. Participants were recruited by a private company (*Foule Factory*) in France. We target 1,600 participants (200 participants per treatment), which ensures a sufficient statistical power to detect a significant moral licensing effect or not (Blanken et al., 2015). The experiment is presented to the participants with the neutral title of "Panel" to avoid a potential self-selection bias. Subjects only know that the experiment lasts on average 5 minutes and that the payment for participation is 1€.

At the start of the experiment and after reading the instructions, each subject is randomly assigned to one of the eight experimental treatments. Subjects assigned to treatments T_C[14], T_{Pos} and T_{Neg} are asked to read a short text, answer two comprehension questions and indicate how they feel on a valence scale. Then all subjects play the game i.e. takes his decision that determines his private payoff and his impact on the donation. Subjects are informed that only one out of ten subjects

[13] On this point, they find no significant difference between the two, which is surprising because the negative text should induce a moral cleansing effect.

[14] Only the second control treatments.

will be drawn at the end of the experiment and their decision taken into account for payments. Finally, the subject completes a sociodemographic questionnaire and the Environmental Attitude Inventory (EAI) scale (Milfont and Duckitt, 2010). The version of EAI scale we use is validated in French by Moussaoui et al. (2016). This version uses a 12 item Likert scale with scores for each item ranging from 1 to 7. The sum of these scores indicates the environmental attitudes of individuals. The higher the score, the more importance the individual attaches to the environment. In the result section, we use the median score[15] of this scale to distinguish between individuals with weak environmental attitudes (Low EAI) and individuals with strong environmental attitudes (High EAI). All experimental instructions can be found in Appendix E.

The experimental design has been validated by an ethics committee. The hypotheses and experimental design were preregistered on Open Science Framework.

5. Results

In Section 5.1, we present the summary statistics of the sample. The preregistered hypotheses based on the theoretical model are tested in Section 5.2. In Section 5.3, we perform some econometric analyses on the impact of the two types of compensation on the subjects' behavior. Finally, in Section 5.4, we analyze the role of pro-environmental preferences on the moral compensation.

5.1. Data sample

We collect 1,622 observations. Table 3 presents the sociodemographic characteristics of our sample. We have slightly more women (56.6%) than men (43.4%). The majority of our sample participants are between 25 and 49 years old (66.59%), have an education level higher than a high school diploma (57.9%) and declare

[15]The median score is 4.92 and subjects who have an EAI score lower or equal to the median are considered to have low environmental attitudes.

themselves tight or very tight financially (68.81%). Our sample is relatively well-balanced across all groups with respect to the main socio-demographic variables (see Table C.9 in the Appendix C for a description of the sample by treatment).

5.2. Hypothesis testing

The main objective of our experiment is to analyze whether an energy efficiency improvement leads to a rebound effect, i.e. to less pro-environmental effort. More precisely, we test the existence and magnitude of a probable economic compensation effect (Hypothesis 1) and a probable moral compensation effect (Hypotheses 2). To do so, we compare the mean of individual donations between our six treatments and run a one-tailed Mann-Whitney U test to determine if the difference is significant and consistent with our hypotheses.

Fig. 1 shows the average donation between the different treatments. We observe an economic compensation effect, i.e. donations are higher in the *High impact* treatments than in the *Low impact* ones. To test whether Hypothesis 1 is statistically confirmed, we first run a one-tailed Mann-Whitney U test and compare the average donation between T_{High} and T_{Low}. The first line of Table 4 shows that this difference is highly significant ($p < 0.001$). Next, we check whether this difference is also significant when we compare the different treatments separately. Table 4 shows that economic compensation also occurs for *Control* ($p = 0.008$), *Positive* ($p = 0.014$) and *Negative* treatments ($p < 0.001$). Thus, our results confirm hypothesis H1: the reduction of the marginal damage of a polluting private good leads to a decrease in the pro-environmental effort of individuals and generates a positive rebound effect.

Secondly, for the hypotheses of moral compensation, we expect moral licensing and moral cleansing effects to have opposite impacts on pro-environmental efforts. In other words, compared to T_{Cont}, we hypothesize average donations to be lower in T_{Pos} (H2a) and higher in T_{Neg} (H2b).

For the moral licensing effect, we do not find statistical differences when we compare overall control (T_{Cont}) and positive (T_{Pos}) treatments ($p = 0.936$). No

Table 3: Socio-demographic characteristics of all the sample

Statistic	Number of subjects	Percentage
Gender		
Female	918	56.6
Male	704	43.4
Age		
From 18 - 24 years	191	11.78
From 25 - 34 years	476	29.35
From 35 - 49 years	604	37.24
From 50 - 64 years	296	18.25
Above 65 years	55	3.39
Highest level of education		
No diploma	30	1.85
Junior High school certificate	116	7.15
High school diploma	537	33.11
Bachelor's degree	537	33.11
Master's degree	320	19.73
More than master's degree	82	5.06
Perceived financial situation		
Very tight	320	19.73
Tight	796	49.08
Secure	473	29.16
Very secure	33	2.03
EAI		
Low EAI	853	52.6
High EAI	769	47.4
Total	1622	100

Figure 1: Mean on donations to SP ($\overline{y}$), by treatments

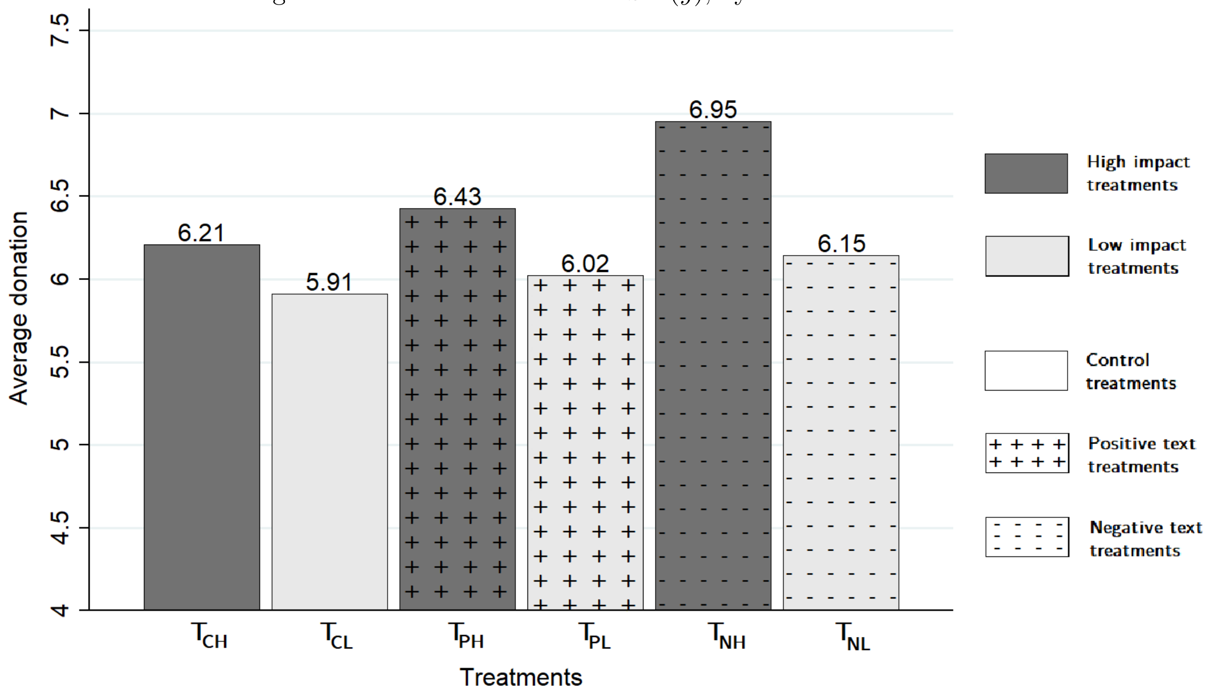


Table 4: Test of the economic compensation hypothesis with the Mann-Whitney U test

	High impact		Low impact		$T_{High} > T_{Low}$
	N	Mean y (SD)	N	Mean y (SD)	p-value
Global	823	6.535 (2.991)	799	6.025 (2.880)	0.000***
Control	273	6.209 (2.904)	286	5.913 (2.777)	0.008***
Positive	269	6.428 (2.957)	246	6.024 (2.987)	0.014**
Negative	281	6.954 (3.069)	267	6.146 (2.892)	0.000***

Significant levels *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

significant effect occurs either when specifically analyzing *High impact* treatments T_{High} ($p = 0.853$) and *Low impact* treatments T_{Low} ($p = 0.837$). We therefore reject hypothesis H2a. Indeed, we do not find evidence of moral licensing, despite the fact that we have induced the desired emotions (see Table C.10 for the result of the manipulation check). This result is similar to other studies that fail to find a moral licensing effect (Blanken et al., 2014; Urban et al., 2019, 2020; Eberling et al., 2019; Rotella and Barclay, 2020). Contrary to our hypothesis, the average donation is higher in the positive treatments than in the control treatments. This suggests that imagining having made a pro-environmental effort induces a consistency effect (i.e., a good deed generates another good deed (Mullen and Monin, 2016)) rather than a moral licensing effect. This consistency effect is significant at the 10% level when we compare overall control and positive treatments (one-tailed Man Whitney U, $p = 0.064$) but this is no longer the case when we separately compare the *High impact* (one-tailed Man Whitney U, $p = 0.147$) and the *Low impact* (one-tailed Man Whitney U, $p = 0.163$) treatments. This result exhibits the same trend as the online experiment of Rotella and Barclay (2020), which finds a consistency effect rather than a moral licensing effect.

For the cleansing effect, subjects in the *Negative text* treatments (T_{Neg}) give on average 0.5 more tokens than subjects in the *Control* treatments T_{Cont}. This difference is highly significant ($p = 0.0003$). For the *High impact* treatments and the *Low impact* treatments, the moral cleansing effect is significant at the 1% ($p = 0.000$) and 10% levels ($p = 0.082$), respectively. These results confirm hypothesis H2b: an increase in the perception of environmental responsibility caused by a previous negative behavior reduces the voluntary contribution to the public good.

5.3. Individual donation behaviors

In the previous section we have shown the existence of a significant economic compensation effect, as well as a moral cleansing one on average. To more precisely analyze the mechanism behind these effects on pro-environmental behavior, we use a

Table 5: Test of the moral compensation hypothesis with the Mann-Whitney U test

	$\mathbf{T_{Cont}}$		$\mathbf{T_{Pos}}$		Licensing	Consistency	$\mathbf{T_{Neg}}$		Cleansing
	N	Mean y (SD)	N	Mean y (SD)	$T_{Cont} > T_{Pos}$	$T_{Cont} < T_{Pos}$	N	Mean y (SD)	$T_{Cont} < T_{Neg}$
Global	559	6.057 (2.840)	515	6.235 (2.975)	0.936	0.064*	548	6.560 (3.009)	0.000***
$\mathbf{T_{High}}$	273	6.209 (2.904)	269	6.428 (2.957)	0.853	0.147	281	6.954 (3.069)	0.000***
$\mathbf{T_{Low}}$	286	5.913 (2.776)	246	6.024 (2.987)	0.837	0.163	267	6.146 (2.892)	0.082*

Significant levels *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Cragg-Hurdle model (Cragg, 1971) that details individual donation behaviors. This model is particularly used in dictator game experiments when the data contains a lot of bounded values (Engel, 2011). In our experiment, 10% of the subjects chose to give nothing to SP and 30% of the subjects chose to give all their endowment to SP. The Cragg-Hurdle model allows us to jointly analyze three types of behaviors: notdonating (*Probability of donation*, Probit model), donating the entire endowment (*Probability of donating the maximum*, Probit model) and donating a part of the endowment (*Donation amount*, truncated regression). More precisely, we want to know to what extent economic and moral compensation impact these three types of behaviors. In Table 6 we consider the control treatment with high impact (T_{CH}) as the reference treatment and we include three treatment variables in each model. Variable Low impact isolates the impact of a decrease of delta (economic compensation). Variable Positive text measures the licensing effect and variable Negative text the cleansing effect (moral compensation).

Results show that both a decrease of δ (Low impact) and a negative text reading (Negative text) have a significant impact on the amount donated and on the probability of donating it all (compared to the control group with high impact). As expected, these two effects act in opposite directions. The decrease of δ decreases the donation amount and the probability of donating it all. On the contrary, the negative text reading increases the donation amount and the probability of donating it all. Interesting, none of our treatment variables affects the probability of donating. Free-riders (10% in our sample) seem to be insensitive to the economic and moral compensation effects. Overall marginal effects are transcribed in the last column of Table 6 and indicate the actual monetary impact on the average donation. We can see, with this experimental setup, that the negative effect of economic compensation is almost entirely offset by the moral cleansing effect. We obtain a similar result when we quantify in terms of the rebound effect the magnitude of the economic compensation and the moral cleansing effect (see Appendix D). Table 7 shows the result of the same regression with the addition of control variables. We find similar results for the treatment variables. With the addition of the control variables, we can see that the decision to donate is driven highly by intrinsic individual characteristics such as gender and environmental attitudes. Both variables (Female and High EAI) also have a positive impact on the amount of the donation, which is a common result in the literature (Torgler et al., 2008; Vicente-Molina et al., 2018; Ibanez and Roussel, 2021). Finally, an interesting point to note is that the positive text reading appears significant at the 10% level on the probability of donating it all. Knowing that the coefficient is positive, this means that reading a positive text reinforces motivations to donate all its endowment to SP. This confirms the result obtained in the hypothesis testing: the positive text has generated a consistency effect rather than a moral licensing effect.

Table 6: Cragg Hurdle regression

VARIABLES	(1) Donation amount	(2) Probability of donating	(3) Probability of donating it all	(4) Average marginal effects
Low impact	-0.6169***	0.0696	-0.1741**	-0.4979***
	(0.1114)	(0.0854)	(0.0721)	(0.1450)
Positive text	0.1096	-0.0769	0.1664*	0.1592
	(0.1339)	(0.1051)	(0.0910)	(0.1787)
Negative text	0.3170**	-0.0557	0.3396***	0.4928***
	(0.1348)	(0.1041)	(0.0876)	(0.1758)
Constant	6.4019***	1.2996***	9.0439***	
	(0.1092)	(0.0849)	(0.0739)	
Observations	1147	1622	1622	1622

Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7: Cragg Hurdle regression with control variable

VARIABLES	(1) Donation amount	(2) Probability of donating	(3) Probability of donating it all	(4) Average marginal effects
Low impact	-0.6075***	0.0796	-0.1669**	-0.4698***
	(0.1090)	(0.0874)	(0.0735)	(0.1399)
Positive text	0.1013	-0.0831	0.1767*	0.1525
	(0.1316)	(0.1080)	(0.0931)	(0.1731)
Negative text	0.3038**	-0.0823	0.3500***	0.4513***
	(0.1325)	(0.1077)	(0.0896)	(0.1704)
Female	0.4999***	0.3868***	0.1162	0.8247***
	(0.1125)	(0.0898)	(0.0764)	(0.1436)
Young (under 35 y/o)	-0.0350	0.0816	0.0191	0.0789
	(0.1110)	(0.0885)	(0.0748)	(0.1427)
High educated (above *High School Diploma*)	0.0074	-0.0021	0.1201	0.1195
	(0.1124)	(0.0907)	(0.0765)	(0.1455)
Financial security (above secure financially)	0.0835	0.1602	0.1897**	0.4004**
	(0.1223)	(0.0991)	(0.0803)	(0.1569)
High EAI	0.4673***	0.3527***	0.5162***	1.1585***
	(0.1102)	(0.0907)	(0.0744)	(0.1397)
Constant	5.8956***	0.8733***	8.5475***	
	(0.1638)	(0.1273)	(0.1179)	
Observations	1147	1622	1622	1622

Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5.4. Environmental attitudes and moral compensation

The purpose of this additional analysis is to determine whether individuals' environmental attitudes has an impact on moral compensation[16]. As stated in the literature review, the few studies that have addressed this issue find opposite results. The particularity of these studies is that they use the NEP Scale[17] (Dunlap et al., 2000) as a measure of the environmental attitudes of subjects. Although this scale is one of the most widely used to measure these preferences, its poor correspondence with environmental behaviors can be questioned (Smith et al., 1994; Moussaoui et al., 2016). Faced with this criticism, the EAI scale is supposed to have a better correspondence with environmental behavior (Milfont and Duckitt, 2010).

To do so, we perform the same test as for the H2 hypotheses by separating subjects with weak environmental attitudes (Low EAI) and subjects with strong environmental attitudes (High EAI). Table 8 shows the results of the one-tailed Mann-Whitney U test separating the Low and the High EAI participants. The moral licensing effect always appears not significant for both the Low EAI and High EAI groups. Interestingly, the consistency effect is always significant for each of the three tests for the High EAI groups and never significant for the Low EAI groups. This means that reading a positive text reinforces pro-environmental behaviors for those who are more environmentally oriented. We find similar results for the moral cleansing effect, which is also significant, mainly in the High EAI groups. The findings show that those with the strongest environmental attitude drive the moral cleansing and consistency effects, while there is no notable moral compensation for individuals with the weakest environmental attitude. A possible explanation for this difference is that the texts read upstream did not induce the same emotions in subjects with weak environmental attitude as in subjects with strong environmental

[16] We have done the same analysis for the economic compensation and we found no significant difference between the Low EAI and the High EAI in the way they react to a decrease of δ (see Table C.11 in Appendix C).

[17] This is the abbreviation of the New Ecological Paradigm Scale.

attitude. One element that supports this hypothesis is that there is a significant difference in the valence scale between these two EAI groups for both the positive (Mann-Whitney U test, p = 0.0201) and negative texts (Mann-Whitney U test, p = 0.0000)[18].

Table 8: Pro-environmental attitude and moral compensation

	$\mathbf{T_{Cont}}$		$\mathbf{T_{Pos}}$		Licensing	Consistency	$\mathbf{T_{Neg}}$		Cleansing
	N	Mean y (SD)	N	Mean y (SD)	$T_{Cont} > T_{Pos}$	$T_{Cont} < T_{Pos}$	N	Mean y (SD)	$T_{Cont} < T_{Neg}$
Global									
Low EAI	284	5.599 (2.883)	283	5.590 (3.055)	0.611	0.389	286	5 843 (2.966)	0.107
High EAI	275	6.531 (2.721)	232	7.022 (2.678)	0.99	0.010**	262	7.344 (2.860)	0.000***
$\mathbf{T_{High}}$									
Low EAI	145	5.683 (3.095)	137	5.693 (3.138)	0.475	0.526	148	6.250 (3.117)	0.053*
High EAI	128	6.805 (2.554)	132	7.189 (2.554)	0.937	0.064*	133	7.737 (2.825)	0.000***
$\mathbf{T_{Low}}$									
Low EAI	139	5.511 (2.652)	146	5.493 (2.983)	0.718	0.283	138	5.406 (2.741)	0.453
High EAI	147	6.293 (2.846)	100	6.800 (2.832)	0.933	0.067*	129	6.938 (2.850)	0.016**

Significant levels *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

[18]There is no significant difference for the neutral text, which confirms that this text has had the desired effect (Mann-Whitney U test, p = 0.5494).

6. Conclusion

In this paper, we aim to propose a method which allows us to distinguish economic and moral compensation in the rebound effect. We designed an experiment based on the theoretical framework which allowed to highlight the following interesting results. According to our first hypothesis, our experiment shows that an energy efficiency improvement generates a rebound effect through economic compensation. This means that part of the benefits of using technology that is less harmful to the environment are offset by the fact that an individual will use this technology more and will reduce his pro-environmental efforts.

Contrary to our second hypothesis, imagining having made a prior pro-environmental effort does not lead to a moral licensing effect, even though this text induced the desired emotion in the subjects. This positive text seems to generate more of a consistency effect than a moral licensing effect, especially in individuals with strong environmental attitudes. Our result is similar to that of Rotella and Barclay (2020) who find a consistency effect instead of a moral licensing effect in an online experiment. Similarly, in online experiment, Eberling et al. (2019) failed to find a significant moral licensing effect, despite a successful manipulation check. The moral licensing effect was mostly observed in a field or lab experiment and the few studies that tried to induce it in an online experiment were not successful. A possible explanation for this is that online experiments offer subjects a much less formal and rigorous environment than a lab or field experiments does. In this context, perhaps the classical method of inducing a feeling of having done a good deed by performing a hypothetical act is no longer an effective method for generating a large enough moral boost to observe a moral licensing effect[19]. The moral boost generated would then be large enough to "pass" the manipulation check since there would be a difference in emotion between the different conditions, but not enough

[19] However, it can be noted that the same method works for the cleansing effect. This could be explained by the fact that the emotion that must be induced to observe a moral licensing effect (i.e. pride) is more complicated to induce than that of the moral cleaning effect (i.e. guilt).

to induce a moral licensing effect. This methodological question seems to us to be particularly important for future research on moral licensing effect insofar as online experiments have become widely democratized (Peyton et al., 2021). Moreover, the need to have a large number of subjects per treatment in order to be able to detect a significant moral licensing effect makes an online experiment highly preferable for financial reasons.

According to our third hypothesis, imagining a lack of pro-environmental behaviors lead to a moral cleansing effect by increasing pro-environmental efforts of subjects. We show, however, that this effect is obtained only on individuals with the strongest environmental attitudes. Another interesting point to note is that the cleansing effect impacts the same behaviors (i.e., the intensity of pro-environmental effort and the probability of accomplishing the maximal effort) as economic compensation but in the opposite direction. This result leads us to conclude that the moral cleansing effect could be a policy instrument used to mitigate the rebound effect. Thus we plead for the moral cleaning effect to be more integrated into the literature on the rebound effect. We share the point of view of Santarius and Soland (2016) that all behavioral mechanisms of an energy efficiency improvement should be considered whether these increase or decrease the energy-consumption behaviors.

Finally, this article is part of a recent research trend that considers how behavioral mechanisms can also generate a rebound effect. If the integration of psychological mechanisms through moral compensation appears to be the first step, other mechanisms will have to be taken into account in the future. These may be either other psychological mechanisms (see Santarius and Soland (2018) for a presentation of these other effects) or mechanisms of a different nature[20]. In this paper, we distinguish economic and moral compensation, but the advantage of our experimental design is that it can be reused to identify and distinguish these other mechanisms.

[20]For example, Sorrell et al. (2020) also consider in the rebound effect, time savings that can be reallocated to energy consuming activities. This type of rebound is called 'time use rebounds' in the literature.

Our experimental design could also be used to test different policy instruments to reduce the rebound effect, with the advantage of directly targeting the mechanisms that cause it. In the context of the fight against climate change, the effectiveness of energy policies depends on our understanding of the rebound effect. This implies having efficient methods to analyze the different mechanisms that lead to a rebound effect, which requires efficient methods to analyze the different mechanisms that cause it.

Appendix A. Proof of hypothesis 1

To know how a variation of δ influences y^*, we derive equation (6) with respect to this parameter. We obtain:

$$\begin{aligned} \frac{dU'(y^*(\delta),\delta)}{d\delta} = 0 \Leftrightarrow \frac{\partial U'(y^*(\delta),\delta)}{\partial y^*} \times \frac{dy^*}{d\delta} + \frac{\partial U'(y^*(\delta),\delta)}{\partial \delta} = 0 \\ \Leftrightarrow \frac{dy^*}{d\delta} = \frac{\frac{-\partial U'(y^*(\delta),\delta)}{\partial \delta}}{\frac{\partial U'(y^*(\delta),\delta)}{\partial y^*}} \end{aligned} \tag{A.1}$$

Thus, the influence of δ on y^* is given by the sign of:

$$\begin{aligned} \frac{\partial U'(y^*(\delta),\delta)}{\partial \delta} &= u_2'(.) + u_2''(.)(y-w)(1+\delta) + \lambda[u_3'(.) + u_3''(.)(y-w)(1+\delta)] \\ &= \underbrace{[u_2'(.) + \lambda u_3'(.)]}_{>0} + \underbrace{[u_2''(.) + \lambda u_3''(.)]}_{<0}[\underbrace{(y-w)}_{<0}\underbrace{(1+\delta)}_{>0}] > 0 \end{aligned} \tag{A.2}$$

and:

$$\begin{aligned} \frac{\partial U'(y^*(\delta),\delta)}{\partial y^*} &= u_1''(.) + (1+\delta)^2 u_2''(.) + \lambda[(1+\delta)^2 u_3''(.)] \\ &= \underbrace{u_1''(.)}_{<0} + \underbrace{(1+\delta)}_{>0}\underbrace{[u_2''(.) + \lambda u_3''(.)]}_{<0} < 0 \end{aligned} \tag{A.3}$$

Knowing that $\frac{-\partial U'(y^*(\delta),\delta)}{\partial \delta} < 0$ and $\frac{\partial U'(y^*(\delta),\delta)}{\partial y^*} < 0$, we obtain well $\frac{dy^*}{d\delta} > 0$

Appendix B. Proof of hypotheses 2

For hypotheses 2, we derive equation (6) with respect to λ and we obtain:

$$\begin{aligned} \frac{dU'(y^*(\lambda),\lambda)}{d\lambda} = 0 \Leftrightarrow \frac{\partial U'(y^*(\lambda),\lambda)}{\partial y^*} \times \frac{dy^*}{d\lambda} + \frac{\partial U'(y^*(\lambda),\lambda)}{\partial \lambda} = 0 \\ \Leftrightarrow \frac{dy^*}{d\lambda} = \frac{\frac{-\partial U'(y^*(\lambda),\lambda)}{\partial \lambda}}{\frac{\partial U'(y^*(\lambda),\lambda)}{\partial y^*}} \end{aligned} \tag{B.1}$$

We look the sign of:

$$\frac{\partial U'(y^*(\lambda), \lambda}{\partial \lambda}) = \underbrace{(1+\delta)}_{>0}\underbrace{u_3'(.)}_{>0} > 0 \tag{B.2}$$

and:

$$\begin{aligned} \frac{\partial U'(y^*(\lambda), \lambda)}{\partial y^*} &= u_1''(.) + (1+\delta)^2 u_2''(.) + \lambda[(1+\delta)^2 u_3''(.)] \\ &= \underbrace{u_1''(.)}_{<0} + \underbrace{(1+\delta)^2}_{>0}\underbrace{[u_2''(.) + u_3''(.)]}_{<0} < 0 \end{aligned} \tag{B.3}$$

Knowing that $\frac{-\partial U'(y^*(\lambda),\lambda)}{\partial \lambda} < 0$ and $\frac{\partial U'(y^*(\lambda),\lambda)}{\partial y^*} < 0$ we obtain well $\frac{dy^*}{d\lambda} > 0$

Appendix C. Supplementary results

Table C.9: Sample characteristics - Kruskal Wallis test for equality between treatments

	Total sample *(N=1622)*	T_{CH} *(N=273)*	T_{CL} *(N=286)*	T_{PH} *(N=269)*	T_{PL} *(N=246)*	T_{NH} *(N=281)*	T_{NL} *(N=267)*	*p-value*
Female (%)	56.6	55.3	49,3	59.9	56.9	58.0	60.7	0.216
Young (% under 35 y/o)	41.1	44.3	38.8	41.2	44.3	37.7	40.8	0.696
Highly educated (% above *High School Diploma*)	57.9	61.5	63.6	56.1	55.7	54.5	55.4	0.305
Financial security (% above secure financially)	31.2	28.2	31.5	34.2	32.5	30.3	30.7	0.890
High EAI (% above median)	47.4	46.9	51.4	49.1	40.7	47.3	48.3	0.410

.

Table C.10: Emotional state comparison of positive (negative) text with neutral text

	N	Average emotional state (SD)	Mann-Whitney U two-sided test p-value
Neutral text	293	58.918 (25.735)	-
Positive text	515	78.975 (19.703)	0.000***
Negative text	548	24.573 (26.416)	0.000***

Significant levels *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Table C.11: Economic compensation and environmental attitudes

	High impact		**Low impact**		Mann-Whitney U test
	N	Mean y (SD)	N	Mean y (SD)	p-value
Global					
Low EAI	430	5.881 (3.120)	423	5.470 (2.793)	0.0000***
High EAI	393	7.249 (2.670)	376	6.649 (2.851)	0.0002***
Control					
Low EAI	145	5.683 (3.095)	139	5.511 (2.652)	0.041**
High EAI	128	6.805 (2.554)	147	6.293 (2.846)	0.039**
Positive					
Low EAI	137	5.693 (3.138)	146	5.493 (2.983)	0.110
High EAI	132	7.189 (2.554)	100	6.800 (2.832)	0.112
Negative					
Low EAI	148	6.250 (3.117)	138	5.406 (2.741)	0.0002***
High EAI	133	7.737 (2.825)	129	6.938 (2.850)	0.0009***

Significant levels *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Appendix D. Quantifying the economic and moral compensations from the experimental results

We compute the rebound effect of an energy efficiency improvement related to the individual's net impact on the public good (g). Table D.12 shows the average g for all of our 6 treatments. As expected we notice that this mean is always higher in the *Low impact* than in the *High impact* treatments, independently the text reading. We can notice that an energy efficiency improvement always generates a rebound effect less than 100% and varies according to text reading.

Table D.12: Individual's net impact on the public good by treatments

	T_{CH}	T_{CL}	T_{PH}	T_{PL}	T_{NH}	T_{NL}
Average individual's net impact ($\overline{g}$)	2.42	3.87	2.86	4.04	3.91	4.22

To quantify the magnitude of the two compensations, we use the definition of the rebound effect (R):

$$R = 1 - \frac{AES}{PES}$$

In our experiment, the actual energy savings (AES) corresponds to the difference between the empirical average of g of the subjects in T_{CL} ($\overline{g}_{TCL}$) and the empirical average of g of the subjects in T_{CH} ($\overline{g}_{TCH}$). This corresponds to the benefits actually obtained from switching from a high impact technology to a low impact technology. The potential energy savings (PES) corresponds to the difference between the theoretical average of g if the subjects in T_{CH} had made the same choice while being in T_{CL} ($\overline{g'}_{TCH}$) and the empirical average of g of the subjects in T_{CH}. This corresponds to the benefits that could be expected from switching from a high impact technology to a low impact technology if subjects' behavior would not be impacted by the change in technology. Thus, the rebound effect related to the economic compensation is equal to:

$$R = 1 - \frac{\overline{g}_{TCL} - \overline{g}_{TCH}}{\overline{g}_{TCH} - \overline{g}'_{TCL}} = 1 - \frac{3.87 - 2.42}{4.31 - 2.42} = 23\%$$

This means that 23% of the potential benefit of going from $\delta = 1$ to $\delta = 0.5$ is lost due to the change in the behavior of individuals resulting from economic compensation.

To quantify the magnitude associated to the moral licensing and moral cleansing effect we use the same method. We kept the same value of PES. For the AES, we replace $\overline{g}_{TCL}$ by $\overline{g}_{TPL}$ for the moral licensing effect or by $\overline{g}_{TNL}$ for the moral cleansing effect. The result we obtain is that the rebound effect linked to economic compensation and the moral licensing effect:

$$R = 1 - \frac{\overline{g}_{TPL} - \overline{g}_{TCH}}{\overline{g}_{TCH} - \overline{g}'_{TCL}} = 1 - \frac{4.04 - 2.42}{4.31 - 2.42} = 14\%$$

And the rebound effect linked to economic compensation and the moral cleansing effect:

$$R = 1 - \frac{\overline{g}_{TNL} - \overline{g}_{TCH}}{\overline{g}_{TCH} - \overline{g}'_{TCL}} = 1 - \frac{4.22 - 2.42}{4.31 - 2.42} = 5\%$$

To obtain only the moral compensation part, we remove the part related to economic compensation (i.e., the 23%). Thus, we have a moral licensing effect or, in our case, a consistency effect equal to -9%[21] and a moral cleansing effect equal to -18%.

[21] A "negative" rebound effect means that the benefits obtained are higher than those expected.

Appendix E. Experimental instructions

The following instructions were originally written in French. This corresponds to the instructions for all treatments. Above each set of instructions, we specify which treatment they are intended for. If nothing is indicated, the instructions are common to all treatments.

Figure E.2: General instructions

Panel

Hello,

This survey is conducted by researchers from the Centre d'Economie de l'Environnement de Montpellier (CEE-M) and financed by the Agence De l'Environnement et de la Maîtrise de l'Energie (ADEME).

It is entirely **anonymous** and has no commercial purpose. The data will ve used for research purposes only.

In this survey, **one out of ten participants** will be drawn to receive **money** in addition to their participation fee.

On the last page of this survey you will find a **code** that will allow you to receive your payment.

Figure E.3: Neutral text (Only for T_{CH} and T_{CL}):

To begin, please read the **following text** carefully.

INSEE defines the carbon footprint as the quantity of greenhouse gases (GHGs) induced by a country's domestic final demand (consumption by households, public administrations and non-profit organizations and investments), whether the goods or services consumed are produced domestically or imported.

The carbon footprint of a country is therefore made up of:

- ***direct GHG emissions from households ;***
- ***GHG emissions from the domestic production of goods and services for domestic demand (i.e. excluding exports);***
- ***GHG emissions associated with imported goods and services, for intermediate consumption by companies or for final use by households.***

The Service des Données et Etudes Statistiques estimates that France's carbon footprint in 2020 was 552 Mt CO2 eq.

*Please indicate on the following scale how you feel:

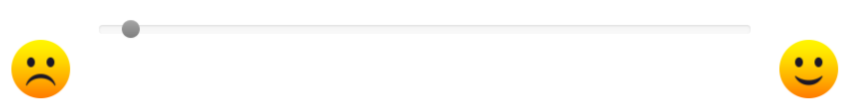
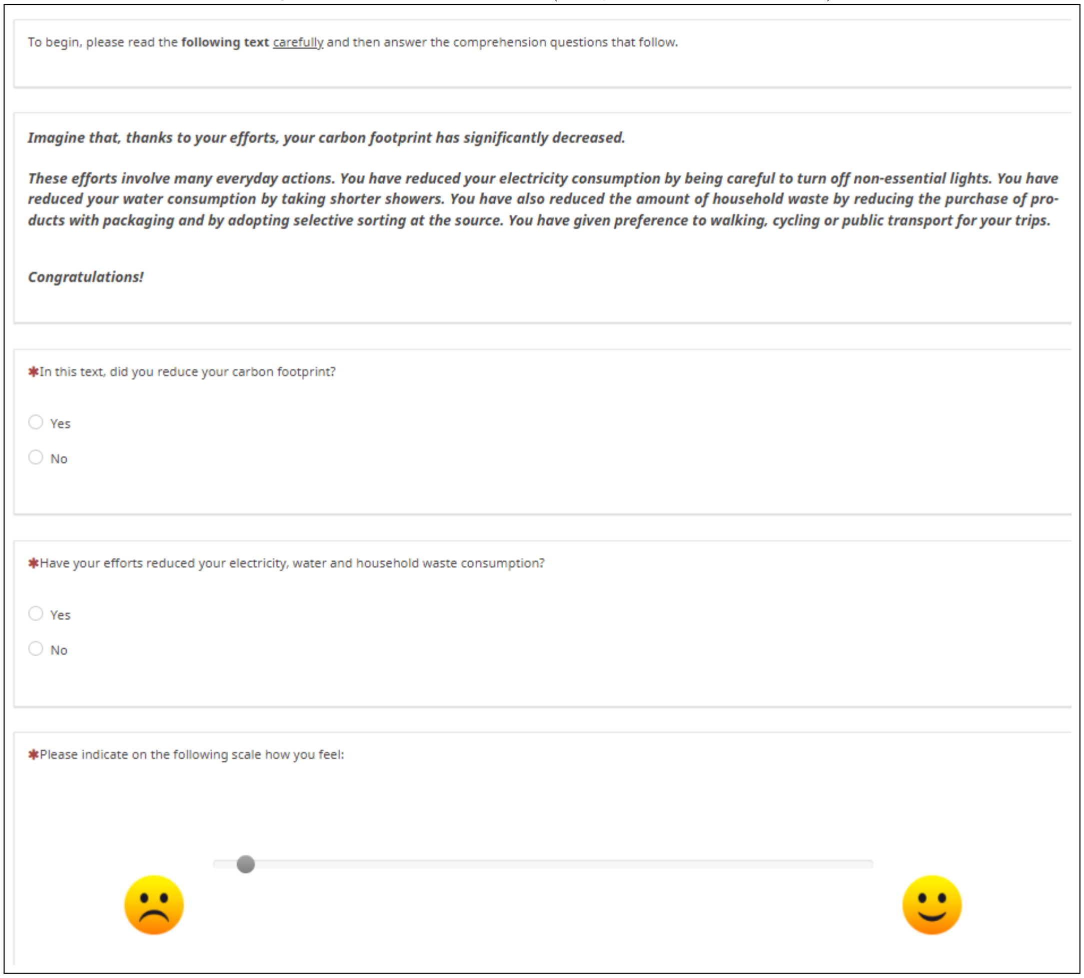


Figure E.4: Positive text (Only for T_{PH} and T_{PL}):



To begin, please read the **following text** carefully and then answer the comprehension questions that follow.

Imagine that, thanks to your efforts, your carbon footprint has significantly decreased.

These efforts involve many everyday actions. You have reduced your electricity consumption by being careful to turn off non-essential lights. You have reduced your water consumption by taking shorter showers. You have also reduced the amount of household waste by reducing the purchase of products with packaging and by adopting selective sorting at the source. You have given preference to walking, cycling or public transport for your trips.

Congratulations!

*In this text, did you reduce your carbon footprint?

- Yes
- No

*Have your efforts reduced your electricity, water and household waste consumption?

- Yes
- No

*Please indicate on the following scale how you feel:

Figure E.5: Negative text (Only for T_{NH} and T_{NL}):

To begin, please read the **following text** carefully and then answer the comprehension questions that follow.

Imagine that in the past year you have not made as much effort to reduce your carbon footprint as you would have liked.

You realize that you've had a big impact on the environment and you realize that your carbon footprint has continued to grow. You have not reduced your electricity consumption as much as you would have liked, nor your water consumption. You have continued to produce a large amount of household waste, without reducing the purchase of products with packaging and without adopting sufficient selective sorting at source. You have not given enough priority to walking, cycling or public transport for your travels.

What a disappointment!

*In this text, did you reduce your carbon footprint?

- Yes
- No

*Have your efforts reduced your electricity, water and household waste consumption?

- Yes
- No

*Please indicate on the following scale how you feel:

Figure E.6: High impact (Only for T_{CH}, T_{PH} and T_{NH}):

To offset the environmental impact of this survey, a donation will be sent to the Souh Pole organization. The goal of this organization is to develop and fund projects around the world that reduce carbon emissions. Thus, every euro donated to South Pole contributes to **reducing CO_2 emissions**.

In the following table you have to choose one of the **11 possibilities.** The column "your earning" indicates the amount you will receive if you are drawn at the end of the survey. The column "your impact on the donation" indicates the impact of your choice on the donation sent to South Pole. For a low earning you have a **positive impact** on the donation (it increases), but for a high earning you have a **negative impact** on the donation to South Pole (it decreases).

*

Rows	Your earning	Your impact on the donation
0	0€	+10€
1	+1€	+8€
2	+2€	+6€
3	+3€	+4€
4	+4€	+2€
5	+5€	0€
6	+6€	-2€
7	+7€	-4€
8	+8€	-6€
9	+9€	-8€
10	+10€	-10€

Order of magnitude

A variation of 1€ for South Pole corresponds to a change of 98.04 kg of CO2 emission in the atmosphere. This is approximately equivalent to a trip of 462.4km with diesel car. That is approximately the distance between Paris and Lyon.

Which row of the table do you choose?

Figure E.7: Low impact (Only for T_{CL}, T_{PL} and T_{NL}):

To offset the environmental impact of this survey, a donation will be sent to the Souh Pole organization. The goal of this organization is to develop and fund projects around the world that reduce carbon emissions. Thus, every euro donated to South Pole contributes to **reducing CO_2 emissions.**

In the following table you have to choose one of the **11 possibilities.** The column "your earning" indicates the amount you will receive if you are drawn at the end of the survey. The column "your impact on the donation" indicates the impact of your choice on the donation sent to South Pole. For a low earning you have a **positive impact** on the donation (it increases), but for a high earning you have a **negative impact** on the donation to South Pole (it decreases).

*

Rows	Your earning	Your impact on the donation
0	0€	+10€
1	+1€	+8,5€
2	+2€	+7€
3	+3€	+5,5€
4	+4€	+4€
5	+5€	+2,5€
6	+6€	+1€
7	+7€	-0,5€
8	+8€	-2€
9	+9€	-3,5€
10	+10€	-5€

Order of magnitude

A variation of 1€ for South Pole corresponds to a change of 98.04 kg of CO2 emission in the atmosphere. This is approximately equivalent to a trip of 462.4km with diesel car. That is approximately the distance between Paris and Lyon.

Which row of the table do you choose?

Figure E.8: Sociodemographic questionnaire

*What is your gender?

- Female
- Male

*In which age group do you fall?

- 18 - 24
- 25 - 34
- 35 - 49
- 50 - 64
- +65

*What is your level of education?

Veuillez choisir ...

*How do you feel financially?

Very just	Just	Secure	Very secure
○	○	○	○

Figure E.9: 12-item Environmental Attitude Inventory

*Finally, please indicate whether you agree with the following statements ?

	1 - Strongly disagree	2	3	4	5	6	7 - Strongly agree
I find it very boring being out in wilderness areas							
I am opposed to governments controlling and regulating the way raw materials are used in order to try and make them last longer							
I would like to join and actively participate in an environmentalist group							
We need to keep rivers and lakes clean in order to protect the environment, and NOT as places for people to enjoy water sports.							
Modern science will NOT be able to solve our environmental problems							
Humans are severely abusing the environment							
I'd prefer a garden that is wild and natural to a well groomed and ordered one							
I am NOT the kind of person who makes efforts to conserve natural resources							
Human beings were created or evolved to dominate the rest of nature							
Protecting the environment is more important than protecting economic growth							
It makes me sad to see forests cleared for agriculture							
A married couple should have as many children as they wish, as long as they can adequately provide for them							

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