Energy Efficiency, Renewable Energy and Household Behaviour: Evidence from OECD countries

Prudence Dato
University Savoie Mont Blanc-IREGE (France)
prudence.dato@univ-savoie.fr

Motivation

- Residential buildings contribute at 23% to the world final energy demand (International Energy Agency IEA, 2007) and 17% to the world CO2 emissions (IEA, 2014).
- Residential energy consumption: Cooking (5%), lighting (5%), water heating (16%), appliances (21%) and space heating (53%) (IEA, 2008b).
- 72% of the global decrease in CO2 emissions between 2010 and 2020 will come from energy efficiency (EE) improvements (Policy scenario of IEA).
- Possible synergies between EE measures and renewable energy (RE) adoption: RE can reduce annual CO2 emissions by 8.6 Gt by 2030; and the combination with EE gains, would be sufficient to set the world on a path to prevent catastrophic climate change (IRENA, 2014).
- There is a huge literature on: either demand for RE or investment in EE in the residential sector. But no specific study that investigates the behaviour of household to jointly adopt RE and to invest in EE and the relatedness of the two decisions.

Main Objectives

1. Investigate the behaviour of household to jointly adopt renewable energy and to invest in energy efficiency and the relatedness of the two decisions: (i) theoretically and empirically.
2. Explain why some households decide to (i) invest both in energy efficiency and in renewable energy, while others decide to (ii) only invest in renewable energy or to only invest in energy efficiency or to (iii) do nothing.

Theoretical predictions

The program of the household (HH)

$$\max_{ee,re} \sum_{t=0}^{p} \beta^t u(ee) + \sum_{t=0}^{q} \beta^t v(re) + \theta \sum_{t=0}^{min(p,q)} \beta^t ee * re,$$
$$st \quad R = k_1 ee + k_2 re$$

where R is the HH's energy budget; k_1 and k_2 are the unit cost of EE and RE, respectively; θ is the pro-environmental index and β is the discount factor.

The FOC gives:

$$\frac{k_2}{k_1}\beta_p u^{'}\left(\frac{R-k_2 re^*}{k_1}\right) + \frac{k_2}{k_1}\theta\beta_{pq} re = \beta_q v^{'}(re^*) + \theta\beta_{pq}\left[\frac{R-k_2 re^*}{k_1}\right]$$

Proposition 1: *There is a threshold on the pro-environmental index θ below (resp. above) which investment decisions in energy efficiency and in renewable energy of the household are substitutes (resp. complements).*

Proposition 2: *A household with a higher energy budget has a higher (resp. lower) threshold on the pro-environmental index $\overline{\theta}$ if his inter-temporal elasticity of substitution in investment in energy efficiency is high (resp. low).*

Corollary: *For a household with a high (resp. low) inter-temporal elasticity of substitution, there exist levels of energy budget R_1 and R_0 such that: (i) for energy budget higher than R_1, the two investments decisions are substitutes (resp. complement) and (ii) for energy budget lower than R_0, the two investments decisions are complements (resp. substitutes).*

Data and Methods

Source of data:

We use two rounds (2008, 2011) large-scale household surveys of Environmental Policy and Individual Behaviours changes (EPIC): **energy**, food, transport, waste and water. The first round (2008) accounts for 10 OECD countries of 10,000 households: **Australia, Canada, France, Korea, Netherlands, Sweden**, Czech Republic, Italy, Norway and Mexico; while the second round (2011) accounts for 11 OECD countries of 12,200 households: common (in bold) plus five additional countries (Chile, Japan, Spain, Israel and Switzerland). As the surveys are independent, we decide to pool the two datasets.

Dependent variables:

RE adoption: HHs that installed over the past ten years, a RE (solar panels for electricity or hot water and wind turbines) (1 for yes, already equipped not considered). Additionally, Energy from electricity provider is already from RE sources (2008) or have chosen the "renewable or green" energy tariff from their electricity provider and using thermal solar panel for water heating (2011).

EE investment: monetary investments (for own installation; already equipped not considered)+ non-monetary investment (always)

Interactions between RE and EE (eere): 3= RE+EE, 2= RE or EE and 1=none of them.

Independent variables:

Socio-economic and dwelling characteristics: age, gender, collective, size of the residence, income of household, ownership, duration, etc.

Attitudinal variables: perception (environmental concerns, air pollution, climate change, resource depletion, etc.); commitment (local vote, charitable organization, environmental organization, local organization) and trust (scientists, local authorities, manufacturers, NGOs.).

Others variables: energy (individual metering, peak Tariff, energy costs, environmental benefits, label, etc.), control (year of the survey, country).

Methods:

Bivariate probit (joint decisions) and Generalized ordered logit (interaction between the two decisions).

Empirical results

Variables	Biprobit ee	Biprobit re	Gologit eere=1	Gologit eere=2
Residential and economic variables				
Living in a non-detached residence	-0.0695*		-0.115	-0.103**
	(0.0364)		(0.0806)	(0.0520)
Size of the residence	0.0657***		0.114**	0.00739
	(0.0233)		(0.0494)	(0.0343)
Income of household	0.0270***	0.00231	0.0455***	0.0162*
	(0.00630)	(0.00509)	(0.0143)	(0.00901)
Ownership	0.151***	0.108***	0.265***	0.184***
	(0.0383)	(0.0322)	(0.0817)	(0.0564)
Perception, commitment and trust				
Environmental concerns (general issues)	-0.00767	-0.0250***	-0.0330	-0.0365**
	(0.0105)	(0.00885)	(0.0241)	(0.0150)
Climate change issues	-0.0649**	0.0797***	-0.0663	0.102**
	(0.0267)	(0.0245)	(0.0545)	(0.0422)
Resource depletion issues	0.0747**	-0.0426	0.0886	-0.0165
	(0.0292)	(0.0273)	(0.0600)	(0.0482)
Participation in local vote	0.0788**	0.0296	0.174**	0.0698
	(0.0369)	(0.0325)	(0.0789)	(0.0549)
Commitment in charitable organization	0.147***	0.122***	0.308***	0.230***
	(0.0412)	(0.0319)	(0.0978)	(0.0539)
Commitment in environmental organization	0.0565	0.134***	0.157	0.275***
	(0.0486)	(0.0389)	(0.105)	(0.0676)
Commitment in local organization	0.115**	0.0918**	0.308***	0.178***
	(0.0475)	(0.0370)	(0.113)	(0.0628)
Trust in scientists	0.0549***	0.0818***	0.125***	0.121***
	(0.0147)	(0.0146)	(0.0308)	(0.0265)
Trust in local authorities	0.00202	0.0332***	0.0227	0.0402*
	(0.0136)	(0.0124)	(0.0299)	(0.0224)
Energy use				
Energy costs before buying or renting a house	0.103***	0.00844	0.144*	0.0946*
	(0.0367)	(0.0308)	(0.0801)	(0.0525)
Individual metering	0.0700		0.334*	0.0507
	(0.0856)		(0.172)	(0.129)
Peak Tariff	0.0472		-0.120*	-0.557***
	(0.0333)		(0.0724)	(0.0483)
Label to reduce energy use	0.172***		0.364***	0.375***
	(0.0561)		(0.111)	(0.104)
rho	0.1618***			
	(0.0234)			
Log pseudolikelihood	-9183.1129		-8096.1711	
Pseudo R2			0.1955	
Observations	11198		11198	

***1%, **5%, *10% and ()= robust std errors.

Joint decision of RE adoption and investment in EE (Bivariate probit):

- **Tests:** $\rho = 0.1018$ and Bivariate probit (Prob>chi2=0.000, with $\rho = 0.1618$) is then more appropriate than separate univariate probit models because the two decisions are interrelated and cannot be estimated independently. The goodness of fit and prediction test (53.22 %) are favourable.
- **Economic and dwelling characteristics**: Income on ee (*Energy poverty*) and on re (many financial supports and incentives); Ownership on re and ee: *Split incentive problem* and type of dwelling and its size on ee (*energy consumption*).
- **Environmental and attitudinal motivations:** Environmental issues on re (to reduce CO2 emissions) and on ee (environmental and saving money); commitment in environmental organization on re (*public good*); commitment in local and charitable organizations positively affect the two decisions (*local problem and altruism*) and trust in researchers, scientists and experts on ee and re (*large consensus on climate change*).
- **Robustness check:** (i) extension of ee to non-monetary investments (9%) $\rightarrow$ factors that are related to the monetary capacity of the HH become non significant on ee. (ii) With and without attitudinal characteristics $\rightarrow$ no change.

Interaction between RE adoption and investment in EE (Gologit):

- **Tests:** Ordered probit (oprobit) and ordered logit (ologit) methods are good candidates. AIC, BIC, log-likelihood; cut points cut1 and cut2; Brant test that checks the assumptions of the parallel-lines $\rightarrow$ Generalized ordered logit (gologit); prediction (69.05%)
- Positive effect of the HH income on the joint investment in EE and in RE if none of these investments has been undertaken; and if any of them is undertaken, it becomes less significant (10%).

Conclusions

- The paper fills the gap in literature (theoretical and empirical): RE and EE are interrelated and cannot be estimated independently.
- Policy implications from HH behaviour to boost energy transition:
  1. Regulation of the housing markets to solve split incentives.
  2. Green grants (interest-free) that target only energy poor HH.
  3. Existing charitable/local/environmental organisations to communicate on the energy transition.
  4. Scientists, national/local authorities should be more involved in sensitization and academic findings should be more vulgarized.

Forthcoming Research

Energy conservation and integration of renewable energy through micro-grids, smart-grids, smart meters and storage devises.