Air pollution and hazard mitigation: a framed public good experiment*

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Abstract

We investigate how people engage in prevention activities when the health risk arises from air pollution. In one experiment, we find that health-oriented and pollution-oriented messages impact the distribution of individual between reducing collective risk (by contributing to a public good) or reducing individual risk (by investing in self-protection). Health-oriented messages trigger investments in self-protection, whereas pollution-oriented messages have a greater impact on the total amounts invested, regardless of their purpose. Our results shed light on the importance of the framing of public risk communications to promote prevention behaviors, particularly in the case of noncommunicable disease.

Keywords: Public goods game; Experimental Economics; Air pollution; Health risk; Risk communication.

JEL code: C9, D00, I12, Q53.

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1 Introduction

Pollution has multiple sources, as pesticides/herbicides, endocrine disruptors, heavy metals, persistent organic pollutants and its negative impact on physical and mental health is now well documented (see Fotourehchi (2015)). Moreover, according to the Global Burden of Disease Study (2019), risks issued from pollution present a significant health burden worldwide, causes 9 million deaths. Deaths from modern pollution risk factors have risen by 7% since 2015 and by over 66% since 2000 (Fuller et al. 2022). An European valuation of the health impact of air pollution in twenty-five major European cities shows that life expectancy could increase by up to 22 months for people aged 30 years and over, if the annual average levels of PM2.5 were reduced to the threshold of 10 micrograms per cubic meter, the guide value recommended by the WHO (Pascal et al. 2013). Compliance with this guide value would result in a gain of approximately 31.5 billion euros corresponding to the reduction of health expenses, the cost of absenteeism, and the costs associated with the loss of well-being, quality of life and life expectancy (Chanel et al. 2016).

The regulation of diseases due to a degraded environment requires the prevention of the risks of noncommunicable diseases (NCD) that is a global public health priority (WHO 2013). At an individual level, two types of measures can be adopted: (i) measures protecting individual health from pollution consequences and (ii) measures improving environmental quality by reducing emissions and adopting environmentally friendly behaviors. In addition, risk communication is an essential tool for preventing and controlling diseases as it influences risk perception, increases awareness, and might lead to change in behaviors and/or stimulate risk-reducing behavior (Infanti et al. 2013). Integrating non-communicable diseases into the field of risk communication, currently taken into account by many governments, is one of the priorities in health risk management today (Kostova et al. 2021).

In this paper, we investigate the trade-off between taking prevention actions with respect to personal health risk vs. environmental quality and the impact of risk communication on these individual behaviors, in an experimental setting. First, we experimentally explore a number of predictions that arise from a theoretical model we develop for to consider optimal prevention decisions. We then investigate the effect of alternative framing messages on such decisions. We find that the framing of risk-related messages has an influence on the trade-off between the different prevention actions. A health-oriented message limits the free rider phenomenon in the sense that more individuals choose to invest in collective prevention (benefiting everyone). Whereas a pollution-oriented message encourages more investment in prevention.

This present study contributes to the empirical research of the role of risk communication of noncommunicable diseases in individual decisions. It highlights the importance of the choice of message oriented towards the individual (personal health) or the collective (environmental quality) in triggering the prevention decision.

On the theoretical front, we consider a problem of risk prevention and of contribution to a public good. In decision theory under risk, self-protection consists to reduce the probability of occurrence of an undesirable event. The literature on health risk attitudes has explored self-protection or prevention following the seminal paper of Ehrlich and Becker (1972). Health models in health economics have also used a similar framework (Courbage & Rey (2006), Brianti et al. 2018). On the other hand, as the environmental quality has the characteristics of a public good, individuals are also willing to voluntarily contribute to its improvement (see among others Pearce & Turner (1990) and Kolstad (2000)). In addition, by contributing to environmental quality, individuals collectively reduce the risk of pollution-related illness. Thus, the public good effect is twofold.

In this context, we develop a model in which prevention decisions are multiple: a so-called individual prevention (self-protection) and a so-called collective prevention linked to voluntary contributions to environmental quality. Individual preferences under risk are represented by the

Prospect theory model proposed by Kahneman & Tversky (1979). For the reference point we use the approach proposed by Koszegi & Rabin (2006) where the reference point is determined endogenously by the economic environment. More recently, Guo et al. (2016) and Eeckhoudt et al. (2018) have proposed a reference-dependent utility model to analyze insurance demand in which the utility function depends upon two arguments: the final wealth and the level of losses or gains relative to a reference level. In our set-up, the reference point corresponds to the expected outcome without prevention. We show that individuals are all the more incited to invest in health and environmental prevention as they are sensitive to environmental quality and loss averse.

As the reduction of pollution is done by voluntary contributions to environmental quality considered as a public good, we use an adaption of the Public Goods Game (PGG) in our experiment. PGG is a well-established experimental paradigm, used by experimental economists as a tool to study social dilemmas and cooperation (Kent 2020). There is a vast experimental literature, including evidence that cooperative behavior is enhanced by communication (Chaudhuri 2011). Concerning environmental quality and more particularly climate change, Hasson et al. (2010) propose a modified, one-shot public goods game to study the trade-off between adaptation and mitigation in countries' investments decision. To this basis, we follow Dubois et al. (2015) who introduce environmental context and information provided through illustrations to a stag hunt game in order to analyze its effects on possible pro-environmental behavior. We differ from the literature by proposing, for the first time according to our knowledge, that participants allocate their wealth between three types of investment. In addition to investing in private good (self-protection or individual prevention) and public good (collective prevention), participants can choose to not invest in the first two goods and keep the amount of wealth. Moreover, we introduce risk through a probability of getting sick. As it has been shown in different contexts, risk generally discourages cooperative behavior (Kocher et al. (2011), Harrison et al. (2013), Bergantino et al. (2021)). Hence, the presence of three types of investment allows us to highlight the phenomena of free riding but also the precautionary saving behavior. Moreover, we explore several types of message addressed to the participants: messages oriented towards the impact of air pollution on health, messages oriented towards the impact of air pollution on the environment, and a neutral treatment (no message). Our results show that messages addressed and their type impact contributions of the public good.

The rest of the paper is organized as follows. In Section 2, we develop a theoretical model and we detail our hypotheses and predictions resulting from literature and the model. In section 3, we describe the experimental design of the experiment, which will allow us to test all the hypotheses raised. In Section 4, we describe the data by some descriptive statistics. Section 5 presents the econometric results. Section 6 ends with a discussion and conclusion, leading to some recommendations in terms of public policies.

2 Theoretical model and testable predictions

2.1 The model

We propose a simple, one period model, describing the relation between environmental quality and health and their impact on individual utility. We consider N individuals. Each individual i derives utility from wealth, w_i, environmental quality, E and health status H_i. Health status can take two values. With a probability p_i, the individual is sick and her health status is equal to $H_i = \underline{H}$. With probability $1 - p_i$, her health status is equal to $H_i = \overline{H}$ with $\overline{H} > \underline{H}$. Disease has a financial cost of D.

Health status and environmental quality are not independent: pollution increases disease probability. Individuals can reduce health risk by investing in prevention. We consider two types of prevention instruments : individual prevention measures, that decrease only individual probability of disease; collective prevention measures that improve environmental quality (reducing water consumption, getting out private cars, etc.) and thus decrease disease probability for all individuals. Hence, the environmental quality is equal to an initial level, E_0, plus the sum of the individuals contributions, that are the investment in collective prevention measures, e_i, $E = E_0 + \sum_{j=1}^{N} e_j$. In addition, the individual i probability of disease is a decreasing function of her investment in individual prevention measures, h_i and the level of environmental quality, E, $p(h_i, E) = p_0 - ah_i - bE$ with p_0, the initial probability without any prevention, $a, b > 0$ such that for all possible values of (h, E), $0 \leq p(h, E) \leq 1$.

Individual decisions. Individual preferences under risk are represented by the Prospect Theory model where the reference point corresponds to the expected wealth without prevention and good health status. Indeed, in our case, it is not an average level of health that could be sought but the level of good health (Courbage and Rey, 2006). Individual utility is assumed to take the following form:

$$V(w) = \begin{cases} V^+(w, H, E) & = V(w, H, E) + \eta \left[V(w, H, E) - V(w_i - p_0 D, \overline{H}, E_0) \right] \quad if w \geq w_i - p_0 D \\ V^-(w, H, E) & = V(w, H, E) + \lambda\eta \left[V(w, H, E) - V(w_i - p_0 D, \overline{H}, E_0) \right] \quad else \end{cases} \tag{1}$$

where $\eta > 0$ is the weight given to the reference-dependent component of the overall utility and $\lambda > 1$ is the measure of loss aversion.

Moreover, we suppose that function V_i is additively separable: $V_i(w, H, E) = u_i(w) + H + \beta_i v(E)$, with u_i and v are increasing and concave functions and β_i measures the environmental sensitivity.

Each individual has to allocate her wealth between consumption and prevention (individual and collective). Hence, the individual i's objective is to choose h_i and e_i to maximize

$$U_i(h_i, e_i) = p(h_i, E)(1 + \lambda\eta) \left(u_i(\underline{w_i}) + \underline{H} \right) + (1 - p(h_i, E)(1 + \eta) \left(u_i(\overline{w_i}) + \overline{H} \right) \right) + \beta_i v(E) \tag{2}$$

where $E = E_0 + \sum_{j \neq i} e_j + e_i$, $\underline{w_i} = w_i - D - ch_i - e_i$, $\overline{w_i} = w_i - ch_i - e_i$ and c is the cost of individual prevention.

In order to ensure an interior solution,[1] we add the following assumption:

Assumption 1 $\frac{a}{c} > b$.

This condition means that interior solution is possible only when the efficiency/cost ratio is in favor of individual prevention investment.

The first order conditions are given by:

$$\begin{aligned}\frac{\partial U_i}{\partial h_i} &= -a\left[(1+\lambda\eta)(u_i(\underline{w_i}) + \underline{H}) - (1+\eta)(u_i(\overline{w_i}) + \overline{H})\right] \\ &\quad -c\left[p(h_i, E)(1+\lambda\eta)u_i'(\underline{w_i}) + (1 - p(h_i, E))(1+\eta)u_i'(\overline{w_i})\right] = 0\end{aligned} \tag{3}$$

$$\begin{aligned}\frac{\partial U_i}{\partial e_i} &= -b\left[(1+\lambda\eta)(u_i(\underline{w_i}) + \underline{H}) - (1+\eta)(u_i(\overline{w_i}) + \overline{H})\right] \\ &\quad +\beta_i v'(E) - \left[p(h_i, E)(1+\lambda\eta)u_i'(\underline{w_i}) + (1 - p(h_i, E))(1+\eta)u_i'(\overline{w_i})\right] = 0\end{aligned} \tag{4}$$

At the individual level, the marginal cost of prevention is equal to its marginal benefit. Notice that the marginal benefit for a collective prevention is double: a reduction in probability of being sick and an improvement of environmental quality.

Proposition 1 *Under Assumption 1, an increase in loss aversion, λ, as well as an increase in environmental sensitivity, β_i, incite individuals to decrease individual prevention h and increase collective prevention e. The level of wealth that is not invested in prevention, that is $w_i - (ch + e)$, increases.*

[1] see Appendix A.

Proof. See Appendix B ■

First, loss aversion works to make the individual more "cautious" and invests a smaller amount in prevention (individual as collective ones) in order to consume more (less wealth invested in prevention). Second, individual and collective prevention are substituable in the sense where they vary in the opposite directions. This second effect counteracts the first one. The first direct effect prevails for individual prevention but not for collective one. Indeed, the second indirect effect is reinforced by the incentive to improve the environmental quality and thus obtain a certain gain. On the other hand, an increase in environmental sensitivity directly incites individuals to increase environmental quality.

Our final set of comparative statics results are about how changes in health status, $\underline{H}$, and initial environmental quality, E_0, values affect prevention decisions.

Proposition 2 *A worst bad health will increase individual prevention and decrease collective prevention and consumption.*

A decrease in environmental quality incites the individuals to decrease individual prevention and increase collective prevention. The level of consumption decreases.

Proof. See Appendix C ■

In a more severe situation (deterioration of bad health or environmental quality), individuals invest more in prevention and the level of consumption decreases (direct effect). When the change of situation is due to a degradation of the health status, the magnitude of the effect on individual prevention is very large and the substitutability of individual and collective prevention ultimately leads to a decrease in collective prevention. The opposite is true when the change is due to a degradation of the environmental quality. Hence, prevention decisions change according to the deterioration factor.

Suppose now that individuals have not quite accurate information about these two variables without knowing it and let us turn to the social optimum in this set-up.

The social optimum. Suppose that the government gets more information about the level of environmental quality and the effect of pollution on health. The central planner criterion is the sum of reference-dependent utilities with objective values, $\widehat{E_0}$ and $\widehat{\underline{H}}$. The social welfare function, W, writes:

$$W(h,e) = \sum_{i=1}^{N} p(h_i, \widehat{E})(1+\lambda\eta)\left(u(\underline{w_i}) + \widehat{\underline{H}}\right) + (1 - p(h_i, \widehat{E})(1+\eta)\left(u(\overline{w_i}) + \overline{H}\right)) + \beta_i v(\widehat{E}) \quad (5)$$

with $\widehat{E} = \widehat{E}_0 + \sum_{j=1}^{N} e_j$, $h = (h_1, h_2, ..., h_N)$ and $e = (e_1, e_2, ..., e_N)$.

If all agents are identical, it comes easily that the level of optimal collective prevention, e^*, as the level of optimal individual prevention, h^* cannot be both lower than the ones at equilibrium. In the other cases, we cannot compare the level of social optimum prevention and the *laisser-faire* one. Let us assume that public communication on health environmental risk could give relevant information. More precisely, a public risk communication is formalized as a message, m, which could modify individuals' values given to environmental quality, $E(m) = E_0(m) + Ne$, or health status, $\underline{H} = \underline{H}(m)$. Hence, we implicitly suppose that individuals' valuation of environmental quality and bad health status are bijective functions of message. In our framework, the social optimum can be decentralized by two different messages.

Proposition 3 *In the case of a linear utility function v, the social optimum can be decentralized by means of the following instruments: (i) A health risk message, m_H, that modifies bad health status:* $\underline{H}(m_H) = \widehat{\underline{H}} + \frac{(N-1)cb}{(a-cb)(1+\lambda\eta)}\left[(1+\eta)(u(\overline{w}^*) + \overline{H}) - ((1+\lambda\eta)(u(\underline{w}^*) + \widehat{\underline{H}}) + \frac{\beta}{b}\right]$*;*

(ii) An environmental message, m_E, that modifies environmental quality:
$p(h^*, E_0(m_E) + Ne^*) = p(h^*, \widehat{E}_0 + Ne^*) - \frac{a(N-1)}{a-cb}\frac{\left[(1+\eta)(u(\overline{w}^*)+\overline{H}) - ((1+\lambda\eta)(u(\underline{w}^*)+\widehat{\underline{H}})\right]+\frac{\beta}{b}}{\mathcal{B}}$.

Proof. See Appendix D ■

Individual valuations of environmental quality and bad health with message should be larger than the objective values. This is due to the externality of collective prevention that distorts the individual behaviors. We can notice that health risk message does not depend on the environmental quality level whereas environmental message is positively correlated to the true value of bad health status. A decrease in the true value of environmental quality needs a more incisive message since environment messages should make people more pessimistic in the sense that they believe that the environmental quality is worse than they thought. The effect of bad health on health message is not clear. If $\frac{a}{cb} < N$, a decrease in the true value of bad health must result in a higher level of $\underline{H}(m_H)$, that means a less incisive health message. Simultaneously, since $E_0(m_E)$ is decreasing in $\widehat{\underline{H}}$, environment message should be less incisive too. In addition, it is easy to see that a higher loss aversion implies a weaker health risk messages whereas a higher environmental sensitivity implies a more incisive environmental health messages.

2.2 Hypothesis to be tested

In this section, we discuss the main empirical implications that emerge from the model outlined above. Notice that these implications are not unique to our model. We consider that preferences are represented by a model, generalizing expected utility that introduces a reference point and loss aversion. We highlighted the impact of loss aversion and environmental sensitivity on the two types of prevention measures: individual health prevention and collective environmental prevention. We thus propose an experimental design with two objectives: (i) testing the main predictions of our theoretical model and (ii) testing the efficiency of risk communication messages) to increase prevention levels.

The first two hypothesis have to do with optimal prevention levels following a change in loss aversion and environmental sensitivity. According to our results in proposition 1, the hypothesis we test are:

(H1) *An increase in loss aversion (H1.a) decreases individual prevention; (H1.b) increases collective prevention; and (H1.c) increases consumption (wealth amount not invested in prevention).*

(H2) *An increase in environmental sensitivity (H2.a) decreases individual prevention; (H2.b) increases collective prevention; and (H2.c) increases consumption (wealth amount not invested in prevention).*

Information messages are commonly used by health authorities to encourage individuals to adopt prevention actions (stop smoking, healthy eating). Risk communications that describe a hazard with the purpose of motivating behavior change are often conceptualized as fear appeals. They are used extensively for public health messaging. Access to information impacts perceptions of environmental health risks. In our experimental design, we test two types of messages: A message on the impact of pollution on health; And a message on the impact of pollution on environmental quality. As a result of the health message, individuals may revise their assessment of the consequences of pollution on their health status. In our approach, this would mean a lower value of the perceived bad health status, $\underline{H}$. Similarly, as a result of the environmental message, individuals might revise their evaluation of environmental quality. In our model, this would mean a lower value of environmental quality, E_0. First, in proposition 2, we show that a decrease in $\underline{H}$ or in E_0 incites the individuals to increase their level of prevention or decrease their level of consumption. Therefore, we suggest the following hypothesis.

(H3) *A message on health or environmental quality incites individuals to increase the investment in prevention (decrease consumption / wealth not invested in prevention).*

Second, the effect of messages on prevention should depend on the type of the message. According to our proposition 2 we test the next hypothesis:

(H4) *A message on health (H4.a) increases individual prevention and (H4.b) decreases collective prevention.*

(H5) *A message on environmental quality (H5.a) decreases individual prevention and (H5.b) increases collective prevention.*

3 Experimental design

The experimental design is divided into two parts. The first part corresponding to the main task, is an adapted version of a public good game (PGG) and consists in several periods and a series of choices in terms of investment in prevention. The second part consists in incentivized preference elicitation tasks (risk and loss aversion), and a questionnaire on environmental preferences and societal aspects, and socioeconomic questions.

3.1 Design and treatments

The experiment relies on a PGG in which we introduce risk and context. Participants are divided into groups of $N = 4$ members that remain fixed throughout the rounds. They are assumed to live in Paris and face the risk of getting sick because of air pollution. The initial probability of disease is 0.25 and the monetary costs of disease is 10 ECUs (Experimental Currency Units). In every round, groups play the same public goods game and every player receives an endowment of 20 ECUs of which she can invest in prevention to reduce the risk of disease for herself and/or for all the members of her group. Reducing the risk for all the group corresponds to a contribution to a public good (actions improving environmental quality) and has as side effect a positive impact on collective welfare since individuals are supposed to derive utility from environmental quality.

More precisely, each player has to allocate her endowment between three available accounts. Investing in account 1 corresponds to an investment in individual primary prevention, h, and exclusively reduces the individual probability of disease.[2] Investing in account 2 correspond to an investment in collective prevention, e. It is a contribution to the public good and it reduces the probability of disease for all members of the group but also increases payoffs for all of them *via* the improvement of the environmental quality.[3] Finally, investing in account 3 simply corresponds to not invest in prevention (hoarded money - savings) and does not allow to a risk reduction, s.
The stage game payoff to player i is given by $W_i = \Pi_i - 10 \times L_i$ where Π_i is the return of investment, $\Pi_i = (20 - h_i - e_i) + 0.4E$ and L_i is a random variable, that takes two values. If the disease occurs, that happens with the probability $p(h_i, E) = 0.25 - \frac{0.4}{100}h_i - \frac{0.25}{100}E$, the health loss is $L_i = 1$. Else, there is no loss and $L_i = 0$.[4] Notice that Assumption 1 is well satisfied.

The benefits of an investment of 1 ECU according the three accounts in terms of monetary gains and of disease probability reduction are summarized in Figure 1.

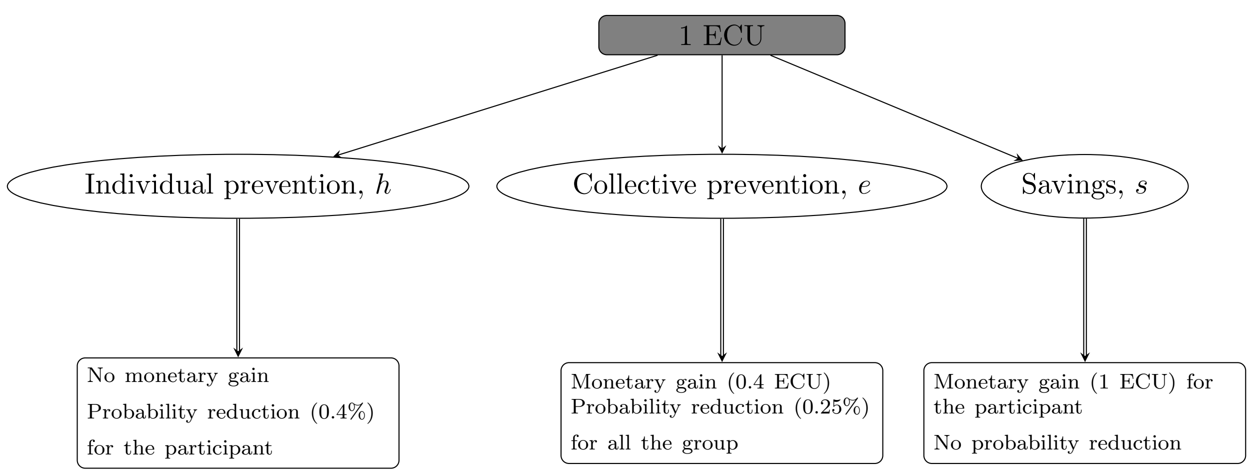


Fig. 1: Simplified scheme of the game

[2]It is assimilated to individual risk reduction measures as avoiding doing activities physical outdoors during peak hours, buy an air purifier for indoor use, wear a mask.
[3]It can be assimilated to air pollution reduction actions as driving less, reducing water consumption and electricity consumption.
[4]If $0.25 - \frac{0.4}{100}h_i - \frac{0.25}{100}E \leq 0$, we force p_i to be equal to zero.

The participants take part in 10 rounds. One of the rounds is selected for payment at the end of the experiment. At the end of each round, participants receive feedback.

The experimental design involves three treatments according to the messages provided to the subjects concerning the impact of air pollution on health or environmental quality. Treatment 1 is the controlled one and there is no message. In Treatment 2, participants read a health message and see pictures of pollution-related diseases in order to reinforce the impact of messages. In a similar way, in Treatment 3 we propose an environmental-oriented message.

Treatments are administrated randomly to the groups of subjects. The same treatment is applied to all the members of a group for the 10 periods of the game. Each treatment is applied to 14 groups of 4 subjects, that is to 56 subjects.

3.2 Experimental sessions and monetary incentives

The experiment was conducted in the Laboratoire d'Economie Experimentale de Paris (LEEP). Participants were adults, recruited without special characteristics. Overall, we ran 14 sessions from November 26, 2019 to January 31, 2020. In each session, groups of 4 individuals were formed. A total of 168 individuals participated in the experiment, composed of 44.05% men and 55.95% women. The average age of the participants is 37 years (mean: 36.61, sd: 0.39). Almost the entire sample, 98.21%, live in the Paris area. 31.55% know of an organization that provides information on air pollution in their city. The design was programmed on z-Tree software and the data were analyzed with Stata 16.

After the ten rounds were completed, the participants entered two incentivised preferences elicitation tasks and and a questionnaire on environmental, political and social sensitivity. To elicitate risk aversion, we use the very popular Holt and Laury (2002) elicitation method. To elicitate loss aversion, we use the original task proposed by Kahneman and Tversky (1979) in which the subjects have a choice between different 50 : 50 lotteries. Then, to measure individual environmental sensitivity, social preferences, and individual point of view on the state intervention, we use a subset of the NEP (New Ecological Paradigm) scale questionnaire and add some questions more adapted to our setting. More precisely, fifteen statements in relation with environmental, social and political preferences are proposed to the subjects (see Appendix E). Nine of them are taken from the standard NEP scale (Dunlap et al., 2000), the others are adapted to our experimental context. This questionnaire allows the construction of three variables measuring respectively environmental concern, political aspects and social preferences. Finally, the participants were asked a few socio-demographic questions. Sessions lasted, on average, 1 hour including the reading of the instructions and answering control questions and questionnaires.

When all these tasks were completed, the participants were informed of their payoffs, that are the sum of three components. First, they received a fixed participation fee of 5 euros. Second, one of the 10 periods of the public good game was randomly drawn and used for remuneration.[5] Third, one choice in the risk aversion and loss aversion tasks was randomly drawn and used for remuneration too. On average, participants earned from the experimental tasks 102.58 ECUs with a standard deviation of 1.13 ECUs. The applied conversion rate was 10 ECUs = 1 euro. The average total gains (including partcipation fees) were thus of 15.26 euros.

4 Descriptive statistics and overview

Before we conduct hypotheses testing, we provide some descriptive statistics to give the reader an overview of our results in terms of individual preferences and contributions to the game.

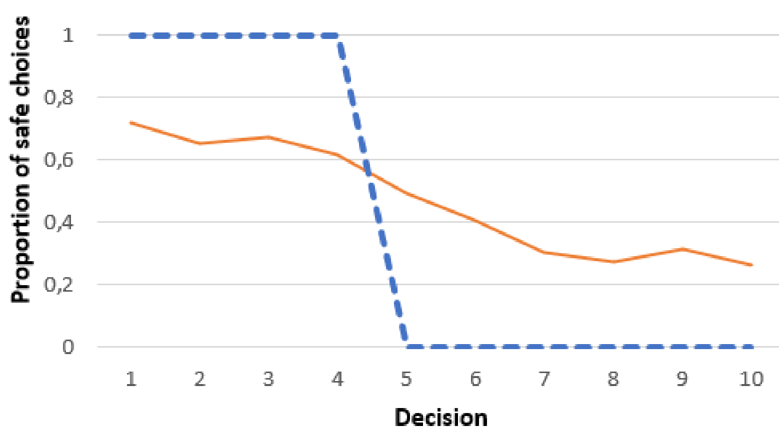
[5] This has been shown to be an efficient way to allocate payment in experiments with repeated choices, see Baltussen et al. (2012).

4.1 Individual preferences

4.1.1 Risk and loss aversion

As in Holt and Laury (2002), the total number of “safe” A choices is used as an indicator of risk aversion. We can classify individuals according to their choices: risk adverse, risk lover and risk neutral. If an individual switches from an option to another, and then switches again, the individual is considered irrational. Figure 2 displays the proportion of A choices for each of the ten decisions. The horizontal axis is the decision number, and the dotted blue line shows the predictions under an assumption of risk neutrality[6]. The full orange line shows the observed frequency of Option A choices in each of the ten decisions. For the first choices, individuals would appear to be more risk-loving, while for the following choices, they would appear to be more risk-averse (relative to the risk-neutral prediction).

Fig. 2: Proportion of ”safe” choices in each decision (risk aversion elicitation task)

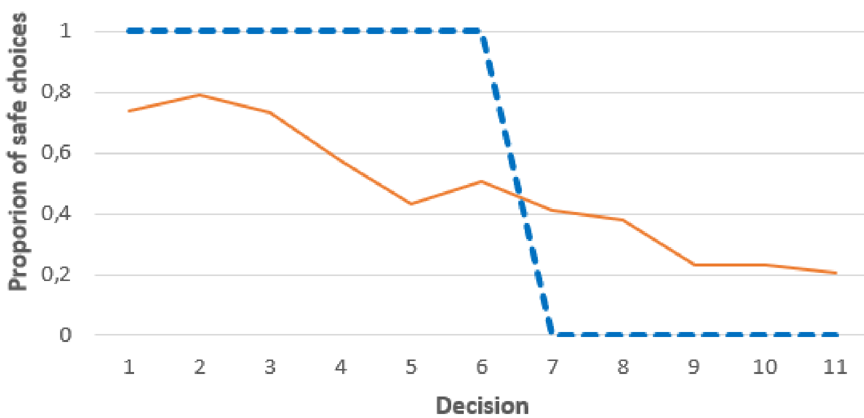


In our sample, 37.08% of individuals are Risk lovers, 20.60% are Risk averse and 42.32% are irrational. We note two specific features of our sample: a high proportion of Risk Lovers and a high proportion of irrational individuals. The individual had the option to switch choices between

[6] The probability that the safe Option A is chosen is 1 for the first four decisions, and then this probability drops to 0 for all remaining decisions.

Lottery A and Lottery B multiple times which creates irrationality, wherease a rational individual only has one tipping point.

Fig. 3: Proportion of "safe" choices in each decision (loss aversion elicitation task)



Similarly, Figure 3 represents the proportion of "safe choice" in each decisions (11 in the loss aversion elicitation task). The dotted blueline indicate the behavior of a loss neutral individual. For loss aversion, we observe a result close to the risk aversion elicitation. In our sample, 39.35% are averse to loss, 6.55% are "loss lover", 54.11% are irrational.

4.2 Environmental concern, State's intervention and Social Preferences

We analyse the data from the questionnaire. First of all, the environmental sensitivity question block consists in 10 questions. These questions are based on the role of human action in environmental degradation, as well as questions on the perceived seriousness of climate change. Secondly, the block of questions regarding State's intervention is composed of 6 questions on the perceptions of government actions to reduce inequality, indicating individuals' view of state intervention. Finally, the block of questions concerning societal preferences is composed of 6 questions on societal issues and social inequalities (See Appendix E).

The majority of the individuals in the sample seem to be aware of the planet's limits, the environmental problem that exists and the irreversible consequences that are linked to it. From a political point of view, the individuals in the sample seem to think that the government interferes a lot in their daily life. Finally, the individuals seem to express a desire for a more egalitarian society, especially by taking into account discrimination against minorities as a serious problem.

From these three sets of questions, we constructed 3 scores, used in the model as independant variables: Environmental concern, State's intervention, Social preferences. The higher the score for the "Environmental concern" variable, the more individuals consider that environmental degradation is a major problem and that actions should be taken to reduce its harmful effects. Consider the variable "State's intervention": the higher the score on this variable, the more individuals support government intervention in society. Finally, the higher the score of the "Social preferences" variable, the more individuals consider that inequalities persist in society and that action is needed to reduce them. Table 1 summarizes the statistics of these 3 variables.

Table 1: Summary statistics of the variables from the questionnaire

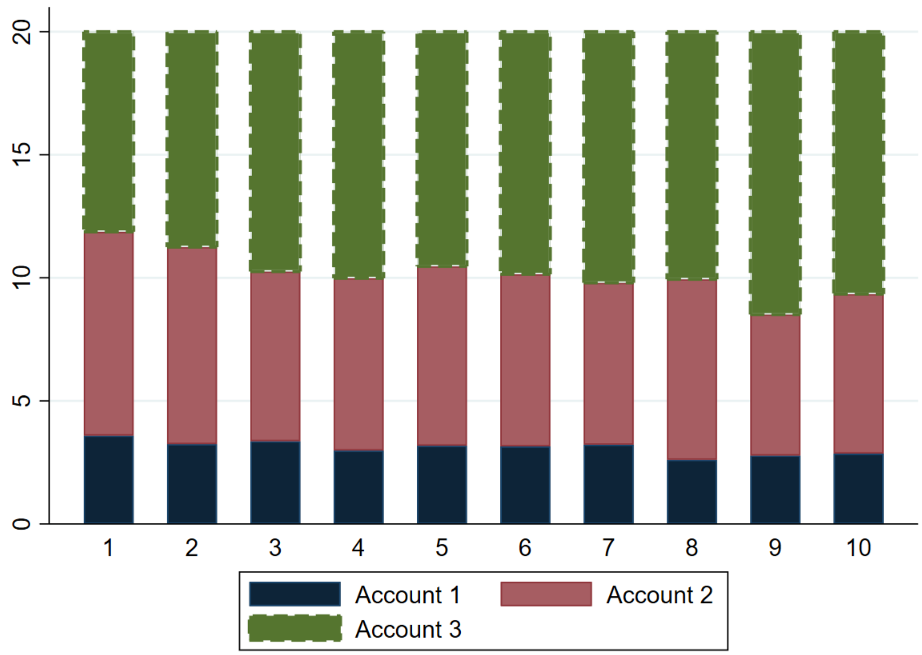
Variables	mean	standard deviation	min	max
Environmental concern	36.46	5.52	22	49
State's intervention	19.05	4.25	9	30
Social preferences	23.33	4.73	6	30

Despite the tendency for pro-NEP attitude, substantial heterogeneity is displayed within the sample as responses are distributed across all response categories.

4.3 Prevention decision

We are now interested in the contribution behaviors of individuals during the game. Individuals can invest in prevention (whether individual or collective, i.e. in accounts 1 and 2) or in the "savings" account (account 3). The latter simply allows them to keep money for consumption. We begin by plotting some histograms to understand how individuals contribute. We consider individual decisions on the distribution of the initial endowment between the 3 accounts (Figure 4).

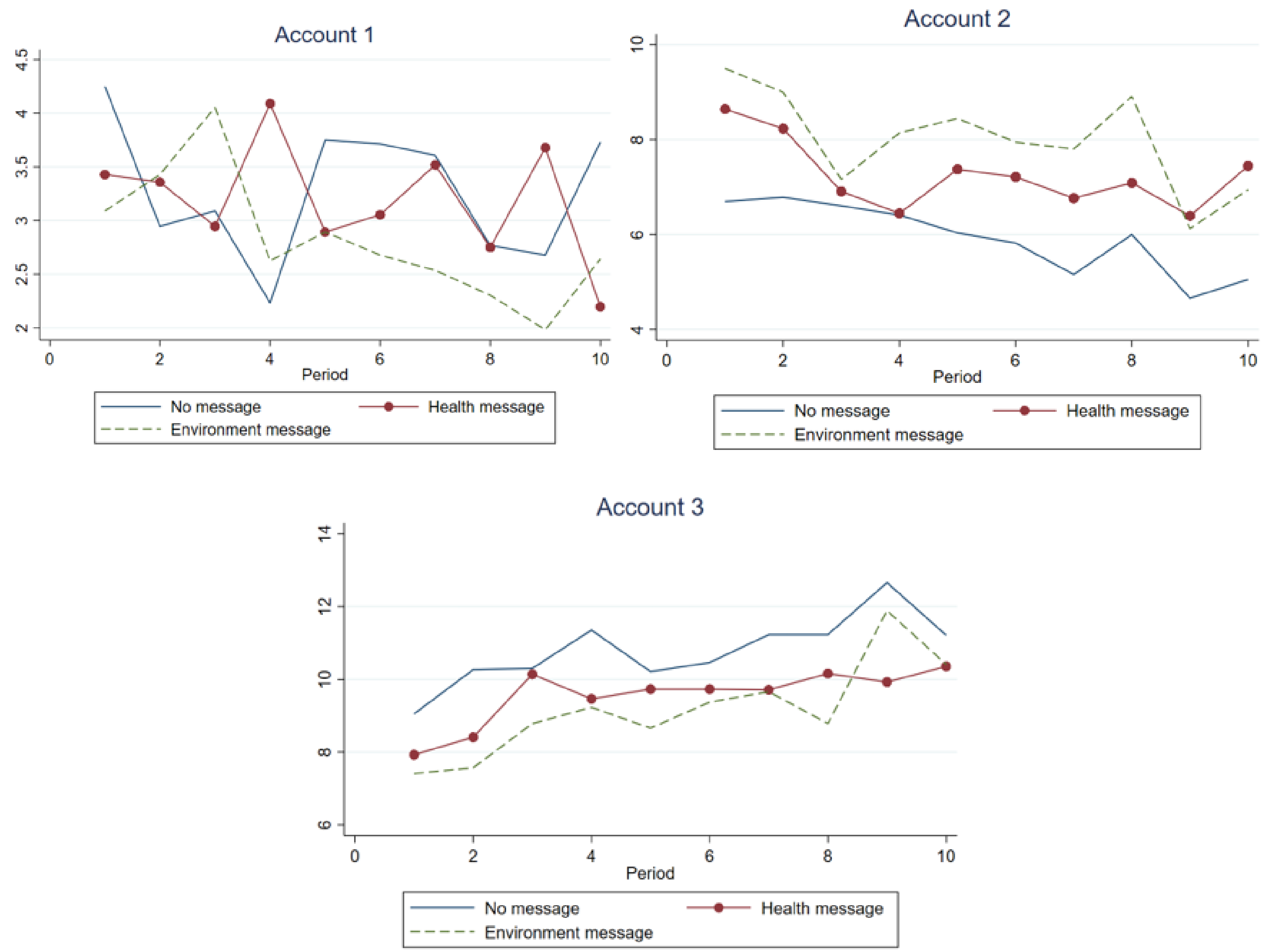
Fig. 4: Average individual investment in the 3 accounts



We can easily see on Figure 4 that individuals invest a strictly positive part of their wealth in the two types of prevention (individual and collective), as well as in the savings account. More in detail, we observe that the average contribution to Account 1 is positive but low, and relatively stable over time. The contribution to Account 2 decreases overt the periods. This result is in line with the existing literature and the traditional results of a voluntary contribution mechanism to a public good. When the game is repeated, the average contribution level to the public good remains positive but gradually decreases over the periods. In other words, there is a significantly non-zero degree of cooperation, as well as a decrease in average contributions.

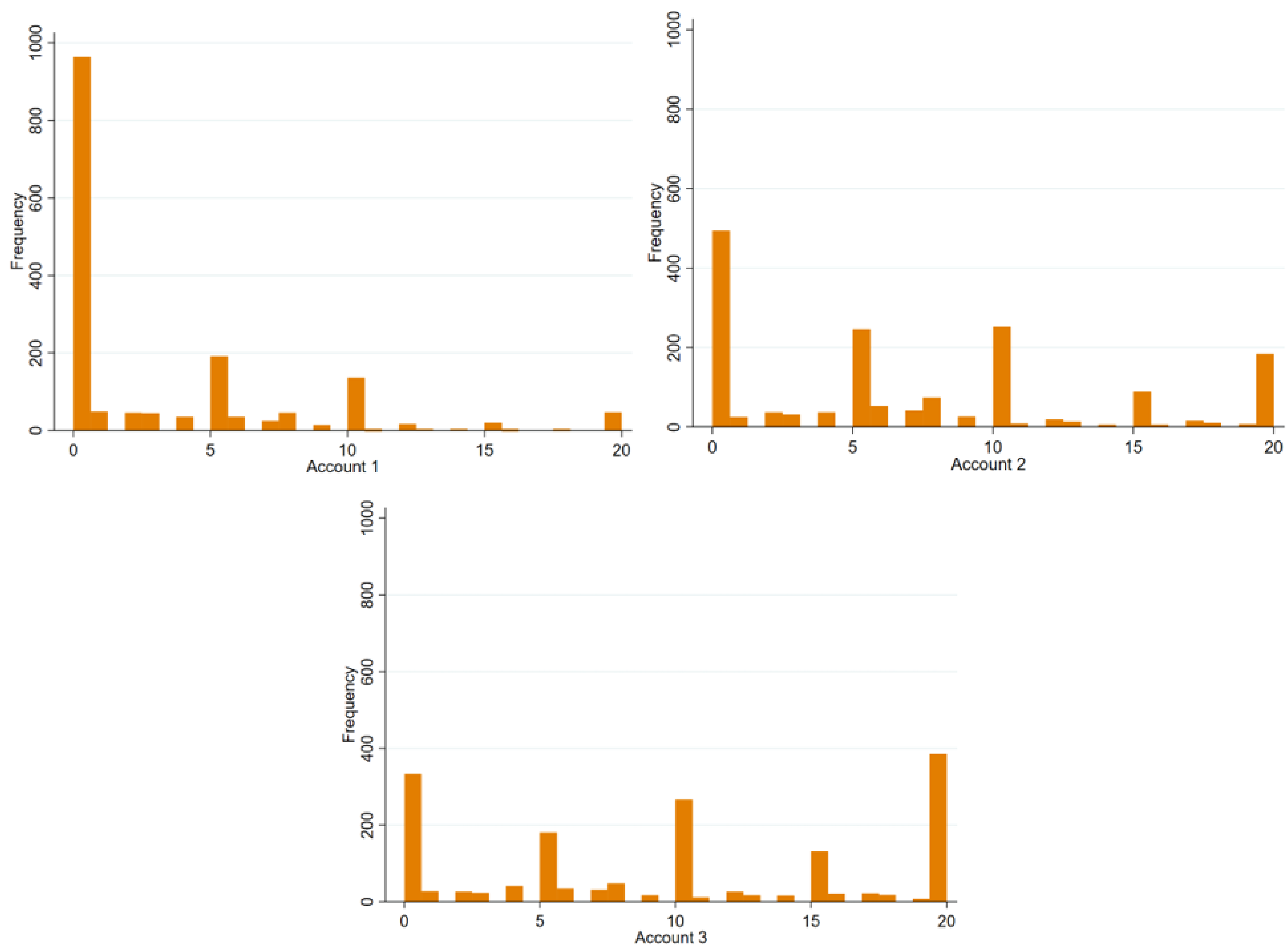
However, and by symmetry, the contribution to Account 3 increases over the periods. Individuals tend to increase the money invested in retained consumption over time (wealth not invested in prevention). As a reminder, individuals have an endowment of 20 ECUs, which they must allocate to the 3 accounts. On average, they contributed 3.1 to account 1, 7.1 to account 2 and 9.8 to account 3. We then observe that individuals preferred to contribute more on average to the savings account.

Fig. 5: Evolution of the average contribution level to the 3 accounts by treatments (messages)



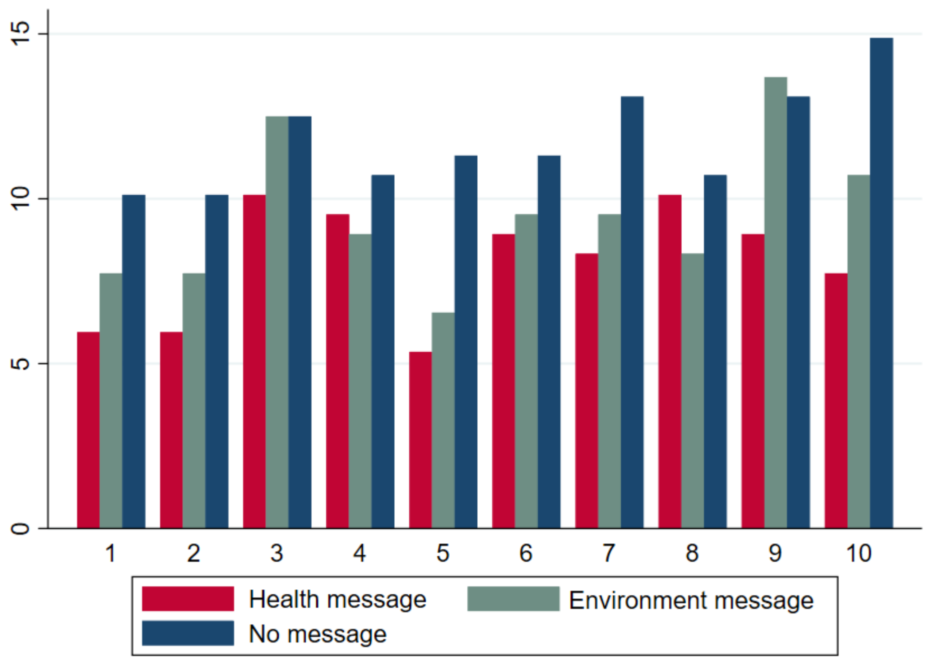
Let's look in detail at the evolution of contributions for each account and each treatment. Figure 5 plots the evolution of the average contribution level for the 3 accounts by treatments (no message, environment message, health message) over the periods. At first glance, it seems difficult to discuss the evolution of the contribution for the individual prevention level (Account 1), as well as the effect of the message. At the collective prevention level (Account 2), we still notice this decrease in contribution over time, with an average contribution that seems higher for an environment message, lower in the no message treatment. Regarding the savings account (Account 3), this increase is again noticeable over the periods, with a higher average contribution in the treatment without message. An interesting element is that for the three treatments, we observe an increase in the average contribution for the last period of the game. This can be explained by the fact that subjects anticipate that this is the last period of the game, and then try to make up for it in terms of reputation, social norms or guilt.

Fig. 6: Frequency of contributions



In terms of contribution level frequencies (Figure 6), we note that there is the most zero contribution for account 1, compared to the other two accounts. For accounts 2 and 3, individuals contribute 0, 5, 10, 15 or 20. We then observe an ”all or nothing” type of game behavior. **REF assurance choix etremes**. Most contribute nothing, or contribute their entire endowment.

Fig. 7: Percentage of free riders by message types over the period for account 2



Let’s analyze the behavior of free riders for account 2, that is to say those who contribute 0 to the public good. Figure 7 represents the different percentage of free riders depending on the type of message over the periods for the collective prevention. The percentages of free riders increases very slightly over the periods. The histogram above clearly shows that in each period the percentage of free riders is significantly higher in the ”no message” treatment (except for period 9) and lower in the health treatment (except for periods 4 and 8).

At this stage of the analysis, we can then ask ourselves which message leads to a greater reaction among participants, in other words, which message is more effective in increasing the contribution, particularly to the public good (collective prevention). Using an independent group t-test, designed to compare means of same variable between two groups, we show that the means of contribution for account 2 between those who received a message and those who don't is different from 0. After that, we perform the same type of analysis by comparing the mean contribution for Account 2 between the group who received an "environment" message and the those who received a "health" message or no message at all. Here again, we show that the difference of means in contributions is different from 0 (see tables in Appendix).

Fig. 8: Average individual contributions to the public good by message type (treatments)

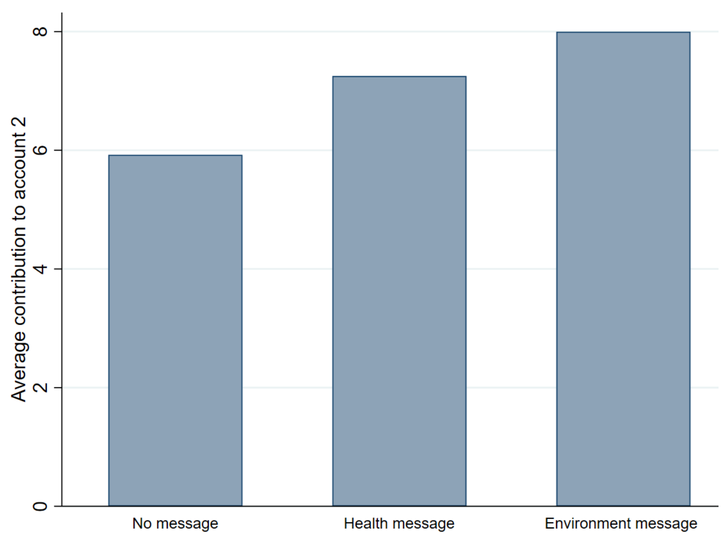


Figure 8 represents the average individual contributions to the public good by message type. It can be seen graphically that the average contribution is highest when an environmental impact oriented message is sent to the participants (mean 8). We can also see graphically that the average contribution is lowest for the no message treatment (mean 5.92).

Two strong results can be observed. On the one hand, a message related to health (and environment to a lesser extent) triggers the willingness to contribute to the public good because there is less free riding in these two treatments. On the other hand, a message related to the environment increases the amount invested in the public good. We observe a complementarity in the messages that must be sent to individuals. Thus, to increase the contribution to the public good and decrease the number of free riders, health and environment messages can be effective. Indeed, when no message is addressed, there are both more free riders and fewer average contributions to the public good.

To summarize, we can clearly see that there is complementarity in the investment choices of ECU between the three accounts. Indeed, individuals would tend to contribute a portion to individual prevention, collective prevention and savings.

5 Testing the hypotheses

5.1 Econometric model

For the hypotheses to be tested, we implement an econometric analysis. Our aim is to investigate the role of the type of messages and we considered three specifications, for the three accounts, where we evaluate if receiving messages (health, environment or none) influence the contribution in each account. Therefore, we conduct the study by analyzing the contributions to the three different accounts. Because of the protocol and the richness of the experiment with 3 possible accounts, we take the share of the contribution in each account as the dependent variable. The dependent variables in our model are:

$$Contribution_k = \frac{account_k}{\sum_{k=1}^{3} account_k} \text{ for } k=1,2,3$$ [7]

The variable of interest is the existence of a message addressed or not to the subjects (binary variable if the subject received a message or not). It is an indicator variable according to the types

[7] The sum is equal to 20 ECUs.

of messages addressed to the subjects. Therefore, we work with a polytomous variable Z:

$$Z = \begin{cases} 1 \text{ if "no message"} \\ 2 \text{ if "health message"} \\ 3 \text{ if "environment message"} \end{cases}$$

Then we represent the variable Z by the vector z of 3 dummy variables, with z_1 a dummy taking the value 1 if "no message" and 0 otherwise; z_2 a dummy taking the value 1 if "health message" and 0 otherwise; z_3 a dummy taking the value 1 if "environment message" and 0 otherwise (with "no message" being the reference category in the estimation).

We also control for different potential characteristics that may impact the participants' contributions. X is a vector of explanatory variables composed of individual characteristics (age, gender), her preferences (risk and loss, environmental concern, political ideology and social preferences), her knowledge about organizations related to environment, regular use of a car and the period of the game.

The literature using the public good game data shows that several methods can be applied depending on the objective. Some authors use OLS regressions (Clark, 2002, Ashley et al., 2010). This model is used in most studies that go beyond graphical comparisons or central tendency comparisons (comparisons of mean or median outcomes) to analyze individual data.

Another way is to estimate in panel data, since these data offer an opportunity to understand how an individual's behavior evolves over time in response to feedback on the behavior of others (Ashley et al., 2003). In our case, we are interested in studying the determinants of contribution and the effect of treatment, not necessarily the dynamics of behavior in these games, so we do not use this method.

In our case, since the dependent variable is continuous and censored, a Tobit model is applied;

it allows us to estimate the determinants of the amount of the contribution.[8] We estimate a Tobit regression to take into account the fact that the dependent variable is censored. Tobit models generally refer to regression models in which the domain of definition of the dependent variable is constrained in one form or another. In our case, our dependent variable is limited: it is continuous but only observable on a certain interval [0,1]. Our Tobit model can be written as the latent regression model:

$$y^* = X\beta + \varepsilon$$

with a continuous outcome. Following Cong (2000), the observed outcome is defined as:

$$y = \begin{cases} y^* \text{ if } 0 < y^* < 1 \\ 0 \text{ if } y^* \leq 0 \\ 1 \text{ if } y^* \geq 1 \end{cases}$$

with y^* the latent variable. The econometric model we estimate is as follows:

$$Contribution_i = \alpha + \beta_1 HealthMessage + \beta_2 EnvironmentMessage + \beta_3 Period + \beta_4 RiskAverse + \beta_5 LossAverse + \beta_6 Gender + \beta_7 Age + \beta_8 InfoOrg + \beta_9 CarRegularly + \beta_{10} EnvConcern + \beta_{11} StateInterv + \beta_{12} SocialPref + \varepsilon$$

with α the intercept, ε the term of error of the model. In more detail, the variables in the model are as follows: Health Message, a binary variable, which indicates the presence of a health message relative to no message ; Environment message, a binary variable, which indicates the presence of an environment message relative to no message ; Period, indicate the period of the game ; Risk averse, binary, indicates whether the individual is risk averse ; Loss averse, binary, indicates whether the individual is loss averse ; Gender, binary, equal to one if the individual is a

[8] The results with OLS give similar results for robustness.

man, 0 otherwise ; Age, Information Organisation, binary, which indicates whether the individual knows organizations related to air pollution ; Car regularly, which indicates whether the individual drives a car regularly, Environmental concern, State Intervention, Social Preferences (see previous section for explanation of these variables).

Table 2 presents the result of the estimation of the three different models. Before going into the details of the hypotheses to be tested, we first look at the effect of framing. In specification (1), the dependent variable is the share of the contribution to account 1 (individual prevention). Environmentally oriented messages have a significant and negative impact on the individual prevention contribution. In specification (2), the dependent variable is the share of the contribution to account 2 (collective prevention). Both health and environment messages have a significant and positive effect on the contribution to the public good. In specification (3), the dependent variable is the share of the contribution to account 3 ("savings"). Both health and environment messages have a significant and negative effect on the contribution to the savings account.

Mainly, at this stage, we can retain that the messages allow to increase the contribution to the preservation of the environment, while they tend to reduce the amount invested in "savings". This effect therefore seems interesting from a public policy point of view. Let us now look in detail at the hypotheses tested.

Table 2: Results of the estimation of the model parameters (tobit): effect of the type of message

	(1) contrib_1	(2) contrib_2	(3) contrib_3
Health message	-0.0180	0.0960**	-0.0924*
	(-0.55)	(3.01)	(-2.56)
Environment message	-0.0789*	0.146***	-0.118**
	(-2.32)	(4.54)	(-3.23)
Period	-0.0112*	-0.0152***	0.0204***
	(-2.42)	(-3.43)	(4.07)
Risk averse	-0.0548	0.0336	-0.00318
	(-1.55)	(1.04)	(-0.09)
Loss averse	-0.106***	-0.119***	0.162***
	(-3.69)	(-4.43)	(5.32)
Gender	0.0648*	0.0224	-0.0296
	(2.19)	(0.80)	(-0.93)
Age	0.00709***	0.00485***	-0.00880***
	(7.80)	(5.55)	(-8.80)
Info Org	-0.0867**	-0.0477	0.0869*
	(-2.69)	(-1.56)	(2.50)
Car regularly	0.119***	-0.0875**	0.0348
	(3.47)	(-2.60)	(0.91)
Env_concern	0.00312	-0.00216	-0.00355
	(1.18)	(-0.85)	(-1.24)
Pol_ideology	0.0191***	-0.00876**	-0.000967
	(5.81)	(-2.84)	(-0.28)
Social_pref	0.00361	0.0202***	-0.0189***
	(1.12)	(6.38)	(-5.40)
_cons	-0.796***	-0.0608	1.293***
	(-5.91)	(-0.48)	(8.99)
var(e.contrib_1)	0.221***		
	(15.86)		
var(e.contrib_2)		0.242***	
		(19.94)	
var(e.contrib_3)			0.312***
			(19.30)
N	1680	1680	1680

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5.2 Hypothesis 1: Impact of loss aversion

Hypothesis 1 suggests that an increase in loss aversion decreases individual prevention; increases collective prevention; and decreases the total prevention (increases "savings",the wealth amount not invested in prevention). The variable "loss averse" is significant in the 3 specifications (Table 2). We show that an increase in loss aversion has a positive impact on the savings account (0.162^{***}) and has a negative impact on the individual prevention (-0.106^{***}). On the other hand, we find that the effect is negative on collective prevention (-0.119^{***}), that does not support the prediction. Indeed, the more loss averse the individual is, the more they will contribute to both types of prevention. This result suggest that the direct effects outweigh indirect effects for both types of prevention.

5.3 Hypothesis 2: Impact of environmental sensitivity

Hypothesis 2 states that an increase in environmental sensitivity decreases individual prevention; increases collective prevention; and increases "savings" (the total prevention decreases). Theoretically, the coefficient for the contrib-1 should be negative, contrib-2 positive and contrib-3 positive. While the estimated coefficients of the variable "environmental concern" in regression have opposite signs to the predictions (0.003, -0.002, -0.003), they are not significant. A possible interpretation could be that people are already aware of the environment, so a message would not change their choices. However, we can notice that there is an effect of the variable "State's intervention": a positive impact on individual prevention and a negative impact on collective prevention. *The more pro-government interventionist one is, the less one contributes to the public good. This result is explained by the fact that individuals would consider that it is up to the government to protect the environment.*

5.4 Hypothesis 3: Impact of a message on precautionary savings

Hypothesis 3 suggests that a message on health or environmental risk incites individuals to increase the prevention (decrease wealth not invested in prevention or "savings"), which our results confirm. Both types of messages have a significant and negative on the savings account (-0.0924^{*} for health-oriented message and -0.118^{**} for environment-oriented one). From our theoretical model, an increase in total prevention can be explained by a deterioration in health status in case of illness and/or a deterioration in environmental quality. The messages would thus act as a deterioration of health status and/or environmental quality. This suggests that the initial perceived health status in case of illness and environmental quality (before the messages) would be higher than the objective values and that the messages would correct this distortion or misinformation.

5.5 Hypothesis 4: Impact of a health message

Hypothesis 4 predicts that a message on health risk increases individual prevention and decreases collective prevention. We find that a health message has a significant and positive impact on the collective prevention (0.096^{**}). In contrast, there is no significant results for individual prevention. Therefore, our forth hypothesis H4 is not validated. Assuming that the health-oriented message modifies the value given to health status in the case of illness (lower value), this message should encourage individuals to increase their investment in individual and collective prevention (direct effect). The econometric result thus suggests that the direct effect on collective prevention prevails contrary to our theoretical results.

5.6 Hypothesis 5: Impact of an environmental message

Hypothesis 5 states that a message on environmental risk decreases individual prevention and increases collective prevention. Our results are consistent with this prediction. The environment-oriented message has significant and negative impact on the individual prevention (-0.078^{*}) and a significant and positive impact on collective prevention (0.146^{***}). So, in detail and with the aim of identifying the optimal messages in order to preserve the public good (the environment), we notice that environment-oriented messages have the desired impact on the contribution to the public good.

5.7 Additional results

Other results emerge from the regression table, especially when looking at the control variables. The "age" variable is significant in all three specifications. On the one hand, we note that the older the individuals, the more they will decide to invest in prevention, whether collective or individual. On the other hand, as age increases, the contribution to the savings account decreases. The period of the game is also always significant. In detail, as the period of play increases, the contribution to the savings account increases. However, the opposite relationship is observed for the accounts related to prevention (this is what we found graphically earlier). Gender is significant only for account 1. Thus, men would tend to contribute more to the individual prevention account.

In addition, concerning the variable "info org", the latter is significant and negative for account 1 and significant and positive for account 3. People who know organizations related to air pollution will be more likely to increase their contribution to the savings account, and to reduce their individual prevention contribution.

Finally, driving a car regularly has a negative impact on the contribution to account 2. The more likely the individual is to drive a car on a regular basis, the less they will contribute to account 2. This result seems intuitive since driving regularly is not an environmentally friendly action. On the contrary, driving a car has a significant and positive impact on account 1. This result can be justified by the fact that individuals, less sensitive to the environment in their actions, will prefer to take their personal cars rather than taking public transport. The profile of this type of individual is therefore more altruistic and does not contribute to the public good, he will prefer to contribute to the preservation of his own individual health.

6 Conclusion

In a context of air pollution, we sought to analyze how individuals arbitrate between making preventive decisions for their individual health, or contributing to the public good by preserving the environment through reducing their emissions, or just save for consumption. Our results corroborate with the existing literature on the fact that the voluntary contribution to the public good is positive but decreasing with the periods of the game. The savings-consumption account, which is an original feature of the experiment, has shown that individuals tend to contribute a lot to this account.

Our experimental findings support the majority of our theoretical predictions and suggest that participants are influenced by messages on risk. Some results can help identify the optimal communication policies to encourage the adoption of pro-environmental and health prevention behaviors. On the one hand, we find that health-oriented messages would tend to trigger a willingness to contribute to the public good. On the other hand, it is rather the environment-oriented messages that would determine the amount of the contribution to the public good. Two strong results emerge from our study: environment-oriented messages seem to have a stronger impact on the contribution to the public good, yet there seem to be fewer free riders when a health-oriented message is addressed to subjects.

The results help to improve our understanding of the role of risk communication and how public authorities should communicate about diseases due to poor environmental quality or air pollution to change prevention behaviors. According to our results, messages that focus solely on pollution will only weakly trigger pro-environmental or preventive behaviors. However, if individuals are aware of these risks, then it is effective to insist on this aspect. Conversely, if individuals are already aware of the health risks due to pollution, it is less effective to carry health-oriented messages. It is therefore crucial to determine the degree of awareness of these issues among the different target populations in order to design the policy.

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7 Appendices

A Second Order Conditions

First, suppose the second order conditions hold, thus the first order conditions writes:

$$\frac{\partial U_i}{\partial h_i} = -a\left[(1+\lambda\eta)(u_i(\underline{w_i})+\underline{H})-(1+\eta)(u_i(\overline{w_i})+\overline{H})\right] \\ -c\left[p(h_i,E)(1+\lambda\eta)u_i'(\underline{w_i})+(1-p(h_i,E))(1+\eta)u_i'(\overline{w_i})\right]=0 \tag{A.1}$$

$$\frac{\partial U_i}{\partial e_i} = -b\left[(1+\lambda\eta)(u_i(\underline{w_i})+\underline{H})-(1+\eta)(u_i(\overline{w_i})+\overline{H})\right] \\ +v_i'(E)-\left[p(h_i,E)(1+\lambda\eta)u_i'(\underline{w_i})+(1-p(h_i,E))(1+\eta)u_i'(\overline{w_i})\right]=0 \tag{A.2}$$

We then obtain:

$$(-a+cb)\left[(1+\lambda\eta)(u_i(\underline{w_i})+\underline{H})-(1+\eta)(u_i(\overline{w_i})+\overline{H})\right]=cv_i'(E) \tag{A.3}$$

Since the term into brackets is assumed to be negative, a necessary condition is $-a+cb<0$.

Second, let us twice derive the utility:

$$\frac{\partial^2 U_i}{\partial h_i^2} \equiv U_{hh} = 2ca\mathcal{B}+c^2\mathcal{D} \tag{A.4}$$

$$\frac{\partial^2 U_i}{\partial e_i^2} \equiv U_{ee} = 2b\mathcal{B}+\mathcal{D}+v_i''(E) \tag{A.5}$$

$$\frac{\partial^2 U_i}{\partial e_i \partial h_i} \equiv U_{he} = (a+cb)\mathcal{B}+c\mathcal{D} \tag{A.6}$$

with

$$\mathcal{B} \equiv (1+\lambda\eta)u_i'(\underline{w_i}) - (1+\eta)u_i'(\overline{w_i}) > 0, \tag{A.7}$$

$$\mathcal{D} \equiv p(.)(1+\lambda\eta)u_i''(\underline{w_i}) + (1-p(.))(1+\eta)u_i''(\overline{w_i}) < 0. \tag{A.8}$$

Notice that $U_{hh} < 0$, $U_{ee} < 0$ and $U_{he} < 0$ under assumption 1. Moreover, $U_{hh}U_{ee} - U_{he}^2 = \mathcal{B}^2(-a+cb)^2 + v_i'' \times U_{hh} > 0$.

B Proof of Proposition 1

Let us derive the FOC with respect to λ:

$$\frac{\partial^2 U_i}{\partial h_i \partial \lambda} \equiv U_{h\lambda} = -\eta a(u_i(\underline{w}_i) + \underline{H}) - c\eta p(.)u_i'(\underline{w}_i) \tag{B.9}$$

$$\frac{\partial^2 U_i}{\partial e_i \partial \lambda} \equiv U_{e\lambda} = -\eta b(u_i(\underline{w}_i) + \underline{H}) - \eta p(.)u_i'(\underline{w}_i) \tag{B.10}$$

The sign of $\frac{dh_i}{d\lambda}$ is given by the sign of the following expression:

$$\begin{aligned} U_{e\lambda}U_{he} - U_{h\lambda}U_{ee} &= -U_{h\lambda}v_i''(E) + \eta\mathcal{D}(u_i(\underline{w}_i) + \underline{H})(a-cb) \\ &\quad -\eta\mathcal{B}\left[(a-cb)(u_i(\underline{w}_i) + \underline{H}) + pu_i'(\underline{w}_i)(a-cb)\right] \end{aligned} \tag{B.11}$$

This expression is negative under Assumption 1.

The sign of $\frac{de_i}{d\lambda}$ is given by the sign of the following expression:

$$\begin{aligned} U_{h\lambda}U_{he} - U_{e\lambda}U_{hh} &= \eta(u_i(\underline{w}_i) + \underline{H})(a-cb)\left(-c\mathcal{D} + p_h\mathcal{B}\right) \\ &\quad +\eta\mathcal{B}(a-cb)cpu_i'(\underline{w}_i) \end{aligned} \tag{B.12}$$

Notice that $-c\mathcal{D} - a\mathcal{B} > 0$ since $U_{hh} < 0$. We obtain that this expression is positive under

Assumption 1.

Now let us turn to precautionary savings defined by $s = w - ch + e$, the effect of λ is given by:

$$-c\left[U_{e\lambda}U_{he} - U_{h\lambda}U_{ee}\right] - \left[U_{h\lambda}U_{he} - U_{e\lambda}U_{hh}\right] > 0 \tag{B.13}$$

under A1.

Let us derive the FOC with respect to β_i:

$$\frac{\partial^2 U_i}{\partial h_i \partial \beta_i} \equiv U_{h\beta} = 0 \tag{B.14}$$

$$\frac{\partial^2 U_i}{\partial e_i \partial \beta_i} \equiv U_{e\beta} = v'(E) > 0 \tag{B.15}$$

The sign of $\frac{dh_i}{d\beta_i}$ is given by the sign of $U_{e\beta}U_{he}$ which is negative.

The sign of $\frac{de_i}{d\beta_i}$ is given by the sign of $-U_{e\beta}U_{hh}$ which is positive.

Finally, the sign of $\frac{s}{d\beta_i}$ is given by the sign of $U_{e\beta}\left[-cU_{he} + U_{hh}\right] > 0$ under A1.

C Proof of Proposition 2

Let us derive the FOC with respect to $\underline{H}$:

$$\frac{\partial^2 U_i}{\partial h_i \partial \underline{H}} \equiv U_{h\underline{H}} = -a(1 + \lambda\eta) < 0 \tag{C.16}$$

$$\frac{\partial^2 U_i}{\partial e_i \partial \underline{H}} \equiv U_{e\underline{H}} = -b(1 + \lambda\eta) < 0 \tag{C.17}$$

The sign of $\frac{dh_i}{d\underline{H}}$ is given by the sign of the following expression:

$$\begin{aligned} U_{e\underline{H}}U_{he} - U_{h\underline{H}}U_{ee} &= -(1 + \lambda\eta)\left(bU_{he} - aU_{ee}\right) \\ &= -(1 + \lambda\eta)\left[(cb - a)\left(b\mathcal{B} + \mathcal{D}\right) - av''(E)\right] \end{aligned} \tag{C.18}$$

We know that $a\mathcal{B} + c\mathcal{D} < 0$, then $b\mathcal{B} + \mathcal{D} < \frac{\mathcal{D}}{a}(a - cb)$ that is negative. Thus, the expression between brackets is positive and the sign of $\frac{dh_i}{d\underline{H}}$ is negative.

The sign of $\frac{de_i}{d\underline{H}}$ is given by the sign of the following expression:

$$U_{h\underline{H}}U_{he} - U_{e\underline{H}}U_{hh} = -(1+\lambda\eta)\left(aU_{he} - bU_{hh}\right) \tag{C.19}$$

$$= -(1+\lambda\eta)(a-cb)(a\mathcal{B} + c\mathcal{D})$$

Since $c\mathcal{D} + a\mathcal{B} < 0$, this expression is positive under Assumption 1.

Finally, the sign of $\frac{ds_i}{d\underline{H}}$ is given by the sign of $\frac{d(ch_i+e_i)}{d\underline{H}}$:

$$-(1+\lambda\eta)\left[(cb-a)^2\mathcal{B} - acv''(E)\right] > 0. \tag{C.20}$$

Let us derive the FOC with respect to E_0:

$$\frac{\partial^2 U_i}{\partial h_i \partial E_0} \equiv U_{hE_0} = cb\mathcal{B} \tag{C.21}$$

$$\frac{\partial^2 U_i}{\partial e_i \partial E_0} \equiv U_{eE_0} = \beta_i v''(E) - b\mathcal{B} \tag{C.22}$$

The sign of $\frac{dh_i}{dE_0}$ is given by:

$$U_{eE_0}U_{he} - U_{hE_0}U_{ee} = \beta_i v''(E)\left(c\mathcal{D} + a\mathcal{B}\right) + b\mathcal{B}^2(a-cb) > 0 \tag{C.23}$$

The sign of $\frac{de_i}{dE_0}$ is given by:

$$U_{hE_0}U_{he} - U_{eE_0}U_{hh} = -\beta_i v''(E)U_{hh} - bc\mathcal{B}^2(a-cb) < 0 \tag{C.24}$$

The effect of E_0 on savings is given by the sign of $-ac\beta_i v''(E)\mathcal{B}$ which is positive.

D Proof of Proposition 3

The first order conditions in a decentralized economy writes:

$$\frac{\partial U}{\partial h} = -a\left[(1+\lambda\eta)(u(\underline{w})+\underline{H}(m_H)) - (1+\eta)(u(\overline{w})+\overline{H})\right] \quad \text{(D.25)}$$
$$-c\left[p(h,E(m_E))(1+\lambda\eta)u'(\underline{w_i}) + (1-p(h,E(m_E)))(1+\eta)u'(\overline{w})\right] = 0$$

$$\frac{\partial U}{\partial e} = -b\left[(1+\lambda\eta)(u(\underline{w})+\underline{H}(m_H)) - (1+\eta)(u(\overline{w})+\overline{H})\right] \quad \text{(D.26)}$$
$$+\beta v'(E(m_E)) - \left[p(h,E(m_E))(1+\lambda\eta)u'(\underline{w}) + (1-p(h,E(m_E)))(1+\eta)u'(\overline{w})\right] = 0$$

The first order conditions at the social optimum writes:

$$\frac{\partial W}{\partial h} = -a\left[(1+\lambda\eta)(u(\underline{w})+\widehat{\underline{H}}) - (1+\eta)(u(\overline{w})+\overline{H})\right] \quad \text{(D.27)}$$
$$-c\left[p(h,\widehat{E})(1+\lambda\eta)u'(\underline{w_i}) + (1-p(h,\widehat{E}))(1+\eta)u'(\overline{w})\right] = 0$$

$$\frac{\partial W}{\partial e} = -bN\left[(1+\lambda\eta)(u(\underline{w})+\widehat{\underline{H}}) - (1+\eta)(u(\overline{w})+\overline{H})\right]$$
$$+N\beta v'(\widehat{E}) - \left[p(h,\widehat{E})(1+\lambda\eta)u'(\underline{w}) + (1-p(h,\widehat{E}))(1+\eta)u'(\overline{w})\right] = 0 \quad \text{(D.28)}$$

Suppose that v is linear, by comparing Eq.(D.25) and Eq.(D.27), and Eq.(D.26) and Eq.(D.28), we have:

$\underline{H}(m_H) = \widehat{\underline{H}} - \frac{cb}{a(1+\lambda\eta)}\mathcal{B}\left[\widehat{E}_0 - E_0(m_E)\right]$ and thus

$E_0(m_E) = \widehat{E}_0 + \frac{a(N-1)}{a-cb}\frac{\left[(1+\eta)(u(\overline{w})+\overline{H})-((1+\lambda\eta)(u(\underline{w})+\widehat{\underline{H}})\right]+\frac{\beta}{b}}{\mathcal{B}} > \widehat{E}_0$

and $\underline{H}(m_H) = \widehat{\underline{H}} + \frac{(N-1)cb}{(a-cb)(1+\lambda\eta)}\left[(1+\eta)(u(\overline{w}) + \overline{H}) - ((1+\lambda\eta)(u(\underline{w}) + \widehat{\underline{H}}) + \frac{\beta}{b}\right] > \widehat{\underline{H}}$.

E Instructions

The experiment you will be participating in is designed to study the decision-making of air pollution risk reduction. Please read the instructions in full. These instructions should allow you to understand the experience. In this experiment, you will be able to earn up to XX euros (including between 5 and 15 euros participation fee).

Your earnings will depend on your decisions as well as the decisions of other participants. All your answers will be processed anonymously and will be backed up via a computer system. You will tell your choices to the computer you are sitting at and the computer will calculate your earnings made during the experiment. The total amount of money earned during the experiment will be paid to you, in cash, at the end of the experiment.

From now on, we ask you not to speak. If you have a question, raise your hand and an experimenter will come and answer in private.

The experiment has two parts. The first part consists of several periods and a series of choices, The second part includes a questionnaire. The choices you make in the first part will allow you to earn money depending on the decisions made. At the end of the experiment, one of the choices among all those you have made in the first part will be drawn and will be used for remuneration. Your experience-related earnings will be equal to a fixed participation payment to which will be added the winnings in the random choice. Earnings are expressed in euros.

If this is not already the case, consider that you live in the Paris region. The air quality in this region is sometimes poor. Scientific studies have established an impact of air pollution on environmental quality and health.

Message processing (1 message per subject): 3 Possible Messages: M1 no message, M2: health message, M3: environment message

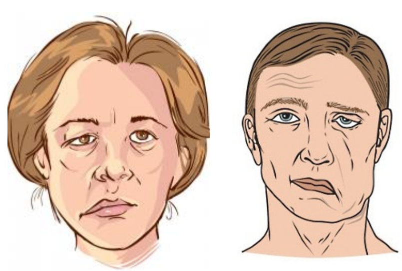
CONTROL (T1): no specific impacts specified

HEALTH (T2): Specifically, scientists have shown that air pollution increases the risk of chronic obstructive pulmonary disease, the risk of heart disease, the risk of stroke and the risk of lung cancer.

Lung with chronic obstructive disease:

A heart attack:

Paralysis resulting from a stroke:



Cancerous lung:

ENVIRONMENT (T3): In particular, scientists have shown that air pollution increases climate disruption, leading to an expansion of the habitat for ticks, tiger mosquitoes, and other tropical insects, an increase in the frequency of heat waves and pollution clouds that obscure the sun and darken buildings, and an increase in acid rain that harms flora. Destruction of the flora:

Tiger mosquitoes:

Pollution cloud:

Blackened building:

Your probability of illness due to air pollution depends: (i) on your actions that reduce air pollution, (ii) actions that reduce air pollution of other inhabitants of Paris,(iii) your personal actions to protect against air pollution. We are interested in this part of the experience to your choices in the face of air pollution and its effects.

The part consists of several periods and a series of choices. At the beginning of this game, the central computer will randomly form groups of 4 participants. The composition of the groups will remain unchanged throughout the experiment. You can't identify other members of your group and they won't be able to identify you. The game consists of 10 periods. At the beginning of each period, you, along with the three other members of your group, have an endowment of 20 euros that you can invest in various actions to deal with air pollution that can reduce your likelihood of illness due to this air pollution.

Your initial probability of illness due to air pollution is 25%; or 1 in 4.

In case of illness, you lose 10 euros. At the end of each period of the experiment, a random draw made by the computer will determine whether you get sick or not, and therefore if you lose 10 euros. The likelihood of illness will depend on your choices and those of the other 3 members of your group.

Here's what your choices can be. At the beginning of each period, you, along with the three other members of your group, have an endowment of 20 euros. You have to decide how to divide these euros between three accounts. In general, every euro gives the possibility of reducing air pollution. At the end of each period, your gain will depend on the euros you have invested in each account.

We now present these three accounts:

Account 1: Euros placed in this account finance so-called Type 1 gestures. This investment is measures to protect you and you alone from the harmful effects of air pollution. For example, avoiding travelling and doing physical activities outdoors during peak hours, prefer less congested streets when walking, buying an indoor air purifier, wearing a mask or taking food supplements. The quantitative benefits of this investment will be clarified later.

Account 2: Euros placed in this account finance so-called Type 2 gestures. This investment is measures to reduce your polluting emissions, and therefore protect you and other members of your group from the harmful effects of air pollution. For example, driving less (by taking public transit or carpooling), reducing your electricity consumption (by turning off the lights when you go out,improving the insulation of the house, or drying laundry in the open rather than in a tumble dryer). The quantitative benefits of this investment will be clarified later.

Account 3: Euros placed in this account are spared, they are not invested in Type 1 gestures or type 2 gestures. They have no effect on reducing pollution.

Euros placed in these three accounts can have two types of benefits for you: a monetary benefit (type A) and an increase in the chances of not getting sick (type B). Below is an explanation of both types of benefits.

Type A profits: The distribution of 20 euros between the 3 accounts has an impact on your monetary gains: in each period, the euros placed in these three accounts can earn (or not) euros.

- Every euro invested in Type 1 gestures does not earn you euros,so do not earn you a Profit of Type A, only a Profit of Type B (described below)

- Every euro invested in Type 2 gestures earns 0.4 euros to all members of your group, including you. These euros represent the quality of the environment, which is improving thanks to a reduction in polluting emissions.

- Every euro saved (count 3) earns you 1 euro alone.

RISK TREATMENT The initial probability of suffering from a disease caused by pollution is 25%, or 1 in 4. This means that one in four people will be sick. The choice of investing euros in the accounts has an impact on this probability that we will describe.

Every euro invested in Type 1 gestures reduces the probability of being sick by 0.4% for you and you alone. For example, if you invest your 20 euros in Type 1 gestures, this would reduce your probability of being sick by 0.4 x 20 = 8%. Therefore, your final probability of getting sick will be 17%, i.e. about one in six chances instead of a one in four chance.

Every euro invested in Type 2 gestures reduces the probability of getting sick by 0.25% for all members of your group, including you. For example, if all members of your group, including you, invest the 20 euros in Type 2 gestures, this would reduce your probability of being sick by 0.25 x 80 = 20%. Therefore, your final probability of getting sick will be 5%, i.e. a one in 20 chance instead of a one in four chance.

Each euro saved (account 3) has no impact on the probability of being sick at the end of the period.

To help you better understand Type B benefits, we will offer other examples. Let's take the three examples used for Type A profits. As a reminder, in these examples, the total number of euros invested by other members of your group in the type 2 gesture account is 30 euros. As a result, these choices help reduce the chances of you getting sick by 0.25 x 30 = 7.5%.

Let's look at the consequences on your chances of getting sick from three examples of choices for you.

Example 1: You have invested all your 20 euros in Type 1 gestures. Your investment will reduce the likelihood of being sick by 0.4% x 20 =8%. In addition, the reduction will be due to the decisions of the members of your group. Your final probability of getting sick will therefore be 25% - 8% - 7.5% = 9.5%.

Example 2: You have invested all your 20 euros in Type 2 gestures. Your investment will be in addition to that of other members of your group and your probability of getting sick will be reduced by: 0.25% x (30-20) = 12.5%. Your final probability of being sick will therefore be equal to 25% - 12.5% = 12.5%.

Example 3: You have saved all your 20 euros. This investment will not reduce your likelihood of being sick beyond the investments of other members of your group on the Type 2 gesture account, which reduces your probability of getting sick by 0.25% x 30 = 7.5%. Your final probability of getting sick will therefore be 25% - 7.5% =17.5%.

At the end of each period, the computer will calculate your total earnings. These total gains therefore depend on your Type A profits (euros reported from your investments) and your Type B profits (whether or not you are affected by the disease). To determine whether or not you are suffering from an illness, there will be a draw corresponding to your final probability of getting sick at each period. This draw will be done by the computer. For example, suppose the probability of getting sick is 10%, everything will happen as if there were a bag containing 10 balls including 1 red ball and 9 blue balls. Then a ball is drawn from the bag. If the ball pulled is red, you are considered to get sick during this period.

To help you make your decision, we present you in the table below various examples. If your final gain is less than zero, we will deduct this amount from your participation fee initially equal to 15 euros. (In any case, at the end of the experiment, you will leave with a positive monetary sum).

Gains from the proportion of the budget invested in both types of actions

My choice			Average choice others			Likelihood of getting sick		Earnings in euros if you don't get sick	Earnings in euros if you get sick
Type 1	*Type 2*	*Savings*	*Type 1*	*Type 2*	*Savings*				
20	0	0	20	0	0	17%	about 1 in 6	0	-10
20	0	0	0	20	0	2%	1 in 50	24	14
20	0	0	0	0	20	17%	about 1 in 6	0	-10
0	20	0	20	0	0	20%	1 in 5	8	-2
0	20	0	0	20	0	5%	1 in 20	32	22
0	20	0	0	0	20	20%	1 in 5	8	-2
0	0	20	20	0	0	25%	1 in 4	20	10
0	0	20	0	20	0	10%	1 in 10	44	34
0	0	20	0	0	20	25%	1 in 4	20	10
10	10	0	10	10	0	11%	about 1 in 9	16	6
10	0	10	10	0	10	21%	about 1 in 5	10	0
0	10	10	0	10	10	15%	about 1 in 7	26	16
5	5	10	5	5	10	13%	about 1 in 8	21	11

Final details All members of your group (including you) make their decisions simultaneously. When all members of the group have made their decisions, a "Recap" screen appears. This screen reminds you of the number of euros you have placed in each of the three accounts and informs you of the total number of euros placed by the other members of your group on the Type 2 gesture account, if you have been affected by the disease, as well as your gain in euros for the period. At any time, by clicking the "History" button, you can access the history of previous periods. The history shows for past period, the number of euros you placed in each of the three accounts, the total number of euros placed by your group in the Type 2 gesture account, if you have been affected by the disease, and your gain in euros for the period.

Understanding questionnaire

Screens

- Group constitution of 4 participants

- Screen Period 1

  1st choice of investment in different accounts

  Euros in account 1: choice of subject between 0 and 20: C1

  Euros in account 2: choice of subject between 0 and 20: C2

  Euros in account 3: C3 - 20 - C1 - C2,

- Summary screen Period 1

  Your choice

  Choice of other members of the group: sums of euros invested by others in the 3 accounts

  Your probability of illness

  Your earnings if you don't get sick

  Your earnings if you get sick

- Screen Drawing Illness or not

  Period 1 earnings

- Screens Period 2 to 10

  Identical to Period 1, with an additional Historical button that displays for each period spent, the number of euros placed by the subject on each of the three accounts, the total number of euros placed by her group on the account of Type 2 gestures, if he was affected by the disease, and her gain in euros for the period.

F Elicitation questionnaire

[ALL TREATMENTS]

From now on, you are no longer in a group. Your choices have no impact on others and others' choices have no impact on your earnings.

F.1 Risk aversion elicitation

[ALL TREATMENTS]

From the following ten choices, please indicate which lottery you prefer. If one of these choices is drawn at the end of the experiment, you will be paid according to the outcome of the chosen lottery.

Lottery A				Lottery B				Selected option	
Gain (ecus)	probability	Gain (ecus)	probability	Gain (ecus)	probability	Gain (ecus)	probability	Lottery A	Lottery B
20	1/10	16	9/10	38.5	1/10	10	9/10		
20	2/10	16	8/10	38.5	2/10	10	8/10		
20	3/10	16	7/10	38.5	3/10	10	7/10		
20	4/10	16	6/10	38.5	4/10	10	6/10		
20	5/10	16	5/10	38.5	5/10	10	5/10		
20	6/10	16	4/10	38.5	6/10	10	4/10		
20	7/10	16	3/10	38.5	7/10	10	3/10		
20	8/10	16	2/10	38.5	8/10	10	2/10		
20	9/10	16	1/10	38.5	9/10	10	1/10		
20	10/10	16	0/10	38.5	10/10	10	0/10		

F.2 Loss aversion elicitation

[ALL TREATMENTS]

In each line, please indicate which alternative you prefer between Alternative A (lottery) and Alternative B (certain amount). If one of these choices is drawn at the end of the experiment, you will be paid according to the result of this choice.

Alternative A (lottery)		Alternative B (certain amount)	
	Choice of A	Choice of B	
Likelihood: 50% Gain: 50 ecus			50
			40
			30
			20
			10
			0
Likelihood: 50% Loss: 50 ecus			-10
			-20
			-30
			-40
			-50

F.3 Questionnaire

[ALL TREATMENTS]

Environmental attitudes and social preferences, individual characteristics

1/ To what extent do you agree or disagree with each of these statements?

declaration	Disagree at all 1	Rather disagree 2	I do not know 3	Rather agree 4	Quite agree 5
We are approaching the limit number of people the earth can feed					
Human beings have the right to change the natural environment according to their needs					
When human beings try to change the course of nature it often produces disastrous consequences					
Human ingenuity will ensure that we will NOT make the earth unlivable					
Human beings are seriously mistreating the environment					
The land would have an infinite number of natural resources if only we knew how to make better use of it					
Plants and animals have as much right as human beings to exist					
The balance of nature is strong enough to cope with the effects of modern industrial nations					
Humans will one day learn enough about how nature works to be able to control it					
If things continue at the current rate, we will soon experience a major ecological disaster					

2/ Not all people in our society agree on the limits of their ability to make decisions for themselves. To what extent do you agree or disagree with each of these statements?

declaration	Disagree at all	Disagree	Rather disagree	Rather agree	All right	Quite agree
Government interferes far too much in our daily lives.						
Sometimes the government has to impose laws to prevent people from harming themselves.						
It is not the government's business to try to protect people from themselves.						
The government should stop telling people how they should live.						
The government should do more to achieve societal goals, even if it means limiting individuals' freedom and choices.						
The government should limit the choices that individuals can make so that they do not interfere with what is good for society.						

3/ In our society, people often disagree on issues of equality and discrimination. To what extent do you agree or disagree with each of these statements?

declaration	Disagree at all	Disagree	Rather disagree	Rather agree	All right	Quite agree
We have gone too far in promoting equal rights in this country.						
Our society would be better off if the distribution of wealth were more egalitarian.						
We need to significantly reduce inequalities between rich and poor and between women and men.						
Discrimination against minorities remains a very serious problem in our society.						
It seems that immigrants, women or homosexuals do not want equal rights, but special rights for them.						
Society as a whole has become too soft and feminine.						

4/ Please indicate your agreement or disagreement with the following statements:

	Disagree at all	Disagree	Rather disagree	Rather agree	All right	Quite agree
I am informed about the problem of air pollution.						
My location is served by public transport.						
I have respiratory or cardiovascular problems (for example, asthma).						
I always feel like I can control the direction my life is going.						

G Results

Fig. 9: Difference of means in contributions: Message vs no message

```
. ttest contrib_2, by(Message)

Two-sample t test with equal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
       0 |     560    .2961607    .0131703    .3116671    .2702913    .3220301
       1 |   1,120      .38125    .0100199    .3353286    .3615902    .4009098
---------+--------------------------------------------------------------------
combined |   1,680    .3528869    .0080509    .3299868    .3370961    .3686777
---------+--------------------------------------------------------------------
    diff |           -.0850893    .0169568               -.1183479   -.0518306
------------------------------------------------------------------------------
    diff = mean(0) - mean(1)                                      t =  -5.0180
Ho: diff = 0                                     degrees of freedom =     1678

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000
```

Fig. 10: Difference of means in contributions: environment message vs health or no message

```
. ttest contrib_2, by(environment)

Two-sample t test with equal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
       0 |   1,120     .329375    .0095521    .3196758    .3106329    .3481171
       1 |     560    .3999107    .0145879    .3452139    .3712568    .4285646
---------+--------------------------------------------------------------------
combined |   1,680    .3528869    .0080509    .3299868    .3370961    .3686777
---------+--------------------------------------------------------------------
    diff |           -.0705357    .0169965               -.1038723   -.0371991
------------------------------------------------------------------------------
    diff = mean(0) - mean(1)                                      t =  -4.1500
Ho: diff = 0                                     degrees of freedom =     1678

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000
```