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Céline Nauges and Sarah Ann Wheeler

Toulouse School of Economics

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Céline Nauges[a] and Sarah Ann Wheeler[b]

a. Toulouse School of Economics & INRA, France and Honorary, School of Economics, University of Queensland, Australia.

b. Global Food Studies, University of Adelaide, Australia and Adjunct, School of Commerce, University of South Australia, Australia.

Abstract

Climate change will require commitment by all levels of the community, but there is still uncertainty surrounding the best way to influence individual mitigation behaviour. This study analyses household survey data on water and energy climate change mitigation behaviour from eleven OECD countries in 2011, and provides new evidence of a form of maladaptation, namely a complex rebound relationship between climate change attitudes and mitigation behaviour. First, results confirm other studies that climate change concerns and economic incentives (in terms of electricity and water charges) positively influence mitigation behaviour. Second, we find that the more costly, in terms of time and/or money, are the mitigation actions of a household, the more likely undertaking such actions directly lessens respondents' climate change concerns. This negative rebound effect is more likely to occur in 'environmentally-motivated' households, who are more likely to have stated they believe human actions can help mitigate climate change. Conversely, economic incentives in driving energy and water pro-environmental behaviour work better in non-environmentally-motivated households. This highlights that a portfolio of policies is needed to drive mitigation behaviour.

Key Words: economic incentives; rebound effect; mitigation behaviour; climate change attitudes

1. Introduction

There is an increasing awareness that climate change must trigger fundamental changes in consumer, producer and industry behaviour to reduce carbon footprints (Adger et al., 2005). Consumers are clearly important because aspects of daily life, such as heating and cooling homes and patterns of water use, have a significant impact on greenhouse gas emissions. People's views and behaviour also play a key role in influencing their government public policy on climate change (Lo, 2015). Hence, it is critical to understand what influences consumer behaviour and how behaviour is influenced to allow us to successfully design effective and efficient policy to maximise behavioural change. This study extends the literature on climate change attitudes and household mitigation behaviour by concentrating on two key areas: water and energy.

Previous research (Stern, 2000; Russell and Fielding, 2010, among others) have suggested that there are three key determinants of water and energy behaviour: beliefs, attitudes and values; personal capabilities (knowledge, income and time); and contextual influences (country influences, economic incentives, institutions). Individuals' climate change beliefs, found to be a reflection of environmental attitudes, national policies, age, personal experience, location, education, gender, political beliefs and income among other factors, are often named as one of the most important influences on mitigation behaviour (Myers et al., 2012; Zaval et al., 2014; Buys et al., 2011; Kaesehage et al., 2014; Lo, 2015). Values held by individuals are also important (Dietz et al., 2005; Oreg and Katz-Gerro, 2006; Ajzen, 1991; Hines et al., 2010; Hawcroft and Milfont, 2010) and a distinction is usually made between different types of people, such as altruists, who are more likely to evaluate environmental issues based on the costs or benefits to humanity as a whole; or egoists, who define nature purely in terms of a personal basis; and finally biospherics who judge environmental issues on the basis of costs or benefits to ecosystems (Milfont et al., 2006).

Economists on the other hand argue that people wish to maximise utility and minimise opportunity costs. Although utility takes environmental attitudes and preferences of people into account, the economics literature emphasises in particular that pro-environmental behaviour that saves money is more likely to be undertaken, but behaviour that is high-cost relative to the perceived benefits or requires inconvenient lifestyle changes is less likely to be adopted (Stern, 2000; Diekmann and Preisendörfer, 2003; Giles et al., 2014). As a consequence economic incentives are often found to be an effective policy tool in changing

water and energy behaviour (Grafton et al., 2012; Ohler and Billger, 2014; Giles et al., 2014; Allcott and Mullainathan, 2010), especially when just one policy instrument can be recommended or adopted.

However, when evaluating household environmental behaviour there are many potential issues. One is trying to understand causality between attitude and behaviour. Is it attitudes that drive behaviour, or can doing certain actions change one's attitudes? In addition, it is clear that adapting to climate change at times is not true adaptation, it can be 'maladaptation'. Barnett and O'Neill (2010: 211) define maladaptation as "action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups". They describe five main types of maladaptation in response to the implementation of desalination plants in Victoria, Australia: increasing emissions of greenhouse gases; disproportionally burdening the most vulnerable; high opportunity costs; reduction of incentives to adapt; and path dependency.

One part of maladaptation, the reduction of incentives to adapt, often occurs after the adoption of mitigation technology by households. Although resource use is meant to decrease due to new technology, it has often been found that resource use actually increases instead (or does not decrease as much as was proposed). This is known as the rebound effect, and this has been well shown in the energy literature in particular (e.g. Tiefenbeck et al., 2013). What has not been as well documented is how attitudes are malleable and can be affected by environmental behaviour. This study uses a unique and highly detailed OECD survey database across eleven countries to investigate further the relationships between a) climate change attitudes and environmental mitigation behaviour; b) economic incentives and environmental mitigation behaviour and c) the causality between attitudes and environmental mitigation behaviour. The analysis is also divided into households that clearly hold different values and beliefs, to allow for any potential differences in the influence of household's climate change attitudes, socio-economic characteristics and the impact of surrounding regional characteristics on their behaviour.

2. Literature review

There is a very large literature that focuses upon the psychological and socio-economic attributes of individuals and their impact on behaviour (Dietz et al., 2005; Oreg and Katz-

Gerro, 2006). This long-standing tradition has examined many things, including: beliefs, values, attitudes, norms, locus of control (perceived and actual) and intentions in relation to behaviour (e.g. Ajzen, 1991). Attitudes play a key role in this literature, with findings generally indicating a positive, significant influence of attitudes on behaviour (e.g. Hines et al., 2010). Oreg and Katz Gerro (2006) note that the literature often interchanges between attitudes and values, and there has been little analysis that has attempted to systematically analyse both, whilst accounting for the inter-relationships between them. Kollmuss and Agyeman (2002) also argue that too frequently attitude measurement is too broad. It should instead focus on attitudes to specific environmental issues, particularly when trying to specify the relationship between environmental attitudes and behaviour.

The influence of socio-demographics and location is also highly important, with other common findings in the environmental literature that the 'typical' person engaged in pro-environmental behaviour was a young woman who was highly educated, politically liberal, lived in an urban area and was involved in organized religion (Van Liere and Dunlap, 1980; Berenguer et al., 2005; Hunter et al., 2004; Sharp and Adua, 2009). The impact of the surrounding region (in terms of their climate, culture, and behaviour of neighbours) is clearly important, and is also an understudied area on mitigation behaviour. For example, Janmaat (2011) found that neighbours actions in watering lawns significantly increased people surrounding to also water their lawns.

The existing literature has also tended to sum various behaviours together to create one index of behaviour. A recent review by Markle (2013) of 49 recent studies found 42 unique measures of pro-environmental behaviour. As Stern (2000) points out, given that the determinants of environmentally-related behaviour can differ significantly, it is important that each targeted behaviour should be theorized and modelled separately. The other important aspect that needs considering when modelling environmental behaviour is the cost aspect of such behaviour. Some behavioural change (e.g. habits) is very low cost, while other behavioural change (e.g. solar panels) is very high cost (Hawcroft and Milfont, 2010). As Russell and Fielding (2010) point out for water use, there is quite a difference between behavioural aspects of habits and behavioural aspects of high-technology adoption. This study attempts to overcome these shortcomings by analysing four different forms of specific climate-change related mitigation behaviour (divided up into water and energy domains, plus low and high-cost behaviour).

Although much of the psychological and social literature emphasise the role of attitudes and values in behaviour, Bamberg and Moser (2007) argue that environmental concern and behaviour is an uneasy and unstable mix of altruism and self-interest. The economics literature strongly emphasises the self-interest side of human nature in changing behaviour. Economic instruments such as pricing, charging, subsidies, taxes, markets and other demand management strategies are often promoted as the most effective way to change (i.e. reduce) water and energy use behaviour (Grafton et al., 2012; Baerenklau et al., 2014; Ohler and Billger, 2014; Giles et al., 2014; Allcott and Mullainathan, 2010; Grafton and Ward, 2008),

There is also an emerging literature on the unintended consequences of adoption of pro-environmental behaviour, in particular the consequence of the rebound effect. The rebound effect represents the fact that environmentally-friendly adoption to reduce a resource's consumption may lead to a higher demand of that resource. For example, where adopting more efficiency-boosting energy technologies to reduce greenhouse-gases is offset by a rise in electricity demand (Santarius, 2012; Peters et al., 2012; Tiefenbeck et al., 2013; Clot et al., 2014). Or, the adoption of more efficient water-using irrigation infrastructure leads to an increase in water use as reflows into groundwater decrease, and farmers either adopt more water-intensive crops or bring more land into irrigated production (Wheeler et al., 2013).

This rebound effect may be driven by both financial (e.g. household money that is freed up from adopting energy-efficient technology funds more of the same consumption) and psychological influences. The rebound effect is explained by psychologists as arising from number of reasons: a) the moral hazard trap that because the item is more efficient they can use more of it; b) moral leaking where one's conscience is salved and consequently they care less about the issue overall; and c) moral licensing where the purchase of pro-environmental technology justifies unfriendly behaviour in another area (Peters et al., 2012; Tiefenbeck et al., 2013; Clot et al., 2014). Other similar terms include guilt reduction, moral cleansing and the warm glow effect (Tiefenbeck et al., 2013). While there is emerging research investigating how these moral psychological effects impact behaviour, little is known of their magnitude or which populations are more susceptible. It is possible that the more a mitigation action meets a person's needs satiation, then the more likely that the rebound psychological effect will exist.

The presence of the rebound effect draws particular attention to the causality issue between an individual's climate change belief and mitigation action. Although the literature has

studied in depth the causality relationship running from individuals' beliefs to actions, on the other hand we are not aware of any analyses of the possible feedback effect from household actions to beliefs (albeit reverse causality has been found between irrigators' climate change beliefs and their farm adaptation behaviour (Wheeler et al., 2013)). In other words we argue that households who have the ability to protect themselves against the adverse consequences of climate change (and do so) may consequently feel less concerned. Such evidence exists at the country level: it has been clearly shown that wealthier countries and countries which have a greater ability to cope with the consequences of climate change are less concerned in general (Lo, 2015). In this study we investigate if the same could happen at the household level. We propose that climate change attitudes will positively influence greater mitigation behaviour in a household, but if there is a feedback effect, this implies that climate change concern would cause endogeneity bias in a regression setting where pro-environmental actions are modelled as a function of climate change concern and appropriate regression methodology is required.

In summary, we believe there are four potentially important areas that have been overlooked or understudied in the literature on pro-environmental adoption and mitigation behaviour. They include the need to: i) distinguish between individuals/households with different values and beliefs; ii) assess the importance of both economic incentives and attitudes on household environmental behaviour; iii) divide environmental behaviour up into high-cost and low-cost categories; and iv) examine path effects and causality, especially when in regards to the causal relationship from climate change belief to household environmental mitigation.

Using data from an OECD environmental behaviour survey covering 12,202 households in eleven countries, we test three hypotheses on the relationship between climate change beliefs and actions: 1) climate change concern is a positive driver of household pro-environmental behaviour; 2) household environmental behaviour in turn will rebound psychologically on their climate change concern if households believe they can contribute to climate change mitigation or reduce resource use by their actions (hence are meeting a needs satiation); and 3) the rebound effect is similar to what is observed across countries (e.g. Lo, 2015), hence a negative feedback from actions to concerns will be found.

3. Description of the data

The data is from a 2011 household survey on Environmental Policy and Individual Behaviour Change conducted by the OECD Environment Directorate (for greater details on the survey, see OECD, 2014). 12,202 households were surveyed in eleven OECD countries: Australia, Canada, Chile, France, Israel, Japan, Korea, the Netherlands, Spain, Sweden and Switzerland. In each country, the online survey sample was stratified according to age, gender, income and region. Households were surveyed on their opinions, attitudes and behaviour related to the environment in five areas: waste recycling, water use, energy use, transportation, and food. The main variable of interest in this study is respondents' climate change concern, which is measured on a scale from 0 (climate change is not serious at all) to 10 (climate change is extremely serious). We assess its influence on households' behaviour and test and control for a possible rebound or feedback effect (that is, the possibility that behaviour could in turn influence climate change concern). The definition and summary statistics of the main variables are shown in Table 1.

Four measures of household environmental behaviour are built: two low-cost behaviour indexes, one for water and one for energy, that account for habits and routines or behaviour that does not cost much in terms of time or money (Table 2). Low-cost indexes include actions such as turning off lights when leaving a room and watering the garden in the coolest part of the day to reduce evaporation, for the energy- and water-related indexes respectively. Two high-cost behaviour indexes are built that account for adoption of costly water-saving and energy-saving equipment/technology such as dual-flush toilets or energy-efficient windows. All four indexes are standardised between 0 and 100. In all cases, a higher index value indicates that households have adopted greater mitigation actions. Table 2 provides greater details on the definition and construction of these four indexes. High-cost actions are more effective mitigation tools than low-cost actions so we hypothesize that the rebound effect should be more likely to occur for the former.

Table 1. Definition and summary statistics of the main variables

Variables definitions	Mean	Min	Max
Respondent's ranking of climate change seriousness on a scale from 0 (not at all serious) to 10 (extremely serious).	7.62	0	10
Respondent's gender: takes the value 1 if the respondent is a male, and 0 otherwise.	0.49	0	1
Respondent's age measured in number of years.	42	18	69
Respondent's education: takes the value 1 if the respondent completed one or more years of education after high school, and 0 otherwise.	0.79	0	1
Respondent's employment status: takes the value 1 if the respondent is either an employee or self-employed, and 0 if he/she is retired, homemaker, unemployed, student, or unable to work.	0.63	0	1
Household's size: number of household members.[a]	2.89	1	5
Number of household members who are below 18 years of age.[a]	0.64	0	5
Household annual after tax income in thousand euros.[b]	37.9	2.3	159. 1
Ownership status: takes the value 1 if the respondent or a member of his/her household owns the current primary residence, and 0 otherwise.	0.63	0	1
Location: takes the value 1 if the household lives in a major town/city or in a suburban area, and 0 otherwise.	0.66	0	1
Type of residence: takes the value 1 if the household lives in a detached or semi-detached/terraced house, and 0 otherwise.	0.54	0	1
Life satisfaction index: respondent's ranking of his/her satisfaction with life at the moment from 0 (very dissatisfied) to 10 (very satisfied).	6.39	0	10
Respondent's involvement in charitable organisations: takes the value 1 if the respondent has supported or participated in the activities of charitable organisations (includes membership, personal time, and/or financial donations), and 0 otherwise.	0.27	0	1

Electricity charge: takes the value 1 if the household pays for electricity according to how much electricity is used, and 0 otherwise.	0.91	0	1
Water charge: takes the value 1 if the household pays for water according to how much water is used, and 0 otherwise	0.73	0	1
Trust in experts: respondent's opinion on trustworthiness with regard to information on claims about the environmental impact of products, coming from researchers, scientists, and experts, on a scale from 0 (not at all trustworthy) to 10 (very trustworthy).	7.01	0	10
Local environment satisfaction index: respondent's average level of satisfaction towards air quality, water quality (in lakes, rivers, sea), access to green spaces, level of noise, and management of litter and rubbish in his/her local environment.[c]	-0.15	-2	1.8

[a] The variable was set equal to 5 if the respondent answered "five or more".

[b] Respondents were asked to choose one of 10 income intervals (intervals were adjusted for each country in order to ensure a reasonable distribution across the different bands). Responses were then converted into a continuous income variable: midpoints were taken for the eight intermediate intervals and non-linear curves were fit for each country in order to generate the values for the lowest and highest income bands.

[c] For each of these five items the respondent had to indicate its level of satisfaction on a five-degree scale: -2 (very dissatisfied), -1 (dissatisfied), 0 (no opinion), 1 (satisfied), and 2 (very satisfied). The index is the average of the five scores.

Table 2. Water and energy low- and high-cost indexes

Water		Energy	
***Low-cost*[1]**	***High-cost*[2]**	***Low-cost*[1]**	***High-cost*[2]**
• turning off the water while brushing teeth; • plugging the sink when washing the dishes by hand; • watering the garden in the coolest part of the day to reduce evaporation and save water; • collecting rainwater or recycling waste water; • rinsing dishes before putting them in the dishwasher; • taking showers instead of baths.	Current adoption of the following: • low volume or dual flush toilets; • water flow restrictor taps/low flow shower heads; • water tank to collect rainwater.	• turning off lights when leaving a room; • cutting down on heating/air conditioning to limit energy consumption; • only running full loads when using washing machines or dishwashers; • washing clothes using cold water rather than warm/hot water; • switching off standby mode of appliances/ electronic devices; • using air-dry laundry rather than a clothes dryer.	Current adoption of the following: • top rated energy-efficient appliances; • low-energy light bulbs; • energy-efficient windows; • thermal insulation of walls/roof; • heat thermostats; • solar panels for electricity of hot water; • wind turbines; • ground source heat pumps.

Notes: 1. For each of these two low-cost habits, household gets a score of 1 if it never performs it, 2 if it performs it occasionally, 3 if it performs it often, and 4 if it always performs it. A missing value indicates that the question was not relevant. The index is the mean of scores calculated over the number of non-missing responses.
2. Both indexes are based on the household's adoption of relevant equipment/devices over the past ten years. For each of these items, household gets a score of 1 if it has been installed in its current primary residence over the last ten years, and 0 otherwise. The score is set to missing if installation of the equipment was not possible (for example because the household is renting its residence and only the landlord could install the equipment). The index is the mean of scores calculated over the number of non-missing responses.

In order to allow for possible differences between households with different intrinsic motivations, we distinguish between environmentally-motivated households and the rest (includes environmental sceptics, technological optimists and extreme responders). These classes were defined by the OECD following the application of a clustering methodology (see Appendix A1 for greater details). Environmentally-motivated households (46% of the sample) believe that climate change exists and that human actions can help mitigate the negative consequences of climate change. The rest (non-environmentally motivated) undertake pro-environmental actions for a variety of other reasons, including financial motives. Comparing the average statistics of the households, environmentally-motivated respondents are more likely to have more children, a lower income, rent, live in urban/suburban areas, be female, younger and a member of charity organizations (Table A2 in Appendix). Given that the needs satiation should be greatest for environmentally-

motivated households, we hypothesise that their rebound psychological impact of high-cost environmental behaviour on climate change attitudes will be the largest.

In Table 3 we show the average of the four behavioural indexes along with average climate change concern and the proportion of environmentally-motivated households in each country covered by the survey.

Table 3. Country-average water and energy adoption behaviour indexes (0-100 scale), climate change (CC) concern (0-10 scale), and proportion of environmentally-motivated households

	Energy		Water			
	low-cost	***high-cost***	***low-cost***	***high-cost***	***CC concern***	***Env-motivated***
Australia	84	37	86	47	6.88	0.42
Canada	78	42	77	36	7.35	0.46
Chile	87	26	72	26	8.87	0.54
France	85	42	83	48	7.40	0.56
Israel	82	30	70	41	7.93	0.64
Japan	78	23	58	17	7.54	0.30
Korea	84	36	65	20	8.77	0.38
Netherlands	78	37	77	43	6.60	0.28
Spain	88	37	78	36	7.95	0.37
Sweden	67	39	74	32	7.21	0.55
Switzerland	76	38	75	36	7.48	0.48

Respondents from the Netherlands and Australia are the least concerned about climate change while the average level of concern is at its highest in Korea and Chile. The proportion of environmentally-motivated households varies from 28% in the Netherlands to 64% in Israel. Adoption of habits and other low-cost behaviour in both the water and energy domains is quite widespread in all countries; most of the average low-cost indexes being above 75 on a scale from 0 to 100. Adoption of costly equipment is less common in general (average high-cost indexes vary for the most part between 30 and 40 on a 0-100 scale).

3. Estimation methodology

The presence of a feedback or rebound effect from behavioural adoption to beliefs would imply that the variable measuring climate change concern is endogenous. In such a case, usual regression techniques such as Ordinary Least Squares (OLS) will produce biased

estimates. An appropriate methodology to test and (if necessary) correct for this endogeneity problem is the two-stage control function approach that we describe below. For greater details on the control function approach we refer the readers to Wooldridge (2010).

The model of interest describing household *i*'s adoption of environmental behaviour *j* (where *j* varies from 1 to 4 and represents the four low- and high-cost water- and energy-saving behaviours) is written as follows:

$$ENVIND_{ij} = \alpha_j CCconcern_i + \mathbf{X_{ij}'\beta_j} + u_{ij}, \text{ for j = 1,…, 4,} \quad (1)$$

where *ENVIND* is the behavioural index, *CCconcern* is the variable measuring respondents' concern about climate change, **X** is the vector of exogenous variables (including a constant term), α_j and $\boldsymbol{\beta_j}$ are unknown parameters to be estimated, and u_{ij} is the error term. The exogenous variables were chosen from the literature review, and the available questions asked in the OECD survey (see Table 1) and any other regional area information that was available. In order to test and control for endogeneity bias, the following equation is specified:

$$CCconcern_i = \mathbf{X_{ij}'}\theta_j + \mathbf{Z_i'}\boldsymbol{\kappa} + \varepsilon_{ij}, \text{ for j = 1,…, 4.} \quad (2).$$

In Model (2) climate change concern becomes the dependent variable and is regressed on the set of exogenous variables (**X**) and a vector of instruments (**Z**). Instruments should be such that they are correlated with climate change concern (*CCconcern*), and uncorrelated with both the behavioural index (*ENVIND*) and the error term in the main equation (u_{ij}).

The control function approach is as follows: we first estimate Model (2) using OLS and get an estimate of the residuals $\hat{\varepsilon}_{ij}$. In the second-stage an augmented version of Model (1), which includes the estimated first-stage residuals as an additional explanatory variable, is estimated by OLS:

$$ENVIND_{ij} = \alpha_j CCconcern_i + \mathbf{X_{ij}'\beta_j} + \chi\hat{\varepsilon}_{ij} + \omega_{ij}, \text{ for j = 1,…, 4.} \quad (3)$$

A rejection of the null assumption that $\chi = 0$ in this model provides evidence for endogeneity of climate change concern. If **Z** are valid instruments then the OLS estimation of Model (3) provides consistent estimates of α_j and $\boldsymbol{\beta_j}$. If the feedback effect from behaviour to beliefs is negative, then not controlling for endogeneity would lead to the coefficient of

climate change concern being biased downwards and the sign of the χ coefficient would be negative in Model (3). Because the control-function approach involves two steps, bootstrap techniques are used in the second-stage to obtain accurate standard errors of the estimated coefficients.

The application of the method described above relies on the choice of variables that meet the definitions of valid instruments. Such variables can be hard to find, in particular because most variables that have an effect on the endogenous variable (here climate change concern) may also have a direct effect on the variable to be explained (here pro-environmental behaviour). Instruments validity can only be assessed through a series of tests, which include checking for both under- and over-identification of the model and a test for the possible weakness of the instruments: a model is said to be under-identified when the instruments are not correlated with the endogenous regressor, and over-identified when the instruments are uncorrelated with the error term and correctly excluded from the estimated equation; instruments would be considered weak if they are only weakly correlated with the endogenous variable.

We were able to find three instruments that passed these three tests and that can be confidently used to measure and correct for the endogeneity bias. The first instrument is the respondent's opinion on trustworthiness with regard to information on claims about the environmental impact of products, coming from researchers, scientists, and experts. It is measured from a scale varying from 0 (not at all trustworthy) to 10 (very trustworthy). The second instrument is the respondent's average level of satisfaction towards their local environment including air quality, water quality (in lakes, rivers, sea), access to green spaces, level of noise, and management of litter and rubbish. For each of these five items the respondent had to indicate their level of satisfaction on a five-degree scale: -2 (very dissatisfied), -1 (dissatisfied), 0 (no opinion), 1 (satisfied), and 2 (very satisfied). The proposed instrument is an index equal to the average of the five scores. The third instrument is the country Environmental Performance Index (EPI - For greater details about the EPI, see http://epi.yale.edu/). This 0-100 index was built by researchers from Yale University and includes measures of protection of human health (e.g., child mortality, air pollution, access to drinking water and sanitation) and protection of ecosystems (e.g., wastewater treatment, pesticide regulation, change in forest cover, fish stock, trend in carbon intensity).

4. Discussion of estimation results

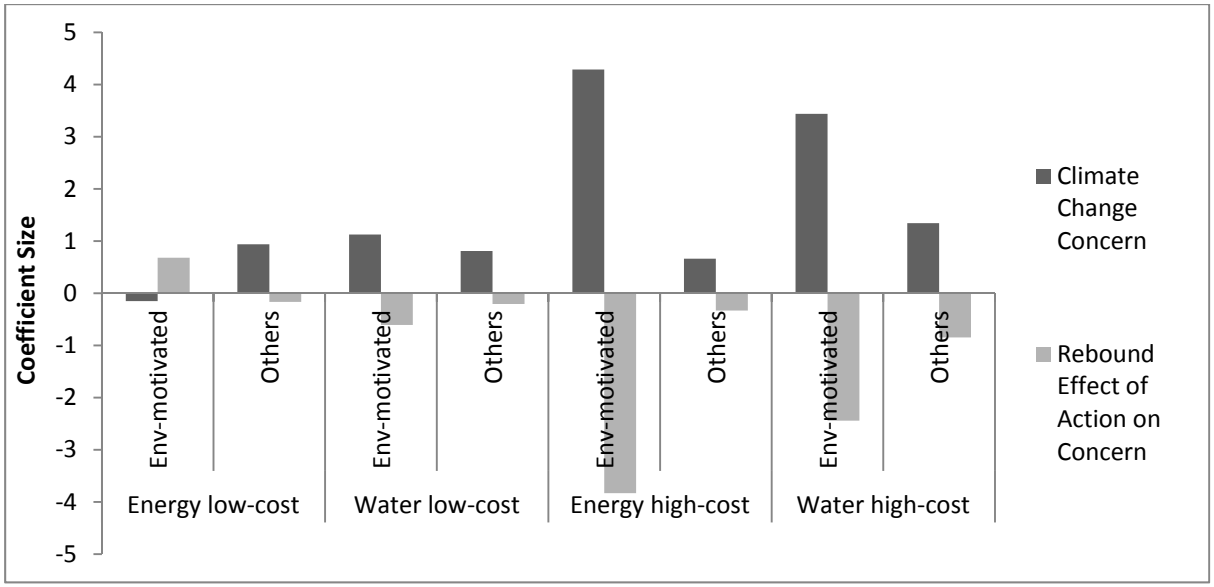
Table 4 presents the outcomes of eight regression models. The dependent variables are the four behavioural indexes representing adoption of low- and high-cost behaviour for water and energy-related items separately. First-stage results for the eight models are not shown but are available upon request. The three instruments were found to be highly significant in all cases: a higher trust in experts' opinion, a lower satisfaction about the quality of the local environment, and a lower country EPI increase respondent's perception of the seriousness of climate change.

Table 4. Results for low- and high-cost pro-environmental behaviour in energy and water; by environmentally-motivated (env. mot.) and other households

Adoption type	**Energy low-cost**		**Water low-cost**		**Energy high-cost**		**Water high-cost**	
Household cluster	***Env-mot.***	***Other***	***Env-mot.***	***Other***	***Env-mot.***	***Other***	***Env-mot.***	***Other***
Respondent's characteristics								
Respondent is a male†	-2.146***	-2.299***	-0.198	-0.653	-1.702**	-1.069	-0.538	1.821*
Respondent's age	0.069***	0.035**	0.141***	0.083***	0.086***	0.085***	0.331***	0.198***
Post high-school educ.†	0.872*	0.255	0.356	-0.314	2.295**	2.113**	0.537	2.470**
Employee status†	0.076	-1.004**	0.384	-0.677	-0.237	-0.661	0.337	-0.835
Life satisfaction index	0.153*	0.086	0.077	0.090	-0.051	0.147	0.441	0.052
Charity involvement†	1.026***	0.465	1.748***	2.421***	2.676***	2.810***	4.008***	5.413***
Climate change concern	-0.148	0.939***	1.127**	0.809***	4.288***	0.664	3.440**	1.344**
First-stage residuals	0.681	-0.165	-0.606	-0.205	-3.830***	-0.329	-2.442*	-0.847
Household's (HH) characteristics								
HH size	0.098	-0.316	0.084	0.375	0.494	0.710	0.798	1.976***
HH members below 18	0.290	0.153	0.414	0.017	0.977*	0.706	1.683**	-0.584
HH annual income	-0.043***	-0.034***	-0.036***	-0.033***	0.070***	0.030	0.011	-0.001
HH ownership†	-0.225	-0.319	0.168	0.723	-4.186***	-3.747***	3.071**	4.684***
Town or suburban area†	0.248	0.012	0.085	-0.877*	-0.145	-0.700	0.995	-1.562
House†	0.888**	1.287***	0.865*	0.751	-3.860***	-2.399***	5.292***	0.364
Economic incentives								
Electricity charge†	2.405***	3.751***	-	-	1.001	4.784***	-	-
Water charge†	-	-	1.889***	1.154**	-	-	4.461***	3.937***
Region								
Regional adoption	0.236**	0.183*	0.304***	0.310***	0.071	0.368***	0.084	0.193*
Model characteristics								
Number of observations	4,611	5,355	4,611	5,355	4,542	5,269	4,212	4,948
R-squared	0.22	0.19	0.25	0.22	0.08	0.06	0.12	0.12
Tests of instruments validity								
Under-identification test	267.2	649.5	265.2	651.1	265.3	636.8	220.6	619.7
p-value	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
Over-identification test	0.139	0.244	0.499	0.063	0.036	3.256	0.002	0.066
p-value	*0.709*	*0.621*	*0.480*	*0.802*	*0.851*	*0.071*	*0.962*	*0.798*

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$. † indicates the variable takes values 0 and 1 only. Country-specific dummies are not shown here but are available upon request, and are shown in the Appendix's full sample results.

Figure 1. Impact of climate change concern and the rebound effect by household type and environmental behaviour



Our key results are that in general, increases in climate change concerns impact positively on household environmental behaviour. Climate change concern has a more significant and larger impact on high-cost mitigation behaviour (in particular energy) than low-cost (habits) behaviour. Impact of concern on actions was stronger in magnitude for the environmentally-motivated households (as these households believe that climate change can be mitigated by actions).

As predicted (reflected in Figure 1), the rebound effect (shown by the shaded row of the first-stage residuals in Table 4) was significant only for the environmentally-motivated households and was present only in high-cost environmental household behaviour (and was significantly greater for energy rather than water mitigation behaviour). As far as we can tell, this is the first time that the negative rebound effect has been found in differentiated environmental action. Given the novelty of these results, there are many possible reasons for their presence. Results may be driven by a moral leaking psychological impact, that is: the more environmentally-motivated households undertake costly, effective mitigation behaviour, the more this satiates their needs/desires to address climate change and the more this rebounds and reduces their overall climate change concerns. This effect was not present or significant in other pro-environmental household habit behaviour.

Our results across eleven OECD countries indicate that in terms of driving household pro-environmental behaviour, economic incentives induce high-cost energy mitigation only for the non-environmentally-motivated. This is similar to Clot et al. (2014) who found (in experiments) that regulation did not work well on environmentally-motivated individuals but it did work well with other non-intrinsically motivated individuals. Economic incentives are also a much stronger influence on energy habit low-cost behaviour of the non-environmentally motivated. However, water pricing economic incentives positively influence both water high-cost and low-cost resource behaviour of both environmentally and non-environmentally motivated households. These findings reiterate Bamberg and Moser's (2007) arguments that an adequate model of the antecedents of environmental behaviour must combine elements of both altruism (e.g. in our model climate change beliefs) and self-interest (e.g. economic incentives), as well as other cognitive, social, knowledge and emotional factors. In addition Bamberg and Moser (2007) claim guilt and shame are important elements of forming an individual's moral norm construct—an element they claim is overlooked in most studies. Our model attempted to control for as many of these factors as possible, across eleven different OECD countries.

In addition, it seems that it is higher household income that enables environmentally-motivated households to adopt high-cost energy mitigation, while it is the cost of energy/economic incentives that is the more relevant driving factor for non-environmentally motivated households. Higher household income is a negative influence on low-cost behaviour: poorer households are much more likely to be careful about energy and water-use than richer households. Therefore, having a higher income may allow environmentally-motivated households to 'buy' their way out feeling guilty over using a lot of energy or water by investing in high-cost actions. Poorer households, on the other hand, address their climate change concerns by undertaking more low-cost resource actions.

The above discussion highlights that a portfolio of policies is needed to drive mitigation behaviour.

5. Conclusion and policy recommendations

Using a household survey covering eleven OECD countries, we confirmed that: a) households' climate change concerns do impact on mitigation behaviour (and the more that

behaviour is effective in mitigation behaviour the more influence climate change concerns have on it); and b) economic incentives are positive significant influences on mitigation behaviour. We also found new evidence of how maladaptation can work in reducing incentives to adapt, and added to the literature further information about different costs of adaptation and the existence of the rebound effect on attitudes. Namely, undertaking costly pro-environmental behaviour lessens individuals' concerns about climate change. In addition, the rebound effect occurs primarily in households that hold certain environmental values, namely environmentally-motivated households who believe human actions can help mitigate climate change. This means there is a very real risk is that the level of concern (and hence willingness to take action) will decrease once households get better equipped, and for some of these environmentally-motivated households, economic incentives do not seem to work as effectively. Albeit, the OECD data only allowed us to test very basic water and electricity charging across regions and countries, it is not possible to say whether more sophisticated pricing schemes (e.g. as outlined for water in California by Baerenklau et al., 2014) would work in incentivising households who hold such environmental values.

However, like Bain et al. (2015) and Clot et al. (2014), even in the face of such rebound effects we believe that there is cause to be positive as there are tools available to change people's behaviour. No-one policy choice (e.g. regulation/economic incentives/education) will be the answer; a portfolio of targeted incentives and information is needed. Economic incentives (e.g., pricing, subsidies and taxes) can play a significant and positive role, especially when households do not have any intrinsic motivation to take pro-environmental actions. For different population cohorts, sustainability education, environmental awareness, emphasising the co-benefits of increased action (Bain et al., 2015), and environmental messaging about avoiding overestimating benefits (Clot et al., 2014) may be one of the best ways to change behaviour and limit the rebound effect, especially when that behaviour includes very high-cost actions. Finally, there is also a need to continue focussing on 'nudges' and new 'soft policy' approaches, developed from behavioural economics that encourage the voluntary adoption of individual behaviours supportive of sustainable resource use (Shogren, 2012) .

Further research will need to be conducted to confirm or reject the negative rebound effect of behaviour on different types of actions. Our results are based on one year of data only and further insights could be gained from experiments, as well as building repeated cross-sections or panel datasets that follow households' beliefs and actions over time.

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Appendices

A1. Description of the clustering methodology

The clustering was performed by the OECD Environment Directorate (for greater details, see OECD, 2014). A latent class analysis was used to identify attitudinal profiles of the respondents. Three major classes were identified based on the respondents' level of agreement (strongly disagree, disagree, agree, strongly agree, no opinion) with the following seven statements about environmental policy: i) Policies introduced by the government to address environmental issues should not cost me extra money; ii) I am willing to make compromises in my current lifestyle for the benefit of the environment; iii) Protecting the environment is a means of stimulating economic growth; iv) Environmental issues will be resolved in any case through technological progress; v) Environmental impacts are frequently overstated; vi) I am not willing to do anything about the environment if others don't do the same; and vii) Environmental issues should be dealt with primarily by future generations. The three classes were labelled by the OECD as: *environmentally motivated*, *environmental sceptics*, and *technological optimists*. Quoting the OECD: "The *environmentally motivated* comprise just under half of the pooled sample [...] They believe that environmental problems are real and express a willingness to make compromises in their lifestyle to solve them. Members of this class also expressed the least need for reciprocation from others in order to undertake action to solve environmental problems. *Environmental sceptics* believe that environmental issues are overstated and do not wish to pay for government environmental policies. But, on the other hand, they do report a general willingness to make compromises for the benefit of the environment, though not to the same degree as the other two substantive classes. *Technological optimists* share the belief with the *environmentally motivated* cluster that environmental problems are real and appear willing to make lifestyles compromises to solve them. The key difference between the two clusters is that the first group expresses a greater belief in the potential of technological progress to solve environmental problems." (OECD, 2014).

A2. Mean characteristics of environmentally-motivated households versus the rest and outcome of mean comparison test

Variables[a]	Env-motivated	Others	Significance of t-test[b]
Adoption behaviour			
Low-cost energy	82	80	***
Low-cost water	76	73	***
High-cost energy	36	34	***
High-cost water	37	34	***
Respondents' characteristics			
Respondent is a male†	0.40	0.56	***
Respondent's age	41.1	42.8	***
Post high-school educ.†	0.79	0.78	n.s.
Employee status†	0.63	0.63	n.s.
Life satisfaction index	6.39	6.39	n.s.
Charity involvement†	0.31	0.24	***
Climate change concern	8.4	7.0	***
Household's characteristics			
Household size	2.91	2.88	n.s.
HH members below 18	0.67	0.61	***
HH annual income	36.995	38.593	***
Ownership of the resid.†	0.61	0.64	***
Town or suburban area†	0.67	0.65	**
House†	0.52	0.55	***
Economic incentives			
Electricity charge†	0.91	0.91	n.s.
Water charge†	0.70	0.74	***

a: A † following the name of a variable indicates that the variable takes values 0 and 1 only. HH stands for households.
b: *** $p < 0.01$; ** $p < 0.05$; n.s. for not significant.

A3. Estimation results for low- and high-cost pro-environmental actions in energy and water; full sample

Adoption type	Energy		Water	
Variable[a]	Low-cost	High-cost	Low-cost	High-cost
	Coef.[b]	Coef.	Coef.	Coef.
Respondent's characteristics				
Respondent is a male[†]	-2.392***	-1.133*	-0.488	0.653
Respondent's age	0.048***	0.091***	0.110***	0.266***
Post high-school educ.[†]	0.541*	1.980***	-0.055	1.568*
Employee status[†]	-0.498*	-0.570	-0.214	-0.210
Life satisfaction index	0.105	0.027	0.074	0.257
Charity involvement[†]	0.821***	2.720***	2.180***	4.614***
Climate change concern	0.708***	1.639***	0.970***	1.860***
First-stage residuals	0.050	-1.208***	-0.316	-1.119**
Household's characteristics				
Household size	-0.123	0.596*	0.212	1.445***
HH members below 18	0.256	0.821**	0.263	0.534
HH annual income	-0.038***	0.049***	-0.033***	0.000
Ownership of the resid.[†]	-0.164	-4.084***	0.542	4.153***
Town or suburban area[†]	0.113	-0.276	-0.429	-0.392
House[†]	1.026***	-2.794***	0.669*	2.625***
Economic incentives				
Electricity charge[†]	2.994***	3.119***	-	-
Water charge[†]	-	-	1.563***	4.088***
Regional adoption and country dummies				
Regional adoption	0.199***	0.226***	0.292***	0.147*
Korea (ref.)	-	-	-	-
Australia	1.967***	4.706***	16.619***	25.737***
Canada	-2.794***	7.344***	10.199***	15.524***
Chile	2.030***	-5.819***	3.731***	2.509
France	1.882***	7.269***	14.088***	25.446***
Israel	-0.772	-3.349**	3.932***	19.049***
Japan	-3.085***	-8.623***	-3.710***	-1.983
Netherlands	-3.513***	5.709***	9.281***	22.335***
Spain	3.725***	2.071*	9.644***	13.975***
Sweden	-12.287***	5.794***	7.923***	13.844***
Switzerland	-3.802***	0.791	9.222***	17.728***
No. of obs.	10,155	9,979	10,151	9,326
R-squared	0.2033	0.0671	0.2268	0.1138
Tests of instruments validity				
Under-identification test	1163.23***	1144.36***	1157.65***	1060.76***
Over-identification test	0.012	1.155	0.376	0.000

a: A [†] following the name of a variable indicates that the variable takes values 0 and 1 only. HH stands for households.
b: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.