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Energy Sustainability

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HOUSEHOLD ELECTRICITY DEMAND IN SPANISH REGIONS. PUBLIC POLICY IMPLICATIONS

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ABSTRACT: This paper analyses the determinants of household electricity demand with a panel data, partial adjustment model of Spanish regions in the 1998-2009 period. The results show that electricity demand responds positively and significantly to electricity demand in the previous year, income, temperature range, penetration of electric water heating in households and the number of heating and cooling degree days. It is significantly and negatively related to electricity prices, gas prices, penetration of electric heating in households and whether households have at least one member being 64 years or older. Price elasticities in the preferred model are -0.26 (short-term) and -0.37 (long-term). Income elasticities are 0.31 (short-term) and 0.43 (long-term). Several implications for electricity-efficiency policies are derived from the results of the analysis.

JEL Codes: Q41, Q43, Q55

Keywords: Electricity demand, residential sector, partial adjustment model

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1. Introduction

Electricity demand from the residential sector in Spain has significantly increased in the last decade. Although the economic crisis has led to negative growth rates of residential electricity demand of -0.47% in the 2008-2010 period, the average annual growth rate between 2000 and 2007 was 5.05%**.** The residential sector in Spain is responsible for about 17% of the country's total final energy consumption and 25% of total electricity consumption (the shares in the EU are, respectively, 25% and 29%) (IDAE 2011a). Electricity represents 35% of overall energy consumption in the residential sector, 5%, 13% and 44% of all energy used for heating, water heating and cooking, respectively and 100% of all energy used for air conditioning and lighting (IDAE 2011b).

These data suggest that electricity is a crucial product in our modern daily life. However, it also has negative side-effects and, thus, reductions of electricity demand have generally been defended on environmental and energy security grounds[1]. On the other hand, although the electricity generation mix is relatively diversified in Spain, this country is not endowed with significant fossil fuel reserves.[2] Thus, it has to import most of these resources from countries with geo-strategic risks[3]. Finally, reducing electricity demand helps to reduce expensive electricity infrastructure in peak periods.

Thus, having accurate information on the determinants of electricity demand and, particularly, on income and price elasticities is important for projecting the future demand of electricity and in planning the required capacity to meet future electricity consumption (Lee and Lee 2010, Yoo et al 2007 and Narayan et al 2007). Such knowledge on elasticities indicates policy makers the extent to which prices need to increase in order to reduce internal consumption (Lee and Lee 2010). The implementation of policies aimed at reducing electricity demand is thus contingent upon an analysis of the determinants to electricity demand.

Therefore, the aim of this paper is to identify the impact of a variables set on household electricity demand in Spain and, based on the findings, to derive policy implications on the most effective instruments to manage such demand. A partial adjustment modelling framework is used to estimate both short and long-run elasticities (Jamil and Ahmad 2011). We use panel-data on socio-economic and climate-related variables for 18 Spanish regions in the 1998-2009 period.

Spain is an interesting case to analyze given the profound social, economic, cultural and demographic changes experienced in the last two decades. But, to our best knowledge, only Labandeira et al (2012) and Blázquez et al (2013) have analysed the drivers to residential electricity demand. Those previous studies show differing results. Our paper is different from Blázquez et al (2013) in several respects. Furthermore, while several explanatory variables are common in both studies (lagged electricity consumption, electricity price, income, household size, heating degree days (HDD) and cooling degree days (CDD)), we also use additional variables (temperature range, gas price, percentage of households with electric heating, with electric water heating and at least one member being 64 years or older). They use population and gas penetration, which are not in our model. On the other hand, the estimation strategy is slightly different from Blázquez et al (2013). Firstly, we have estimated a basic model which includes the influence of habit, electricity price and income. This initial stage has helped us choose the most appropriate dynamic estimator. We then estimate an extended model with the rest of variables (climate, electrical appliances and socioeconomic factors). The policy implications of the results are discussed in detail.

Accordingly, the paper is structured as follows. The next section reviews the literature on electricity demand. The econometric model is developed in section 3, while section 4 discusses the data used to estimate the model. The results of the estimations are provided in section 5 and discussed in section 6. Section 7 concludes.

2. Literature review

The literature on residential electricity demand, both for developed and developing countries is abundant. These studies can be grouped in two major categories: analyses with aggregate (macro) data and analyses with disaggregate microdata (Yoo et al 2007, Wiesmann et al 2011, Filippini and Pachauri 2004). In addition, two different types of models have been used, i.e., static and dynamic ones. Table 1 provides a detailed revision of studies.

Models with aggregate and disaggregate data have their advantages and disadvantages (see Wiesmann et al 2011). At the aggregated level there is usually good historic data that allows the price elasticities of electricity demand to be identified. However, due to data availability, the number of variables in aggregated studies is quite limited, i.e., the use of aggregate data results in the loss of much information related to individual behaviour (Labandeira et al 2012). Studies with disaggregated data usually exhibit more detailed information about the households and the dwellings. However, these data are often cross-sectional and, therefore, studying the influence of price changes on consumption is more difficult (Wiesmann et al 2011).

Models on residential electricity demand are estimated with a wide range of econometric approaches. One of the most relevant, and also the one followed in this paper, is dynamic adjustment electricity demand models. Two of the most relevant econometric difficulties when using type of models are the correlation between the lagged demand and the error, and also the risk that wrong measurements could affect the average price of energy (Alberini and Filippini, 2011). These issues generate bias and inconsistency in LSDV and GLS estimators (Alberini et al 2011). To solve these problems, different estimators has been developed by authors like Kiviet (1995), Anderson and Hsiao (1981) or Arellano and Bond (1991). However in the literature, and to the best of our knowledge, only few studies have addressed these issues (Alberini and Filippini, 2011; Alberini et al, 2011; Blázquez et al, 2013).

Most studies use a linear or logarithmic functional form since there is not a consensus in the literature about the most appropriate functional form and this choice is somewhat arbitrary (Wiesmann et al 2011, Labandeira et al 2012). The explanatory variables included in the analysis are diverse (table 1). In addition to the income and electricity price variables, others are also included (temperature and natural gas), while others are only included in a few papers, such as lagged electricity demand. A group of variables pertaining to the purchase of electronic equipment and household characteristics are only used in disaggregated data models.

The results of the estimations generally show statistical significant relationships between the dependent and the income and price variables. The sign of the price elasticity of demand is negative, whereas the income elasticity is positive. Price elasticities are generally below one in absolute value, i.e., demand is price-inelastic. Long-run price elasticities are higher (in absolute value) than short-run ones, but also small. While short-run income elasticity is always lower than 1, long-run elasticities are often greater than one. Electricity demand is more responsive to changes in income than to changes in prices. Temperature and the lag of electricity demand are generally also significant, both with a positive sign. The statistical significance of other variables differs across studies. The revision in table 1 suggests that differences regarding price or income elasticities between aggregate/disaggregate data and static/dynamic models cannot be observed.

Two studies on electricity demand in Spain have recently been published, both use panel data, but one uses disaggregate data (Labandeira et al 2012), and the other uses aggregate data (Blázquez et al 2013). Price and income elasticities and temperature/climate have the expected sign and are significant in both studies. However, results differ regarding those elasticities. Price elasticity in Labandeira et al (2012) is -0.25, and -0.07 (short run) and -0.19 (long run) in Blázquez et al (2013). Differences are even greater regarding the income elasticities (0.23 in the short run and 0.61 in the long run for Blázquez et al 2013 and 0.7 in Labandeira et al 2012). In addition, Blázquez et al (2013) show a significant impact of lagged electricity demand, population, household size and gas penetration on electricity demand.

Table 1. Summary of studies on residential electricity demand*.

Static Models				
	Methodology	**Explanatory variables**	**Scope**	**Main results****
Azevedo et al (2011).	Panel data models with AD and DD.	Electricity price, per capita consumption expenditure, annual average heating degree days.	1990-2003 (EU) 1990-2004 (U.S.)	Price elasticity: -0.2 to -0.25. Income elasticity: -0.157 to 0.381 Significant variables: Electricity price (-), Temperature for the US (+), consumption expenditure for EU (+).
Dulleck and Kaufmann (2004).	Econometric time series model with AD based on traditional models of electricity demand.	Disposable income, electricity price, temperature, seasonal dummies, trend accounting for population growth and technological change, gradual implementation of the program (dummy).	Ireland. 1976–1993.	Long-run: Income elasticity (0.389), price elasticity (0.011). Significant variables: income (+), program implementation (-), temperature (-). Short-run: income and price elasticities non-significant. Significant variables: lags of electricity demand variation 1,2,…8 (+), (-)…(-) respectively.
Fullerton et al (2012).	Dynamic error correction modelling approach and cointegration model (AD)	Price, personal income, heating degree days, employment and population	Seattle 1960-2007	Long-run: Income elasticity (-0.2947), price elasticity (-0.3656) Significant variables: personal income (-), price (-), temperature (+). Short-run: Income elasticity (0.2614), price elasticity (-0.2442) Significant variables: personal income (+), price (-), temperature (+).
Halvorsen and Larsen (2001)	Two-step discrete–continuous approach probit model with DD	Household appliances recently purchased by households, number of household appliances owned by the household, prices of electricity and heating fuel, household's annual gross income, household characteristics, heating degree-days and a trend variable	Norway 1976-1993	Long-run: income elasticity (0.06 to 0.13), price elasticity (−0.442) Short-run: price elasticity (−0.433). Significant variables: new appliances (only washing machine)(+), stock of appliances (+), electricity price (-), kerosene price (+), heating oil price (-), income (+), central heating (-), block of flats (−), high net floorage (+), One-person household (−), recently moved to present residence (−), household size (+), year of construction (+), bathroom (+), free electricity (−). Temperature (+ but not significant).
Labandeira et al (2012)	Random effects panel data model (DD)	Gas price, electricity prices, household income (pre-calculated) and dummies for year, month and province, Heating and Cooling Degree Days.	Spanish provinces: 2005-2007. Monthly data.	Income elasticity (0,7), cross-price elasticity of gas (0,05), price elasticity (−0.2536). Significant variables: personal income (+), electricity price (-), temperature variables (+). Higher absolute elasticities correspond to interior provinces.
McLoughlin et al (2011).	Models with DD	Type of dwelling, head of household age, household composition, occupation of the head of household (HoH), heating water system, cooking system, belief of the head of household about saving electricity. Kind of appliances: tumble dryer, dishwasher, kind of shower, electrical cooker, heater, freezer, water pump, number of TVs, number of computers and number of videogames.	Ireland 2010.	Significant variables (model 1): dwelling type (-), number of bedrooms (+), HoH (+), household composition (+), social class (-), water heating (+), cooking type (+), beliefs about efficiency (+). Significant variables (model 2): all (except shower) (+). Electricity demand increases with dwelling size, HoH age between 36–55, with higher professionals and with dwellings that use electricity for water heating and cooking.
Narayan and Smyth (2009)	Panel data models with AD: panel unit root, panel cointegration, granger causality and long-run structural estimation.	Real income and exports	Iran, Israel, Kuwait, Oman, Saudi Arabia, and Syria. 1974-2002.	Long-run: Income elasticity: -3.07 (Saudi Arabia) to 4.50 (Syria). Exports elasticity: -0.66 (Syria) to 0.85 (Saudi Arabia). Significant variables (for some countries): Income (+), exports (+).
Inglesi-Lotz (2011)	Model with AD using Kalman filter methodology of state-space models.	Real average electricity price and GDP.	South Africa. 1980–2005	Average Elasticities (1980-2005): price elasticity (-0.237), income elasticity (0.799). The effect of income on electricity demand has become more significant over time.
Wiesmann et al (2011)	OLS models with AD and DD.	1. Variables in models with AD : average wage, persons per household, building age, rooms per dwelling, dwellings per building, dwelling density, heating and cooling degree-days, latitude, longitude. 2. Variables in models with DD: total household income, persons per household, nº appliances, children, occupancy type, building age, dwelling area, dwelling type, urbanization level, region.	AD model: Portugal 2001. DD model: Portugal 2005-2006.	Models with AD: income elasticity (0.2115). Significant variables: Income (+), household size (-), Building age (-), dwellings per building (-), dwelling density (+), heating degree-days (-), Latitude (-), Longitude (+) Models with DD: income elasticity (0.1282). Significant variables: Income (+), household size (-), nº appliances (+), children (+), owner (+), area of dwelling (+), kind of urbanization (+), region (-).

Zachariadis and Pashourtidou (2007)	Unit root tests, cointegration tests, Vector Error Correction models, Granger causality tests and impulse response functions (AD).	Private final consumption expenditure as a proxy for household income, cooling and heating degree days.	Cyprus: 1960-2004.	Long-run: Income elasticity (> 1), price elasticity: (-0.4 to -0.3) Short-run: 1. Electricity consumption is rather inelastic, 2. Weather fluctuations are the most significant cause of short-term variation,
Arthur et al (2012)	Model based on Deaton's method.	Earnings, expenditure in energy, expenditures per source (non-zero purchasing households): firewood, charcoal candles, kerosene, electricity.	Mozambique. 2002-2003.	Income elasticity (0.52 to 0.66), price elasticity (-0.49 to -0.97). Small cross-price elasticities between sources suggest that the prices of one kind of energy do not significantly affect the demand of the rest.
Lee and Chiu (2011)	Panel smooth transition regression (PSTR) model with AD.	Real GDP per capita, electricity price, temperature.	24 OECD countries. 1978–2004	Income elasticity (0.919 to 1.685). Price elasticity: (-0.233 to -0.065). Significant variables: GDP per capita (+), Temperature (-).
Nakajima and Hamori (2010)	Panel cointegration test and dynamic OLS with AD	Electricity price, real personal income, heating and cooling degree-days.	United States 1993-2008: 48 states.	Income elasticity: (0.33 to 0.41 (1993-2000)) (0.76 to 1 (2001-2008)). Price elasticity: (-0.34 (1993-2000) (-0.17, -0.12 (2001-2008)). Significant variables: personal income (+), electricity price (-), temperatures (+). No difference in the price elasticity between deregulated and non-deregulated states.
Bartusch et al (2012)	Statistical data analysis using independent samples t-tests, ANOVA and UNIANOVA (with DD).	UNIANOVA heating system and geographic area. ANOVA: ventilating system, type of electric underfloor heating, supplementary insulation, family composition, household size, time spent at home during weekdays and indoor temperature.	Sweden: 2009	Variance in electricity demand by dwellings is explained using variables related to household and building characteristics, behavioural aspects and the stock of appliances. Variance of demand is partly explained by temperature changes and household size.
Bianco et al (2009)	Cointegration and stationary time series models with AD	GDP, GDP per capita, population and electricity price.	Italy. 1970-2007.	Long-run: income elasticity (1.164), price elasticity (-0.240). Short-run: income elasticity (0,29), price elasticity: (-0.06)
Nakajima (2010)	Panel unit root test, cointegration test and group-mean dynamic OLS (AD)	Household income, electricity price	Japan 1975-2005	Income elasticity (0.602 to 0.651) (+), price elasticity (-1.204 to -1.127) (-) Both explanatory variables are significant.
Xu et al (2008)	Hybrid social model and social influence model (DD).	Family incomes, housing conditions; household appliances; area and weather, electricity saving technologies, pricing strategies for discouraging inefficient use of electricity; public social education, financial incentive programs for encouraging efficient use of electricity.	China 2006-2010	Income growth is the main reason behind electricity demand growth. Public social education and information policy improve electricity saving and efficient electricity using, education can save 2% electricity per capita /year.
Aroonruengsawat, Auffhammer Sanstad (2012)	Panel data model using OLS and fixed effects (AD)	Electricity price, price of natural gas, real per capita income, cooling and heating degree days, building code construction share, building code intensity	48 US states 1970-2006,	Effects: income elasticity (-0.1 to 0.35), price elasticity (-0.22 to 0.14), cross-price elasticity gas (-0.23, 0.09, 0.35). All variables are significant and positive except own price, building code construction share and building code intensity, that have negative sign.
Adom et al (2012)	ARDL Bounds cointegration approach and error correction models (AD).	GDP per capita, industry efficiency, structural changes in the economy, degree of urbanisation.	Ghana: 1975-2005	Long-run: income elasticity (1.591). Short-run: income elasticity (0.837) Significant variables: long-run: GDP per capita (+), industry efficiency (-), structural changes in the economy (+), degree of urbanisation (+). Short-run: GDP per capita (+), industry efficiency (-), degree of urbanization (+).
Filippini and Pachauri (2004)	Cross-section model using OLS based on AD and DD.	Electricity price, kerosene price, Liquid petroleum gas price, personal income, covered area of the dwelling, household size, age of the household head, size of town, regional differences.	India 1993-1994	Effects: income elasticity (0.604 to 0.637), price elasticity (-0.507 to-0.292), cross-price elasticity gas (-0.652 to 0.260), cross-price elasticity kerosene (-0.058 to -0.006). Significant variables: Income (+), electricity price (-), gas price (+/-), covered area of the dwelling in square feet (+),household size (-), age of household head (-),size of town (+), regional differences (+)
Yoo et al (2007)	Univariate and bivariate specification of a sample selection model: a binary outcome (DD)	Electricity price, income, household size, house size, dummies for having a Plasma TV, an air conditioner and a refrigerator.	Seoul. 2005	Univariate model effects: income elasticity (0.1089), price elasticity (-0.2456), household size elasticity (0.1438). Bivariate model Effects: income elasticity (0.0593), price elasticity (-0.2463), household size elasticity (0.1434). Significant variables: household size (+), house size (+), having a plasma TV (+), an air conditioner (+), income (+), electricity price (-)

Sa'ad (2009)	Econometric model based on structural time series (AD)	GDP per capita, electricity price, underlying energy demand trend	South Korea: 1973-2007	Long-run effects: income elasticity (1.33), price elasticity (-0.27). Significant variables: per capita GDP (+), electricity price (-), energy demand trend (+)
Fan and Hyndman (2011)	Semi-parametric additive model (AD)	Population, Gross State Production, lagged electricity price, cooling and heating degree days.	South Australia: 1996-2008	Price elasticity (-0.363 to -0.428). The strongest price responsiveness appears at the peak period.
		Dynamic Models		
	Methodology	**Explanatory variables**	**Scope**	**Main results****
Benavente et al (2005)	Panel data partial adjustment model using Bond (2002) methodology and Montecarlo simulations (AD).	Lagged of dependent variable, electricity and gas prices, per capita income, per capita residential consumption.	Chile. 1995-2001	Long-run effects: income elasticity (0.2), price elasticity (-0.39), cross-price elasticity gas (0.178). Short-run effects: income elasticity (0,079), price elasticity (-0.0548), cross-price elasticity gas (0.025). Significant variables: lagged consumption (+), electricity price (-), gas price (+), income (+)
Dilaver and Hunt (2011)	Structural Time Series Model with AD.	Lagged dependent variable, household final expenditure in the previous year, electricity prices, energy demand trend	Turkey. 1960-2008	Long-run: income elasticity (1.57), price elasticity (-0.38). Short-run: income elasticity (0,38), price elasticity (-0.09). All explanatory variables are significant.
Jamil and Ahmad (2011)	Co-integration and vector error correction model (AD)	Private consumption expenditures, price of electricity, price of diesel (substitute good), stock of capital, weighted monthly temperature. Electricity demand and all the explanatory variables have one lag.	Pakistan 1961-2008	Short- run: Income elasticity (0,49), price elasticity (0.07). Both variables are insignificant in the short run.
Narayan et al (2007)	Model based on panel unit root and panel cointegration techniques (AD)	Income per capita, electricity price, price of natural gas, electricity demand with one lag.	G7 countries 1978-2003	Long-run: income elasticity (0.2452 to 0.3119) (+), price elasticity (-1.5634 to -1.4502) (-), cross-price elasticity gas (1.7701 to 2.9655) (+) Short-run: income elasticity (-0.1917), price elasticity (-0.1068), cross-price elasticity gas (-0.0129). Significant variables: all variables are significant in the long-run. In the short run: electricity price(-) and electricity consumption lagged (-)
Ziramba (2008)	Bounds testing approach to cointegration within an autoregressive distributed framework (AD)	GDP per capita, electricity price and lagged dependent variable.	South Africa 1978-2005	Long-run: income elasticity (0.31 to 0.87), price elasticity (-0.04 to -0.01) Short-run: income elasticity (0.30), price elasticity (-0.02). Significant variables: Income elasticity (+)
Gam and Ben Rejeb (2012)	Models based on vector autoregressive regression (AD)	GDP, degree of urbanization, average annual temperature and electricity price. All the explanatory variables have one lag.	Tunisia: 1976-2006	Effects: income elasticity (0.1932), price elasticity (-0.2473). Significant variables: lagged electricity demand (+), lagged GDP (+), lagged price (-). Urbanization (+), temperature (-) but not significant.
Filippini (2011)	Panel data models with AD: LSDV, corrected LSDV and RE models	Lag of electricity consumption, prices during the peak and off-peak periods, household size, taxable income per household, heating and cooling degree days.	22 Swiss cities: 2000-2006.	Dynamic model. Income elasticity peak: (0.035 to 0.114), off- peak:[-0.106 to -0.065]. Short-run: price elasticity (-0.835 to -0.652), cross-price elasticity peak/off-peak (0.793/0.917), cross-price elasticity off-peak/peak (0.363/0.407) Long-run: price elasticity (-2.266 to -1.273), cross-price elasticity peak/off-peak (1.767/2.311), cross-price elasticity off-peak/peak: (0.684/0.919). Significant variables: lagged electricity consumption (+), electricity price (-), cross electricity price (-), income (+), price (-), cooling degree days (-).
Blázquez et al (2013).	Dynamic partial adjustment model	Lagged electricity demand, real disposable income of the household sector, price of electricity, household size, population, percentage of households with access to gas, heating degree days and cooling degree days and time dummy variables.	Spain 1998-2009	The estimated short and long-run own price elasticities are, as expected, negative, but lower than 1 (-0.07 and -0.19 respectively). Income elasticities (+): short run (0.23)/ Long run (0.61). Furthermore, weather variables have a significant impact on electricity demand. Significant variables: Lagged electricity consumption (+) Electricity Price (-), Household Income (+), Population (+), Household size (-) Penetration Gas (-), Heating degree days 15 (+) Cooling degree days 22 (+)

Alberini and Filippini (2011)	Dynamic partial adjustment model (with LSDV and Blundell-Bond estimators)	Lagged electricity demand, price of electricity, price of gas, typical size of a household (population/number of detached houses), income per capita, heating degree days, cooling degree days	48 US states 1995-2007	Short-run price elasticities vary with the estimation technique, between -0.08 and -0.15 and the long-run ones between -0.43 and -0.73 (-). Residential electricity consumption could be discouraged by using price increases. Significant variables: Lagged electricity consumption (+), electricity price (-), gas price (-), household size (-), heating degree days 65F° (+), cooling degree days 65F° (+).

Source: Own elaboration. Notes: *AD: Aggregate data; DD: Disaggregated data. ** The sign between parentheses indicates the type of relationship (positive or negative) between the dependent and the explanatory variables.

3. The model and expected results.

Traditionally, electricity demand from households (*E)* is explained as a function of habit (E_{t-1}), income (*Y)*, price (*p*), climate-related variables (*C)*, use of electrical appliances (A) and other socioeconomic factors (S), including household size:

$$E_t = f(E_{t-1}, Y_t, p_t, C_t, A_t, S_t) \qquad [1]$$

Our model is based on the dynamic partial adjustment model widely used since the seventies by Houthakker and Taylor (1970), Houthakker et al (1974), Houthakker (1980), Shin (1985), Haas et al (1998), Bernstein and Griffin (2006) Alberini et al (2011), Filippini (2011), Alberini and Filippini (2011) and Blázquez et al (2013) among others.

As discussed in section 4, we have estimated, first, a basic model which includes the influence of habit, electricity price and income. This initial stage helps us choose the most appropriate dynamic estimator. Thus, we have used the estimators in differences proposed by Anderson and Hsiao (1981), Arellano and Bond (1991) and Blundel and Bond (1998) as well as the Least Square Dummy Variables Corrected estimator of Kiviet (1995). Then, we estimate an extended model in which the rest of variables considered in expression [1]. This second stage represents a robustness check of the basic estimations. Following this methodological framework, the basic dynamic log-linear model is:

$$E_{it}^{*} = cY_{it}^{\xi} p_t^{\gamma} \qquad [2]$$

where c is the constant, Y is household income per capita and p is the electricity price.

There are different alternatives regarding the choice of electricity price, depending on whether average or marginal prices are considered (see Blázquez et al 2013 for a discussion). In this paper, we have used the average prices for the final consumer. This choice is unlikely to have a substantial impact on the results because, given the complexity of the double-tariff system implemented in Spain (Blázquez et al 2013), the average consumer is unlikely to exactly match its electricity consumption to the current kWh price.

Changes in behavior are more likely to be related to news of tariff changes reported in the mass media.

The desired level of average household consumption E_{it}^{*} is a non-observable variable, whereas the current demand E_{it} is observable. The relationship between E_{it}^{*} and E_{it} can be defined as follows:

$$E_{it} - E_{it-1} = \theta\left(E_{it}^{*} - E_{it-1}\right), \qquad 0 < \theta < 1 \qquad [3]$$

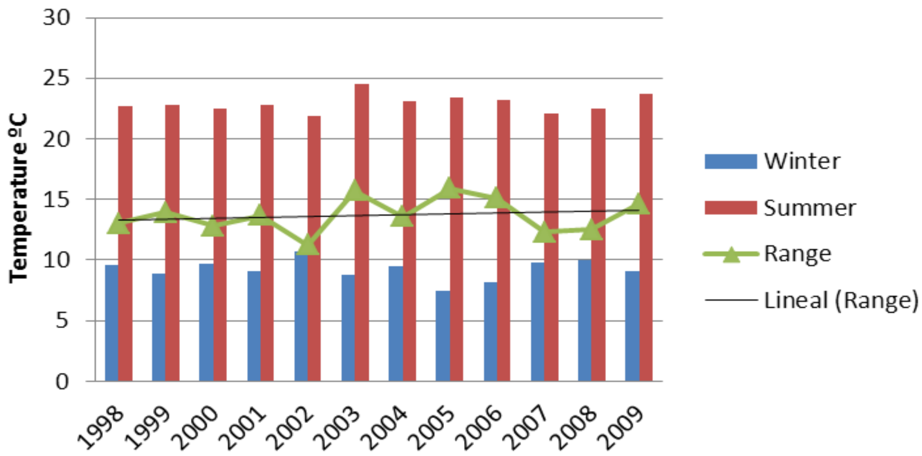
where θ represents the speed of adjustment towards the desired consumption level. E_{it-1} incorporates the partial adjustment process in the model and provides information on habit persistence. The lag allows us to take into account that electricity demand in the long-term could be more related to habit persistence than to cost minimization (Blázquez et al 2013). If we insert equation [2] into [3] and take logs, then:

$$LnE_{it} = C + \lambda LnE_{it-1} + \beta_1 LnY_{it} + \beta_2 Lnp_t + \varepsilon_{ht} \qquad [4]$$

where *Ln* indicates that the variables are expressed in logarithms. Parameter λ captures the habit in fuel consumption. The closer to one, the greater the relevance of habit in the electricity consumption decision. Since the model takes logarithms, β_1 represents the income elasticity of electricity demand and β_2 is the price elasticity of electricity demand. Note that the estimated parameters in equation [4] are interpreted as short-run elasticities[4].

When extending the basic model, there are two alternatives for the analysis of the role of climate in electricity demand. First, we use the difference between the average temperatures in winter and summer observed within a year. However, this alternative has been criticised by some authors because the relationship between temperature and electricity demand may not be linear (Bessec and Fouquau 2008). The greatest average differences between the temperatures observed in the 2000-2009 decade occurred in 2003, 2005 and 2006 (figure 1).

Figure 1. Average Temperatures in Spain 1998-2009



As an alternative, most studies use the number of cooling degree days (*CDD*) and heating degree days (*HDD*) (Blázquez et al, 2013; Labandeira et al, 2012; Alberini and Filippini, 2011; Amato et al, 2005 among others). They are defined as the difference between average daily temperatures and a reference temperature and pick up the sensitivity of electricity demand to changes in the temperature (Valor et al, 2001), allowing the identification of the non-linear relationship between temperature and electricity demand. Furthermore, since other factors affect electricity demand (table 1), the basic model has been extended as follows:

$$LnE_{it} = C + \lambda LnE_{it-1} + \beta_1 LnY_{it} + \beta_2 Lnp_{it} + \beta_3 Lnq_{it} + \beta_4 LnT_{it} + \beta_5 LnHDD_{it} + \beta_6 LnCDD_{it} + \beta_7 LnHeating_{it} + \beta_8 LnWater_{it} + \beta_9 LnHS_{it} + \beta_{10} LnOL_{it} + \varepsilon_{ht} \quad [5]$$

Where q is the gas price, T represents the difference between the average maximum and minimum temperatures observed within a year, *Heating* is the percentage of households with electric heating, *Water* is the percentage of households with electric water heating, *HS* is household size and *OL* is the percentage of households where at least one member is 64 years or older. In equations [4] and [5], the error term has been specified as a one-way error component model $\varepsilon_{it} = \theta(\eta_i + v_{it})$. Unobservable heterogeneity, such as consumer tastes, is captured through the parameter η_i, which represents the specific individual effect of each region.

Regarding **lagged electricity demand**, a positive sign can be expected, due to habit persistence (inertia in electricity consumption). Habit persistence has been a well-researched issue in the general economic literature (see, for example, Abel 1990, Boldrin et al 1997 or Carrasco et al 2005), and has also been analysed in the literature on electricity demand (see table 1). The **electricity price and income** have a negative and a positive relation, respectively, with electricity demand, as suggested by economic theory. If gas and electricity are substitutes in final energy consumption, an increase in the **price of gas** would result in an increase in the demand for the later (i.e., a positive relation). If they were complementary goods, the relationship between both variables would be negative[5].

The **temperature range** has a positive impact on electricity consumption. A wider range means that the region is relatively warmer in the summer or relatively colder in the winter or both, triggering either a greater use of air-conditioning devices or heating. Figure 2a shows that, generally, wider temperature ranges can be expected in the inner regions and less so in the coast. Thus, higher electricity use is associated with regions with wider temperature ranges[6]. Obviously, **HDDs and CDDs** have a positive impact on electricity demand.

Obviously, those regions with a greater penetration of **electric heating** and **electric water heating** would have a higher electricity demand. A priori, one may think that temperature range and electric heating are related but a wide temperature range may be due to very high temperatures in the summer rather than cold winters, which would not affect the use of electric heating (but the use of air conditioning). Comparing the colours in figures 2a and 2c, the darkness does not exactly match in both figures. Furthermore, although heating in general is less widespread in the Mediterranean coast, electric heating is more common in this area (IDAE 2011a, IDAE 2011b).

Regarding **household size**, as argued by Blázquez et al (2013, p.650), there might be economies of scale in demand and larger households would use the equipment more intensively (hot water and cooker usage) and, thus, consumption would be lower.

Finally, it is impossible to tell a priori whether **older households** would demand more electricity than younger ones. Although the use of some electric devices (TV) may be more associated with older people (Filippini and Pachauri 2004 and Schipper et al 1989), younger households may make more use of others (i.e., computers and electric kitchens in new households) (MYTIC 2007, MEPSYD, 2008). McLoughlin et al (2011) argue that the largest electricity demand occurs when household heads are between 36–55 years old due to the presence of children.

Figure 2. Relevant features of regions in Spain.

Fig. 2a. Temperature ranges (degrees)

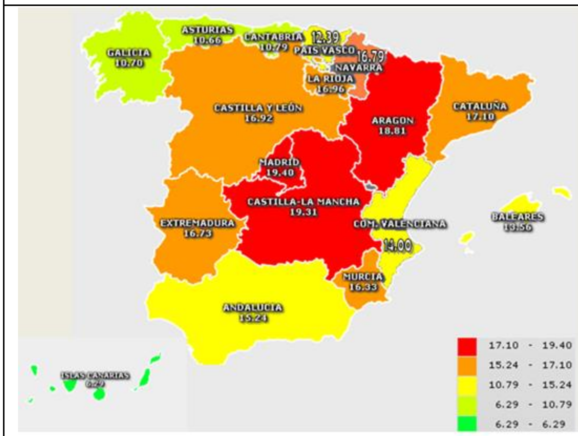


Fig. 2b. Population >64 years (%).

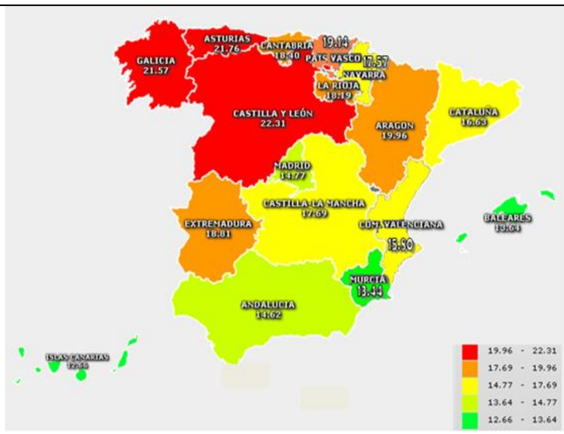
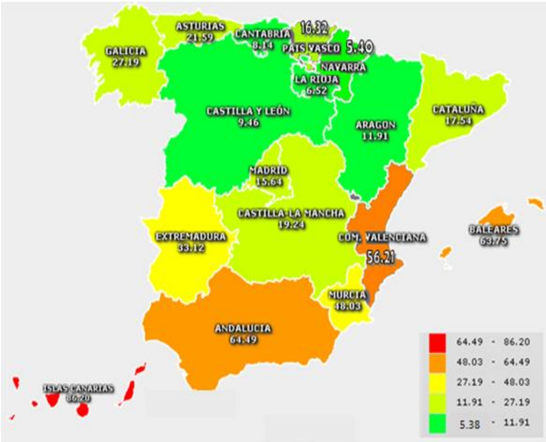
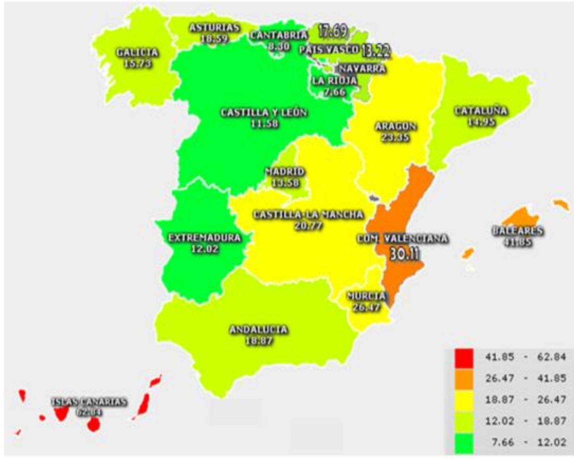


Fig. 2c. Penetration of electric heating (% of all households in the region)

Fig. 2d. Penetration of electric water heating (% of all households in the region).





Source: own elaboration from ECPF (INE 2012).

Table 3 summarises the expected sign of each variable.

Table 3. Expected sign of the variables included in our analysis.

Variable	Expected sign	Supporting evidence.
Lagged electricity demand	(+)	Dilaver and Hunt (2011), Adom et al (2012), Sa'ad (2009), Filippini (2011), Gam and Ben Rejeb (2012), Benavente et al (2005), Bianco et al (2009).
Electricity price	(-)	Inglesi-Lotz (2011), Jamil and Ahmad (2011), Filippini and Pachauri (2004), Leighty and Meier (2011) and, Gam and Ben Rejeb (2012), Narayan et al (2007), Yoo et al (2007), Fullerton et al (2012), Halvorsen and Larsen (2001), Labandeira et al (2012), Nakajima and Hamori (2010), Nakajima (2010), Dilaver and Hunt (2011).
Income	(+)	Inglesi-Lotz (2011), Dulleck and Kaufmann (2004), Jamil and Ahmad (2011), Filippini and Pachauri (2004), Adom et al (2012), Sa'ad (2009), Filippini (2011), Narayan et al (2007), Yoo et al (2007), Nakajima and Hamori (2010), Bianco et al (2009), Nakajima (2010), Ziramba (2008)
Gas price	(+)	Narayan et al (2007), Aroonruengsawat et al (2012), Halvorsen and Larsen (2001), Benavente et al (2005).
Temperature range	(+)	Filippini (2011), Gam and Ben Rejeb (2012), Fan and Hyndman (2011), Hekkenberg et al (2009), Wiesmann et al (2011), Azevedo et al (2011), Jamil and Ahmad (2011), Fullerton et al (2012), Halvorsen and Larsen (2001), Labandeira et al (2012), Aroonruengsawat et al (2012), Nakajima and Hamori (2010).
Electric heating	(+)	Leighty and Meier (2011), Fullerton et al (2012), Halvorsen and Larsen (2001).
Electric water heating	(+)	Borg and Kelly (2011), Halvorsen and Larsen (2001), Leighty and Meier (2011), McLoughlin et al (2011).
> 64 years	(?)	Filippini and Pachauri (2004), Schipper et al (1989), McLoughlin et al (2011)
Household size	(-)	Blázquez et al (2013), Filippini and Pachauri (2004), Filippini (2011), Wiesmann et al (2011)
HDDs, CDDs	(+)	Blázquez et al (2013), Nakajima and Hamori (2010), Tol et al (2012), Alberini and Filippini (2011)

4. Data

We use panel data on annual electricity consumption in the 18 Spanish regions in the 1998-2009 period. We use average household electricity consumption (in kWh) as the dependent variable. The data have been obtained from the Statistics of the Electricity

Industry published by the Ministry of Industry, Energy and Tourism (MINETUR 2013). Regional GDP per capita (in constant 1998 euros) is used as a proxy of household income (data from the National Statistical Office, INE). The price of electricity and gas (both in €/kWh) have been transformed into constant 1998 prices and the resulting values have been weighted by the consumer price index of each region (Autonomous Communities). The Official National Bulletin (BOE) provides these price data. "Differences in temperature" refers to difference between the average temperatures in winter and summer provided by the National Meteorological Agency. In addition, the heating degree days (HDD) and cooling degree days (CDD) are included. There are different approaches to calculate these variables. We use the daily average temperature, an approach followed by other authors (e.g., Blázquez et al, 2013; Amato et al, 2005). HDD and CDD are thus defined as

$$HDD = \sum_{i=1}^{n} \max(0; T^* - Ta) \quad [6]$$
$$CDD = \sum_{i=1}^{n} \max(0; Ta - T^*)$$

where *n* represents the number of days in a year, *T** is the threshold temperature of cold or heat and *Ta* is the average temperature observed on a specific day. There is not a specific value on the base (threshold) temperature and it is difficult to define globally representative ones (Sebastian et al, 2010; Bessec and Fouquau, 2008). Regarding studies on electricity demand in Spain, it is typical to set the threshold for HDDs and CDDs at 18°C (Labandeira et al, 2012; Blázquez et al, 2013). In our case, we use two different thresholds for HDD and CDD, following those previous studies in Spanish and the Spanish Technical

System Operator, which uses 15°C and 22ºC for HDD and CDD respectively (REE, 1998)[7].

Finally, data on the percentage of households which use electric heating and electric water heating, households with at least a member being older than 64 years and household size are provided by the National Statistical Institute. Table 2 shows the descriptive statistics for the variables used in the estimations. Regarding average electricity consumption, the data show substantial differences, with values in a wide range between 1,764 and 4,779 kWh. Likewise, several variables influencing electricity consumption also show wide ranges, including average income level, HDDs and CDDs or percentage of households with electric heating or electric water heating.

Table 2. Descriptive statistics

Variables	Average	Std	Min	Max
Average electricity consumption (Kwh)	2,749.65	490.81	1,764.60	4,776.12
Income (€)	15,788.54	3,246.81	8,536.00	23,280.53
Electricity Price (€/Kwh)	0.071	0.0077	0.058	0.087
Gas Price (€/Kwh)	0.029	0.002	0.025	0.035
Temperature range (ºC)	13.69	3.52	3.92	20.63
Heating degree days (15º C)	910.55	471.65	133.7	2,086.32
Heating degree days (18º C)	1,504.50	595.66	365.59	2,804.74
Cooling degree days (18º C)	641.71	321.58	82.85	1,186.57
Cooling degree days (20º C)	397.49	234.86	11.3	854.83
Cooling degree days (22º C)	222.16	152.82	0.75	557.37
Households with electric heating (%)	24.93	23.31	0,00	100.00
Households with electric water heating (%)	16.06	12.68	0.72	63.89
Average household size	2.94	0.26	2.49	3.71
Households with at least one member ≥ 64 years old (%)	17.19	3.21	10.53	22.63

5. Results

Following the estimation strategy discussed in section 3, we first estimate the basic model (equation [4]). The model is dynamic as it includes a lagged dependent variable on the right-hand side of the equation, which generates endogeneity problems. This variable might be serially correlated and hence correlated with the error term, leading to biased and inconsistent traditional Fixed Effects (FE) and Random Effects (RE) estimators. Instrumental variable (IV) estimators specifically developed for dynamic models are a traditional procedure to overcome this problem. Therefore, we have used, first, the Anderson and Hsiao (1981) estimator (FD), which applies first-differences to the variables in the model, $\Delta y_{it} = y_{it} - y_{it-1}$, with Δy_{it-2} or y_{it-2} being the valid instruments. None of these instruments are correlated with the first differences of the error term $\Delta \varepsilon_{it} = \varepsilon_{it} - \varepsilon_{it-1}$. Thus, the estimation of equation using FD is consistent, although asymptotically inefficient.

Next, we use the GMM estimator in first differences (DIFF-GMM), developed by Holtz-Eakin et al. (1988) and Arellano and Bond (1991), which provides a more efficient alternative for dynamic models, although this type of estimators has a strong bias in finite samples (see Kiviet, 1995, Blundell and Bond, 1998 among others). FD and DIF-GMM suffer from a weak instrument problem when the coefficient of the lagged variable is closer to one, due to strong habit persistence (see Staiger and Stock, 1997, Stock and Wright, 2000 and Han and Phillips, 2006, 2010 among others). However, this does not seem to be a serious problem in our case, since the parameter of the lagged variable of the DIF-GMM estimator is 0.28 (table 4). The basic idea behind the SYS-GMM estimator proposed by Arellano and Bover (1995) and Blundell and Bond (1998), as an alternative to DIFF-GMM, is the estimation of a system of equations in first-differences and also in levels where the instruments used in the later are lagged first-differences of the series (Bond et al., 2001). SYS-GMM has a better behaviour than DIFF-GMM with respect to finite sample bias and efficiency (Blundell and Bond 1998 and Blundell et al 2000). However, SYS-GMM uses more instruments than the DIF-GMM (Roodman, 2009). This involves a strong constrain when, as in our case, the number of cross sections is small, given the rule of thumb that the number of instruments should be lower than the number of regions

A well-known weakness of GMM-based estimators is that they can be severely biased and imprecise in panel data with a small number of cross-sectional units (Bruno, 2005). In this context, the Least Square Dummy Variables Corrected estimator (LSDVC) based on Kiviet (1995), Bun and Kiviet (2006) and Bruno (2005) was proposed to test the robustness of the GMM-based estimators. The two step LSDVC estimator eliminates the unobserved individual effects and is an appropriate method to deal with the endogeneity of the lagged dependent variable. The Monte Carlo analyses undertaken by Judson and Owen (1999) and Kiviet (2005) show that, when T≤20 and N≤50 (as in our case) the LSDVC and FD estimators have a better behavior than the DIFF-GMM estimator.

Table 4 shows that the estimated parameters have the expected sign (income is positive and prices are negative). If we focus on the dynamic estimators, income is not statistically significant in the FD and LSDVC estimations, whereas the electricity price is not significant in both SYS-GMM estimations. The results of the FD estimator when Δy_{t-2} is used as instrument are very poor given the weakness of this instrument, as reflected in the weak identification test. In contrast to the DIFF-GMM estimators, the SYS-GMM estimators do not comply with the rule of thumb on the number of instruments (the number of cross sections is 18 and the number of instruments is 26). In addition, the LSDVC estimation has a major drawback since there are both first and second-order serial correlation.

Therefore, the DIFF-GMM estimations (both one-step and two-step) are our preferred estimations. They are very similar to each other and, thus, there are no efficiency gains when using the two-step estimator. The commonly used tests to assess the validity of this type of estimators are the first-order and second-order serial correlation tests for the estimated residues (*m1* and *m2*) and the overidentification test which analyses the validity of the instruments used. The GMM-based estimators are consistent if the null hypothesis of existence of first-order serial correlation is rejected but the existence of second-order serial correlation is accepted. The DIF-GMM estimators fulfil these requirements (table 4). The Hansen test indicates that the error term is not correlated with the instruments.

Next, we estimate the extended model (equation [5]) which, in addition to habit, income and price, climate-related variables and the rest of socioeconomic variables discussed in section 4. The results are shown in Tables 5 and 6, where we have used the two-step DIF-GMM estimator. The results shown in these last two tables can be interpreted as a robustness check of the estimates of the basic model. The estimated parameters have the expected sign. The parameter of the lagged variable in the basic model (0.28) is within the range of estimated values of the extended model (0.177 to 0.324). The parameter for the electricity price changes from -0.26 in the basic model to values within the -0.20 to -0.30 range in most estimations. Finally, the income parameter is 0.31 in the basic model, and is within the 0.29 to 0.45 range in all estimations. Therefore, the short-term price and income elasticities estimated with the basic model are in line with those obtained in the robustness analysis.

Table 4. Basic estimations

Variables (in logarithms)	OLS	FD-2SLS[1]		DIFF-GMM		SYS-GMM		LSDVC
		(a)[2]	(b)[3]	One-Step	Two-Step[4]	One-Step	Two-Step[4]	
Lag consumption	0.91293*** (0.043)	1.00260* (0.576)	-0.52543*** (0.090)	0.28478*** (0.118)	0.28348** (0.119)	0.48199*** (0.127)	0.48166*** (0.132)	0.61127*** (0.071)
Income	0.06419** (0.030)	-0.12494 (0.414)	0.19594 (0.259)	0.31257* (0.177)	0.31264* (0.183)	0.41028*** (0.0817)	0.41126*** (0.087)	-0.06646 (0.102)
Electricity price	-0.033597 (0.081)	0.02558 (0.382)	-0.65454*** (0.189)	-0.26731*** (0.084)	-0.26624*** (0.089)	-0.06596 (0.123)	-0.06313 (0.126)	-0.23473** (0.092)
Joint significant test (p-value)	F(3,195)= 7.7e+05 (0.000)	F(3, 159) = 1.98 (0.118)	F(3, 159) = 13.40 (0.000)	$\chi^2(3)$= 89.10 (0.000)	$\chi^2(3)$=80.85 (0.000)	$\chi^2(3)$= 127534.80 (0.000)	$\chi^2(3)$= 110091.47 (0.000)	$\chi^2(3)$=221.97 (0.000)
Underidentification test[5]	---	$\chi^2(1)$=7.44 (0.006)	$\chi^2(1)$=131.453 (0.0000)	---	---	---	---	---
Weak identification test[6]	---	7.766 10% maximal IV size 16.38	684.231 10% maximal IV size 16.38	---	---	---	---	---
AR-1 test (p-value)	-0.93 (0.351)	---	---	-1.91 (0.046)**	-1.78 (0.076)*	-2.04 (0.041)**	-1.88 (0.060)*	$\chi^2(1)$=198.0 (0.000)
AR-2 test (p-value)	-0.75 (0.451)	---	---	-0.78 (0.434)	-0.75 (0.451)	-0.60 (0.545)	-0.63 (0.528)	$\chi^2(1)$=180.0 (0.000)
Hansen test [7] (p-value)	---	---	---	$\chi^2(16)$= 17.94 (0.327)	$\chi^2(16)$= 17.95 (0.327)	$\chi^2(26)$=17.95 (0.878)	$\chi^2(26)$=17.95 (0.878)	--

(***) Significant at 1% level (**) significant at 5% level and (*) significant at 10% level.

Notes: (1) Initial values of the true coefficients in the FD estimation were obtained using the Arellano-Bond estimator. (2) Lagged dependent variable using Δy_{t-2} as an instrument (3) Lagged dependent variable using y_{t-2} as an instrument (4) In the case of the two-step GMM estimator, the Windmeijer (2005) finite sample correction for standard errors has been employed. (5) The underidentification test is the Kleibergen-Paap Wald test (see Kleibergen and Paap, 2006, Kleibergen and Schaffer, 2007) A rejection of the null hypothesis indicates that the instrumental variables are correlated with the instrumented variable. (6) The weak identification test for the instrumental variables is based on Stock and Yogo (2005) (the null hypothesis is the existence of weak instrumental variables). (7) Test of overidentifying restriction under the null hypothesis that the error term is uncorrelated with the instruments.

Table 5. Robustness check (i) using the two-step DIFF-GMM estimator

	Climate and energy								
	HD15	HDD18	CDD18	CD20	CDD22	HD15+CD20	HDD15+CDD22	HDD18+CDD18	HDD18+CDD22
Lag consumption	0.17847** (0.089)	0.20674** (0.08445)	0.21178* (0.12340)	0.26298** (0.107)	0.27611** (0.11991)	0.17503** (0.089)	0.17788* (0.09776)	0.16065 (0.10110)	0.20459** (0.08861)
Income	0.31192 (0.192)	0.29975 (0.19449)	0.39245* (0.21193)	0.38719* (0.206)	0.35076 (0.23905)	0.33881 (0.235)	0.29778 (0.23857)	0.35841 (0.24536)	0.33594 (0.24707)
Electricity price	-0.30660*** (0.104)	-0.32458*** (0.11504)	-0.20208** (0.09159)	-0.20637** (0.094)	-0.23386* (0.12156)	-0.27785** (0.141)	-0.31763** (0.15889)	-0.27955** (0.12477)	-0.29789** (0.14515)
HDD	0.17894** (0.086)	0.34423** (0.16056)	---	---	---	0.16557* (0.085)	0.18478* (0.10483)	0.31795* (0.17617)	0.33514** (0.16851)
CDD	---		0.05401** (0.02488)	0.04078** (0.017)	0.01288 (0.01970)	0.01414 (0.024)	-0.00374 (0.02267)	0.04247 (0.02875)	0.01007 (0.01978)
Joint significant test (p-value)	$\chi^2(4)$= 54.54 (0.000)	$\chi^2(4)$= 62.00 (0.000)	$\chi^2(4)$= 44.57 (0.000)	$\chi^2(4)$= 86.03 (0.000)	$\chi^2(4)$= 88.83 (0.000)	$\chi^2(5)$= 37.37 (0.000)	$\chi^2(5)$= 42.27 (0.000)	$\chi^2(5)$= 36.88 (0.000)	$\chi^2(5)$= 63.48 (0.000)
AR-1 test (p-value)	-2.00 (0.045)	-2.10 (0.036)	-1.70 (0.090)	-1.64 (0.102)	-1.75 (0.079)	-1.96 (0.050)	-1.92 (0.054)	-1.94 (0.052)	-2.03 (0.042)
AR-2 test (p-value)	-0.58 (0.564)	-0.40 (0.692)	-0.85 (0.397)	-0.93(0.353)	-0.76(0.444)	-0.59 (0.555)	-0.56 (0.575)	-0.44 (0.661)	-0.38 (0.701)
Hansen test (p-value)[2]	$\chi^2(15)$=17.01 (0.318)	$\chi^2(15)$=17.43 (0.294)	$\chi^2(15)$=16.99 (0.320)	$\chi^2(15)$=17.11 (0.313)	$\chi^2(15)$=17.86 (0.270)	$\chi^2(14)$=16.93 (0.260)	$\chi^2(14)$=17.01 (0.256)	$\chi^2(14)$=16.62 (0.277)	$\chi^2(14)$=17.14 (0.249)

(***) Significant at 1% level (**) significant at 5% level and (*) significant at 10% level.

Notes (1): In the case of the two-step GMM estimator, the Windmeijer (2005) finite sample correction for standard errors has been employed. (2) Test of overidentification restriction under the null hypothesis that the error term is uncorrelated with the instruments.

Table 6. Robustness check (ii) using the two-step DIFF-GMM estimator

	Other socio-economical and technical issues								
	Gas price	Temperature range	Gas Price + temperature range	Heating	Water heating	Heating + wáter heating	Household size	≥ 64	Household size + ≥ 64
Lag consumption	0.23627** (0.102)	0.23342** (0.114)	0.20012* (0.103)	0.32436*** (0.106)	0.1944** (0.092)	0.31064*** (0.117)	0.27826** (0.122)	0.24158** (0.123)	0.18905 (0.126)
Income	0.38678** (0.166)	0.38656* (0.205)	0.45785** (0.190)	0.38107** (0.150)	0.04166 (0.305)	-0.12059 (0.368)	0.29370 (0.207)	0.17946 (0.226)	-0.06316 (0.250)
Electricity price	-0.24841*** (0.077)	-0.23034** (0.096)	-0.22079*** (0.085)	-0.23178** (0.093)	-0.41860** (0.185)	-0.51432* (0.323)	-0.27165*** (0.090)	-0.55601** (0.226)	-0.69791*** (0.239)
Gas Price	-0.19976** (0.083)		-0.17763* (0.098)						
Heating	---	---	---	-0.06199 (0.045)	---	-0.30877** (0.143)	---	---	---
Temperature range		0.09403*** (0.029)	0.07969** (0.034)	---					
Water heating	---			---	0.08076 (0.065)	0.32446* (0.172)	---	---	---
Household size	---	---	---	---	---	---	-0.02935 (0.158)	---	-0.20664 (0.265)

>64	---	---	---	---	---	---	---	-2.2264** (1.068)	-2.63600** (1.05)
Joint significant test (p-value)	$\chi^2(4)$= 61.14 (0.000)	$\chi^2(4)$= 83.86 (0.000)	$\chi^2(5)$= 70.71 (0.000)	$\chi^2(4)$= 68.81 (0.000)	$\chi^2(4)$= 61.77 (0.000)	$\chi^2(5)$= 29.71 (0.000)	$\chi^2(4)$= 80.73 (0.000)	$\chi^2(4)$= 41.28 (0.000)	$\chi^2(5)$= 32.21 (0.000)
AR-1 test (p-value)	-1.86 (0.063)	-1.80 (0.071)	-1.78 (0.075)	-1.70 (0.089)	-1.75 (0.081)	-1.82 (0.068)	-1.76 (0.078)	-1.66 (0.096)	-1.61 (0.108)
AR-2 test (p-value)	-0.63 (0.531)	-0.81 (0.415)	-0.76 (0.448)	-0.86 (0.388)	-0.80 (0.422)	-1.30 (0.192)	-0.75 (0.450)	-0.82 (0.410)	-0.82 (0.409)
Hansen test (p-value)[2]	$\chi^2(15)$=16.16 (0.371)	$\chi^2(15)$=17.87 (0.270)	$\chi^2(14)$=16.43 (0.288)	$\chi^2(15)$= 16.88 (0.326)	$\chi^2(15)$= 16.17 (0.371)	$\chi^2(14)$= 13.31 (0.502)	$\chi^2(15)$= 17.76 (0.276)	$\chi^2(15)$= 17.80 (0.273)	$\chi^2(14)$= 16.72 (0.272)

(***) Significant at 1% level (**) significant at 5% level and (*) significant at 10% level.

Notes (1): In the case of the two-step GMM estimator, the Windmeijer (2005) finite sample correction for standard errors has been employed. (2) Test of overidentification restriction under the null hypothesis that the error term is uncorrelated with the instruments.

6. Discussing the results of the analysis and policy implications.

All the variables have the expected sign, except for heating and the gas price. Six variables are statistically significant in all the estimations (lagged electricity demand, price of electricity, gas price, temperature ranges, ≥64 and HDD). Four other variables are statistically significant in half of the estimations (income, electric heating, CDD and electric water heating). Household size is not significant. Therefore, our results broadly support the expected relationship between the variables discussed in section 3.

In our preferred model (DIFF-GMM), electricity demand is significantly affected by two variables easily connected to policies: electricity prices and lagged demand. Other variables cannot be influenced directly by policy, although their trends have to be taken into account when the goals of policy are formulated since they have a strong impact on demand.

Table 7 provides a summary of the price and income elasticities found in our study. Compared to other studies on electricity demand in Spain, our short-run price elasticities in the preferred estimations (DIFF-GMM) (-0.26) are higher (in absolute value) than the value of -0.07 in Blázquez et al (2013) but lower than -0.8 in Labandeira et al (2006). As expected, our long-run price elasticities (-0.37) are higher than our short-run ones (-0.26) and also higher than the long-run values in Blázquez et al (2013) (-0.19). Our short-term elasticities are in line with those of Labandeira et al (2012) (-0.25). Both our short-term and long-run price elasticities are slightly within the upper part of the range found in the literature (see table 1).

The higher income elasticities (in absolute value) compared to price elasticities suggest that households are more responsive to income changes than to price changes. Our income elasticities are higher than the value of 0.23 (short-run) and 0.61 (long-run) in Blázquez et al (2013) but clearly below 0.7 in Labandeira et al (2006). While short-run income elasticities are in the middle of the range in the literature, long-run elasticities are in the lower part of such range (table 1).

The relatively higher income elasticity (in absolute value) coupled with substantial increases in income levels during the estimation period suggest that, as with other demand-inelastic products (i.e., gasoline demand), the income effect has offset the price effect, leading to a higher electricity demand. Notwithstanding, the recent reductions in income levels due to the crisis and the higher electricity prices have stopped this trend.

Table 7. Short and long-run price and income elasticities of demand.

	OLS	FD-2SLS (a)	FD-2SLS (b)	DIF-GMM (one-step)	DIF-GMM (two-step)	SYS-GMM (one-step)	SYS-GMM (two-step)	LSDVC
1.Short-run								
Price	n.s.	n.s.	-0.65455	-0.26731	-0.26625	n.s.	n.s.	-0.23473
Income	0,06419	n.s.	n.s.	0.31257	0.31264	0.41028	0.41126	n.s.
2.Long-run								
Price	n.s.	n.s.	-0.42909	-0.37375	-0.37158	n.s.	n.s.	-0.60384
Income	0,73722	n.s.	n.s.	0.43703	0.43633	0.79203	0.79342	n.s.

Elsewhere, it has been argued that, in view of the low price elasticities, an electricity demand control policy based only on the use of a pricing policy (i.e., a tax) which substantially increases electricity prices is not effective to reduce electricity demand. It can be very expensive if the tax rate is set at a high enough level to induce significant reductions in electricity demand (Lee and Lee 2010, Gam and Rejeb 2012, Filippini and Pachauri 2004, Ziramba 2008, Sa'ad 2009), triggering public hostility, negatively affecting fuel poverty and making it politically unfeasible (Agnolucci 2010, Pearce 2006). The traditional lack of price instruments within energy-efficiency policies in Spain lends support to this interpretation. Our empirical results suggest that there is little room to discourage residential electricity consumption using price increases alone, given the low price elasticities.

However, electricity prices for domestic consumers have increased substantially in the recent past, i.e., by 38% on average in the 2006-2011 period (versus 13% in the EU).

With 15.97c€/kWh, Spain currently has the third most expensive residential electricity prices in the EU, only behind Cyprus and Malta (EU average = 12.15 c€/kWh). This is related to several factors, although two stand out: promotion of renewable energy sources and the increase in distribution costs[8]. For a decade, the revenues (electricity prices for utilities) have been below the electricity system costs[9]. This has led to an "Spanish anomaly", i.e., an accumulated so-called "tariff deficit" of 24,000M€ (CNE 2012). Recently, electricity bills have increased in order to reduce such deficit. Electricity price increases to cope with the tariff deficit will continue to be applied in the future, providing a price signal and making a price-based energy efficiency instrument unnecessary.

On the other hand, complementing the price increase with other instruments is still needed to address the barriers and market failures mentioned in section 1, including information for consumers, financial support for the purchase of electricity-efficient electronic appliances and energy efficiency standards (i.e., building energy codes and electric appliance standards). All these instruments have been and are applied in the Spanish context.

Indeed, the positive sign of the lagged demand variable suggests a "long-term habit inertia" in electricity consumption (Agnolucci 2010) or a "memory effect" (Gam and Rejeb 2012) which may be tackled with non-price instruments. Non-price, information instruments should discourage electricity demand by informing consumers about the negative impact of their electricity demand on the environment and on the security of energy supply and the direct financial benefits for households of reducing electricity demand. In this context, better consumption data should be provided to consumers (by energy suppliers, ESCOs) to enable them to better manage their own energy consumption. Clarity and frequency of billing, combined with accurate metering of energy consumption seems crucial in this regard (European Commission 2011).

The results for the other variables are interesting, although their direct energy policy implications are very limited. However, they are still policy-relevant, i.e., they have to be taken into account when implementing electricity-efficient policies.

7. Concluding remarks

This paper has analysed several determinants of household electricity demand in Spain with a panel data, partial-adjustment model. The results show that electricity demand responds positively and significantly to electricity demand in the previous year, income, temperature range, penetration of electric water heating in households and the number of heating and cooling degree days. It is significantly and negatively related to electricity prices, gas prices, penetration of electric heating in households and whether households have at least one member being older than 64 years.

Similarly to other contributions on the topic, a major conclusion is that, given the low level of price elasticity and the greater levels of income and lagged demand elasticities, price instruments have a limited role to play in reducing electricity demand and they need to be complemented with other policies.

However, looking at the results of the empirical study is not enough and some of the features of the Spanish electricity system should also be taken into account. While reductions in electricity demand are generally regarded as an important policy goal in order to mitigate their associated negative environmental effects (particularly, CO2 emissions) and improve the security of energy supply (fossil-fuel dependence), the excess generation capacity in the Spanish case, and the increase in electricity prices reduces the priority to implement policy instruments which promote electricity demand reductions, at least in the short-term. The excess generation capacity in the Spanish case is a joint result of large increases in renewable energy deployment, a "dash-for-gas" in the last decade, reductions in electricity demand in the last five years (due to the economic crisis) and the limited international interconnections which make it impossible to sell most of the excess electricity abroad.

In particular, the (regulated) electricity price increases in order to cope with the higher costs of the system and to reduce the tariff deficit reduces the urgency to implement policy instruments which provide a “price-signal”. The non-price instruments will continue to play a role in order to address the “non-economic” barriers to energy efficiency at the household level. In fact this is the case of the Action Plan 2011-2020 of the Energy Efficiency Strategy, which includes regulatory, information and other instruments.

8. References

Abel, A.B., 1990. Asset prices under habit formation and catching up with the Joneses. The American Economic Review, 80, 38-42.

Adom, P.K., Bekoe, W., Akoena, S.K.K., 2012. Modelling aggregate domestic electricity demand in Ghana: An autoregressive distributed lag bounds cointegration approach. Energy Policy, 42, 530-537.

Agnolucci, P., 2010. Stochastic Trends and Technical Change: The Case of Energy Consumption in the British Industrial and Domestic Sectors. The Energy Journal, 31, 111-135.

Alberini, A., Filippini, M., 2011. Response of residential electricity demand to price: The effect of measurement error. Energy Economics, 33, 889-895.

Alberini, A., Gans, W., Velez-Lopez, D., 2011. Residential consumption of gas and electricity in the U.S.: The role of prices and income. Energy Economics, 33, 870-881.

Amato, A.D., Ruth, M., Kirshen, P., Horwitz, J., 2005: Regional energy demand responses to climate change: Methodology and application to the Commonwealth of Massachusetts. Climatic Change, 71, 75–201.

Anderson, T.W., Hsiao, C., 1981. Estimation of dynamic models with error Components. Journal of the American Statistical Association, 76, 589–606.

Arellano, M., y Bond, S., 1991. Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. Review of Economic Studies, 58, 277-297.

Arellano, M., y Bover, O., 1995. Another look at the instrumental variable estimation of error-components models. Journal of Econometrics, 68 (1), 29-51.

Aroonruengsawat, A., Auffhammer, M., Sanstad, A.H., 2012. The impact of state level building codes on residential electricity consumption. Energy Journal, 33 (1).

Arthur, M.d.F.S.R., Bond, C.A., Willson, B., 2012. Estimation of elasticities for domestic energy demand in Mozambique. Energy Economics, 34, 398-409.

Azevedo, I.M.L., Morgan, M.G., Lave, L., 2011. Residential and Regional Electricity Consumption in the U.S. and EU: How Much Will Higher Prices Reduce CO2 Emissions? The Electricity Journal, 24, 21-29.

Bartusch, C., Odlare, M., Wallin, F., Wester, L., 2012. Exploring variance in residential electricity consumption: Household features and building properties. Applied Energy, 92, 637-643.

Benavente, J.M., Galetovic, A., Sanhueza, R., Serra, P., 2005. Estimando la demanda residencial por electricidad en Chile: El consumo es sensible al precio. Cuadernos de economía, 42, 31-61.

Bernstein, M.A., Griffin, J.M., 2006. Regional differences in the price-elasticity of demand for energy. Report NREL/SR-620-39512. National Renewable Energy Laboratory, California.

Bessec, M., Fouquau, J., 2008. The non-linear link between electricity consumption and temperature in Europe: A threshold panel approach. Energy Economics, 30(5), 2705-2721.

Bianco, V., Manca, O., Nardini, S., 2009. Electricity consumption forecasting in Italy using linear regression models. Energy, 34, 1413-1421.

Blázquez, L., Boogen, N., Filippini, M., 2013. Residential electricity demand in Spain: New empirical evidence using aggregate data. Energy Economics, 36, 648-657.

Blundell, R., and Bond, S., 1998. Initial conditions and moment restrictions in dynamic panel data models. Journal of Econometrics, 87 (1), 115-143.

Blundell, R. W., Bond, S. R., and Windmeijer, F., 2000. Estimation in dynamic panel data models: improving on the performance of the standard GMM estimator. In Baltagi, B., (Ed.), Nonstationary Panels, Panel Cointegration, and Dynamic Panels, Advances in Econometrics, JAI Press, New York, 15, pp. 53–91.

Boldrin, M., Christiano, L.J., Fisher, J.D.M., 1997. Habit persistence and asset returns in an exchange economy. Macroeconomic Dynamics, 1, 312-332.

Bond, S., Hoeffler, A., Temple, J., 2001. GMM estimation of empirical growth models. CEPR Discussion Paper No. 3048.

Bond, S.R., 2002. Dynamic panel data models: a guide to micro data methods and practice. Portuguese Economic Journal, 1, 141-162.

Borg, S.P., Kelly, N.J., 2011. The effect of appliance energy efficiency improvements on domestic electric loads in European households. Energy and Buildings, 43, 2240-2250.

Bruno, G.S.F., 2005. Estimation and inference in dynamic unbalanced panel-data models with a small number of individuals. Stata Journal, 5, 473.

Bun, M.J.G., Kiviet, J.F., 2006. The effects of dynamic feedbacks on LS and MM estimator accuracy in panel data models. Journal of Econometrics, 132, 409-444.

Carrasco, R., Labeaga, J.M., López- Salido, J.D., 2005. Consumption and Habits: Evidence from Panel Data. The Economic Journal, 115, 144-165.

CNE 2012. Report on the functioning of the electricity system (in Spanish). Report 004-12, March 7th 2012. http://www.cne.es

Dilaver, Z., Hunt, L.C., 2011. Modelling and forecasting Turkish residential electricity demand. Energy Policy, 39, 3117-3127.

Dulleck, U., Kaufmann, S., 2004. Do customer information programs reduce household electricity demand?—the Irish program. Energy Policy, 32, 1025-1032.

European Commission 2011. Commission staff working paper annexes to the impact assessment accompanying the document Directive of the European Parliament and of the

Council on Energy Efficiency and amending and subsequently repealing Directives 2004/8/EC and 2006/32/EC. Brussels, 22.6.2011. SEC(2011) 779 final.

Fan, S., Hyndman, R.J., 2011. The price elasticity of electricity demand in South Australia. Energy Policy, 39 (6), 3709-3719.

Filippini, M., 2011. Short- and long-run time-of-use price elasticities in Swiss residential electricity demand. Energy Policy, 39, 5811-5817.

Filippini, M., Pachauri, S., 2004. Elasticities of electricity demand in urban Indian households. Energy Policy, 32, 429-436.

Fullerton Jr., T.M., Juarez, D.A., Walke, A.G., 2012. Residential Electricity Consumption in Seattle. Energy Economics, (In Press Corrected Proof).

Gam, I., Ben Rejeb, J., 2012. Electricity demand in Tunisia. Energy Policy, 45, 714-720.

Haas, R., Biermayr, P., Zoechling, J., and Auer, H., 1998. Impacts on electricity consumption of household appliances in Austria: a comparison of time series and cross-section analyses. Energy Policy, 26 (13), 1031-1040.

Halvorsen, B., Larsen, B.M., 2001. The flexibility of household electricity demand over time. Resource and Energy Economics, 23, 1-18.

Han, C., Phillips, P.C.B., 2006. GMM with many moment conditions. Econometrica, 74, 147-192.

Han, C., Phillips, P.C.B., 2010. GMM estimation for dynamic panels with fixed effects and strong instruments at unity. Econometric theory, 12, 119.

Hekkenberg, M., Benders, R., Moll, H., Schoot Uiterkamp, A., 2009. Indications for a changing electricity demand pattern: The temperature dependence of electricity demand in the Netherlands. Energy Policy, 37, 1542-1551.

Hernández, F., 2012. Interview with Félix Hernández, energy expert. April 10th 2012.

Holtz-Eakin, D., Newey, W., Rosen, H.S., 1988. Estimating vector autoregressions with panel data. Econometrica: Journal of the Econometric Society, 1371-1395.

Houthakker, H. S., 1980. Residential electricity revisited. Energy Journal 1 (1), 29–41.

Houthakker, H.S., Taylor, L.D., 1970. Consumer demand in the United States: analyses and projections. Harvard University Press Cambridge, MA.

Houthakker, H., Philip, S.,Verleger, Jr. K., and Sheehan, D. P., 1974. Dynamic Demand Analyses for Gasoline and Residential Electricity. American Journal of Agricultural Economics, 56 (2), 412–418.

INE. National Statistical Office (INE). 2012. Survey of family budgets (ECPF). http//www.ine.es

Inglesi-Lotz, R., 2011. The evolution of price elasticity of electricity demand in South Africa: A Kalman filter application. Energy Policy, 39, 3690-3696.

Instituto para la diversificación y el ahorro energético (IDAE), 2011a. Proyecto Sech Spahousec: Análisis del consumo energético del sector residencial en España. Informe final.

Instituto para la diversificación y el ahorro energético (IDAE), 2011b. Plan de Acción de Ahorro y Eficiencia Energetica 2011-2020.

http://www.idae.es/index.php/mod.documentos/mem.descarga?file=/documentos_11905_PAEE_2011_2020._A2011_A_a1e6383b.pdf

Jamil, F., Ahmad, E., 2011. The relationship between electricity consumption, electricity prices and GDP in Pakistan. Energy Policy, 38, 6016-6025.

Judson, R.A., Owen, A.L., 1999. Estimating dynamic panel data models: a guide for macroeconomists. Economics Letters, 65 (1), 9-15.

Kiviet, J.F., 1995. On bias, inconsistency, and efficiency of various estimators in dynamic panel data models. Journal of Econometrics, 68, 53-78.

Kleibergen, F., Paap, R., 2006. Generalized reduced rank tests using the singular value decomposition. Journal of Econometrics, 133, 97-126.

Kleibergen, F., Schaffer, M.E., 2007. Ranktest: module for testing the rank of a matrix using the Kleibergen-Paap rk statistic. Statistical software component.Boston College Department of Economics.

Labandeira, X., Labeaga, J.M., Rodríguez, M., 2006. A residential energy demand system for Spain. Energy Journal, 27, 87–112.

Labandeira, X., Labeaga, J.M., López-Otero, X., 2012. Estimation of elasticity price of electricity with incomplete information. Energy Economics, 34 (3), 627-633.

Lee, C.C., Lee, J.D., 2010. A panel data analysis of the demand for total energy and electricity in OECD countries. The Energy Journal, 31, 1-24.

Lee, C., Chiu, Y., 2011. Electricity demand elasticities and temperature: Evidence from panel smooth transition regression with instrumental variable approach. Energy Economics, 33, 896-902.

Leighty, W., Meier, A., 2011. Accelerated electricity conservation in Juneau, Alaska: A study of household activities that reduced demand 25%. Energy Policy, 39 (5), 2299–2309.

McLoughlin, F., Duffy, A., Conlon, M., 2011. Characterising domestic electricity consumption patterns by dwelling and occupant socio-economic variables: An Irish case study. Energy and Buildings, 48, 240-248.

Ministerio de Educación, Política Social y Deporte (MEPSYD), 2008. Economía y Personas Mayores. Colección Estudios Serie Personas Mayores, Nº 11003, IMSERSO. http://www.imsersomayores.csic.es/documentos/documentos/dizy-economia-01.pdf. Last access June 2012

Ministerio de Industria, Energía y Turismo (MINETUR), 2013. Statistics of the Electricity Industry http://www.minetur.gob.es/energia/balances/Publicaciones/ElectricasAnuales/Paginas/ElectricasAnuales.aspx. Last accessed: January 30th, 2013.

Ministerio de Industria Turismo y Comercio (MITYC), 2007. Comercialización de electrodomésticos en España. Dirección General de Política comercial. http://www.comercio.gob.es/es-ES/comercio-interior/Distribucion-Comercial-Estadisticas-y-Estudios/Pdf/InformeElectrodomesticos_2007.pdf Last access June 2012

Ministerio de Industria Turismo y Comercio (MITYC), 2011. La energía en España 2010. Secretaría de Estado de Energía.

http://www.minetur.gob.es/energia/balances/Balances/LibrosEnergia/Energia_Espana_2010_2ed.pdf Last accessed June 2012

Nakajima, T., 2010. The residential demand for electricity in Japan: An examination using empirical panel analysis techniques. Journal of Asian Economics, 21, 412-420.

Nakajima, T., Hamori, S., 2010. Change in consumer sensitivity to electricity prices in response to retail deregulation: A panel empirical analysis of the residential demand for electricity in the United States. Energy Policy, 38, 2470-2476.

Narayan, P.K., Smyth, R., Prasad, A., 2007. Electricity consumption in G7 countries: A panel cointegration analysis of residential demand elasticities. Energy Policy, 35, 4485-4494.

Narayan, P.K., Smyth, R., 2009. Multivariate granger causality between electricity consumption, exports and GDP: Evidence from a panel of Middle Eastern countries. Energy Policy, 37, 229-236.

Pearce, D., 2006. The political economy of an energy tax: The United Kingdom's Climate Change Levy. Energy Economics, 28, 149-158.

REE- Red eléctrica de España, 1998. Atlas de la demanda eléctrica Española-Proyecto INDEL.

Roodman, D., 2009. A Note on the Theme of Too Many Instruments*. Oxford Bulletin of Economics and Statistics, 71, 135-158.

Sa'ad, S., 2009. Electricity demand for South Korean residential sector. Energy Policy, 37, 5469-5474.

Schipper, L., Bartlett, S., Hawk, D., Vine, E., 1989. Linking life-styles and energy use: a matter of time? Annual review of energy, 14, 273-320.

Sebastian, P., Rehdanz, K., Tol, R.S. J., 2010. The Impact of Temperature Changes on Residential Energy Consumption. Kiel Institute for the World Economy, Working paper No. 1618 |

Shin, J., 1985. Perception of Price When Information is Costly: Evidence from Residential Electricity Demand. Review of Economics and Statistics, 67, 591-98.

Staiger, D., and Stock, J.H., 1997. Instrumental variables regressions with weak instruments. Econometrica, 65, 557-586

Stock, J.H., Wright, J.H., 2000. GMM with weak identification. Econometrica, 68, 1055-1096.

Stock, J. H., and Yogo M., 2005. Testing for Weak Instruments in IV Regression, in: Andrews, D.W.K., Stock, J.H. (Eds.), Identification and Inference for Econometric Models: A Festschrift in Honor of Thomas Rothenberg. Cambridge University Press, pp. 80–108.

Tol, R.S.J., Sebastian, P., Rehdanz, K., 2012. The Impact of Temperature Changes on Residential Energy Use. University of Sussex, Economics Department Working Paper Series No. 44-2012

Valor, E., Meneu, V., Caselles, V., 2001. Daily Air Temperature and Electricity Load in Spain. Journal of Applied Meteorology and Climatology, 40, 1413-1421

Wiesmann, D., Lima Azevedo, I., Ferrão, P., Fernández, J.E., 2011. Residential electricity consumption in Portugal: Findings from top-down and bottom-up models. Energy Policy, 39, 2772-2779.

Xu, M., Hu, Z., Wu, J., Zhou, Y., 2008. A hybrid society model for simulating residential electricity consumption. International Journal of Electrical Power & Energy Systems, 30, 569-574.

Yoo, S.H., Lee, J.S., Kwak, S.J., 2007. Estimation of residential electricity demand function in Seoul by correction for sample selection bias. Energy Policy, 35, 5702-5707.

Zachariadis, T., Pashourtidou, N., 2007. An empirical analysis of electricity consumption in Cyprus. Energy Economics, 29, 183-198.

Ziramba, E., 2008. The demand for residential electricity in South Africa. Energy Policy, 36, 3460-3466.

Endnotes

[1] Fossil-fuel fired electricity generation leads to significant emissions of local and global pollutants. Lower electricity demand reduces the emissions of greenhouse gases (GHG) to the atmosphere. Growing concerns over the effects of GHG emissions on climate change have placed pressure on the world's leading economies to improve the efficiency of energy use (Narayan et al 2007).

[2] In 2010, 18% of electricity generation came from non-hydro renewables, 14% from hydro, 8.5% from coal, 32% from gas and 20% from nuclear.

[3] For example, the natural gas imported comes from Algeria (29%), Nigeria (21%), Qatar (15%), Trinidad and Tobago (8%) and Egypt (8%). 40% of the coal used by thermal plants is domestic and 60% is imported (MITYC 2011).

[4] Long-term elasticities are easily obtained by dividing the short-term elasticities by $(1-\lambda)$.

[5] In Spanish households, they can be a substitute for each other regarding electric vs. gas kitchens, less so concerning heating and virtually no substitute between each other regarding water heating (Hernández 2012).

[6] This is consistent with the finding of a survey of penetration of heating, air conditioning and electric appliances in Spain, recently carried out by the Ministry of Industry (IDAE 2011a).

[7] We also show the results of the estimation when the threshold values are 18ºC for HDD and CDD and 20ºC for CDD, reflecting the thresholds often considered in the literature.

[8] The Spanish government decided to remove the support scheme for renewable electricity plants installed after January 2012. This drastic measure is not retroactive, however. Thus, since support for pre-existing plants is guaranteed at least for 20 years, electricity consumers will continue to pay the financial burden associated with such support. Indeed, if the removal of support continues, the annual savings for electricity consumers are estimated to be around 1,500€ in 2020, or about 14% of the 10,400 M€ which would have been paid without such removal (CNE 2012).

[9] While the cost of the system increased by 140% in the 2006-2010 period, the revenues only increased by 70%. While the costs were around 8,000M€ in 2006, they more than doubled by 2011 (18,000M€). In 2011, the major cost components were: feed-in tariff support for renewable electricity (38% of total costs), transport and distribution costs (37%), payment of the accumulated debt of the system (11%) and costs of electricity generation in the Balearic Islands, Canary Islands, Ceuta and Melilla (7%). The major contributors to the increase in system costs over the period have been the feed-in tariffs and payment for the accumulated debt, which have increased five-fold since 2006 (CNE 2012).

2011

2011/1, Oppedisano, V; Turati, G.: "What are the causes of educational inequalities and of their evolution over time in Europe? Evidence from PISA"
2011/2, Dahlberg, M; Edmark, K; Lundqvist, H.: "Ethnic diversity and preferences for redistribution"
2011/3, Canova, L.; Vaglio, A.: "Why do educated mothers matter? A model of parental help"
2011/4, Delgado, F.J.; Lago-Peñas, S.; Mayor, M.: "On the determinants of local tax rates: new evidence from Spain"
2011/5, Piolatto, A.; Schuett, F.: "A model of music piracy with popularity-dependent copying costs"
2011/6, Duch, N.; García-Estévez, J.; Parellada, M.: "Universities and regional economic growth in Spanish regions"
2011/7, Duch, N.; García-Estévez, J.: "Do universities affect firms' location decisions? Evidence from Spain"
2011/8, Dahlberg, M.; Mörk, E.: "Is there an election cycle in public employment? Separating time effects from election year effects"
2011/9, Costas-Pérez, E.; Solé-Ollé, A.; Sorribas-Navarro, P.: "Corruption scandals, press reporting, and accountability. Evidence from Spanish mayors"
2011/10, Choi, A.; Calero, J.; Escardíbul, J.O.: "Hell to touch the sky? Private tutoring and academic achievement in Korea"
2011/11, Mira Godinho, M.; Cartaxo, R.: "University patenting, licensing and technology transfer: how organizational context and available resources determine performance"
2011/12, Duch-Brown, N.; García-Quevedo, J.; Montolio, D.: "The link between public support and private R&D effort: What is the optimal subsidy?"
2011/13, Breuillé, M.L.; Duran-Vigneron, P.; Samson, A.L.: "To assemble to resemble? A study of tax disparities among French municipalities"
2011/14, McCann, P.; Ortega-Argilés, R.: "Smart specialisation, regional growth and applications to EU cohesion policy"
2011/15, Montolio, D.; Trillas, F.: "Regulatory federalism and industrial policy in broadband telecommunications"
2011/16, Pelegrín, A.; Bolancé, C.: "Offshoring and company characteristics: some evidence from the analysis of Spanish firm data"
2011/17, Lin, C.: "Give me your wired and your highly skilled: measuring the impact of immigration policy on employers and shareholders"
2011/18, Bianchini, L.; Revelli, F.: "Green polities: urban environmental performance and government popularity"
2011/19, López Real, J.: "Family reunification or point-based immigration system? The case of the U.S. and Mexico"
2011/20, Bogliacino, F.; Piva, M.; Vivarelli, M.: "The impact of R&D on employment in Europe: a firm-level analysis"
2011/21, Tonello, M.: "Mechanisms of peer interactions between native and non-native students: rejection or integration?"
2011/22, García-Quevedo, J.; Mas-Verdú, F.; Montolio, D.: "What type of innovative firms acquire knowledge intensive services and from which suppliers?"
2011/23, Banal-Estañol, A.; Macho-Stadler, I.; Pérez-Castrillo, D.: "Research output from university-industry collaborative projects"
2011/24, Ligthart, J.E.; Van Oudheusden, P.: "In government we trust: the role of fiscal decentralization"
2011/25, Mongrain, S.; Wilson, J.D.: "Tax competition with heterogeneous capital mobility"
2011/26, Caruso, R.; Costa, J.; Ricciuti, R.: "The probability of military rule in Africa, 1970-2007"
2011/27, Solé-Ollé, A.; Viladecans-Marsal, E.: "Local spending and the housing boom"
2011/28, Simón, H.; Ramos, R.; Sanromá, E.: "Occupational mobility of immigrants in a low skilled economy. The Spanish case"
2011/29, Piolatto, A.; Trotin, G.: "Optimal tax enforcement under prospect theory"
2011/30, Montolio, D; Piolatto, A.: "Financing public education when altruistic agents have retirement concerns"
2011/31, García-Quevedo, J.; Pellegrino, G.; Vivarelli, M.: "The determinants of YICs' R&D activity"
2011/32, Goodspeed, T.J.: "Corruption, accountability, and decentralization: theory and evidence from Mexico"
2011/33, Pedraja, F.; Cordero, J.M.: "Analysis of alternative proposals to reform the Spanish intergovernmental transfer system for municipalities"
2011/34, Jofre-Monseny, J.; Sorribas-Navarro, P.; Vázquez-Grenno, J.: "Welfare spending and ethnic heterogeneity: evidence from a massive immigration wave"
2011/35, Lyytikäinen, T.: "Tax competition among local governments: evidence from a property tax reform in Finland"
2011/36, Brülhart, M.; Schmidheiny, K.: "Estimating the Rivalness of State-Level Inward FDI"
2011/37, García-Pérez, J.I.; Hidalgo-Hidalgo, M.; Robles-Zurita, J.A.: "Does grade retention affect achievement? Some evidence from Pisa"
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2014

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