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Exploring domestic energy-saving: The role of environmental concern and background variables

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ABSTRACT

The main purpose of this paper is to investigate whether residents' environmental concern has any effect on their energy-saving curtailments and efficiency investments. The novelty of the present work lies in the fact that it seeks to investigate this topic in a multi-country setting, exploiting data from nine OECD countries (Australia, Canada, Czech Republic, France, Italy, South Korea, Netherlands, Norway and Sweden), and also in that it employs a latent variable model which allows us to examine the conditions necessary for the results to be comparable across different countries. Novel in this paper is also the focus on the role of environmental concern as a factor of several curtailments and efficiency investments. Our results suggest that people with higher environmental concern are on average more likely to perform energy-saving curtailments and also are more likely to have some energy-efficiency retrofits installed in dwellings. Most of the socio-economic and demographic variables have mixed effects on efficiency investments and curtailments. However, some interesting patterns emerged with respect to the age of respondents, household income, education and gender of respondents, and also the size of household.

1. Introduction

Nowadays, OECD member countries, with only about 18% of the world's population, account for about 54% of its consumption of electricity and 24% of heat, with the household sector being the key player in energy consumption. In the OECD, residential energy contributes about 20% of total energy use, whereas residential electricity and heat represent both about one third of the grand total.

Although the increasing trend in final consumption of residential energy in the OECD – with about 8% growth in the 1980s and 16% growth in the 1990s – has slowed down during the last decade, residential energy consumption still grew and in 2009 was about 2% larger than in the year 2000. Electricity consumption in the OECD residential sector has increased by 16% since 2000 until now.

Residential energy use varies widely among OECD countries (see Fig. 1), reflecting climatic conditions, wealth, consumption habits and behavioral patterns. The residential sectors in Norway, Canada, USA and Sweden have almost double or more electricity use per capita than is the average in OECD countries (2.4 MW h per capita a year in 2009), energy use in France and Australia is about the average, households in Korea, Hungary and Italy use about half of the average, while countries such as Turkey, Chile or Mexico use about 20% of what is the average energy consumption in OECD countries. The rate of growth in electricity consumption varies widely among OECD countries as well (see Fig. 1); Belgium, Slovakia, Estonia and Sweden decreased residential electricity use between 2000 and 2009, while, electricity use increased by less than 10% in the same period in the Czech Republic, Canada, Australia, Italy, USA and the UK, and by more than 10% in such countries as in Portugal, Chile, Korea, Spain and Turkey (see Figure 1 for details). The multi-country survey exploited in this study covers OECD countries with different consumption levels, different rates of growth and different geographical regions.

Increasing energy use not only has economic consequences, and an effect on energy security, but also generates damage. As shown by, for example, Weinzettel et al. (2012), energy consumption leads to large negative externalities, especially adverse health effects and large effects due to climate change. Further, Máca et al. (in press) have found that the level of external costs internalization by economic instruments is fairly low for existing fossil-fired power plants and even if the subsidization of renewable electricity was also accounted for, the level of internalization would remain rather low, between 9 to 55%, especially for non-gas fossil-based electricity generating technologies.

Households can minimize adverse environmental effects related to their energy consumption particularly by reducing

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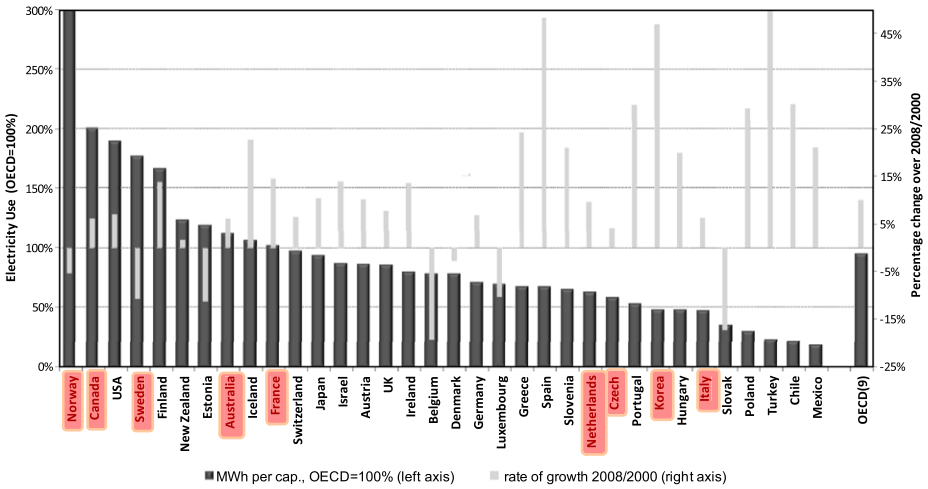

Fig. 1. Electricity use and rate of growth in electricity use p.c. in OECD countries in 2009 (IEA/OECD, 2011). *Note*: highlighted are the countries covered in the present study.

the use of energy-consuming household appliances (this type of energy-saving activity is referred to as "curtailments") or by increasing the energy efficiency of their stock of appliances (by making "efficiency investments"). It has been argued that energy curtailments and efficiency investments are fast, convenient and relatively cheap ways to achieve significant reduction in adverse environmental effects of modern societies in the short and medium term horizons, especially with respect to greenhouse gas emissions (Dietz et al., 2009; Gardner and Stern, 2008; Vandenbergh at al., 2008).

However, motivation that leads individuals and households to adopt energy-saving activities is very complex (Steg, 2008). As a rule, economic factors (e.g., saving money on energy bills, paying less for energy-efficiency appliances) are most often cited motivations for curtailments and energy investments, while environmental motives are mentioned as less important together with convenience, health-related motivation, habits, availability of products or their easier identification through labels (OECD, 2011; Whitmarsh, 2009). It is therefore not surprising that certain studies no not find any effect of environmental concern on some energy curtailments (Carlsson-Kanyama et al., 2005; Whitmarsh and O'Neill, 2010) and also no effect on some efficiency investments (Achtnicht, 2011; Whitmarsh and O'Neill, 2010).

In any case, environmental motivation behind energy-saving may be interesting from a policy perspective for several reasons. First, environmental concern seems to be a very solid motive for energy saving because it is independent of the attractiveness and cost effectiveness of the energy saving behavior (Steg, 2008) and because it is a "situation invariant orientation pattern" (Bamberg, 2003, p. 22). Because of this, environmental concern can actually lower some of the unintended negative consequences of improved energy efficiency, such as the rebound effect because it orients consumers towards energy-saving regardless of decreasing marginal costs of energies and also independently on whether particular type of energy-saving pays back. Second, environmental motivation may be interesting also because of the cross-situational influences of pro-environmental motivation (Whitmarsh, 2009), which may result in a spill-over of environmentally-friendly behavior from one specific area to a different one (Diekmann and Preisendörfer, 1998; Thøgersen, 2004; Thøgersen et al., 2006). This means that increasing environmental motivation for one type of energy-saving is likely to spill-over to different types of energy-saving because they can also deliver environmental benefits.

The purpose of this article is to investigate whether there is any systematic effect of environmental concern on energy saving curtailments and energy-efficiency investments in the residential sector. Specifically, this study seeks to examine this question from a multi-country perspective, when controlling for background confounding variables, thus testing the generalizability of the answer to the first research question across nine OECD countries and also its sensitivity to confounding effects of socio-demographic variables.

The novelty of the present work lies in the fact that it seeks to investigate this topic in a multi-country setting and also in that it employs a latent variable model which allows us to examine the conditions necessary for the results to be comparable across different countries and therefore it does not take the comparability of the latent construct as a hidden assumption. Novel in this paper is also the focus on the role of environmental concern as a factor of several curtailments and efficiency investments measured simultaneously.

This paper proceeds as follows. First, we introduce the concept of energy saving activities as consisting of curtailments and efficiency investments and review pertinent literature which deals with the effects of environmental concern and background variables on curtailments and efficiency investments. Second, the data and method used in this study are introduced. Third, the main results of this study are presented. The final section provides a discussion of the results, their policy relevance and also puts forward some suggestions for future research.

2. Energy-saving behavior

Energy saving includes a wide range of activities from very simple habitual actions (e.g., turning off lights when leaving a room) to very sophisticated and costly energy-efficiency measures (for example, the installation of thermal insulation in walls and roofs). The literature in the field makes a distinction between two types of residential energy-saving activities: efficiency investments and curtailments. Jansson et al. (2009) argue that efficiency investments are different from curtailment behavior in that they involve the acquisition of new technologies and products, with the side effect of increasing consumers' comfort. In addition, they also argue that efficiency investments are high-involvement activities, in that they incur considerable monetary costs and also require time and planning activity necessary for their selection and implementation, and also that decisions to introduce efficiency measures are usually not driven by moral motivation. As a matter of fact, internal motivational factors play a minor role when the action depends on external conditions

(availability, cost, feasibility, availability of infrastructure) (Guagnano et al., 1995), which is probably the case of the major efficiency investments and therefore situational rather than motivational factors were found to affect efficiency investments as opposed to curtailments (Black et al., 1985). Other authors argue that an important feature of efficiency investments is that they are not easily reversible (Dillman et al., 1983) and also that their energy-saving potential is often underestimated by laymen in spite of the fact that it is actually higher than that of curtailments (Attari et al., 2010).

Various energy-saving actions interact. Previous empirical studies have found that curtailments tend to be correlated (Barr et al., 2005; Jansson et al., 2009; Whitmarsh and O'Neill, 2010) as do efficiency investments (Barr et al., 2005; Whitmarsh and O'Neill, 2010) and also energy-saving actions in general (e.g., Sardianou, 2007). However, some studies suggest that people are not completely consistent in their energy-saving efforts (Kaiser and Wilson, 2004). One of a situation when people are not consistent in their energy-saving activities may be the rebound effect (Khazzoom, 1980; Sorrell and Dimitropoulos, 2008), when increased energy-efficiency leads to increased demand for energy and/or lower willingness to curtail energy consumption.

2.1. Energy saving and environmental concern

Most of the early studies on energy conservation from the 1970s did not find any effect of environmental concern on energy consumption and energy saving (see review study by Heslop et al. (1981)) and this was probably the reason why subsequent studies did not pay much attention to the role of environmental concern as a factor of energy use (see the review of studies on energy use from 1975 to 2000 by Guerin et al. (2000)), with the notable exception of the study by Black et al. (1985). However, empirical evidence has accumulated since the late 1980s which indicates that environmental concern has significant effects on various environmentally-relevant behaviors (Hines et al., 1986), including also curtailments (Barr et al., 2005; Diekmann and Preisendörfer, 1998, 2003; Scherbaum et al., 2008), efficiency investments (Barr et al., 2005; Diekmann and Preisendörfer, 2003; Whitmarsh and O'Neill, 2010), and also compound measure of energy saving (Sardianou, 2007; Whitmarsh, 2009). Environmental concern is thought to influence behavior by affecting the cognitive basis of attitudes to pro-environmental behavior (Bamberg, 2003; De Groot and Steg, 2007; Gardner and Abraham, 2010).

Several authors have also reported indirect evidence for an underlying pro-environmental motivation for curtailments by showing that these are influenced by pro-environmental beliefs and values (Ibtissem, 2010; Jansson et al., 2009; Whitmarsh and O'Neill, 2010) and by concern related to specific environmental problems (Whitmarsh and O'Neill, 2010). Several other studies have also found the positive effect of environmental concerns on variables that are closely linked to energy saving such as willingness to accept energy-saving policies and energy-saving measures (Poortinga et al., 2002, 2004; Poortinga et al., 2003; Steg et al., 2011; Steg et al., 2005).

However, there are some studies that show limited or no effect of environmental concern on energy saving. Carlsson-Kanyama et al. (2005) found that the effect of environmental concern on curtailments varies and can be even insignificant for some of them, even though the behaviors are very similar in terms of the difficulty of their enactment. In addition, Steg et al. (2011) found no effect of environmental concern on willingness to accept energy saving measures when values and pro-environmental worldviews were controlled for. None of the studies known to us have attempted to study the effect of environmental concern on energy conservation in a multi-country context.

2.2. Confounding variables

As noted earlier, energy conservation in households is affected by many factors. The focus of the present study is the role of environmental concern as a factor of energy-saving. When we want to study the effect of environmental concern on energy conservation we should pay particular attention to those factors that have an effect both on environmental concern and on conservation behavior, because they can become confounding variables and bias estimates of the effect of environmental concern on energy saving activities. To put it more technically, we assume that environmental concern is ignorable condition on socio-demographics that are entered as additional explanatory variables in the model. All factors that influence conservation behavior and are not explicitly captured in the model are assumed to be independent of the explanatory variable (environmental concern) and enter the error term of the dependent variable.

Our literature review has revealed (see Electronic Annex 1 in the online version of this article) that the age of respondents, their gender and education, household size, presence of children in the household and household income are likely to become such confounding variables. There are many other socio-demographic and economic variables (e.g., ownership of the residence, size of the flat), structural variables (e.g., energy metering, prices of energy, available energy sources) and cultural variables (e.g., beliefs about ambient indoor temperature) that are known to influence energy conservation in households (Black et al., 1985; for their review see, e.g., Guerin et al. (2000); Steg, 2008). However, to the best of our knowledge, none of these factors has been demonstrated to also influence environmental concern so that it should be considered a confounding variable as defined in this study.

3. Data and method

3.1. Data

The data for this study come from a survey originally conducted in 10 OECD countries (Australia, Canada, Czech Republic, France, Italy, South Korea, Mexico, Netherlands, Norway, and Sweden) in 2008 and coordinated by the OECD's Environment Directorate. The survey was specifically designed to cover OECD countries with above-the-average (Norway, Canada, and Sweden), average (Australia, France) and below the average (Netherlands, Czech Republic, Korea, Italy and Mexico) electricity consumption and also to capture high variability that exists among the OECD countries in terms of electricity consumption growth (viz. Fig. 1).

The data were collected using web-based questionnaires. The samples of respondents were selected by stratified random sampling from an internet panel provided by a marketing research company. Samples were stratified by age, gender, region, and socio-economic status in each country to get samples resembling the adult population of each of the countries. The marketing company used several tools (such as incentive mode and a maximum number of surveys to which a panelist can respond) in order to avoid problems known to be associated with internet-based panels (biased samples, professional respondents, random responses etc.). In addition, panel sizes, recruitment, management and representativeness of the samples were scrutinized to ensure the validity of results. Further details of the sampling procedure are reported elsewhere (see OECD, 2011).

Sample sizes varied between 701 observations (Czech Republic) and 1417 observations (Italy), and totaled 9242 observations. Data corroboration revealed that the country samples were only

slightly different from the general adult population of the 10 countries in that respondents were generally wealthier, younger, and better educated than those in national populations. Detailed corroboration of the indicators relevant for energy consumption and energy saving behavior (household appliance penetration and energy sources used in households) revealed that only the Mexican sample was biased to a considerable degree. We attribute this bias to lower internet penetration in this country, which probably led to the over-representation of respondents who were open to new technologies (for details of data corroboration see OECD (2008)). Consequently, we decided to drop the Mexican sample and use only data from the nine remaining OECD countries.

3.2. Measures

All measures of energy-conservation activities were based on self-reports.

The survey covered five specific curtailment activities:

- switching off lights when leaving a room (*c_light*)
- turning down AC or heating when leaving a room (*c_ac_heat*);
- economic use of the washing machine and dishwasher (*c_wash*);
- turning off unused appliances (*c_appl*);
- turning off standby mode in household appliances (*c_standby*).

Respondents indicated on a 4-point Likert-type scale ranging from "always" to "never" how frequently on average they performed these curtailments.

In addition, the survey also captured examples of five efficiency investments, specifically the installation of:

- energy-efficiency-rated appliances (*i_appl*);
- low-energy light bulbs (*i_light*);
- thermal insulation (walls/roof insulation, double-glazing) (*i_insul*);
- energy-efficiency rated water heater (*i_heat*);
- renewable resources (*i_renew*).

For each of these efficiency investments, respondents were asked whether their household had installed the measure within the last 10 years.

Most studies conceptualize environmental concerns as attitudes towards environmental issues (Fransson and Gärling, 1999; Schultz and Zelezny, 1999; Thompson and Barton, 1994). However, the literature on environmental concern is "fragmented and disorganized", in spite of the fact that research on environmental concern has been now on-going for more than 30 years, not least because many studies adopt an a-theoretical approach to the topic and use different measures of environmental concern (Xiao and Dunlap, 2007, p. 472). This situation is probably due to the fact that the term itself has been adopted from political discourse and lacks a clear definition (Bamberg, 2003). Measures of environmental concern differ in how they capture the subject of environmental concern (i.e., multiple vs. single topic measures) and also what expressions of environmental concern they capture (i.e., single expression vs. multiple expression) (Dunlap and Jones, 2002).

The present study uses a multiple-topics-single-expression approach classified among policy-relevant measures of environmental concern (Dunlap and Jones 2002). Specifically, our study is similar to the study by Gardner and Abraham (2010) in that it asks respondents to rate how concerned they are with various environmental problems. We originally included eight environmental topics in our measure but decided to drop two of them

Table 1
Sample descriptives: means and standard deviations (in parentheses).

		AUS	CAN	CZR	FRA	ITA	KOR	NOR	NLD	SWE
Age	Age of respondent (continuous)	43.9 (13.1)	43.2 (14.4)	39.5 (13.3)	45.7 (15.5)	43.5 (14.9)	38.6 (13.8)	43.5 (13.7)	45 (14.1)	42.1 (13.8)
Income	Per capita net annual household income [thousands of €] (continuous)	35 (19.8)	38.5 (22.5)	11.7 (5.6)	32.3 (14.8)	30.7 (16.1)	24.9 (15.7)	58.6 (28.3)	28.5 (12.4)	28.7 (15.9)
Hschool	1 if respondent has secondary education, 0 otherwise (dummy)	0.611 (0.488)	0.628 (0.484)	0.526 (0.5)	0.409 (0.492)	0.579 (0.494)	0.459 (0.499)	0.416 (0.493)	0.67 (0.47)	0.575 (0.495)
Uni	1 if respondent has university education, 0 otherwise (dummy)	0.248 (0.432)	0.303 (0.46)	0.127 (0.333)	0.211 (0.408)	0.296 (0.457)	0.489 (0.5)	0.512 (0.5)	0.255 (0.436)	0.301 (0.459)
Male	1 if respondent is male, 0 otherwise (dummy)	0.447 (0.497)	0.488 (0.5)	0.491 (0.5)	0.497 (0.5)	0.483 (0.5)	0.495 (0.5)	0.521 (0.5)	0.47 (0.499)	0.44 (0.497)
Pers	Number of household members (continuous)	2.872 (1.377)	2.632 (1.291)	3.023 (1.369)	2.568 (1.257)	3.119 (1.431)	3.704 (1.346)	2.556 (1.328)	2.296 (23)	2.309 (1.325)
Kidsin	1 if there are children in the household, 0 otherwise (dummy)	0.412 (0.492)	0.319 (0.466)	0.468 (0.499)	0.326 (0.469)	0.329 (0.47)	0.478 (0.5)	0.357 (0.479)	0.265 (0.442)	0.363 (0.481)
Number of observations		1006	1003	701	1075	1417	1000	1019	1015	1006

from the questionnaire (concern with noise and concern with GMO) since ex-post analysis showed that the two items measured different latent variable than the remaining six items.

The final set of items included following:

- waste generation (*waste*);
- air pollution (*air*);
- climate change (*climate*);
- water pollution (*water*);
- natural resources depletion (*resources*);
- endangered species and biodiversity (*species*).

For each item respondents rated on a 4-point Likert-type scale how concerned they were with these environmental issues.

Several socio-economic and demographic variables were included in the final model as confounding background variables, including age, gender, education attainment, per capita household income, number of household members, and presence of children in the household. A detailed description of these variables is presented in Table 1.

3.3. Method

The data were analyzed using structural equation modeling (Bollen, 1989). SEM is particularly useful for the purpose of our study because it helps us to test a model of the hypothesized relationships between background variables and a latent variable of environmental concern on the one hand and energy-saving curtailments and investments on the other. In fact, SEM is more general than the regression models employed frequently in econometrics as it allows for the inclusion of latent variables, the estimation of measurement errors of exogenous variables, and also accommodates cases when some of the independent variables are endogenous.

The model tested in this paper is depicted in the form of the path diagram in Fig. 2.

In each country, the latent variable of environmental concern (*concern*) is regressed on background variables (*age* through *kidsin*) with the vector of regression weights $\boldsymbol{\alpha}$ and a residual error term η's. Further, latent variables of curtailments (*c_light** through *c_standby**) and efficiency investments (*i_appl** through *i_renew**) are regressed on environmental concern, with the vector of regression weights $\boldsymbol{\beta}$. Curtailments and efficiency investments are also regressed on background confounding variables, with the matrix of regression weights $\boldsymbol{\Delta}$.

The measurement model for the latent variable *concern* consists of six latent indicators (*waste** through *species**) that are linked to *concern* with the regression weights λ_1 through λ_6, and a vector of measurement errors of latent indicators ($\boldsymbol{\varepsilon}$). Latent indicators of environmental concern and latent variables representing curtailments and efficiency investments are not observed directly, but are linked to their manifest indicators (denoted with the same labels but without asterisks) through a threshold model proposed by Muthén (1983). The threshold model allows for the use of categorical manifest outcome variables and avoids biases known to exist for indicators with fewer than five outcome categories (Finney and DiStefano, 2006, pp. 276–277).

In our model, we allowed residuals of curtailments and efficiency investments, ζ's, to be inter-correlated. This mirrors an observation made in previous studies that curtailments and efficiency investments are subject to similar factors and constraints which leads to their, often spurious, correlation (cf., Black et al., 1985).

To estimate the model parameters, we use weighted least squares mean variance adjusted (WLSMV) estimator with theta parameterization (Muthén and Muthén 2010). The choice of theta parameterization is justified by our hypothesis that residual variances of efficiency investments and curtailments, ζ's, may be mutually correlated. The WLSMV estimator is the most appropriate estimator for non-normal data and for categorical variables (Flora and Curran, 2004); other methods, such as maximum-likelihood estimation, lead to biased estimates of standard errors and generally attenuate the relationships between observed variables under these circumstances (Brown, 2006).

Our analysis proceeds in two steps. In the first step we establish invariance level for the measurement model, which is an important condition for the interpretation and comparison of results across the nine countries. In the second step, we estimate the full model with covariates, as depicted in Fig. 2, taking into account established invariance or lack thereof.

The invariance is crucial in any empirical analysis that uses a measurement model for unobserved latent variables across different sub-populations (for discussion of invariance see, e.g., Steenkamp and Baumgartner 1998; Meredith 1993). The lowest level of invariance, configural invariance, requires that specific set of observed indicators measures well each latent construct. The next level of invariance, measurement invariance, is fulfilled when the factor loadings, i.e., λ's in our case, are constant across the countries (Rock et al. 1978). Some authors are less restrictive, claiming that it is enough to have two loadings of observed variables constrained to be equal across the groups in order to

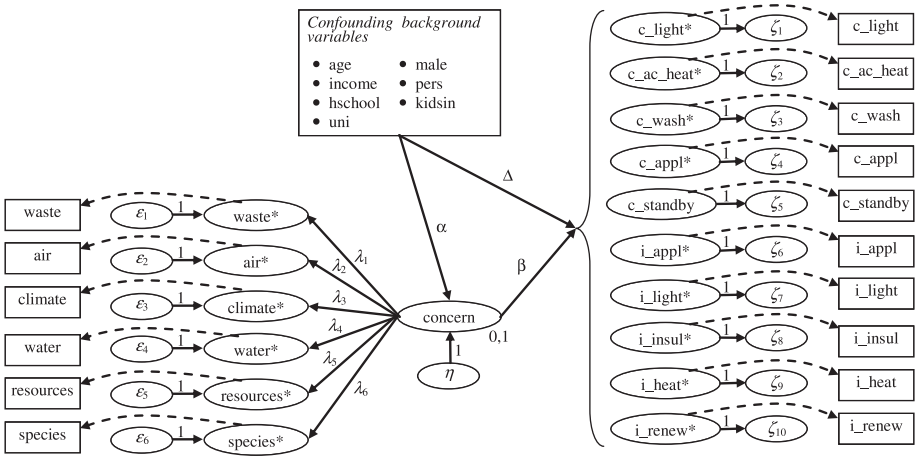

Fig. 2. Path diagram of the country-specific model.

establish partial metric invariance which justifies comparison of effects related to latent variable across subsamples (Byrne et al. 1989; Steenkamp and Baumgarten 1998). However, it is only the highest level of invariance, scalar invariance, in combination with the lower levels of invariance that also makes mean levels of latent variables comparable across the countries. Scalar invariance requires that the vector of intercepts, or thresholds in our case, is constant across the countries. A corrected chi-square test for nested models is used to compare the fit of unconstrained and constrained models.

Models were estimated in the software Mplus (Muthén and Muthén, 1998-2010). We report the results of the analysis in the next section. However, due to model complexity, we were not able to report all the details of the results and refer interested readers to the supplementary material for this study (?see Electronic Annex 2 in the online version of this article).

4. Results

The average rating of the seven indicators of environmental concern across the nine OECD countries is depicted in concise form in Fig. 3. Overall, respondents seemed to be relatively concerned about all of the environmental problems. However, both ordering of these issues and average scores differ slightly across the countries. Water pollution and air pollution seem to be the highest ranking issues, while issues of endangered species, biodiversity and waste generation seem to be lest important. Interestingly, the issue of climate change seems to rank very low in some countries (the second least important in Czech Republic), while it is considered very important in others (the second most important in Sweden).

Average frequency scores of performing the five curtailment behaviors are reported in Fig. 4, graphs (a)–(e). Turning off lights in an unused room, together with fully loading washing machines and dishwashers are the most frequently enacted curtailments. On the other hand, turning off standby mode in appliances is the most neglected activity. Fig. 4, graphs (f)–(j), summarizes also the average probability of the five efficiency investments. Installation of efficient light bulbs and appliances were the most frequent, while installation of renewables and efficient water heaters were the least frequent efficiency investments.

Before proceeding to further analysis, we merged two response categories of environmental concern, i.e., "not concerned" and "slightly concerned" because the former category was only rarely reported by respondents, resulting in few observations. For the same reason we have also merged two response categories of curtailments, namely "never" and "very rarely".

The internal consistency of the environmental concern measure, evaluated separately in each of the nine countries, was satisfactory, with Cronbach's alpha ranging between 0.85 and 0.88 and exceeding the threshold of 0.7 as recommended by Hair et al. (1998). The unidimensionality of the measure of environmental concern was checked using exploratory factor analysis. To improve the fit of the model, the residual errors of items *water* and *climate* were allowed to correlate in Norway.

To gain further evidence for configural invariance, we have fitted the measurement model separately in each of the nine countries using confirmatory factor analysis. The results suggest a relatively good fit of the model across the nine countries. The RMSEA ranged between 0.058 and 0.077, suggesting that the fit was relatively good (i.e., not exceeding the threshold of 0.8) but not excellent (i.e., exceeding the more stringent threshold of 0.05) (cf. Browne and Cudeck, 1993; Hu and Bentler, 1999), and CFI ranged between 0.989 and 0.995, exceeding the threshold of 0.95 recommended for good fitting models by Hu and Bentler (1999). We also conducted the chi-square test for model fit, but this test was significant (the same result was basically obtained for any model reported in this paper) at any conventional level of significance, which would be an indication of a serious discrepancy between the model and the data. However, the chi-square test for model fit is known to be too sensitive to any misspecification with larger samples (Ibtissem, 2010; Jansson et al., 2009; Whitmarsh and O'Neill, 2010) and therefore we do not use this fit index.

In order to ascertain measurement invariance of the measurement model for the latent variable *concern*, we compared the fit of model with parameters λ free to vary across the countries and the nested model where these parameters were set to be constant across the countries. The corrected chi-square test for nested models revealed that the hypothesis of full measurement invariance has to be rejected. However, the hypothesis of partial measurement invariance, with λ_2 (for indicator *air*) and λ_5 (for indicator *resources*) set constant across the nine countries was not rejected by the corrected chi-square test. In addition, change in CFI due to imposition of measurement invariance was equal to 0.001, i.e., safely below the threshold value of 0.01 recommended as a cut-off value for deciding whether to reject the hypothesis of measurement invariance (Cheung and Rensvold, 2002). Partial invariance should be sufficient for the effects related to latent variable to be comparable across the countries (Byrne et al. 1989; Steenkamp and Baumgarten 1998). Further inquiry also indicated that scalar invariance cannot be established, indicating that means of latent variables are not directly comparable across countries.

After establishing partial measurement invariance of the measurement model for environmental concern, we have estimated the full model as depicted in the path diagram in Fig. 1, by

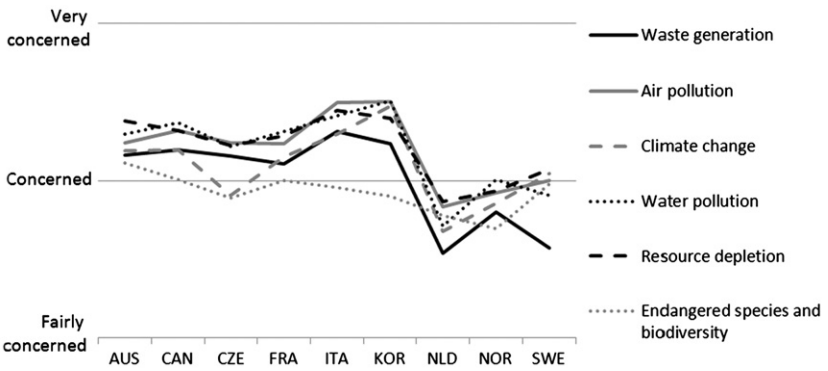

Fig. 3. Average score of environmental concern items across 9 OECD countries.

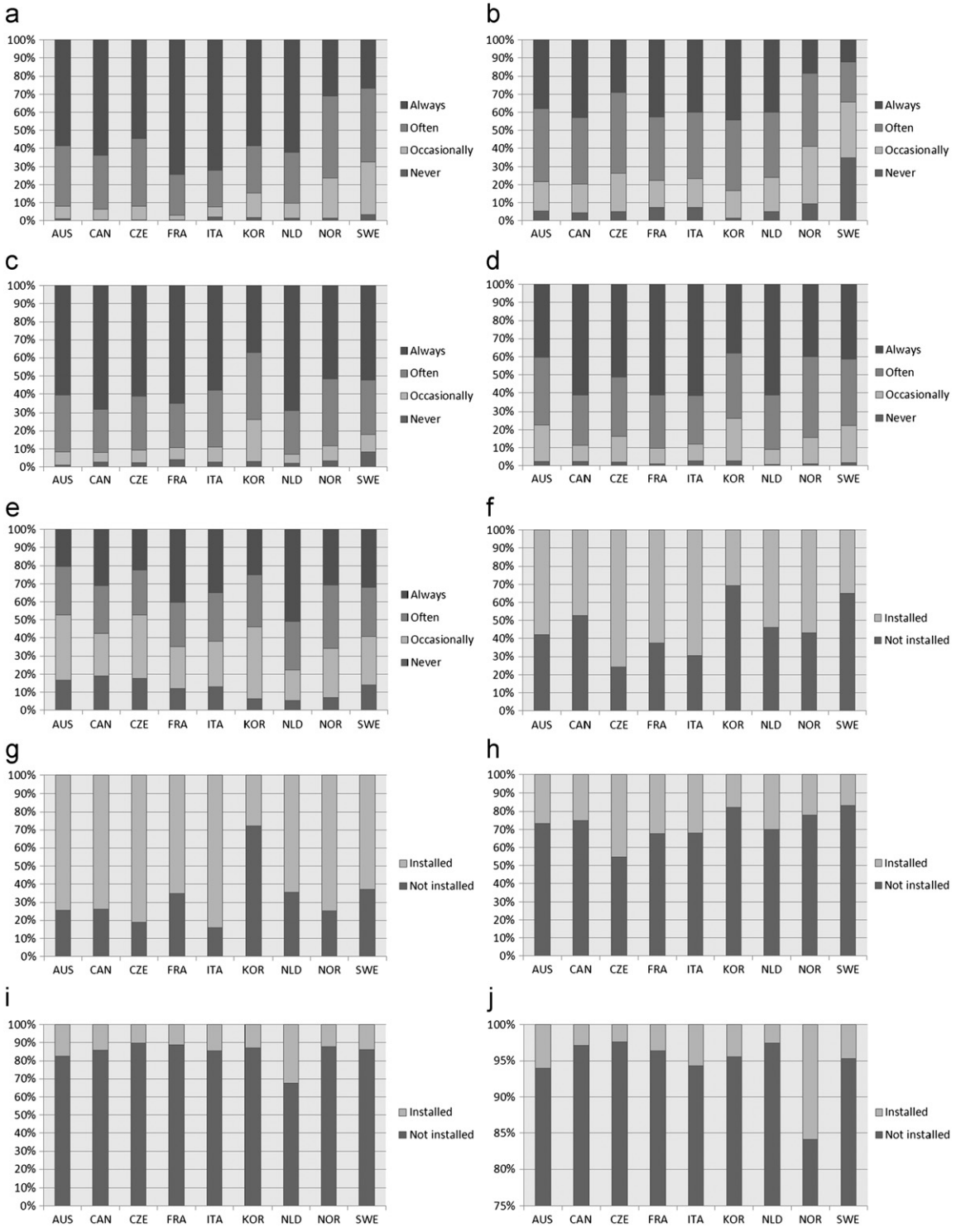

Fig. 4. Frequency of curtailments ((a)–(e)) and presence of efficiency installations in dwellings ((f)–(j)). (a) Turning of lights (c_light), (b) Cutting down on heat./AC (c_at_heat), (c) Loading fully w.m./d.w. (c_wash), (d) Turning off appliances (c_appl), (e) Switch off standby (c_standby), (f) Efficient appliances (i_appl), (g) Efficient lightbulbs (i_light), (h) Thermal insulation (i_insul), (i) Efficient waterheater (i_heat) and (j) Renewable resources (i_renew).

including also background variables as predictors of both environmental concern and the two types of energy saving actions. The purpose of estimating this model was specifically to control for endogeneity of environmental concern with respect to socio-demographic and economic characteristics of the samples.

The fit of the model seems to be good, with RMSEA equaling to 0.028, and its upper confidence not exceeding the value of 0.031, and with CFI being equal to 0.995. Estimates of the factors loadings (λ) from the measurement model of environmental concern are all significantly different zero (see Table 2) suggesting sufficient convergent validity.

Estimates of the effect of background variables on environmental concern (vector of parameters $\boldsymbol{\alpha}$) are displayed in Table 3. The age of respondents seems to have a positive effect on environmental concern as does, in some countries, their university education, while the coefficients are insignificant in other

countries. People with secondary education are on average not different from people with primary education in terms of their average level of environmental concern, and again, the effect of education is insignificant in some countries. Those with high per capita household income and also males are generally less concerned about the environment, with this pattern being insignificant in some of the countries. Finally, the size of household and the presence of children in the household seem to have no direct effect on environmental concern.

Tables 4 and 5 report estimated effects of environmental concern and background variables on curtailments and efficiency investments respectively, and suggests that the effect of environmental concern on energy curtailments is always positive and significant in most countries. As matter of fact, the effect of environmental concern on frequency of cutting down on heating or AC is significant in all countries. Environmental concern has also positive effect on three of the five efficiency investments, namely installation of efficient appliances, energy-saving light bulbs and thermal insulation. Interestingly, we do not find any significant effect of environmental concern on the two major efficiency investments, i.e., installation of energy-efficient water heating boilers and installation of renewables. Importantly, the direction of these effects and their statistical significance remains unchanged, whether or not the background variables are included in the model.

Detailed examination of Table 5 shows that most of the background variables have a mixed effect on energy curtailments in terms of their directions, with two exceptions: income and age of respondents. We found per capita household income to have a negative effect and age to have a positive effect on energy curtailments. The effects of all remaining background variables were found to be mixed across the nine countries.

The positive income effect that can be observed for all of the efficiency investments is probably related to capital costs associated with the introduction of efficiency retrofits. The positive effect of the presence of children on installation of thermal insulation may be due to parents' motivation to ensure higher thermal comfort for their children. The effect of education seems to be mixed and rather weak. Interestingly, age seems to be positively associated with probability of installation of three efficiency investments: purchase of efficiency appliances, energy-saving light bulbs and installation of renewables. Size of household seems to be positively associated with most of the efficiency investments except for installation of energy-saving bulbs.

To summarize our results, we can safely say that environmental concern increases both frequency of energy saving curtailments and probability of efficiency investments. This result is in line with several previous studies that have found positive effect of environmental concern on energy curtailments (Barr et al., 2005; Carlsson-Kanyama et al., 2005; Diekmann and Preisendörfer, 1998, 2003; Scherbaum et al., 2008) and energy investments (Barr et al., 2005; Diekmann and Preisendörfer, 1998; Whitmarsh and O'Neill, 2010). However, our study also points to the fact that comparability of the latent construct of environmental concern across countries cannot be taken for granted but must be carefully tested.

Most of the background variables have a mixed and/or insignificant direct effect on environmental concern and the two types of energy-saving activities. However, there are a few exceptions worth mentioning. First, age seems to be positively associated with environmental concern, energy curtailments and also some of the efficiency investments. Increasing age can have therefore both direct and indirect positive effects on energy savings. Household per capita income has a negative effect on environmental concern, a negative effect on energy curtailments but a positive effect on efficiency investments. In fact the indirect effect of income on efficiency investments is overweighed by its positive direct effect. Consequently, the total effect of increasing income is negative on curtailments and positive on efficiency investments. Education seems to have a clear positive direct affect only on environmental concern and not on energy saving activities. Also gender seems to have an effect (negative for males) only on environmental concern. Importantly, household size has a positive effect on most of the efficiency investments, with the exception of installation of energy-saving light bulbs. Finally, the presence of children in a household increases the probability of introducing thermal insulation in the dwelling. Mixed effect of socio-demographic variables is also found in most of the literature (?see Electronic Annex 1 in the online version of this article for an extensive survey of the literature).

Table 2
Measurement model of environmental concern (loadings).

Items	AUS	CAN	CZR	FRA	ITA	KOR	NLD	NOR	SWE
Waste	0.813	0.804	0.637	0.767	0.696	0.827	0.745	0.733	0.725
Air	0.858	0.858	0.858	0.858	0.858	0.858	0.858	0.858	0.858
Climate	0.77	0.714	0.622	0.833	0.756	0.867	0.806	0.811	0.812
Water	0.817	0.812	0.721	0.834	0.792	0.889	0.82	0.785	0.823
Resources	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833
Species	0.734	0.735	0.641	0.784	0.642	0.661	0.741	0.676	0.696

Note: All factor loadings are significantly different from 0 at the 0.001 significance level.

5. Conclusions

The main purpose of this paper was to investigate whether residents' environmental concern has any effect on their energy saving curtailments and efficiency investments. The novelty of the present work lies in the fact that it seeks to investigate this topic in a multi-country setting, exploiting the data from nine OECD countries (Australia, Canada, Czech Republic, France, Italy, South Korea, Netherlands, Norway and Sweden) and also in that it employs a latent variable model which allows us to examine the conditions necessary for the results to be comparable across different countries and novel in this paper is also the focus on

Table 3
Explanation of environmental concern (regression weights, significance).

Indep. var.	Dep. var.	AUS	CAN	CZE	FRA	ITA	KOR	NLD	NOR	SWE
Age	− − > concern	.009*	.006	−.002	−.004	−.005	.01*	.007	.018***	.004
Income		−.001	.001	.009	.004	−.005*	.003	−.004	.001	−.007*
Hschool		.008	−.089	−.096	−.158	.112	.217	−.009	.153	.182
Uni		.284	−.154	−.254	−.131	−.058	.217	.032	.354*	.107
Male		−.29**	−.101	−.246*	−.117	−.183**	.081	−.331**	−.226***	−.318***
Pers		−.032	−.011	.01	.078	−.037	.009	−.077	−.027	−.038
Kidsin		−.108	−.133	−.094	−.104	−.014	.128	−.071	.192	.147

Note: ***stands for sig. level 0.001; ** for sig. level 0.01 and * for sig. level 0.05.

Table 4
Explanation of curtailments (regression weights, significance).

Indep. var.	Dep. var.	AUS	CAN	CZE	FRA	ITA	KOR	NLD	NOR	SWE
Concern	– – > c_light	.147**	.113*	.123*	.18**	.276***	.206**	.04	.121**	.046
Age		.014**	.007*	.003	.001	.004	.007	.002	.001	.002
income		–.001	.003	–.003	–.005	.001	–.005	.001	–.002	–.005
Hschool		–.018	–.017	–.235**	–.003	.314*	.327	–.112	–.206	.053
Uni		–.169	–.114	–.147	–.043	–.015	.651*	–.194	–.353*	.134
Male		–.241*	.04	.048	–.29*	.089	–.289*	–.27*	–.065	–.019
Pers		.015	–.055	.007	.054	–.066*	–.029	.014	–.076	.154**
Kidsin		.067	.311*	–.088	–.185	–.055	.004	–.344*	–.057	–.39**
Concern	– – > c_ac_heat	.202***	.211***	.137*	.203***	.209***	.232***	.136*	.23***	.164**
Age		.001	.012***	.007	.011**	.011***	.01*	.006	.006	.014***
Income		–.004	.001	.006	–.005	–.005*	.003	.001	–.001	–.005
Hschool		–.055	–.239	.081	–.125	.081	.437	–.443*	–.242	.066
Uni		–.024	–.391	.026	.023	.029	.537	–.516*	–.196	.087
Male		–.041	–.006	.241*	–.358**	–.058	–.282*	–.036	–.152	–.115
Pers		–.015	–.063	–.032	.03	–.062*	–.009	–.101	–.044	.155**
Kidsin		.041	.371**	–.087	–.074	.124	–.036	–.006	.003	–.092
Concern	– – > c_wash	.183***	.171**	.113	.242***	.331***	.168**	.041	.128**	.203***
Age		.001	.001	.001	.005	.006*	.011*	.013**	.003	.001
Income		–.003	–.001	–.013	–.004	–.004	.004	.005	–.004**	.001
Hschool		.147	–.033	–.185	.016	.093	.476	.142	–.099	–.081
Uni		.062	–.132	.072	–.002	.118	.556	.043	–.047	–.071
Male		–.387***	–.238*	–.131	–.513***	–.109	–.306*	–.47***	–.332***	–.336***
Pers		–.009	–.063	–.032	.228***	–.054*	–.02	–.051	.056	.161**
Kidsin		.125	.296	.129	–.206	–.047	–.068	.142	.104	.216
Concern	– – > c_appl	.135**	.08	.048	.247***	.242***	.267***	.076	.102*	.201***
Age		.009*	.012**	.013**	.012**	.007***	.01*	.02***	.007*	.015***
Income		–.005	–.002	–.011	–.006	–.001	–.002	–.009*	–.001	.003
Hschool		.147	–.236	–.022	–.059	.049	.032	.148	–.355*	–.284*
Uni		.13	–.288	–.053	–.049	–.028	.26	.054	–.42*	–.287
Male		–.182	.023	–.006	–.218*	–.097	.021	–.27*	–.353***	–.41***
Pers		.016	–.065	.03	.063	–.05	–.058	.002	–.019	.087
Kidsin		–.033	.256	–.014	–.233	–.103	.093	–.073	.06	–.278*
Concern	– – > c_standby	.114*	.172**	–.036	.231***	.175***	.167**	.057	.071	.169***
Age		–.003	.006	.01*	.008*	.001	.002	.02***	.011**	.007*
Income		–.009**	–.003	–.015	–.004	–.002	.002	–.012**	–.001	–.003
Hschool		–.012	.122	–.113	.029	–.034	.224	.032	–.076	–.224
Uni		.072	–.005	–.041	–.055	–.122	.064	–.24	–.229	–.081
Male		– –.088	.033	–.284**	–.384***	–.13	.043	–.316**	–.409***	–.239**
Pers		.04	–.037	.016	.046	–.017	–.038	–.011	.027	.007
Kidsin		–.095	.279*	–.025	–.19	–.09	–.013	.093	.042	–.125

Note: ***stands for sig. level 0.001; ** for sig. level 0.01; * for sig. level 0.05.

the role of environmental concern as a factor of several curtailments and efficiency investments.

Our results suggest that people with a higher environmental concern are on average more likely to perform energy-saving curtailments and also are more likely to have some energy-efficiency retrofits installed in their dwellings. However, our study also found that environmental concern has no statistical effect on whether or not people have made two major efficiency investments, specifically whether they have invested in the purchase of efficiency-rated water heaters and whether they have installed renewable resources in their dwellings. Importantly, our analysis also revealed that these results are generalizable to the nine OECD countries examined in this study and are relatively insensitive to the confounding effect of background variables. The fact that environmental concern has either no effect or a relatively weak one on those energy-saving actions which are more demanding in terms of their capital costs, time needed for their purchase and implementation, and also which are subject to other external constraints, is well in line with literature which assumes a lesser role of internal motivation in such instances.

This finding has very practical policy implications because it suggests that a strengthening of environmental concern through policy intervention can actually lead to an increase in both curtailments and efficiency investments. Although the efficiency of such policy instruments would need to be tested, possibly using experimental evidence, it is clear that the synergic effect of environmental concern on diverse energy-saving actions is very advantageous from a practical point of view. In fact, these results support the contention that awareness-raising campaigns could be employed to minimize the rebound effect (cf. Bio Intelligence Service, 2011, pp. 66–68) precisely because environmental concern can stimulate both efficiency investments and also everyday energy-saving curtailments.

Besides the effect of environmental concern, our study also analyzed the effects of various background variables on environmental concern, curtailments and efficiency investments. Our results, again in line with existing empirical evidence, suggest that most of the socio-economic and demographic variables have mixed effects on the three variables. However, some interesting patterns emerged with respect to the age of respondents, household income, education and gender of respondents and also the size of household.

One of the important findings of our study is that older people are usually more concerned about the environment and are also

Table 5
Explanation of efficiency investments (regression weights, significance).

Indep. var.	Dep. var.	AUS	CAN	CZE	FRA	ITA	KOR	NLD	NOR	SWE
Concern	– – > i_appl	.051	.059	−.129	.1	.215***	.12	.137*	.068	.001
Age		.01*	.017***	.01	.011**	.003	.01*	.018***	.003	.009**
Income		.007**	.005*	.037**	.006	.001	.004	.01*	.004*	.014***
Hschool		−.068	.268	−.277	−.022	.069	.604	.272	.019	−.087
Uni		−.153	.29	−.284	.083	−.14	.414	.251	.085	.052
Male		−.124	.133	.183	−.173	.117	−.275*	−.052	−.003	.122
Pers		.131*	.213***	−.066	.162*	−.015	.107	.062	.094	.184**
Kidsin		−.038	.071	.212	.017	−.035	−.125	.237	.212	.081
Concern	– – > i_light	.022	.132*	.2**	.225***	.334***	.149*	.156*	.087	.054
Age		.022***	.008	.01	.011**	.008*	.015**	.028***	.025***	.011***
Income		.004	.002	−.001	−.003	−.004	.002	−.001	.004	.014**
Hschool		−.058	.003	−.356*	.007	.275	.129	.048	−.007	.291
Uni		.013	.086	.055	.293	−.021	.09	.019	.006	.572**
Male		−.11	.041	−.043	−.107	.02	−.019	−.24	−.202	.12
Pers		.118	.166**	.136*	.052	−.084*	.129*	.016	.033	.025
Kidsin		.042	−.177	−.102	.086	.007	−.106	.285	.325*	.28
Concern	– – > i_insul	−.024	.03	.011	.035	.102***	.078	.014	−.021	.039
Age		.021***	.015***	−.002	.016***	.005*	.013**	.008	.01**	.006
Income		.008**	.005*	.027**	.008*	.001	.007	.015**	.005**	.013***
Hschool		−.083	−.079	−.152	−.113	.038	.191	−.235	−.08	−.327*
Uni		.041	−.059	−.045	−.182	−.077	−.01	−.432	.07	−.296*
Male		.029	.139	.025	.127	.016	.138	.158	.072	.074
Pers		.153**	.198***	−.035	.062	.045	.047	.199**	.09	.135*
Kidsin		−.019	−.225	−.09	.278	.063	−.225	−.011	.14	−.039
Concern	– – > i_heat	−.086	.007	.012	.032	.073	.046	−.016	−.013	.001
Age		.005	.008*	−.01*	.005	−.004	.007	.016***	.013**	.009**
Income		.006*	.003	−.018	.011**	.003	.002	.018***	.004*	.013***
Hschool		−.095	.146	.196	−.098	.019	−.14	−.149	.202	−.178
Uni		.029	.195	.165	−.049	−.155	−.331	−.046	.14	−.281
Male		−.121	.219*	−.166	.039	−.061	.135	.089	.024	.144
Pers		.123*	.169**	.149**	.057	.035	.077	.234***	.17**	.142*
Kidsin		−.024	−.113	.071	.262	.043	−.244	.001	.026	.052
Concern	– – > i_renew	−.053	.048	−.071	.059	−.01	−.007	.034	−.034	−.035
Age		.007	−.004	−.007	.01**	−.007*	.004	−.003	.018***	.004
Income		.004	.007**	.002	.002	−.004	.001	.01*	.003	.01**
Hschool		−.07	−.218	.119	.069	−.05	.205	.252	.033	−.26
Uni		.123	−.145	.292	−.139	−.054	.039	.215	.132	−.227
Male		.095	.378**	.036	.388**	.127	.052	.501***	.061	.211*
Pers		.02	.127*	.107*	.119*	.105**	−.005	.127	.186***	.124*
Kidsin		.203	−.056	.111	.292	−.004	−.096	−.14	.042	.142

Note: ***stands for sig. level 0.001; ** for sig. level 0.01 and * for sig. level 0.05.

more likely to introduce efficiency measures and perform curtailments. Thus age seems to have both direct and indirect effects on energy conservation. Another important finding is that people living in wealthier households tend to be less concerned about environmental problems, tend to curtail less, but are more likely to invest in energy efficiency. Our study has also confirmed the findings of previous studies that the level of formal education plays no decisive role in differentiating between those who conserve energy and those who do not.

Energy policies in the OECD countries have largely ignored the role of socio-psychological variables as factors of energy consumption and energy-saving over the last 30 years, and instead they use mainly monetary incentives, legal regulations and/or information measures such as efficiency labeling and provision of feedback information on energy consumption (Geller et al., 2006). The present study shows that energy policies may benefit by using policy tools that would exploit the role of environmental concern as a factor of energy-saving. Environmental concern, being a "situation invariant orientation pattern" influences how decision problems are framed, helps to implement and plan actions of individuals, and also increases their effort to overcome barriers that they encounter in the course of these actions (Bamberg, 2003, p. 22). All of these functions that environmental concern as a factor of behavior plays could be very useful for policies that aim at promotion of curtailments and efficiency investments in the residential sector.

The limitations of the present study, as we see them, should be acknowledged as well. Probably the most important limitation lies in the fact that this study uses only one specific multiple-topic-single-expression instrument to measure environmental concern. Unfortunately, there is no widely accepted and theoretically well-grounded measure of environmental concern and therefore any instrument that measures environmental concern can be susceptible to this type of criticism at the present moment. Research aimed at the development and testing of complex measures of environmental concern, particularly in a multi-country setting, is very much needed.

Another limitation of the study is given by the fact that the data come from nine developed and rich OECD countries. As a consequence, this fact may limit the generalizability of our results to countries at a similar level of economic development. However, we think that our study is not limited to one cultural or geopolitical region as it exploits data from four continents and several language cultures.

Last but not least, this study is based on cross-sectional data and correlational evidence. Although the statistical model used in

this study is relatively complex and although we made sure to base this model conceptually on previous empirical evidence and theory, our results may be criticized for failing to provide evidence of causal effect of environmental concern on energy conservation. We acknowledge this limitation and hope that future research will make an effort to collect empirical evidence more relevant for the formulation of similar causal statements, particularly evidence from experimental and panel studies conducted simultaneously in several countries.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.enpol.2012.04.018.

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