How Beliefs Influence the Willingness to Contribute to Prevention Expenditure

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Abstract

We study how beliefs affect individuals' willingness to contribute to prevention expenditure through a two-type, N-person public good game and test several results empirically. We show analytically that pessimistic agents will invest more in prevention expenditure than optimists. We also demonstrate how small differences in beliefs may induce substantial differences in type-related prevention expenditure. The more atomistic agents are the less they will contribute to the public good. Pessimistic beliefs then lead to a 'double deprivation' and we discuss potential issues and remedies. The more optimistic the society the lower will be its total green expenditure. We then use a large international survey to study how beliefs and additional controls determine prevention expenditure. We rely on several proxies for beliefs and the willingness to contribute to prevention expenditure which we combine through Principal Component Analysis. In addition, we investigate the role of environmental education for the relationship between beliefs and the willingness to contribute. Because of potential endogeneity bias due to unobserved variables that are likely to affect both beliefs and the willingness to contribute we follow the theoretical analysis and resort to a recursive bivariate model. Our main findings are very much in line with the theoretical predictions. We find, across all specifications, that more optimistic beliefs lead to a lower willingness to contribute. Environmental education affects the willingness to contribute only indirectly through its impact on beliefs.

Key words: beliefs, bivariate probit estimation, environment, Nash game, public goods, willingness to contribute

JEL classification: H0, Q50.

There has been little emphasis on the importance of beliefs when it comes to understanding an individual's attitude towards prevention expenditure. Indeed, one would imagine that an individual's beliefs are among the main drivers of environmental attitude and behavior. In that case, different beliefs are clearly a crucial aspect to study when one is concerned with decisions under uncertainty, policy implications, the effect of information and contributions to public goods. The objective of this article is to investigate whether and how beliefs affect the willingness to contribute to the environment. Our main contribution in this article is to show that, indeed, beliefs are significant drivers of an individual's willingness to contribute to prevention expenditure.

The theoretical contribution consists of analyzing the effects of beliefs on prevention expenditure in a general N-player public good game. Our model is embedded in the literature of private provision of public goods, starting with Samuelson (1954, 1955) and further developed by Bergstrom, Blume, and Varian (1986) and Cornes and Sandler (1996).[1] Here we study a specific version of these models, namely a N-player public good game with different beliefs. In particular, we suggest that there are two types of agents, pessimistic and optimistic ones, where those that are pessimistic believe that environmental shocks have a stronger impact on their net income than those that are optimistic. Within this setting we study how beliefs affect the willingness to contribute to prevention expenditure. Then we examine whether the predictions of the model carry forward to the data and study the importance of beliefs for explaining differences in the willingness to contribute to prevention expenditure.

While there exists a growing number of articles that explain why a certain belief evolves through society,[2] these articles do not study how the beliefs impact decision making. Hence, in this article we assume that individuals already hold certain beliefs and investigate how these affect investments in a public good (prevention expenditure). In line with much of the recent theoretical literature, our model predicts that agents who are pessimistic and believe that environmental degradation is likely to be a serious threat to their welfare will

invest more in prevention than optimists. Furthermore, the more optimistic the society the lower will be its total green expenditure. We also demonstrate how even small differences in beliefs may induce substantial differences in type-related prevention expenditure. This difference in beliefs ultimately leads to what we call a 'double deprivation': pessimistic agents are worse off, i.e. have a lower indirect utility, because they hold both pessimistic beliefs and at the same time spend more on prevention expenditure than optimists. We discuss potential policy issues and remedies that may arise from this double deprivation.

We then use a large international survey that covers 22 countries to study determinants of prevention expenditure. Based on the analytical model we proxy both beliefs and the willingness to contribute through sets of variables that we combine via Principal Component Analysis. As controls we resort to a standard set of socio-economic characteristics, namely gender, age, marital status, religion and social class. One additional variable that we place stronger emphasis on is environmental education. We hypothesize that environmental education affects the willingness to contribute through its effect on the respondents' beliefs. Our econometric model then is a recursive bivariate model, with one equation determining the willingness to contribute and one equation determining the beliefs. In line with the predictions we find that a respondent's beliefs have a highly statistically significant impact on the willingness to contribute to prevention expenditure. However, environmental education shapes this relationship. As a general result we find that environmental education affects the respondents' willingness to contribute only via its impact on beliefs. We find these results to be robust to additional controls that have been shown to bear significant effects on individuals' attitudes towards prevention expenditure, as well as to a variety of different specifications and modeling assumptions.

There already exists a larger literature on the determinants of individuals' attitudes towards prevention expenditure. However, the main variables that have been focused on are socio-demographic ones like age and gender (Whitehead 1991; Carlsson and Johansson-Stenman 2000; Howell and Laska 1992; Nord, Luloff, and Bridger 1998), marital sta-

tus (Dupont 2004), in addition to education (Blomquist and Whitehead 1998; Engel and Pötschke 1998; Danielson et al. 1995), wealth (Stevens, More, and Glass 1994; Popp 2001; Israel and Levinson 2004), geographic locality (Veisten et al. 2004; Bulte et al. 2005) and political interests (Torgler and García-Valiñas 2007) or social capital (Ostrom 1990; Owen and Videras 2007). An excellent overview of much of the literature can be found in Torgler and García-Valiñas (2007). Thus, we basically contribute to this literature by studying whether and how beliefs and their determinants affect the willingness to contribute to prevention expenditure.

We proceed as follows. In the next section we study how beliefs affect contributions to safety or environmental maintenance in a simple public good game. Following this is a section with an empirical investigation of the effect of beliefs on the willingness to contribute to the environment. We use this to study whether the intuition from the model carries forward into the real world. The final section concludes.

The Model

The model that we propose here is a two-type, N-player public good game, where each player takes the optimal decisions of the other players as given when choosing the own strategy. The public good in this model is the sum of prevention expenditure which reduces the impact of a shock on final wealth. One may, for example, have in mind here a nation's abatement effort to reduce climate change. The public good would then be the total prevention expenditure. The setup that we present here follows closely that of the standard public good literature, see e.g. Bergstrom, Blume, and Varian (1986) and Cornes and Sandler (1996). The players may choose to invest an amount $x_i \geq 0$, where $i = 1, ..., N$, of their wealth $w > 0$ into prevention expenditure. This reduces the impact of an expected shock on net wealth $w - x_i$, where the shock comes as a percent $1 - F_i$ of net wealth. The two types differ only in their belief of the extent to which they are impacted by the shock. Pessimists, denoted by subscript p, believe that the shock has a stronger impact on their final wealth

than optimists, denoted by subscript o. There are N_o optimists and consequently $N - N_o$ pessimists. We write the shock as $\Omega_i = 1 - F(\sum_{i=1}^{N} x_i, k) \in (0,1)$, where $k \geq 1$ denotes the types' beliefs on the shock. Optimists are assumed to believe that $k = 1$, while pessimists believe that $k > 1$. The shape of function $F(\sum_{i=1}^{N} x_i, k) \in (0,1)$ follows $F(0,k) > 0$, $F(\infty,k) = 1$, $F_x > 0$, $F_x(0,k) = \infty$, $F_k < 0$, $F_{xk} > 0$ and $F_{xx} < 0$.

The utility functions are assumed to be linear in final wealth and thus take the form

$$(1) \quad V_i = (w - x_i) F\left(\sum_{i=1}^{N} x_i, k\right).$$

This functional form has been analyzed in Bergstrom and Cornes (1981), with the main difference being that we allow here for different beliefs. For our later analysis we assume that utility is cardinal and fully comparable. This holds, for example, if the units of utility are denoted in monetary terms.[3]

In this N-person game each player i has a strategy set Ω_i, with $x_i \in \Omega_i$, and a pure strategy payoff function V_i that gives utility $V_i(\mathbf{x}) = V(x_i, x_{-i})$ for each strategy profile $\mathbf{x} = (x_1, ..., x_n) \in \Omega = \Omega_1 \times \cdots \times \Omega_n$. The strategy set Ω_i consists of $\Omega_i \in [0, w]$. We write the game in normal form as $\Gamma = [N, \Omega_i, V_i(\cdot)]$.

Definition 1 *A strategy profile* $\boldsymbol{x} = (x_1, ...x_n)$ *is a Nash-equilibrium of game* $\Gamma = [N, \Omega_i, V_i(\cdot)]$ *if, for all* $i = 1, ..., n$, $V_i(x_i, x_{-i}) \geq V_i(x_i', x_{-i})$, *for all* $x_i' \in \Omega_i$.

Assume that agents choose according to the Nash game as defined above. Then the first-order condition of player i is

$$(2) \quad w - x_i \leq \frac{F(\sum_{i=1}^{N} x_i, k)}{F_x(\sum_{i=1}^{N} x_i, k)},$$

which holds with equality if $x_i > 0$. There are N of these first-order conditions. The second-order condition is given by

$$(3) \quad -2F_x(\sum_{i=1}^{N} x_i, k) + (w - x_i) F_{xx}(\sum_{i=1}^{N} x_i, k) < 0.$$

Proposition 1 *The game* $\Gamma = [N, \Omega_i, V_i(\boldsymbol{x})]$ *has a unique Nash equilibrium.*

All proofs can be found in the supplementary appendix online. Having defined the Nash game and having shown that a unique Nash equilibrium exists, we now proceed to derive the main properties of this setup. At the Nash equilibrium, all optimists will choose the same x_o and all pessimists the same x_p. Consequently, we obtain the two type-dependent first-order conditions

$$w - x_p \leq \frac{F(N_o x_o + (N - N_o)x_p, k)}{F_x(N_o x_o + (N - N_o)x_p, k)}, \tag{4}$$

$$w - x_o \leq \frac{F(N_o x_o + (N - N_o)x_p, 1)}{F_x(N_o x_o + (N - N_o)x_p, 1)}, \tag{5}$$

where equation (4) holds with equality if $x_p > 0$, and (5) holds with equality for $x_o > 0$. Prevention expenditure x_i reduces initial wealth w, while it increases final wealth through diminishing the damage that a shock S causes. Clearly, the higher the damage the larger will be the optimal prevention expenditure. Furthermore, the higher the marginal contribution of x_i towards damage reduction the larger should be the optimal prevention expenditure.

Also, it can be shown that prevention expenditure of both types are substitutes, in the sense that $\frac{dx_p(x_o)}{dx_o} < 0$.[4] Thus, if optimists were to reduce their prevention expenditure (for whatever reason, e.g. a preference change or wealth change) then pessimists increase theirs. This is a result of the Nash game setting and the fact that prevention expenditure of both types is assumed to be a linear combination in the loss function. It means that there is no difference in who provides the public good - for the public good a dollar from a pessimist is the same as a dollar from an optimist. However, this also implies that if pessimists become more pessimistic (e.g. due to new information on climate change), then while they will increase their prevention expenditure, the optimists will reduce theirs. Thus, there is clearly an issue of some degree of free-riding on the pessimism of the others. While this free-riding is the result of optimal decisions at Nash Equilibrium and not due to moral hazard, it would, for example, pose an issue if beliefs can be subjectively chosen.[5]

We now summarize the results in the following proposition.

Proposition 2 *Given the game* Γ*, we find that, at the Nash equilibrium as defined in Definition 1, the following results hold:*

1. *either* $x_p > 0$ *and* $x_o = 0$*, or* $x_p > 0$ *and* $x_o > 0$*;*
2. $x_p > x_o$*;*
3. $\frac{dx_p}{dk} > 0$.

Part 1 of Proposition 2 implies that pessimists are always willing to have a positive amount of prevention expenditure, while optimists either have a corner solution or an interior one.[6]

Part 2 holds that, ceteris paribus, optimists would be willing to contribute lower amounts towards the public good prevention expenditure than pessimists. The last part of Proposition 2 states that pessimists will increase their prevention expenditure if they believe that a shock has a stronger impact. Combining this with the result that prevention expenditures of the two types are strategic substitutes we know that an increase in the differences of beliefs will lead to a lower optimal amount of prevention expenditure of the optimists.[7]

A simple numerical example (available in the supplementary appendix online) shows furthermore that even minor differences in beliefs may lead to significant differences in the optimal green expenditure at Nash equilibrium.[8] This means that the distribution, or the variety, of the beliefs may play a significant role in the total amount of prevention expenditure at this decentralized equilibrium. Consequently, a society with many optimists but only few pessimists may see a significant degree of free-riding on the beliefs of the pessimists.

Another variable that affects whether an individual will want to undertake preventive action depends on his or her belief as to whether or not the individual's actions have an impact on the environment. A respondent who believes that he alone cannot improve environmental quality will not resort to the same level of prevention expenditure as those individuals who believe that they may actually have an influence. Based on our model above we can

derive this result mathematically as follows. Define the number of optimists as $N_o + m$, where $m > 0$, while we keep the number of pessimists constant. Then function F can be re-written as $F = F((N_o + m)x_o + (N + m - N_o - m)x_p, 1)$. The comparative statics at Nash equilibrium then lead to

$$\frac{dx_o}{dm} = -\frac{F_x^2 - FF_{xx}}{F_x^2 + (N_o + m + (N - N_o)\frac{\partial x_p}{\partial x_o})(F_x^2 - FF_{xx})} x_o < 0, \tag{6}$$

with an equivalent result for dx_p/dm. As a consequence, atomism, namely the degree to which one believes one can affect the environment, has a negative impact on one's willingness to contribute to prevention expenditure.

On the 'Double Deprivation'

What we learn from this is, essentially, that environmental pessimists are subject to a 'double deprivation'. By this we mean that, firstly, their indirect utility is lower than the one from optimists for they believe that a shock will destroy more of their net wealth. Secondly, their indirect utility will be reduced further because they are willing to contribute more to prevention. In addition, the bigger the difference in beliefs between optimists and pessimists, the larger will be the prevention expenditure of the pessimists. Thus, *indirectly* through the Nash equilibrium, the beliefs of the optimists impose a burden on the pessimists. This can be most clearly observed in the climate change debate, where several countries hold the position of climate pessimists and strongly contribute to emission reductions, while other countries have optimistic beliefs and free-ride on the beliefs of the pessimists. Here we discuss some policy-relevant points that arise from the double deprivation.

Assuming that beliefs fall like mana from heaven and agents get randomly assigned a pessimistic or optimistic belief, then we have shown above that in a simple, non-cooperative game where all agents maximize utility subject to their constraints and taking the other agents' decisions as given, then the differences in beliefs lead to potentially substantial

differences in indirect utility. As a result, fairness falls short since those with pessimistic beliefs are subject to the double deprivation, while optimists may even free-ride on the beliefs of the pessimists. Consequently, should those that hold pessimistic beliefs also be required to pay for these beliefs? One may forward that this may require a policy intervention from a fairness perspective, with several positions being possible here depending on what one views as a fair, or just, situation.[9] While there exists a larger literature that makes a case for redistribution under utilitarianism with asymmetric preferences, see e.g. Cornes and Sandler (1993), it is generally unclear in which direction this redistribution should go. However, most people, when asked about their understanding as to what constitutes a just allocation, would propose some variant of equality of welfare.[10] Simply speaking, equality of welfare means striving for equal happiness across individuals. Since we assume that the individuals' beliefs are given and cannot be chosen by the individuals, then the fact that this makes pessimists subject to the double deprivation requires redistribution from most egalitarian theories of justice. The purpose of this section is to show that, under the more extreme notion of equality of welfare, a policy maker would want to redistribute in approximately the opposite way compared to the allocations chosen in the non-cooperative game outlined above.

Based on the model above, if a just outcome is perceived to be one where all agents are equally happy, then this requires equalization of indirect utility.[11] In this setting, equality of welfare suggests that pessimists should not get penalized for their stronger beliefs. Hence, a policy maker will attempt to influence prevention expenditure (through some kind of policy intervention like taxes) such that we obtain $(w-x_o)F\left(\sum x_i,k\right)=(w-x_p)F\left(\sum x_i,1\right)$. As the pessimists believe a shock to be more likely than optimists, equality of welfare demands optimists to contribute more to prevention expenditure than pessimists. Consequently, pessimists obtain a 'compensation' for their pessimistic beliefs.

In order for a policy intervention like this to be successful requires attention to other, more practical problems. For example, how can a policy maker really elicit who holds

which kind of belief? This is clearly a problem of asymmetric information which, essentially, gives rise to moral hazard from optimists. The optimists will try to pose as pessimists, since then they face lower taxes and consequently end up with a higher indirect utility. Whether the pessimists will announce to the policy maker that they are pessimists or optimists depends on whether the higher costs of the additional prevention expenditure that the pessimists would need to bear if they pose as optimists exceed those from the higher expected damage due to the lower total contribution if the pessimists announce that they are pessimists. As one can see, the attempt to elicit who holds which kind of belief will face substantial difficulties due to strategic behavior. Indeed, the policy maker will have to design a good mechanism that would prevent this kind of strategic behavior that feeds on the asymmetric information.

Clearly, the fairness problem exists because of the asymmetric beliefs. These tend to arise through non-Bayesian updating of beliefs (Bikhchandani, Hirshleifer, and Welch 1998; Ehrbeck and Waldmann 1996; Carroll 2003; Rabin and Schrag 1999; Lord, Ross, and Lepper 1979) or simply asymmetric information. Hence, in reality it cannot be expected that individuals hold 'correct' beliefs. In many cases the policy maker can follow the strategy to influence those beliefs via information provision, advertisement or education, in order to bring beliefs closer to the correct beliefs. Here, moral hazard or asymmetric information will be of secondary importance, especially if agents' beliefs strongly adjust to information. In the empirical section we show the importance of education for the willingness to contribute via its effect on beliefs. Hence, environmental education can play the important role of directing beliefs in a way such as to reduce the double deprivation.

Econometric Evidence

In this section we study if different beliefs have consequences for the willingness to contribute to prevention expenditure and whether the analytical results from the economic model carry forward to the data. To do so we utilize the International Social Survey Pro-

gram 2000 Environment II survey (ISSP 2003). We have a sample of 13,844 individuals from 22 countries that are interviewed about personal views and characteristics. The complete variable description is given in table 1.

Variables and Hypotheses

We rely on three variables that describe how willing an individual would be to contribute to prevention expenditure.[12] The first one, which we call *status*, asks individuals "would you be willing to accept cuts in your standard of living in order to protect the environment?" This question attempts to extract information on whether an individual would accept changes to his status quo to protect the environment. Our second proxy is *prices*, and the question asked is "How willing would you be to pay much higher prices in order to protect the environment?" Our third proxy is *taxes*, and it derives from the question "How willing would you be to pay much higher taxes in order to protect the environment?"

These proxies provide three ways in which an individual may wish to contribute to prevention expenditure, and the common factor underlying these variables is a certain willingness to contribute. It would be possible to rely on one proxy only. However, an individual may give different answers to these questions if she is driven to a lesser extent by status concerns but instead is a liberal that prefers lower tax rates. Thus, in order to reduce this measurement problem we shall combine these three variables into one measure that elicits the underlying willingness to contribute. We discuss this further in the next section.

We now formulate our hypotheses and introduce additional variables.

Hypothesis 1: *People who hold pessimistic beliefs about the environment are willing to contribute more for the environment than optimists.*

This hypothesis derives from Proposition 2 of the theoretical part. We show that individuals who believe that a shock will affect them strongly are willing to resort to more prevention expenditure than those that believe that the shock has a lesser impact.

To analyze this hypothesis, one needs data on the individuals' beliefs about the environment. One would, of course, like to have a survey question directly on the beliefs of individuals. However, since this data is not available, we resort to three proxies. First we use a question from the questionnaire that asks whether individuals agree with the statement that "modern science will solve our environmental problems with little change to our way of life." We dub the variable *science*. Given the predictions of the model we expect science optimists to show a lower willingness to contribute than science pessimists.

Second we use a question that asks individuals whether they believe that "many of the claims about environment threats are exaggerated." This variable we dub *exagg*. In this case, the model predicts a negative relationship between the belief that claims about environmental threats are exaggerated and the willingness to contribute to the environment.

An additional result of the theoretical model is that individuals who believe that they are atomistic have a lower prevention expenditure. To analyze this hypothesis we use a question which asks individuals whether "there is no point in doing what I can for the environment unless others do the same." This is a proxy for how marginal the individual views his or her own contribution to prevention expenditure.[13] We label this variable *atomism*.

All three proxies for a respondent's beliefs are ordinal and range from one to five, with a one denoting that a respondent has a fully pessimistic belief, while a five implies that a respondent is optimistic.

The Role of Education

One aspect alluded to above that clearly plays a role in determining individuals' beliefs is their knowledge of environmental problems, in other words their environmental education. Education has already been found to be an explanatory variable for the willingness to contribute to prevention expenditure in survey studies, for example in Blomquist and Whitehead (1998), Engel and Pötschke (1998), Danielson et al. (1995). The main reason for our specific focus on education is that evidence of education interacting with beliefs

would provide a reasonable base for political intervention to, for example, address the issue of double deprivation. Let us motivate the potential interaction between education and beliefs.

Imagine a rational agent needs to attach probabilities to the statement that 'modern science will solve our environmental problems with little change to our way of life.' In the absence of information, a rational agent should attach an equal probability to each possible state (answer), and thus a rational agent lacking information should be inclined to answer 'Neither Agree nor Disagree' (the middle category 3). Based on this argument, education should provide additional information which could potentially take the answer in each direction: If there are scientific breakthroughs, then a respondent who is informed about this should shift more towards choosing 'Strongly Agree,' while a lack of scientific advances should induce respondents to shift their answer more towards 'Strongly Disagree.' Hence, we suggest that education provides respondents with further information that shapes their beliefs towards being either more optimistic or more pessimistic, depending on the information at hand.

We can hypothesize about the direction of the interaction of environmental education and beliefs. Previous research (cited above) has clearly shown that more highly educated respondents feel more pessimistic about the mankind-nature relationship in the sense that they support more activities that reduce our impact on the environment. As a consequence, we would predict that more highly educated respondents hold more pessimistic beliefs, and that they subsequently have a higher willingness to contribute to prevention expenditure.

We take a proxy for an individual's knowledge about the environmental impact of human activity in order to integrate the level of environmental education into the statistical model. From the survey we use a question where individuals are asked whether "every time we use coal or oil or gas we contribute to the greenhouse effect."[14] We dub this variable *informed*, where a zero indicates someone agreeing with the statement while a four indicates the respondent does not agree. In addition, we combine this via Principal Component Analysis

with a general education variable, dubbed *education*, that gives us information on the general educational attainment of the respondent. An increasing number for variable *education* implies higher educational attainment. We call the new variable that gives us an indication of environmental education simply *ED*. The polychoric correlation between variable *ED* as well as our variables *informed* and *education* is, respectively, $-.72$ and .79, indicating a high correlation with a well-captured common factor. We hypothesize that someone who is informed about environmental issues is also willing to contribute more to the environment.

Hypothesis 2: *The more highly educated a respondent the stronger will be the impact of beliefs on the willingness to contribute to the environment.*

We shall investigate this further in the next section.

Econometric Methodology

We have three dependent variables, *status*, *taxes* and *prices*. Let us denote them respectively as ST_i, T_i and P_i, where i stands for individuals. We have three belief variables, *science*, *exagg* and *atomism*, which we represent by SC_i, EX_i and A_i. In addition, we have an education variable (ED_i) and a set of controls, denoted by $\mathbf{Z}_i$, which contains the standard socio-demographic variables gender, marital status, age, subjective social class and religious association.

We hypothesize that beliefs, education and the controls influence our three dependent variables. In addition, we believe that education plays a role in determining the beliefs, as is most likely the case for the other control variables. Thus, we have a model of the form

$$ST_i = F_1(SC_i, EX_i, A_i, ED_i, \mathbf{Z}_i), \tag{7}$$

$$T_i = F_2(SC_i, EX_i, A_i, ED_i, \mathbf{Z}_i), \tag{8}$$

$$P_i = F_3(SC_i, EX_i, A_i, ED_i, \mathbf{Z}_i), \tag{9}$$

$$SC_i = F_4(ED_i, \mathbf{Z}_i), \tag{10}$$

$$EX_i = F_5(ED_i, \mathbf{Z}_i), \tag{11}$$

$$A_i = F_6(ED_i, \mathbf{Z}_i). \tag{12}$$

All dependent variables here are categorical, and thus an econometric model developed for categorical dependent variables should be preferred to linear models like the ordinary least squares estimator. In addition, the three dependent variables ST_i, T_i and P_i are measuring similar attitudes and should therefore be explained by the same variables. For example, someone who is unwilling to accept cuts in the standard of living (ST_i) in order to protect the environment is also likely to be someone who is unwilling to pay higher prices (P_i) or higher taxes (T_i) in order to improve the environment. This is confirmed by polychoric correlations, with a correlation between ST_i and P_i of .61, between ST_i and T_i .63, and between P_i and T_i it is .75.

Furthermore, these dependent variables are likely to be affected by common unobservable factors. Conclusively, the errors of the three equations explaining *status*, *prices* and *taxes* should be correlated. Thus, relying on separate estimations does not take the non-zero correlation between errors into account. While individual regressions may lead to consistent estimates, a multivariate approach can improve efficiency (Zellner 1962). Hence, we would want to make use of a model that can account for simultaneously determined categorical variables.

In addition, the belief variables SC_i, EX_i and A_i are expected to be determined by the same explanatory variables (ED_i and $\mathbf{Z}_i$) and, since they measure beliefs (albeit different aspects), may also be driven by common unobservable factors. Since our theoretical model predicts that beliefs drive the willingness to contribute to prevention expenditure, this implies a recursive structure in the sense that the proxies for beliefs are our treatment variables, while the proxies for the willingness to contribute to prevention expenditure are our outcome variables. In addition, we expect unobserved correlation between beliefs and the willingness to contribute to prevention expenditure. To summarize, we have to estimate a simultaneous equation model that is recursive and has categorical dependent variables.

The multivariate ordered probit model is a potential candidate (Greene 2008). However, the rather large dataset together with the six simultaneous equations and the required large number of draws resulted in problems of maximization and convergence. We thus took the following approach. Using Principal Component Analysis, we obtained the common factor behind *status*, *prices* and *taxes*. Recoding this variable in a binary form based on the mean resulted in a new variable which we dubbed *WTC*, for Willingness-To-Contribute. We followed the same approach for the belief variables and dubbed the new variable *optimism*. In addition to the reduction of dimensionality, the new variables *WTC* and *optimism* should reduce potential measurement errors. Also, we can use the bivariate probit estimator that relies on the exact maximum likelihood function and not, as it is the case for the multivariate (> 2 equations) probit model, on a simulated one that may easily be biased. This then leads to the following reduced-form model

$$WTC_i = F_1(\text{optimism}_i, ED_i, \mathbf{Z}_i), \tag{13}$$

$$\text{optimism}_i = F_6(ED_i, \mathbf{Z}_i). \tag{14}$$

Thus, given our recursive structure predicted by the theoretical model and the non-negligible correlation, we still prefer a multivariate regression approach. An estimator that fits this structure perfectly is the recursive bivariate probit model.[15] Wilde (2000) has shown that, within this model structure, enough variation in the data, which is assured by the assumption that each equation contains at least one varying exogenous regressor, is sufficient for identification so that one does not need to rely on an exclusion restriction. Additional robustness studies using individual regressions and variables complement the analysis.

We use country dummies to control for possible country-specific effects and robust standard errors that are clustered at the country level. Thus, our model should be robust in case of heteroscedasticity, and through the clustering at the country-level we should have taken

into account the possibility that there are some drivers of our dependent variables that lead to country-specific responses.

Table 2 provides summary statistics. Our final sample size is 13,844 individuals. Within this sample we observe that around half of the respondents are willing to contribute to prevention expenditure (mean of *WTC* is 0.542), and similarly around 50% have optimistic beliefs (mean of *optimism* = 0.504). The mean of the general educational variable *ED* is 0.443.

Econometric Results

We first provide a general overview of the results and then discuss these in more detail. We summarize our main findings as follows.

Result 1 *The beliefs of individuals provide the strongest and most significant impact on the willingness to contribute.*

This thus confirms our first hypothesis, which is that people who hold pessimistic beliefs about the environment are willing to contribute more for the environment than optimists. Our regression results suggest that, among all the variables, an individual's belief matters the most for his or her willingness to contribute to prevention expenditure.

Result 2 *An individual's environmental education affects the willingness to contribute only indirectly via shaping beliefs.*

Our second hypothesis is that more highly educated respondents should have a higher willingness to contribute. Indeed, our regression results confirm this, but indicate that the effect of environmental education works only indirectly through its impact on beliefs. Among the variables explaining an individual's beliefs, environmental education is the most important one.

We now introduce our main results based on table 3. Model (1) is the univariate probit model estimating equation (13), while model (2) estimates equation (14). Model (3) studies

the bivariate version, while models (4) to (6) correspond to models (1) to (3) but introduce controls.

We test model misspecification based on the univariate probit models. One test is the Hosmer-Lemeshow test (HL test), run with 10 groups, the other is the Langrange Multiplier test (LM test). The null hypothesis of the HL test is that the sample frequency of the dependent variable is the same as the sample frequency of the fitted probabilities of observation subgroups. The LM test analyzes whether a generalized h-family logit model provides a better fit for the data. As the null hypothesis it studies whether the model is correctly specified.[16] The HL test suggests some model misspecification for model (1), while the LM test hints at problems in model (5). As the results of the probit models with and without controls correspond very closely, we believe that the misspecification results from models (1) and (5) can safely be ignored.

However, we should not ignore the problem of cross-equation correlation, which may lead to both biased and inefficient estimates. When we look at the bivariate probit regressions in model (3) as well as model (6) that includes controls, then we find significant correlation in the errors. Specifically, the highly statistically significant correlation of the errors in the bivariate probit model (3) is 0.995, while the correlation in model (6) is 0.939. In order to improve the efficiency of the estimates it is thus important to take this correlation into account. Hence, our preferred model is (6) which includes controls.

Comparing models (4) to (6), we find that the probit and bivariate probit results for the *optimism* equation provide congruent results in terms of sign and significance.[17] The main difference comes from the *WTC* equation, with variable *ED* showing up statistically insignificantly different from zero for the bivariate models (3) and (6), while being highly statistically significant in the univariate probit models (1) and (4). As the coefficients of our variables of interest cannot readily be interpreted in this non-linear model we estimate their marginal effects at the actual values of the control variables and then take the means.[18] The predictions are presented in table 4. We only present the effects from our main variables of

interest, namely *optimism* and *ED*. While the marginal effects from univariate models are simple, there are several marginal effects from multivariate models that can be studied.

Columns (a) and (b) in table 4 present the (average) marginal effects for variables *optimism* and *ED* in the univariate probit models. Thus, ignoring the cross-equation correlation, we find that the better informed a respondent is about the mankind-environment relationship the more pessimistic will be his beliefs. The marginal impact of becoming environmentally educated on the probability of having an optimistic belief is -0.136. In addition, the more pessimistic a respondent's beliefs the less likely is he willing to contribute to prevention expenditure (-0.161), while a better informed respondent would be willing to contribute more to prevention expenditure (0.081). These effects are significantly different from zero. The corresponding marginal effects which are based on the estimates from the bivariate model but are taken with respect to one equation only (thus ignore the bivariate nature) are shown in columns (c) and (d). While the marginal effects from the *optimism* equation predicted by the bivariate model (column d) correspond closely to those from the univariate model (column b), this is not the case for the *WTC* equation. In contrast to the univariate model (column a), the effect of the *optimism* variable is nearly four times stronger (-0.584) in the bivariate model (column c), while variable *ED* shows up statistically insignificantly different from zero (-0.015). As a result we can conclude that ignoring the cross-equation correlation would make us falsely believe that being informed about the mankind-nature relationship has a direct impact on one's willingness to contribute to prevention expenditure, while in reality its impact works only indirectly via shaping a respondent's beliefs. Also, ignoring the cross-equation correlation would make us believe that a respondent's beliefs affect his willingness to contribute to prevention expenditure to a much smaller extent than they actually do. Overall we find that the beliefs of individuals provide the strongest and most significant impact on the willingness to contribute. Thus, an econometric model that attempts to explain the determinants of the willingness to contribute but which does not include the beliefs is likely to have biased coefficients. This

omitted variable bias would thus make it difficult to, for example, develop reliable policies that try to influence the willingness to contribute.

We also calculated additional marginal effects for the bivariate model, as shown in columns (e) and (f). The change in the joint probability that a respondent is both willing to contribute and has optimistic beliefs when he becomes informed about the mankind-nature relationship is negative and significantly different from zero (-0.076). In contrast, the change in the joint probability that a respondent is both willing to contribute and has pessimistic beliefs when he becomes informed about the mankind-nature relationship is positive and significantly different from zero (0.061). This again is in line with the theoretical predictions and the hypotheses that we raised above.

Conclusively, our empirical results predict that beliefs play a substantial role for the willingness to contribute to prevention expenditure. Being informed about the mankind-nature relationship impacts the willingness to contribute only indirectly insofar as it changes the beliefs of respondents.

We undertook several robustness tests which are available in the supplementary appendix online. Our comparison is always to the marginal effects presented in table 4 which in turn are derived from the main model in table 3. We ran the regressions without robust and clustered standard errors, which did not change the estimation results. In addition, we estimate bivariate probit models of the three variables that make up our *WTC* variable, namely *status*, *prices* and *taxes*, together with the *optimism* variable, and the results again correspond closely to those from models (3) and (6). As an additional robustness exercise we ran bivariate probit models with the *optimism* variable split up into its components, namely *science*, *exagg* and *atomism*. Again, both the quantitative and qualitative results match those from our main regression very closely. One minor exception is in the robustness exercise for *science*, where our education variable is insignificant in explaining the joint probability $p(WTC = 1, science = 1)$. All other results conform very closely to our main regression. We then split our education variable *ED* into its two components, namely *informed* and

education. The results continue to hold if we introduce *informed* only, or *education* only, or even both.

Conclusion

In this article we analyze how beliefs affect individuals' willingness to contribute to prevention expenditure through a two-type, N-person public good game, similar to the baseline model of Bergstrom, Blume, and Varian (1986). In line with the literature we show analytically that agents who are pessimistic and believe that environmental degradation is likely to bear a significant impact on their wealth will invest more in prevention expenditure than optimists. We also show that the more optimistic the society the lower will be its total green expenditure and that even marginal differences in beliefs may result in significant changes to the contributions of agents in the Nash equilibrium. This consequently leads to a double deprivation, which raises relevant policy questions about equity and responsibility of preferences.

In the second part of this article we investigate empirically whether beliefs affect the willingness to contribute to prevention expenditure. For this we use a questionnaire from the International Social Survey Programme 2000 (ISSP 2003) where 13,844 individuals stated their preferences and basic characteristics. We use a recursive model structure, where we firstly determine respondents' beliefs which in turn determine their willingness to contribute. In order to provide also a more policy-oriented result, we look at how environmental education shapes the relationship between beliefs and the willingness to contribute to prevention expenditure. Our findings lead us to conclude that environmental education drives respondents' beliefs which in turn affects their willingness to contribute, while there is little evidence for a direct channel from (environmental) education to the willingness to contribute.

The results presented in this article give rise to at least two further research questions. One question concerns beliefs themselves. While this article concentrated on understanding

how different beliefs lead to different prevention expenditures, an extension of this work should look into the question of how beliefs themselves are formed. We already partly treated this by studying whether environmental education (and some socio-demographic controls) affect beliefs. However, further studies should treat more clearly what kind of environmental information shapes beliefs, whether the actual state of the environment is more important, or even the political position. The second question, related to the first, would look into the evolution of beliefs through society. For example, if my neighbor is an eco optimist, would this influence my own belief or not? While the first question is a more empirical one, the second one would be more of an analytical kind and could, for example, be approached through a model based on evolutionary dynamics.

Notes

[1]This model has been further studied in a variety of directions such as large economies (Andreoni 1988), impure public goods (Cornes and Sandler 1994), public goods that offset bads (Kotchen 2009), the private provision of public goods (Kotchen 2006), or the relation with corporate social responsibility (Besley and Ghatak 2007).

[2]This is mostly studied through non-Bayesian updating of beliefs, see e.g. Ehrbeck and Waldmann (1996); Carroll (2003); Rabin and Schrag (1999); Lord, Ross, and Lepper (1979). Other approaches are learning or social dynamics.

[3]Within this setup, any affine transformation to the utility function would not change the results.

[4]This can be obtained by studying equation (4). Taking the total derivative with respect to x_o and x_p we obtain

$$\frac{dx_p}{dx_o} = -\frac{F_x^2 - FF_{xx}}{F_x^2(1+N-N_o) - F_{xx}(N-N_o)} < 0.$$

This result is not derived at the Nash equilibrium, but it will still hold at the Nash equilibrium.

[5]Though an important and relevant question per se, we are not going to develop upon this in the current article.

[6]This result is similar to Bergstrom, Blume, and Varian (1986), Andreoni (1988) or Kotchen (2009), who show that agents that benefit more from a public good begin provision at lower wealth levels. Discussions of this can be found in early contributions by e.g. Olson (1965) and Oliver, Marwell, and Teixeira (1985).

[7]These results are closely related to Part 1 of Proposition 2 and also follow from the works cited in the previous footnote.

[8]See Kotchen (2009) for a similar result in a different setting where the public good is used to offset a public bad.

[9]No moral standard is really absolute, and consequently different views of fairness may be applicable from a policy perspective. For obvious reasons we do not take all existing ones into account, and instead refer the reader to the relevant literature. Different approaches or understandings on justice are, for example, utiliarianism (Harsanyi 1955), egalitarianism via equal opportunity (Rawls 1971), or liberitarianism (Nozick 1974).

[10]While the more recent discussion in the literature has been extending the concept of equality of welfare to incorporate issues such as expensive and offensive tastes (Dworkin 1981a), luck and responsibility (Rawls 1971; Dworkin 1981b), these extensions matter little in our setting.

[11]We assume, obviously, that welfare here is measurable (as above) and also fully comparable.

[12]There are two potential measures for the willingness to contribute. One would be a monetary one, the other one would simply elicit the willingness itself. While much of the literature has focused on monetary variables via contingent valuation studies, we believe that problems like framing or hypothetical bias may give rise to biased results (Haab et al. 2013). A more indirect measure like the willingness to contribute may be more appropriate. On the downside, it is obviously then not possible to elicit the monetary effects.

[13]One should keep in mind that atomism is a proxy for one's subjective belief of one's own impact on the environment. The assumption underlying this proxy is that agents are

rational in the sense that they are aware that they have a smaller impact the more people with (differing) attitudes are involved.

[14]Since this question in phrased using the general 'we' instead of 'I', it is unlikely that individuals would perceive this as an indicator of individual marginal impact by the individual.

[15]The recursive bivariate probit model is presented and discussed in Maddala (1983) and Wilde (2000).

[16]For both tests see Cameron and Triveda 2009.

[17]This is to be expected as a univariate probit model is sufficient to provide consistent estimates of the coefficients for the treatment equation *optimism*, see Maddala and Lee (1976). In contrast, due to the high correlation between the errors, the estimates of the outcome equation *WTC* of the univariate probit model are likely to be biased.

[18]The results closely correspond to those from predicting the marginal effects at the means. Both approaches are used in the literature.

References

Andreoni, J. 1988. "Privately Provided Public Goods in a Large Economy: the Limits of Altruism." *Journal of Public Economics* 35:57–73.

Bergstrom, T., L. Blume, and H. Varian. 1986. "On the Private Provision of Public Goods." *Journal of Public Economics* 29:25–49.

Bergstrom, T.C., and R.C. Cornes. 1981. "Gorman and Musgrave are Dual: an Antipodean Theorem on Public Goods." *Economics Letters* 7:371–378.

Besley, T., and M. Ghatak. 2007. "Retailing Public Goods: The Economics of Corporate Social Responsibility." *Journal of Public Economics* 91:1645–1663.

Bikhchandani, S., D. Hirshleifer, and I. Welch. 1992. "A Theory of Fads, Fashion, Custom, and Cultural Change as Informational Cascades." *Journal of Political Economy* 100:992.

—. 1998. "Learning From the Behavior of Others: Conformity, Fads, and Informational Cascades." *The Journal of Economic Perspectives* 12:151–170.

Blomquist, G., and J. Whitehead. 1998. "Resource Quality Information and Validity of Willingness to Pay in Contingent Valuation." *Resource and Energy Economics* 20:179–196.

Bulte, E., S. Gerking, J. List, and A. De Zeeuw. 2005. "The Effect of Varying the Causes of Environmental Problems on Stated WTP Values: Evidence from a Field Study." *Journal of Environmental Economics and Management* 49(2):330–342.

Cameron, A.C., and P.K. Trivedi. 2009. *Microeconometrics using Stata*, vol. 5. Stata Press College Station, TX.

Cappellari, L., and S.P. Jenkins. 2003. "Multivariate Probit Regression using Simulated Maximum Likelihood." *The Stata Journal* 3:278–294.

Carlsson, F., and O. Johansson-Stenman. 2000. "Willingness to Pay for Improved Air Quality in Sweden." *Applied Economics* 32:661–669.

Carroll, C. 2003. "Macroeconomic Expectations Of Households And Professional Forecasters." *Quarterly Journal of Economics* 118:269–298.

Cornes, R., and T. Sandler. 1994. "The Comparative Static Properties of the Impure Public Good Model." *Journal of Public Economics* 54:403–421.

—. 1993. "Optimal Redistribution When Tastes Differ." *Finanzarchiv* 50:149–163.

—. 1996. *The Theory of Externalities, Public Goods and Club Goods*, 2nd ed. Cambridge University Press.

Danielson, L., T. Hoban, G. Van Houtven, and J. Whitehead. 1995. "Measuring the Benefits of Local Public Goods: Environmental Quality in Gaston County, North Carolina." *Applied Economics* 27:1253–1260.

Dupont, D. 2004. "Do Children Matter? An Examination of Gender Differences in Environmental Valuation." *Ecological Economics* 49:273–286.

Dworkin, R. 1981a. "What is Equality? Part 1: Equality of Welfare." *Philosophy & Public Affairs*, pp. 185–246.

—. 1981b. "What is Equality? Part 2: Equality of Resources." *Philosophy & Public Affairs*, pp. 283–345.

Ehrbeck, T., and R. Waldmann. 1996. "Why are Professional Forecasters Biased? Agency Versus Behavioral Explanations." *The Quarterly Journal of Economics*, pp. 21–40.

Engel, U., and M. Pötschke. 1998. "Willingness to Pay for the Environment: Social Structure, Value Orientations and Environmental Behaviour in a Multilevel Perspective." *Innovation: The European Journal of Social Science Research* 11:315–332.

Greene, W.H. 2008. *Econometric Analysis*, 6th ed. Upper Saddle River, NJ: Prentice-Hall.

Haab, T.C., M.G. Interis, D.R. Petrolia, and J.C. Whitehead. 2013. "From Hopeless to Curious? Thoughts on Hausman's "Dubious to Hopeless" Critique of Contingent Valuation." *Applied Economic Perspectives and Policy* 35:593–612.

Harsanyi, J.C. 1955. "Cardinal Welfare, Individualistic Ethics, and Interpersonal Comparisons of Utility." *The Journal of Political Economy*, pp. 309–321.

Howell, S., and S. Laska. 1992. "The Changing Face of the Environmental Coalition: A Research Note." *Environment and Behavior* 24:134–144.

Israel, D., and A. Levinson. 2004. "Willingness to Pay for Environmental Quality: Testable Empirical Implications of the Growth and Environment Literature." *Contributions in Economic Analysis & Policy* 3.

ISSP. 2003. "International Social Survey Programme: Environment II - ISSP 2000." GESIS Data Archive, Cologne.

Kotchen, M.J. 2006. "Green Markets and Private Provision of Public Goods." *Journal of Political Economy* 114:816–834.

—. 2009. "Voluntary Provision of Public Goods for Bads: A Theory of Environmental Offsets." *Economic Journal* 119:883–899.

Lord, C., L. Ross, and M. Lepper. 1979. "Biased Assimilation and Attitude Polarization: The Effects of Prior Theories on Subsequently Considered Evidence." *Journal of Personality and Social Psychology* 37:2098–2109.

Maddala, G. 1983. *Limited Dependent and Qualitative Variables in Econometrics*. Cambridge University Press, New York.

Maddala, G., and L.F. Lee. 1976. "Recursive Models with Qualitative Endogenous Variables." In *Annals of Economic and Social Measurement, Volume 5, number 4*. NBER, pp. 525–545.

Nord, M., A. Luloff, and J. Bridger. 1998. "The Association of Forest Recreation with Environmentalism." *Environment and Behavior* 30:235–246.

Nozick, R. 1974. *Anarchy, State and Utopia*. New York: Basic Books.

Oliver, P., G. Marwell, and R. Teixeira. 1985. "A Theory of the Critical Mass. I. Interdependence, Group Heterogeneity, and the Production of Collective Action." *American Journal of Sociology*, pp. 522–556.

Olson, M. 1965. *The Logic of Collective Action: Public Goods and the Theory of Group*. Harvard University Press Cambridge.

Ostrom, E. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge University Press.

Owen, A.L., and J.R. Videras. 2007. "Culture and Public Goods: The Case of Religion and the Voluntary Provision of Environmental Quality." *Journal of Environmental Economics and Management* 54(2):162–180.

Popp, D. 2001. "Altruism and the Demand for Environmental Quality." *Land Economics* 77:339–349.

Rabin, M., and J. Schrag. 1999. "First Impressions Matter: A Model of Confirmatory Bias." *Quarterly Journal of Economics* 114:37–82.

Rawls, J. 1971. *A Theory of Justice*. Mass.: Harvard University.

Samuelson, P.A. 1955. "A Diagramatic Exposition of a Theory of Public Expenditure." *Review of Economics and Statistics* 37:350–356.

—. 1954. "The Pure Theory of Public Expenditure." *Review of Economics and Statistics* 36:387–389.

Stevens, T., T. More, and R. Glass. 1994. "Interpretation and Temporal Stability of CV Bids for Wildlife Existence: A Panel Study." *Land Economics*, pp. 355–363.

Torgler, B., and M. García-Valiñas. 2007. "The Determinants of Individuals' Attitudes towards Preventing Environmental Damage." *Ecological Economics* 63:536–552.

Train, K. 2003. *Discrete Choice Methods with Simulation*. Cambridge: Cambridge University Press.

Veisten, K., H. Fredrik Hoen, S. Navrud, and J. Strand. 2004. "Scope Insensitivity in Contingent Valuation of Complex Environmental Amenities." *Journal of Environmental Management* 73:317–331.

Whitehead, J. 1991. "Environmental Interest Group Behavior and Self-Selection Bias in Contingent Valuation Mail Surveys." *Growth and Change* 22:10–20.

Wilde, J. 2000. "Identification of Multiple Equation Probit Models with Endogenous Dummy Regressors." *Economics Letters* 69:309–312.

Zellner, A. 1962. “An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias.” *Journal of the American Statistical Association* 57:348–368.

—. 1963. “Estimators for Seemingly Unrelated Regression Equations: Some Exact Finite Sample Results.” *Journal of the American Statistical Association* 58:977–992.

Zellner, A., and D.S. Huang. 1962. “Further Properties of Efficient Estimators for Seemingly Unrelated Regression Equations.” *International Economic Review* 3:300–313.

Zuckerman, M. 1979. “Attribution of Success and Failure Revisited, or: The Motivational Bias is Alive and Well in Attribution Theory.” *Journal of Personality* 47:245–287.

Tables

Table 1. Variable description

Variable	Description
status	How willing would you be to accept cuts in your standard of living in order to protect the environment? (1 - very willing, 5 - very unwilling), when used in bivariate probit model then recoded as (1,2 and 3=1) and (4 and 5=0)
prices	How willing would you be to pay much higher prices in order to protect the environment? (1 - very willing, 5 - very unwilling), when used in bivariate probit model then recoded as (1,2 and 3=1) and (4 and 5=0)
taxes	How willing would you be to pay much higher taxes in order to protect the environment? (1 - very willing, 5 - very unwilling), when used in bivariate probit model then recoded as (1,2 and 3=1) and (4 and 5=0)
WTC	Factor variable combining status, prices and taxes. (1 - willing to contribute, 0 - unwilling to contribute)
science	Modern science will solve our environmental problems with little change to our way of life. (5 - strongly agree, 1 - strongly disagree), when used in bivariate probit model then recoded as (5,4 and 3=1) and (2 and 1=0)
exagg	Many of the claims about environment threats are exaggerated. (5 - strongly agree, 1 - strongly disagree), when used in bivariate probit model then recoded as (5,4 and 3=1) and (2 and 1=0)
atomism	There is no point in doing what I can for the environment unless others do the same. (5 - strongly agree, 1 - strongly disagree), when used in bivariate probit model then recoded as (5,4 and 3=1) and (2 and 1=0)
optimism	Factor variable combining science, exagg and atomism. (1 - optimist, 0 - pessimist)
informed	Every time we use coal or oil or gas, we contribute to the greenhouse effect. (1 - strongly agree, 4 - strongly disagree), when used in bivariate probit model then recoded as (3 and 4=0) and (2 and 1=1)
education	What is your highest achieved level of education? (1 - none; 7 - university completed), when used in bivariate probit model then recoded as (1 to 4=0) and (5 to 7=1)
ED	factor variable combining informed and education. (1 - (environmentally) educated, 0 - (environmentally) not educated)
age	corresponds to actual age of respondent
gender	0 = male, 1 = female
married	0 = single, 1 = married
religious	How often do you attend religious services? (1- once a week or more; 6- never), recoded as (1,2 and 3=1) and (4,5 and 6=0)
class	Which social class do you attribute yourself to? (1-lower class; 6- upper class), recoded as (1,2 and 3=0) and (4,5 and 6= 1)

Table 2. Summary statistics

Variable	Mean	Std. Dev.
dependent variables		
WTC	0.542	0.498
optimism	0.504	0.500
control variables		
ED	0.443	0.497
gender	0.515	0.500
age	45.163	16.143
married	0.627	0.484
religious	0.330	0.470
class	0.566	0.496
variables for robustness study		
prices	0.416	0.493
taxes	0.291	0.454
status	0.372	0.483
science	0.514	0.500
exagg	0.496	0.500
atomism	0.474	0.499
informed	0.843	0.364
education	0.545	0.498

Notes: The sample size is 13,844. The data is from the International Social Survey Program 2000 Environment II survey (ISSP 2003).

Table 3. Main regression results

	(1) Probit	(2) Probit	(3) **Biprobit**	(4) Probit	(5) Probit	(6) **Biprobit**
Dependent variable: WTC						
optimism	-.420***		-1.701***	-.423***		-1.692***
	(.061)		(.035)	(.062)		(.051)
ED	.248***		-.058*	.215***		-.052
	(.033)		(.030)	(.032)		(.046)
gender				-.078**		-.148***
				(.031)		(.021)
age				.000		.003**
				(.001)		(.001)
married				-.038		-.021
				(.023)		(.021)
religious				.097***		.081***
				(.031)		(.024)
class				.174***		.084***
				(.033)		(.028)
Constant	.497***		1.230***	.399***		1.092***
	(.037)		(.027)	(.072)		(.064)
Dependent variable: *optimism*						
ED		-.398***	-.384***		-.369***	-.358***
		(.038)	(.038)		(.036)	(.035)
gender					-.173***	-.169***
					(.031)	(.030)
age					.006***	.006***
					(.001)	(.001)
married					.011	-.001
					(.025)	(.025)
religious					.022	.028
					(.038)	(.039)
class					-.073**	-.070**
					(.028)	(.028)
Constant		.309***	.295***		.199***	.191***
		(.013)	(.013)		(.048)	(.047)
Country dummies	yes	yes	yes	yes	yes	yes
Stand. Err.	rob./clust.	rob./clust.	rob./clust.	rob./clust.	rob./clust.	rob./clust.
Pseudo R^2	.049	.079		.053	.086	
Obs.	13,844	13,844	13,844	13,844	13,844	13,844
log likelihood	-9,076.695	-8,838.447	-17,889.23	-9,037.991	-8,766.401	-17,782.42
ρ			.995			.939
Chi2			9.252			4.212
HL test (chi2)	38.147	3.069		8.511	8.188	
HL test (p-val)	.000	.930		.385	.415	
LM test (chi2)	.396	3.299		.624	4.759	
LM test (p-val)	.529	.069		.430	.029	

Notes: Robust standard errors clustered by country in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 4. Marginal effects (average probabilities) of main regression results (see table 3)

	(a) Probit p(*WTC*=1)	(b) Probit p(*optimism*=1)	(c) Biprobit p(*WTC*=1)	(d) Biprobit p(*optimism*=1)	(e) Biprobit p(*WTC*=1,*optimism*=1)	(f) Biprobit p(*WTC*=1,*optimism*=0)
model: without controls						
Model	(1)	(2)	(3)	(3)	(3)	(3)
optimism	-.161***		-.590***			
	(.023)		(.009)			
ED	.094***	-.148***	-.017*	-.142***	-.081***	.065***
	(.012)	(.014)	(.008)	(.014)	(.011)	(.004)
model: with controls						
Model	(4)	(5)	(6)	(6)	(6)	(6)
optimism	-.161***		-.585***			
	(.023)		(.013)			
ED	.081***	-.136***	-.015	-.132***	-.076***	.061***
	(.012)	(.013)	(.013)	(.012)	(.009)	(.010)

Notes: Robust standard errors clustered by country in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

AJAE Appendix: How Beliefs Influence the Willingness to Contribute to Prevention Expenditure

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Note: The material contained herein is supplementary to the article named in the title and published in the American Journal of Agricultural Economics (AJAE). It includes the proofs of the propositions, the table with the numerical examples on differences in beliefs, as well as the robustness studies.

Proof 1 *By assumption, the strategy space is* $S_i = [0, w]$. *Thus, it is non-empty, closed, bounded and convex. We define*

$$\psi_i(x_i, x_{-i}) = \arg\max_{x_i \in S_i} V_i(x_i, x_{-i}).$$

where $\psi_i(x_i, x_{-i})$ *solves the first-order condition eq (2). Existence and uniqueness follows from the second-order condition eq (3), continuity by the Implicit Function Theorem. We now define* $\omega(\boldsymbol{x}) = (\psi_1(x_1, x_{-1}), ..., \psi_n(x_n, x_{-n}))$. *Thus, by Brouwer's Fixed Point Theorem,* $\exists(\boldsymbol{x}^*) \in S$, *such that* $\boldsymbol{x}^* = \omega(\boldsymbol{x}^*)$.

Proof 2 *Proof of Part 1)*

Assume that, at Nash equilibrium, $x_p > 0$ *and* $x_o = 0$. *From equations (4) and (5) this implies that*

$$w = \frac{F((N - N_o)x_p, k)}{F_x((N - N_o)x_p, k)} + x_p$$

and

$$w \leq \frac{F((N - N_o)x_p, 1)}{F_x((N - N_o)x_p, 1)}.$$

Combining the two conditions yields

$$\frac{F((N-N_o)x_p,k)}{F_x((N-N_o)x_p,k)}+x_p \leq \frac{F((N-N_o)x_p,1)}{F_x((N-N_o)x_p,1)}.$$

Since $d(F/F_x)/dk < 0$, then there exists an $x_p > 0$ such that this inequality is satisfied.

Assume now that, at Nash equilibrium, $x_p = 0$ and $x_o > 0$. Proceeding like above we get

$$w = \frac{F(N_o x_o,1)}{F_x(N_o x_o,1)}+x_o$$

and

$$w \leq \frac{F(N_o x_o,k)}{F_x(N_o x_o,k)}.$$

Combining the two conditions we obtain

$$\frac{F(N_o x_o,1)}{F_x(N_o x_o,1)}+x_o \leq \frac{F(N_o x_o,k)}{F_x(N_o x_o,k)},$$

which is a contradiction since $d(F/F_x)/dk < 0$.

Assume now that, at Nash equilibrium, $x_p > 0$ and $x_o > 0$. Then we obtain

$$w-x_p = \frac{F(N_o x_o+(N-N_o)x_p,k)}{F_x(N_o x_o+(N-N_o)x_p,k)},$$

together with

$$w-x_o = \frac{F(N_o x_o+(N-N_o)x_p,1)}{F_x(N_o x_o+(N-N_o)x_p,1)}.$$

Using the Implicit Function Theorem we can write $x_o(x_p)$. Thus, at Nash equilibrium we obtain

$$w-x_p = \frac{F(N_o x_o(x_p)+(N-N_o)x_p,k)}{F_x(N_o x_o(x_p)+(N-N_o)x_p,k)}.$$

That there exists an $x_p > 0$ that solves this equation has been shown in Proof 1.

Proof of Part 2)

Since $d(F/F_x)/dk < 0$ *the result follows immediately.*

Proof of Part 3)

To show that $\frac{dx_p}{dk} > 0$ *we use equation (4) again and derive*

$$\frac{dx_p}{dk} = -\frac{F_x F_k - F F_{xk}}{F_x^2(1+N_o\frac{\partial x_o}{\partial x_p} - N + N_o) - F F_{xx}(N_o\frac{\partial x_o}{\partial x_p} - N + N_o)} > 0,$$

where $\frac{\partial x_o}{\partial x_p}$ *gives the optimal response of* x_o *to changes in* x_p *at the Nash equilibrium. Since*

$$\frac{dx_o}{dx_p} = -\frac{F_x^2 - F F_{xx}}{F_x^2(1+N_o) - F F_{xx} N_o}(N - N_o) < 0,$$

and it can easily be shown that $N_o\frac{dx_o}{dx_p} + N - N_o > 0$. ■

Tables

Table 1. Optimal solutions for x_o and x_p for changing k and N_o

	N_o					
	1	2	4	6	8	9
k	xo , xp	xo , xp	xo , xp	xo , xp	xo , xp	xo , xp
1	0.099 , 0.099	0.099 , 0.099	0.099 , 0.099	0.099 , 0.099	0.099 , 0.099	0.099 , 0.099
1.005	0.029 , 0.108	0.036 , 0.115	0.052 , 0.131	0.068 , 0.146	0.083 , 0.162	0.091 , 0.170
1.01	0 , 0.082	0 , 0.092	0.006 , 0.163	0.037 , 0.193	0.068 , 0.224	0.084 , 0.239
1.015	0 , 0.083	0 , 0.093	0 , 0.123	0.007 , 0.240	0.053 , 0.285	0.076 , 0.307
1.02	0 , 0.083	0 , 0.094	0 , 0.124	0 , 0.185	0.038 , 0.345	0.069 , 0.374
1.025	0 , 0.084	0 , 0.094	0 , 0.125	0 , 0.186	0.024 , 0.404	0.061 , 0.440
1.03	0 , 0.085	0 , 0.095	0 , 0.126	0 , 0.188	0.009 , 0.462	0.054 , 0.504
1.035	0 , 0.085	0 , 0.096	0 , 0.127	0 , 0.189	0 , 0.368	0.047 , 0.568
1.04	0 , 0.086	0 , 0.097	0 , 0.128	0 , 0.190	0 , 0.370	0.041 , 0.630
1.045	0 , 0.087	0 , 0.097	0 , 0.129	0 , 0.192	0 , 0.373	0.034 , 0.692
1.05	0 , 0.087	0 , 0.098	0 , 0.130	0 , 0.193	0 , 0.375	0.027 , 0.752

Table 2. *

Notes: Chosen parameters are $f = 0.5$, $N = 10$, $w = 10$. Explicit functional form $F(x,k) = \frac{1+x}{f+k+x}$.

Table 3. Robustness: Marginal effects (average probabilities), regressions without robust and clustered standard errors

	(a) Probit p(*WTC*=1) Coef./S.e.	(b) Probit p(*optimism*=1) Coef./S.e.	(c) Biprobit p(*WTC*=1) Coef./S.e.	(d) Biprobit p(*optimism*=1) Coef./S.e.	(e) Biprobit p(*WTC*=1,*optimism*=1) Coef./S.e.	(f) Biprobit p(*WTC*=1,*optimism*=0) Coef./S.e.
model: without controls						
Model	(1)	(2)	(3)	(3)	(3)	(3)
optimism	-.161***		-.590***			
	(.008)		(.009)			
ED	.094***	-.148***	-.017*	-.142***	-.081***	.065***
	(.008)	(.008)	(.008)	(.014)	(.011)	(.004)
model: with controls						
Model	(4)	(5)	(6)	(6)	(6)	(6)
optimism	-.161***		-.585***			
	(.008)		(.013)			
ED	.081***	-.136***	-.015	-.132***	-.076***	.061***
	(.008)	(.008)	(.013)	(.012)	(.009)	(.010)

Notes: Robust standard errors clustered by country in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 4. Robustness: Marginal effects (average probabilities), regressions with individual components of willingness to pay (*WTC*)

	Biprobit (*prices*)		Biprobit (*taxes*)		Biprobit (*status*)	
	p(*prices*=1)	p(*optimism*=1)	p(*taxes*=1)	p(*optimism*=1)	p(*status*=1)	p(*optimism*=1)
	Coef./S.e.	Coef./S.e.	Coef./S.e.	Coef./S.e.	Coef./S.e.	Coef./S.e.
model: without controls						
optimism	-.470***		-.458***		-.474***	
	(.010)		(.013)		(.010)	
ED	0.008	-.144***	0.006	-.145***	-0.01	-.145***
	(.011)	(.013)	(.011)	(.013)	(.010)	(.012)
model: with controls						
optimism	-.466***		-.453***		-.469***	
	(.013)		(.016)		(.015)	
ED	.004	-.112***	.004	-.114***	-.004	-.114***
	(.011)	(.014)	(.010)	(.014)	(.011)	(.014)

Notes: Robust standard errors clustered by country in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 5. Robustness: Marginal effects (average probabilities), regressions with optimism components *science*

	(a) Probit p(*WTC*=1) Coef./S.e.	(b) Probit p(*science*=1) Coef./S.e.	(c) Biprobit p(*WTC*=1) Coef./S.e.	(d) Biprobit p(*science*=1) Coef./S.e.	(e) Biprobit p(*WTC*=1,*science*=1) Coef./S.e.	(f) Biprobit p(*WTC*=1,*science*=0) Coef./S.e.
model: without controls						
Model	(1)	(2)	(3)	(3)	(3)	(3)
science	-.029		-.411*			
	(.018)		(.224)			
ED	.115***	-.079***	.059	-.079***	-.013	.072**
	(.013)	(.012)	(.057)	(.011)	(.026)	(.032)
model: with controls						
Model	(4)	(5)	(6)	(6)	(6)	(6)
science	-.027		-.375*			
	(.017)		(.224)			
ED	.076***	-.058***	.041	-.058***	-.011	.052**
	(.012)	(.013)	(.038)	(.013)	(.019)	(.021)

Notes: Robust standard errors clustered by country in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 6. Robustness: Marginal effects (average probabilities), regressions with optimism component *exagg*

	(a) Probit p(*WTC*=1) Coef./S.e.	(b) Probit p(*exagg*=1) Coef./S.e.	(c) Biprobit p(*WTC*=1) Coef./S.e.	(d) Biprobit p(*exagg*=1) Coef./S.e.	(e) Biprobit p(*WTC*=1,*exagg*=1) Coef./S.e.	(f) Biprobit p(*WTC*=1,*exagg*=0) Coef./S.e.
model: without controls						
Model	(1)	(2)	(3)	(3)	(3)	(3)
exagg	-.154***		-.587***			
	(.026)		(.011)			
ED	.097***	-.132***	-.008	-.128***	-.069***	.062***
	(.012)	(.012)	(.008)	(.012)	(.010)	(.004)
model: with controls						
Model	(4)	(5)	(6)	(6)	(6)	(6)
exagg	-.157***		-.587***			
	(.026)		(.011)			
ED	.083***	-.124***	-.012	-.119***	-.067***	.055***
	(.011)	(.013)	(.007)	(.012)	(.009)	(.004)

Notes: Robust standard errors clustered by country in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 7. Robustness: Marginal effects (average probabilities), regressions with optimism component *atomism*

	(a) Probit p(*WTC*=1) Coef./S.e.	(b) Probit p(*exagg*=1) Coef./S.e.	(c) Biprobit p(*WTC*=1) Coef./S.e.	(d) Biprobit p(*exagg*=1) Coef./S.e.	(e) Biprobit p(*WTC*=1,*exagg*=1) Coef./S.e.	(f) Biprobit p(*WTC*=1,*exagg*=0) Coef./S.e.
model: without controls						
atomism	-.124***		-.568***			
	(.021)		(.008)			
ED	.103***	-.118***	-.001	-.115***	-.062***	.061***
	(.012)	(.009)	(.007)	(.009)	(.007)	(.004)
model: with controls						
Model	(4)	(5)	(6)	(6)	(6)	(6)
atomism	-.120***		-.566***			
	(.021)		(.014)			
ED	.090***	-.103***	.001	-.101***	-.054***	.055***
	(.013)	(.008)	(.015)	(.008)	(.007)	(.012)

Notes: Robust standard errors clustered by country in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 8. Robustness: Marginal effects (average probabilities), regressions with variable *education* only

	(a) Probit p(*WTC*=1) Coef./S.e.	(b) Probit p(*optimism*=1) Coef./S.e.	(c) Biprobit p(*WTC*=1) Coef./S.e.	(d) Biprobit p(*optimism*=1) Coef./S.e.	(e) Biprobit p(*WTC*=1,*optimism*=1) Coef./S.e.	(f) Biprobit p(*WTC*=1,*optimism*=0) Coef./S.e.
model: without controls						
Model	(1)	(2)	(3)	(3)	(3)	(3)
optimism	-.163***		-.589***			
	(.024)		(.009)			
education	.101***	-.129***	-.004	-.123***	-.065***	.061***
	(.016)	(.011)	(.008)	(.011)	(.008)	(.005)
model: with controls						
Model	(4)	(5)	(6)	(6)	(6)	(6)
optimism	-.164***		-.589***			
	(.024)		(.009)			
education	.086***	-.107***	-.002	-.102***	-.053***	.051***
	(.015)	(.013)	(.007)	(.012)	(.009)	(.005)

Notes: Robust standard errors clustered by country in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 9. Robustness: Marginal effects (average probabilities), regressions with variable *informed* only

	(a) Probit p(*WTC*=1) Coef./S.e.	(b) Probit p(*optimism*=1) Coef./S.e.	(c) Biprobit p(*WTC*=1) Coef./S.e.	(d) Biprobit p(*optimism*=1) Coef./S.e.	(e) Biprobit p(*WTC*=1,*optimism*=1) Coef./S.e.	(f) Biprobit p(*WTC*=1,*optimism*=0) Coef./S.e.
model: without controls						
Model	(1)	(2)	(3)	(3)	(3)	(3)
optimism	-.172***		-.589***			
	(.023)		(.009)			
informed	.076***	-.064***	.011	-.060**	-.025*	.036***
	(.020)	(.023)	(.010)	(.023)	(.015)	(.011)
model: with controls						
Model	(4)	(5)	(6)	(6)	(6)	(6)
optimism	-.169***		-.588***			
	(.023)		(.009)			
informed	.077***	-.067***	.011	-.062***	-.026*	.037***
	(.019)	(.022)	(.011)	(.023)	(.014)	(.012)

Notes: Robust standard errors clustered by country in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 10. Robustness: Marginal effects (average probabilities), regressions with both *informed* and *education*

	(a) Probit p(*WTC*=1) Coef./S.e.	(b) Probit p(*optimism*=1) Coef./S.e.	(c) Biprobit p(*WTC*=1) Coef./S.e.	(d) Biprobit p(*optimism*=1) Coef./S.e.	(e) Biprobit p(*WTC*=1,*optimism*=1) Coef./S.e.	(f) Biprobit p(*WTC*=1,*optimism*=0) Coef./S.e.
model: without controls						
Model	(1)	(2)	(3)	(3)	(3)	(3)
optimism	-.161***		-.584***			
	(.023)		(.009)			
informed	.076***	-.064***	.014	-.062***	-.024*	.038***
	(.019)	(.022)	(.012)	(.022)	(.014)	(.011)
education	.101***	-.128***	.000	-.125***	-.065***	.065***
	(.017)	(.011)	(.010)	(.011)	(.008)	(.007)
model: with controls						
Model	(4)	(5)	(6)	(6)	(6)	(6)
optimism	-.162***		-.580***			
	(.023)		(.013)			
informed	.075***	-.066***	.015	-.063***	-.025*	.040***
	(.019)	(.022)	(.012)	(.022)	(.013)	(.012)
education	.086***	-.106***	.004	-.104***	-.052***	.056***
	(.015)	(.013)	(.010)	(.013)	(.009)	(.008)

Notes: Robust standard errors clustered by country in parentheses. * p<0.1, ** p<0.05, *** p<0.01.