Identifying energy demand from discrete changes

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Motivation (I)

- We like to advance in the knowledge of consumers' behavior in Spain. Basic task is to identify key variables which explain individual decisions and thus can be used to propose policies
- Only single equation models but even in this simple scenario we wonder about **what energy demand is**?
- Our (**impossible**) aim is to know how residential demand will be in the future
- Our attainable aim is to decompose the contribution of each factor on the evolution of energy demand and make some "counterfactual exercise"

Motivation (II)

ESTIMATION

- So we consider Y = f (X) and we are interested in estimating (ideally) causal effects of X on Y
  - Y is energy (in the domestic case it could be electricity, natural gas, liquified petroleum, or any other energy source)
  - X contains all (potential) determinants of energy demand (the factors and their number are going to depend on data availability). Some variables should allow identifying responses from **discrete changes**

SIMULATION

- Could this approach be useful to infer evolution of demand or proposing energy policies? Once we identify impact of variables (parameters) we can:
  - Calculate X for a tarjet Y
  - Change X (taxes, for instance) and see the effects on Y
  - Assume a counterfactual and evaluate impacts
  - …

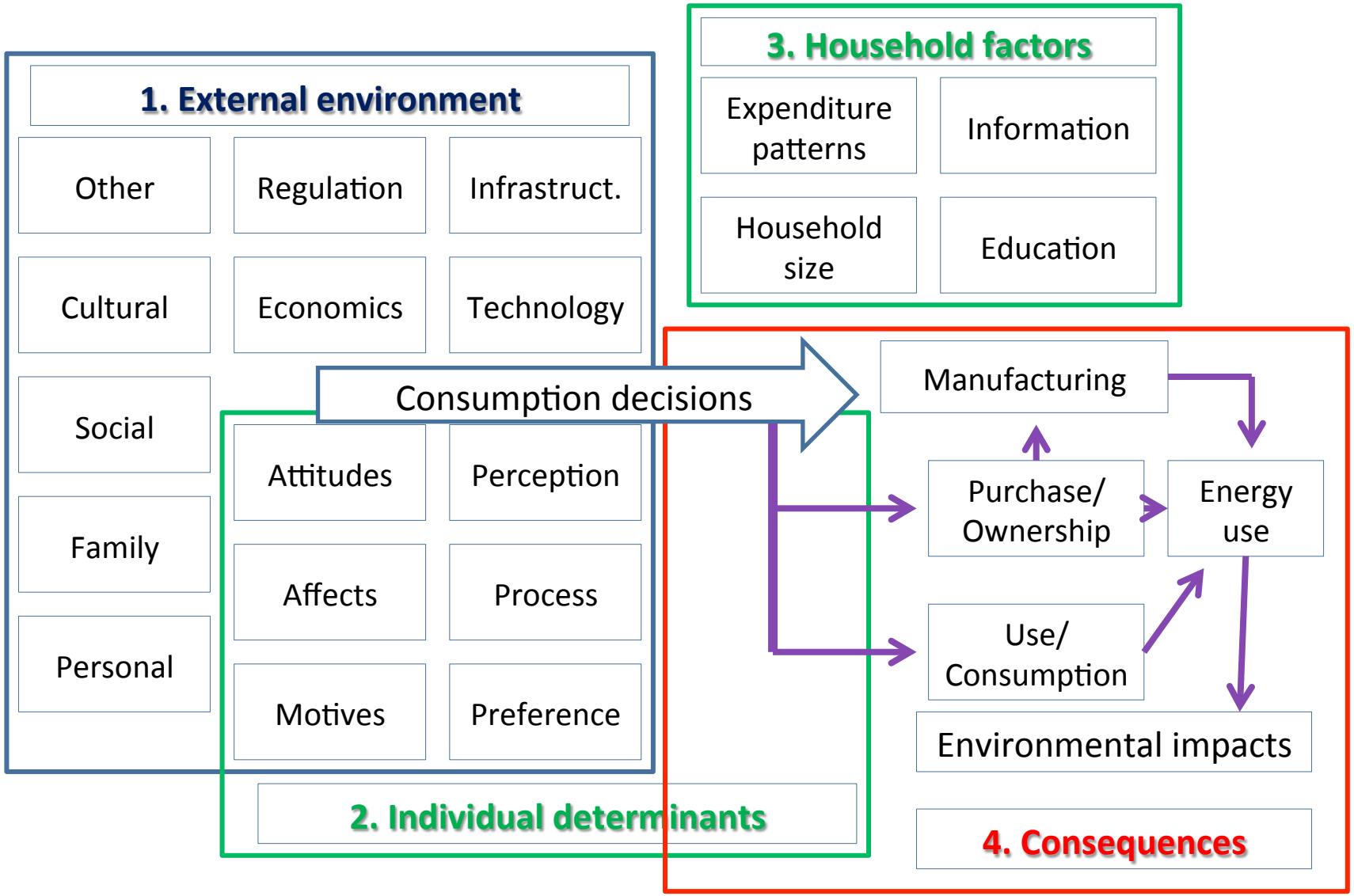
Motivation (III)

- So, we have a number of question to answer:
  - Which characterize the residential energy demand (electricity and gas) in Spain?
  - Is demand responding to economic variables? How? When? Is this response compatible with residential energy reduction (improving energy efficiency)?
  - Are we able to estimate responses of demand using **discrete changes**? Changes of source of energy, changes in equipment, house movements, etc. In other words, are different the responses to economic variables at the **extensive and intensive margins**?

Outline

- Estimating energy demand
- Identifying energy demand from discrete changes
- Conclusions

Estimating energy demand (I)



Estimating energy demand (II)

- How can we derive parameters of Y = f(X) to have causal (or not causal but reduced form) effects of X (determinants) on Y (demand for energy or uses of energy)
  - Which data? Which variables?
  - Do we have the data we need?

- Which data available?
  - Time series
  - Cross-sections
  - Combination of time series – cross-sections

- Which variables do we have?
  - Level of aggregation
  - Physical – monetary
  - Source of variables (administrative records, private records, survey data …)

Estimating energy demand (III)

- Extensive literature on energy demand (housing) in the last decades traced back to the 50's
  - Econometric methods (micro – macro models, univariate – multivariate models, single – simultaneous equations, …)
  - Experiments
  - …
- This literature has evolved due to many reasons:
  - Questions of interest
  - Some theoretical developments
  - And, basically, data availability

Estimating energy demand (IV)

- Our interest could be one of the following equations for Y = f (X) (I am not sure about the correct one if any):

$$\ln(Kwh) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon$$

$$\ln E = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon$$

- Where Kwh are number of kilowats/hour and E is expenditure; X1 to X5 are different determinants of energy demand to take account of observed heterogeneity among households

Estimating energy demand (V)

- For the exercises presented, we mainly use data from the Encuesta de Presupuestos Familiares (Family Expenditure Survey)
  - This is an annual representative sample of consumption and income (with a wide range of demographics and characteristics of the house) of approx. 25,000 Spanish households per year
  - It is a rotating panel with a rotation rate of 0.5 (a household only stays in the sample for a maximum of two years)
  - It contains variables as the amount and sources of households' incomes (**household factors**), their expenditures on goods and services (**household factors**), socio-demographic information (**individual determinants**), sources of energy used (also for some end use), quantity demanded and expenditure (consumption decisions) and physical characteristics of the household (**external environment**)
  - We match price data from the National Bureau of Statistics and weather data from the Spanish Weather Agency

- In terms of the previous equations, X1 contain household income and energy prices, X2 are demographic variables, X3 are house characteristics, X4 are weather variables (HDD and CDD with regional and time variation), X5 is a building year dummy (other dummies) and ε is a random term

Energy demand. Estimation (VI)

- Why do we worry about identifying demand at discrete changes? Because marginal effects of economic variables are estimated to have very limited influence on demand (particularly price elasticities). For Spain:

Authors	Sample	Energy product	Price elasticity	
			short-run	long-run
Labandeira et al. (2006)	1973-1995	Motor Fuels Electricity Natural Gas LPG	-0.058 -0.783 -0.046 -0.249	
Bernstein and Madlener (2011)*	1981-2008	Electricity	[-0.014;0.010]	[-0.350;-0.300]
Labandeira et al. (2012)	2005-2007	Electricity	-0.254 -0.031 (industrial) -0.052 (large consumers)	
Blázquez et al. (2013)	2000-2008	Electricity	-0.070	-0.190
Hanemann et al. (2013)*	2006-2008	Electricity Natural Gas Liquid Fuels	-0.135 -0.184 -0.273	

Energy demand. Estimation (VII)

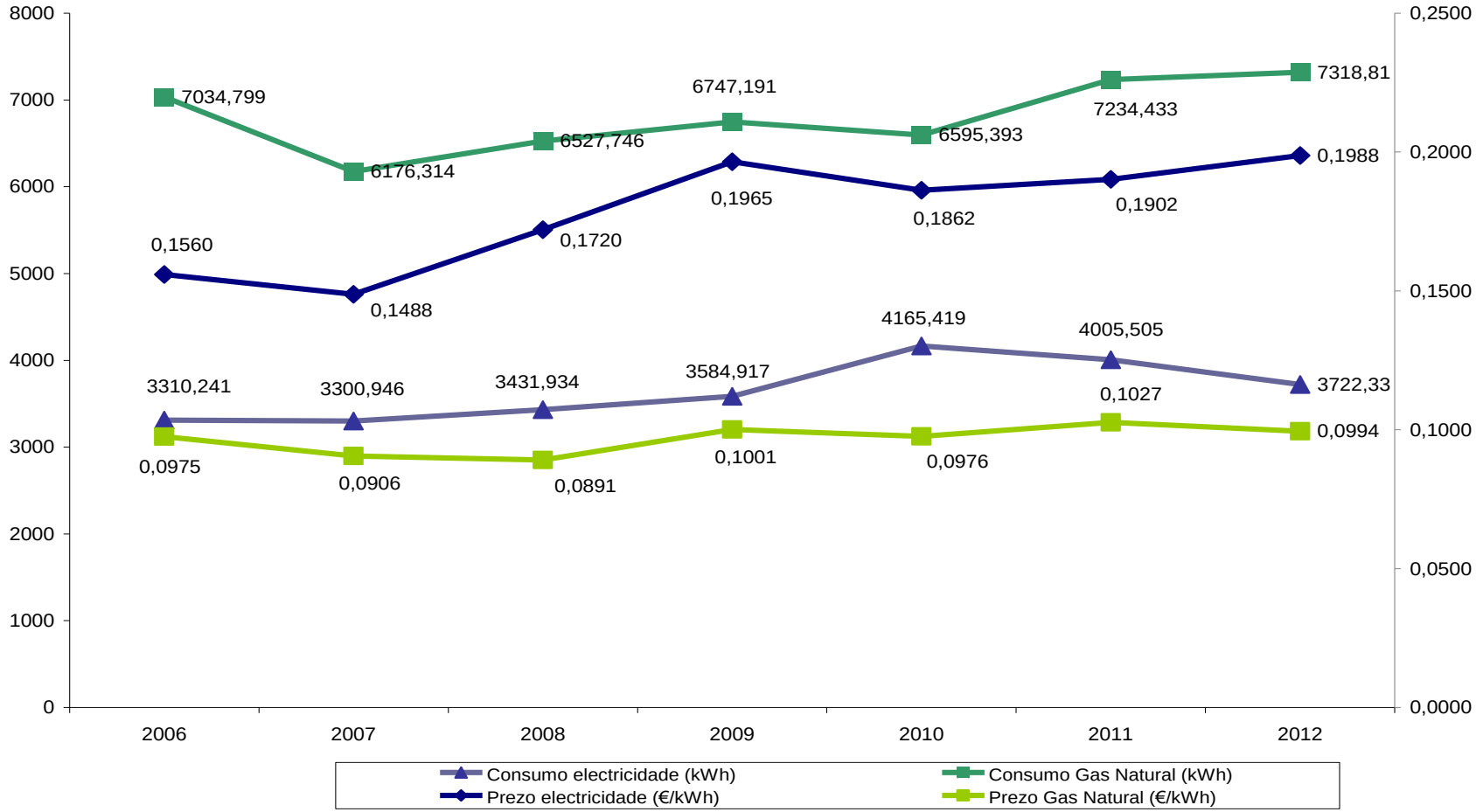
Authors	Country	Sample	Energy product	Price-elasticity
Meier and Rehdanz (2010)	United Kingdom	1991-2005	Natural Gas Heating oil	[-0.56;-0.34] [-0.49;-0.40]
Nakajima (2010)	Japan	1975-2005	Electricity	-1.13 (LR)
Nakajima and Hamori (2010)	USA	1993-2008	Electricity	[-0.33;-0.14] (LR)
Alberini and Filippini (2011)	USA	1995-2007	Electricity	[-0.1524;-0.0832] (SR) [-0.7290; -0.4351] (LR)
Alberini et al. (2011)	USA	1997-2007	Electricity Natural Gas	-0.736 (SR) -0.814 (LR) -0.572 (SR) -0.647 (LR)
Bernard et al. (2011)	Canada	1989-2002	Electricity	-0.51 (SR) -1.32 (LR)
Fan and Hyndman (2011)	Australia	1997-2008	Electricity	[-0.428;-0.363]
Faruqui and Sergici (2011)	USA	2008-2009	Electricity	-0.039
Filippini (2011)	Switzerland	2000-2006	Electricity	[-0.835;-0.652] (SR) [-2.266;-1.273] (LR)
Filippini and Hunt (2011)	29 OECD countries	1978-2006	Energy	[-0.452;-0.200]
Vásquez et al. (2011)	USA	1993-1997	Electricity Natural Gas	[-0.72;-0.28] [-0.41;-0.11]
BuShehri and Wohlgenant (2012)	Kuwait	2000	Electricity	[-0.265;-0.153]
Okajima and Okajima (2013)	Japan	1990-2007	Electricity	-0.397 (SR) -0.487 (LR)

Energy demand. Estimation (VIII)

- In summary: using 50 papers (11 for Spain) we have:
  - The average price elasticity of electricity for domestic use is -0.33 for the short-run and -0.60 for the long run (standard deviation of long term values is 0.51)
  - For gas -0.36 (-0.70) with standard deviation of long run values double than standard deviation of short term values (standard deviation in both cases are around the mean)
  - In Spain these figures are (on average) smaller than averages for the rest of countries (with data covering up to 2012)

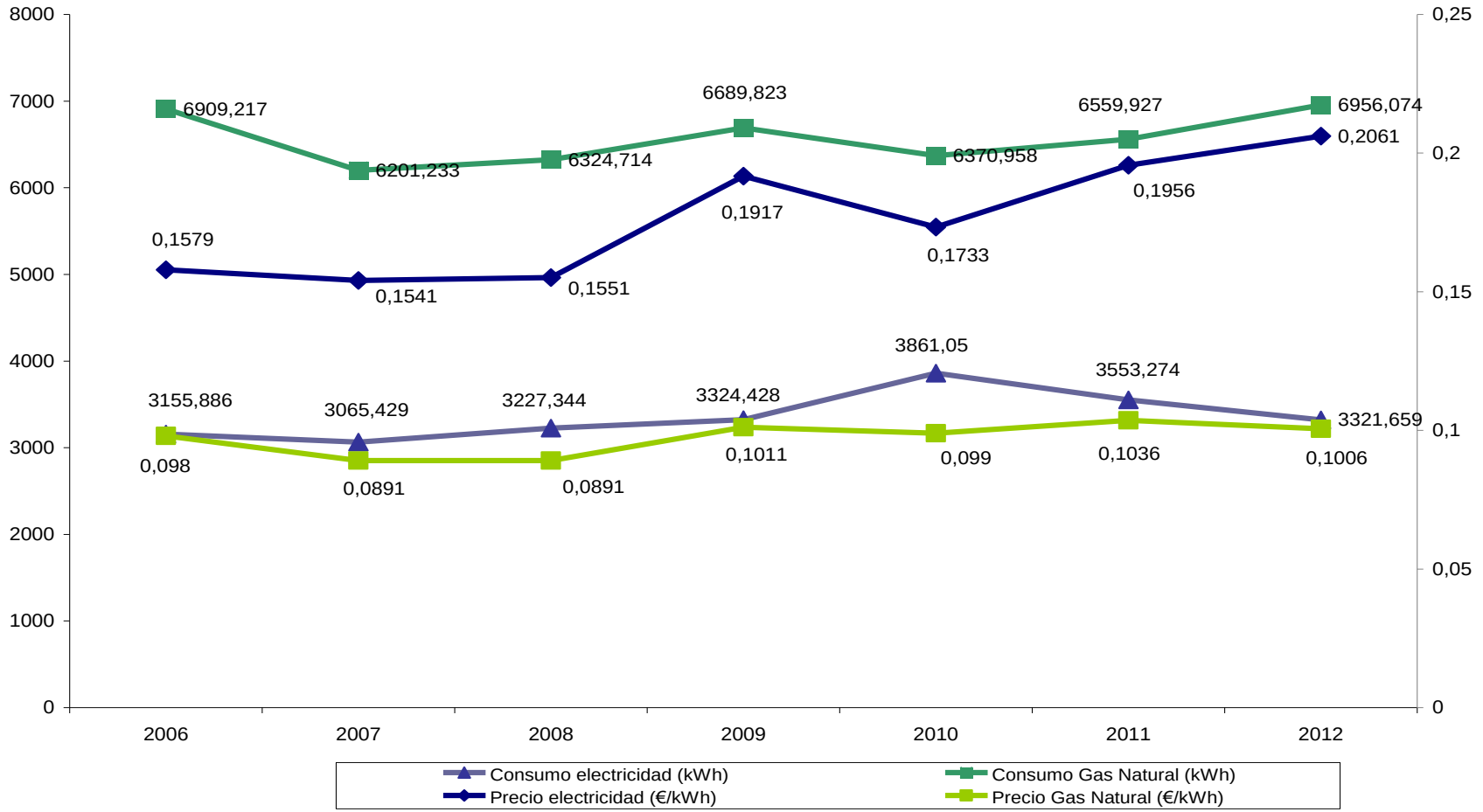
Estimating energy demand (IX)

- Evolution of prices and quantities



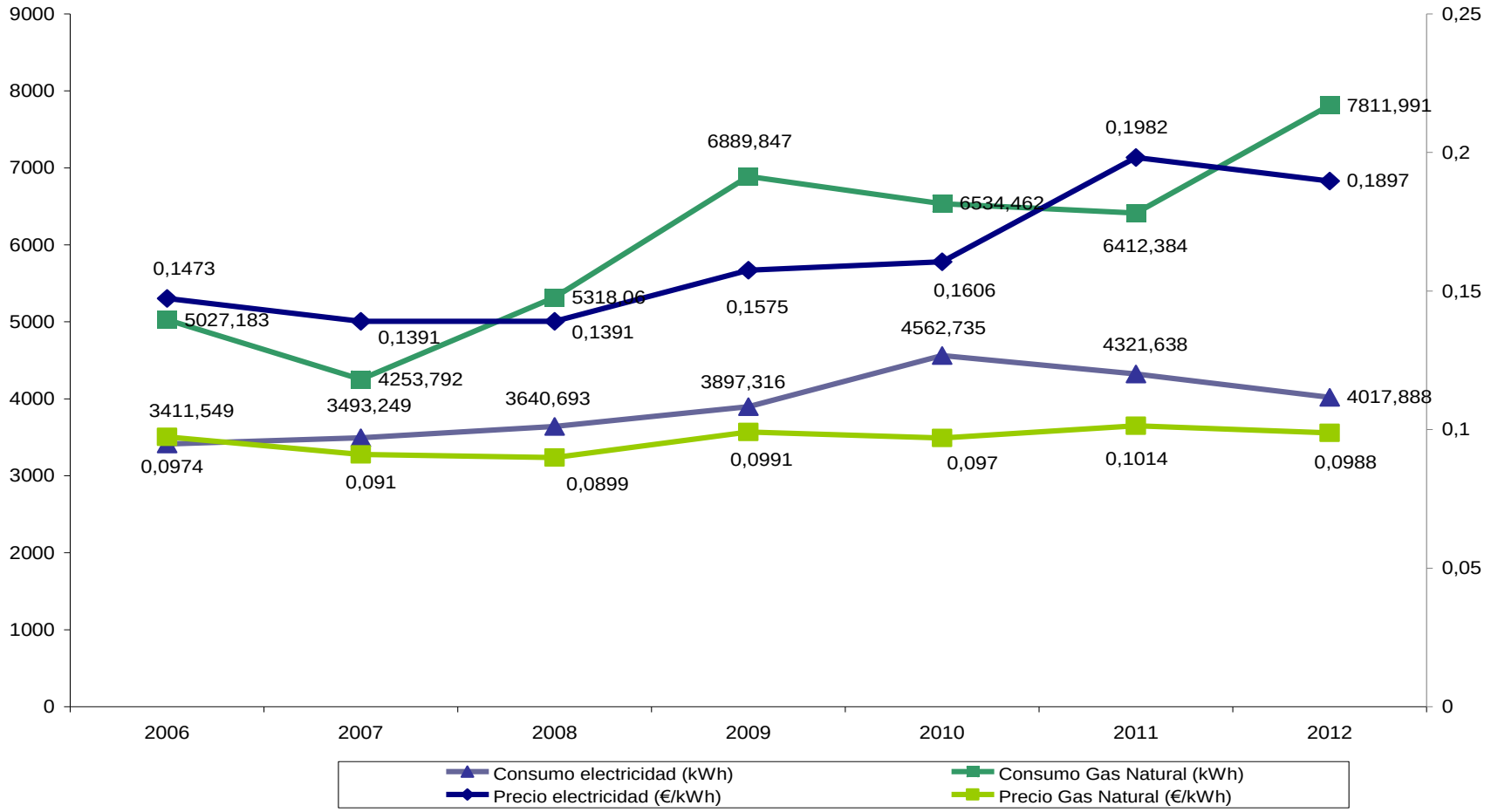
Estimating energy demand (X)

- Evolution of prices and quantities (Madrid, Cataluña, País Vasco and Navarra)



Estimating energy demand (XI)

- Evolution of prices and quantities (Extremadura, Andalucía and Canarias)



Energy demand. Estimation (XII)

- Moreover, if we estimate an equation for the number of Kwh (electricity and gas equivalent), we can built an index and decompose the effects of the set of variables and we have (with a lot of unobserved heterogeneity)
- For electricity

	2006	2009	2012
Total	3924.50	3942.22	3904.08
Prices	-14.35	-18.65	-17.82
Income	189.60	201.46	173.42
Demographics	2587.64	2594.41	2582.49
House	1314.05	1329.49	1349.99
Weather	353.76	345.68	324.80
Building year	53.35	49.39	50.75

Energy demand. Estimation (XIII)

- For gas

	2006	2009	2012
Total	6864.53	7181.66	7485.56
Prices	-1295.17	-1334.22	-1361.61
Income	67.90	71.68	62.35
Demographics	286.42	272.96	250.83
House	6681.13	6717.73	6847.24
Weather	4603.24	4940.31	5166.94
Building year	107.67	99.87	106.48

Identifying energy demand from discrete changes (I)

- First discrete change: change of energy source
  Hanemann, Labandeira, Labeaga and López (2013)
  - Household make decisions about energy source. So, we can adjust behavior about these decisions and then we can model the conditional use of energy services
- Sample
  - Period: 2006-2008, number of observations: NT=63.054; T = 2 (balanced panel)

Identifying energy demand from discrete changes (II)

- Main sources for heating and changes during the 2006-2008 (% and number of households)

2006 \ 2007	Electricity	Natural Gas	Liquid Fuels	Others
Electricity	92.59% (612)	4.39% (29)	1.97% (13)	1.06% (7)
Natural Gas	1.24% (22)	95.16% (1,690)	2.08% (37)	1.52% (27)
Liquid Fuels	1.25% (15)	3.57% (43)	92.77% (1,117)	2.41% (29)
2007 \ 2008	**Electricity**	**Natural Gas**	**Liquid Fuels**	**Others**
Electricity	94.38% (857)	1.87% (17)	2.31% (21)	1.43% (13)
Natural Gas	1.42% (32)	95.53% (2,158)	1.64% (37)	1.42% (32)
Liquid Fuels	0.72% (11)	2.87% (44)	94.91% (1,455)	1.50% (23)

Identifying energy demand from discrete changes (III)

- Second discrete change: change of house
  - Household make decisions about changing house which affect energy use. So, again we can try to identify changes in the energy use at the moment these changes occur
- Sample
  - Period: 2006-2012, number of observations: N2=101,288; N1=49,803
- Number of house owners changing house by year

Year	Number
2007	90
2008	50
2009	70
2010	92
2011	131
2012	108

Identifying energy demand from discrete changes (IV)

- Some results. Price elasticities

Decile	Electricity	Natural gas
1	-0,027	-0,281
2	-0,022	-0,293
3	-0,023	-0,277
4	-0,022	-0,266
5	-0,021	-0,276
6	-0,024	-0,269
7	-0,021	-0,275
8	-0,020	-0,271
9	-0,022	-0,265
10	-0,022	-0,265

Identifying energy demand from discrete changes (V)

- Some results. Change of demand for movers
  - Estimation in both subsamples
  - Estimation in the whole sample identifying movers (effects only on the intercept and also effects on the slopes)
    - We get a significant reduction of electricity (but not different elasticities)
    - We get a significant increase of natural gas (but not different elasticities)
    - Price elasticity of electricity around -0.02 (significantly different from zero) but not different for movers
    - Price elasticity of natural gas around -0.27 (significantly different from zero) but not different for movers
    - Small increase of price elasticities during the crisis (a period with a decline in household income) but we do not find different effects for movers

Conclusions

- In the case of domestic energy consumption we face problems as inexistence of a representative consumer (and observability). This can be dealt through several solutions:
  - Better data (panels, registers, etc.)
  - Adequate models (dynamics and the timing of decisions, modelling continuous-discrete decisions, etc.)
  - Adequate treatment of heterogeneous behavior
  - Different methods (control of heterogeneity, random coefficient models, etc.)
  - Analyze decisions identifying changes (in the case of cars change of car, purchase of an hybrid or electric vehicle)
- Energy demand and energy efficiency are intimately related but economic variables (alone) have a limited impact on "use of energy services" and thus on energy efficiency at the intensive margin

Many thanks