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EUI Working Paper **RSCAS** 2016/25

ISSN 1028-3625

Printed in Italy, April 2016
European University Institute
Badia Fiesolana
I – 50014 San Domenico di Fiesole (FI)
Italy
www.eui.eu/RSCAS/Publications/
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Abstract

Price elasticities of energy demand have become increasingly relevant in estimating the socio-economic and environmental effects of energy policies or of other events with influence on the prices of energy goods. Since the 1970s a large number of academic papers have provided both short and long-term price elasticity estimates for different countries by using several models, data and estimation techniques. Yet the literature offers a rather wide range of estimates for the price elasticities of demand for energy. This paper quantitatively summarizes the recent, but still sizeable, empirical evidence on this matter to facilitate a sounder economic assessment of energy price changes. It does so by using meta-analysis to identify the main factors affecting the elasticity results, both short and long term, for energy in general as well as for specific products: electricity, natural gas, gasoline, diesel and heating oil.

Keywords

Short-term, long-term, electricity, gas, gasoline, diesel, oil.

JEL Classification: C13, C83, Q41

1. Introduction[*]

Energy is a key element in contemporary economies not only for the production of goods and services but also as a direct source of welfare for individuals. It is therefore essential to know how price changes, brought about by market dynamics and/or energy-related public policies, affect energy demand of producers and consumers. Over the last few years energy deregulation and sharp movements in the price of primary energy goods, together with policies related to climate change and energy security concerns, have actually fostered a renewed interest in this area. Energy savings are likely to play a crucial role for the attainment of climate objectives (see e.g. IPCC, 2014), hence the need to correctly quantify actual mitigation potentials within energy demands, and thus energy goods may be particularly exposed to price increases and collateral distributive effects from post-Paris climate policies. Robust evidence on price elasticities of energy demand would therefore allow for a better understanding of the economic, distributional and environmental consequences of varying energy prices and would enable societies to take *ex-ante* informed decisions on energy and environmental matters.

Although the economic literature on energy demand dates back to the last century (it began with Houthakker, 1951), in recent years a large number of academic studies have used several techniques to estimate the (both short and long-term) price elasticity demand of different energy products in various countries, thus yielding quite a sizeable empirical evidence. In this context, and given the above-mentioned practical relevance of price elasticities of energy demand, developing methods that summarize (qualitatively and quantitatively) the existing evidence and that identify the main factors that systematically affect results is particularly interesting. Meta-analysis, or the statistical study of studies in an area, first proposed by Glass (1976) in the field of education but subsequently extended to many other disciplines, seems to be an appropriate and useful approach for these purposes. After the work of Stanley and Jarrell (1989) multiple meta-analyses have been conducted in economics with at least one third of the studies related to environmental and resource economics (Nelson and Kennedy, 2009).

Unfortunately the use of meta-analysis in the field of energy demand has been rather limited, with the few existing exercises focusing almost exclusively on price elasticities of gasoline demand. Therefore a first objective of this paper is to incorporate other energy goods, namely electricity, natural gas, diesel, heating oil and energy in general, so that a richer analysis and conclusions of the growing empirical evidence on price elasticities in the energy domain can be provided. The paper also contemplates both aggregated demand for energy as well as residential, industrial and commercial demand. Moreover, the article just deals with the latest evidence available (papers published as of 1990) for two reasons: the need to update and relate the scarce academic contributions that have previously considered these matters through comparable methodologies, and the increase in the quality and reliability of results due to the significant technical advances in data collection and processing seen over the last two decades.

This piece of research carries out a meta-analysis with the procedure suggested by Nelson and Kennedy (2009) using the methodology of regression analysis (see also Stanley and Jarrell, 1989), that is, it performs a regression analysis employing the entire set of results selected from the literature and an extensive specification of the factors that determine these elasticities. The paper thus responds to the need to determine, as precisely as possible, the value of price elasticities of demand for energy in general as well as those for the demand of the abovementioned energy goods. As a secondary

[*] The authors acknowledge funding from the Spanish Ministry of Science and Innovation projects ECO2012-39553-C04-01 (Labeaga), ECO2013-41183-P (Labandeira) and Cátedra FENOSA at the University of Vigo (Labandeira and López-Otero). The usual disclaimers apply.

outcome, the paper identifies the variables that explain the heterogeneity of the price elasticities reported by the literature.

The article is divided into five sections, including this introduction. The second section describes existing academic literature with the use of meta-analysis to summarize and analyze price elasticities of energy demand. The subsequent part provides details on the empirical application implemented in the article, also describing the factors that influence the estimation of price elasticities of energy demand. Section 4 presents the empirical results from the use of meta-analysis on the updated literature review, and Section 5 concludes the article. Additionally the paper includes two annexes with, respectively, the full estimation results and the list of papers employed in the meta-analysis.

2. Meta-analyses of price elasticities of energy demand

Although numerous papers have provided estimates of the price elasticity of demand for energy (see, e.g., Taylor, 1975, Dahl and Sterner, 1991, Madlener, 1996, Graham and Glaister, 2002b, or Dahl, 2012), relatively few studies in the literature have conducted a meta-analysis of these elasticities. Moreover, as shown by Table 1, the few existing meta-analysis have been mainly applied to the literature on price elasticities of gasoline demand.

In particular, Espey (1996) carried out the first meta-analysis to examine the existence of factors that systematically affect the estimates of gasoline price (and income) elasticities in the United States, including as explanatory variables the characteristics of the data, the model structure and the estimation technique. An extension of this article is provided in Espey (1998), with the use of existing empirical evidence on gasoline demand across the globe and the separate analysis of long-term and short or medium-term elasticities. This paper employs the functional form, the structure of delays, the sampling period, the country, the estimation technique and other structural characteristics of the model as explanatory variables. Subsequently, the UK Department of Transport commissioned two reports (Hanly et al., 2002; Graham and Glaister 2002a) to identify the magnitude and ranges of road transport elasticities provided by the existing literature, and to distinguish price elasticities by type of traffic and different definitions of costs and prices. Within this context the reports also conducted a meta-analysis, akin to that of Espey (1998), on price elasticities of demand for car fuels.

Regarding price elasticities of other energy sources, Espey and Espey (2004) carried out the only meta-analysis that analyzes residential electricity demand. This paper examines how the values of the short and long-term price elasticities are affected by the specification of the demand model, the characteristics of the data used, the country for which the exercise is conducted, the period of analysis and by the estimation technique.

The latest contributions to the literature of meta-price elasticities of energy demand are those of Brons et al. (2008) and Havranek et al. (2012). In the first case the authors performed a meta-analysis to enquire on the variation in empirical estimates of the price elasticity of demand for gasoline, developing an estimation method based on the Seemingly Unrelated Regression (SUR) model and assuming that gasoline demand may be expressed as a multiplicative function of car fuel efficiency, mileage per vehicle and vehicle ownership, which implied a linear relationship between the price elasticity of the total demand for gasoline and the price elasticities of each of these variables. The combination of information on different types of elasticities allowed Brons et al. (2008) to obtain more precise estimates. Havranek et al. (2012), on the other hand, approached this issue through a meta-analysis of the estimates of gasoline demand elasticities across different countries. This study considered that the distribution of the estimated elasticities might be explained by the type of data used, the date of publication of the study and an indicator of whether the data are for the US. The paper employed, for the first time in the field, the so-called Heckman meta-regression (see Stanley and Doucouliagos, 2007) to correct selection bias in the existing publications that report these elasticities.

Biases in average price elasticities occur because positive or non-significant estimates of price elasticities are rarely reported while overly negative elasticities are regularly published.

Table 1. Meta-analyses for price elasticity of demand for energy in literature

Study	Period	Considered papers	Observations	Energy Product	Elasticities
Espey (1996)	1936-1990	41	70	Gasoline	-0.65 (LT)
Espey (1998)	1929-1993	101	640	Gasoline	-0.16 (LT) -0.81 (LT)
Hanly et al. (2002)	1929-1991	69	491	Car fuels	-0.76 (ST) -1.16 (LT) -0.54 (STA)
Graham and Glaister (2002a)	1966-2000	113	600	Car fuels	-0.25 (ST) -0.77 (LT)
Espey and Espey (2004)	1947-1997	36	248	Electricity	-0.35 (ST) -0.85 (LT)
Brons et al. (2008)	1949-2003	43	312	Gasoline	-0.36 (ST) -0.81 (LT)
Havranek et al. (2012)	1974-2011	41	202	Gasoline	-0.09 (ST) -0.31 (LT)

Source: Brons et al. (2008) and the cited literature

Note: LT, long term; ST, short term; STA, result obtained by using only papers that employ statistical models

The results of these studies show a price elasticity of energy products in the short term ranging between -0.09 and -0.76, while they report long-term elasticities between -0.31 and -1.16. The preceding papers also show that, in absolute value, elasticities have a tendency to decrease over time. This phenomenon could reflect income effects as well as the influence of energy-efficiency improvements that would lead consumers to be less sensitive to price changes.

3. Meta-analysis

As suggested by Nelson and Kennedy (2009), in this paper we perform a meta-regression analysis (Stanley and Jarrell, 1989), that is, we carry out a regression analysis of the whole set of coefficients included in the papers selected for this piece of research (see Annex II). Therefore, this article intends to adjust the value of price elasticities of demand for energy as precisely as possible, identifying the factors that explain the differences between the results of the various studies. It does so by estimating the model

$$b_j = \beta + \sum_{k=1}^{K} \alpha_k Z_{jk} + e_j \quad (j = 1,2,...,L) \tag{1}$$

where b_j is the estimation carried out in the j-nth study using the real value of the price elasticity of demand for energy (β), Z are the explanatory variables that measure the relevant characteristics of the empirical study that influence estimated elasticities, α_k are the coefficients of the meta-regressions that reflect the bias introduced by the particular characteristics of the study, e_j is the error term of the meta-regression, and L is the number of studies employed in the analysis. As in previous meta-analyses in this area, different models are estimated for short and long-term elasticities of energy demand.

The papers, whose results were used to conduct the meta-analysis, were selected from a fully updated, comprehensive and detailed review of the existing empirical literature on price elasticities of energy demand. Most papers were actually found by consulting previous surveys and meta-analyses on this matter, although extensive internet search tools (including *Google Scholar* and *ScienceDirect*) were also employed. Among the sources to identify and compile the studies used in this article special mention deserves the *Dahl Energy Demand Database* (Dahl, 2010). In total 416 papers produced between 1990 and 2014 were collected, providing 951 short term price elasticities and 991 long-term price elasticities of energy demand (see Table 1 in the preceding section for a comparison with previous meta-analyses in the field). Table 2 shows a statistical summary of the elasticities that served as the basis for the meta-analysis: estimates of the long-term elasticity range between -22 and 4.189, with an average of -0.598, while short-term elasticity estimates range from -24 to 2.908, with an average of -0.237. The upper panel of Figure 1 shows the density of the total sample of estimated short and long-term elasticities.

As some of the estimated values of elasticities are very extreme and statistically non-significant, usually due to small sample sizes, we decided to exclude 5% of the sample from the meta-analysis (2.5% of values in the upper tail and 2.5% of the values in the lower tail of the distribution) in order to eliminate outliers that may strongly affect the results of the estimation of Equation 1. Table 2 summarizes, under the heading selected sample, the statistics that describe the elasticities used in the analysis, with short-term price elasticities ranging between -0.803 and 0.067 and long-term elasticities in an interval between -1.809 and 0.154, while the lower panel of Figure 1 shows the density of the elasticities actually considered in this paper.

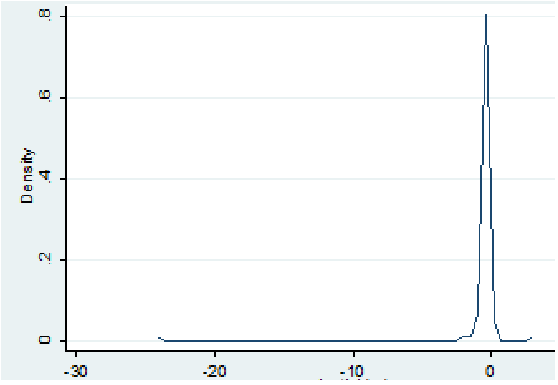
Table 2. Statistics of price elasticities of demand. Total and selected samples

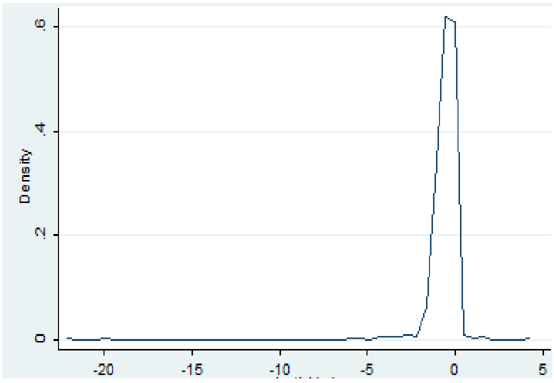
Variable	Observations	Average	Median	Standard Deviation	Minimum	Maximum
Total sample						
ST Elasticity	951	-0.237	-0.139	0.887	-24.0	2.908
LT Elasticity	991	-0.598	-0.427	1.130	-22.0	4.189
Selected sample						
ST Elasticity	903	-0.186	-0.139	0.169	-0.803	0.067
LT Elasticity	941	-0.524	-0.427	1.392	-1.809	0.154

Note: ST, short term; LT, long term

Figure 1. Density of the elasticities. Total and selected samples

Total Sample

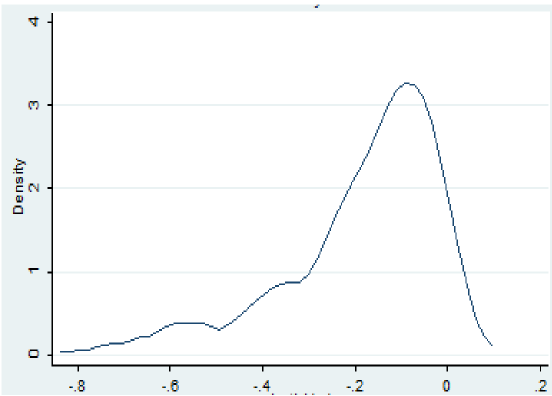


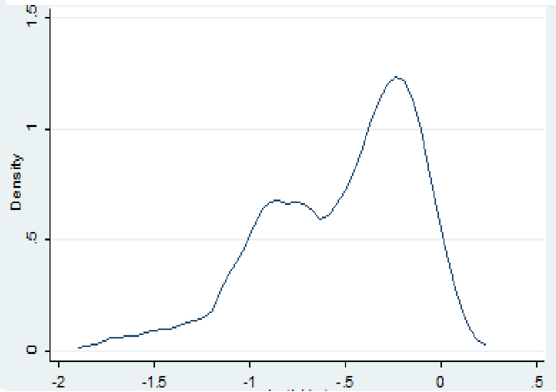


Short-term elasticities

Long-term elasticities

Selected sample





Short-term elasticities

Long- term elasticities

Given the heterogeneity of the selected empirical studies, which brings about an important variation in the estimated elasticities, a number of indicators (constructed as variables 0-1) were introduced to capture the various sources of heterogeneity. We considered eight main factors or determinants that could affect the estimation of elasticities, as listed below and summarized in Table 3:

- *Type of energy product*. Since the reaction of consumers to price changes may be different in function of the energy product consumed, the exercise distinguishes between the studies estimating the price elasticity of demand for energy in general and those estimating the price elasticities of demand for each of the main energy products, i.e., electricity, natural gas, gasoline, diesel and heating oil.

- *Type of consumer*: Energy is used for different purposes in function of the general type of consumer demanding it, which itself influences the effect of prices on demand. The exercise therefore distinguishes between studies estimating residential, industrial, commercial, and total energy consumption.

- *Country (geographical area)*. The behavior of energy consumers can be very different in function of the country under analysis. So in this case the exercise considers two factors that may affect estimated elasticities: stage of economic development (developed and developing countries), and energy trade balance (net energy exporters and importers). For these purposes, the paper uses the Human Development Index (UNDP, 2015) to identify developed countries as those with HDI above the median, and World Bank data (World Bank, 2015) concerning net energy imports/exports of countries.[1]

- *Data.* Another important factor that can influence the results is the type of data used in each particular study. The exercise therefore distinguishes between studies using cross-sectional data, those employing time series data and papers that use panel data.

- *Type of model.* On the one hand, a large part of the existing empirical research on energy demand has employed dynamic (usually error-correction) models estimated with cointegration techniques on aggregate data (Engle and Granger, 1987). However, the validity of the results obtained with these approaches largely rests on the existence of representative consumers, disregarding the information related to the behavior of individual agents and thus being unable to deal with observable and unobservable heterogeneity. An available alternative when information for individual agents (consumers, companies, etc.) exists is to adjust models that explicitly consider these factors. When using micro data, a first option consists in estimating energy demand using standard econometric techniques although, even under these circumstances, it is unlikely that all the decisions of the agents concerning energy demand will be taken into account. For example, the relationship between the discrete decision to purchase durable goods that consume energy and the decision to consume energy is rarely considered. This may lead to inadequate specifications in models, causing a biased estimation of elasticities and thus invalidating the inference relative to public policies and/or price shocks. Within this context, an alternative may be to use continuous-discrete sequential models that assume agents who first take discrete decisions on the purchase of durable energy-consuming goods and, conditioned by them, subsequently decide on how much energy to consume.

On the other hand, most empirical studies in this area have used single-equation econometric models that require separability restrictions. This is a severe disadvantage as it is not possible to estimate cross-price effects between different energy products or consider the effects of non-energy products on the price elasticity of energy goods. An alternative is to estimate price elasticities using complete systems of demand, such as the translog model (Christensen et al., 1973) or the almost ideal demand system (Deaton and Muellbauer, 1980), AIDS, which allow the correction of various econometric problems that usually cause biases in the estimation of elasticities.

- *Sample period*. It is widely accepted that the economic cycle has a strong influence on energy consumption due to income and (indirect cycle-related) price effects. In the case of economic crises, for example, a depression of energy prices may occur and reduced disposable income may lead agents to reduce consumption through improvements in energy efficiency, adjustments to other types of consumption or changes towards other more inexpensive energy goods. Thus the exercise incorporates a series of dummies indicating whether most of the sample period of each considered study is before or after the crises of 1973, 1979 and 2008.

- *Type of publication.* The exercise introduces a dummy to distinguish between papers published in peer-review journals from studies published in alternative formats such as working papers series, reports, etc.

- *Estimation method*. The exercise also considers that the procedure used to estimate the model may affect the results. Thus there is a distinction between papers using least squares methods, from single equations estimated by ordinary least squares (OLS) to iterate least squares (ILS), papers with multiple equations, as seemingly unrelated regression equations (SURE), panel data models estimated by least squares dummy variables (LSDV) and generalized least squares (GLS). Papers with single equation or multiple equation models estimated by instrumental variables as two-stage or three-stage least squares (2SLS or 3SLS) or generalized method of

[1] When a given estimation uses data from several countries, these dummies reflect the type of country that represents a majority within the group.

moments (GMM) are also contemplated. Finally, the exercise also incorporates papers that use alternative estimation approaches such as maximum likelihood methods, Bayesian methods, ridge regression or nonparametric estimation.[2]

Table 3. Main determinants affecting elasticity demand estimation

Determinants	Number of observations	Average elasticity	
		Short-term	Long-term
Good			
Energy	372	-0.149	-0.570
Electricity	516	-0.203	-0.520
Natural gas	229	-0.184	-0.566
Car fuels	82	-0.180	-0.358
Gasoline	465	-0.194	-0.526
Diesel	136	-0.157	-0.391
Heating oil	44	-0.188	-0.534
Consumer			
Residential	693	-0.216	-0.620
Industrial	259	-0.166	-0.508
Commercial	59	-0.230	-0.721
Total	833	-0.162	-0.435
Country			
Net energy exporter	481	-0.189	-0.514
Net energy importer	1363	-0.185	-0.527
Developed	1432	-0.186	-0.515
Developing	412	-0.184	-0.550
Data			
Cross-section	182	-0.337	-0.861
Time series	1174	-0.167	-0.446
Panel data	488	-0.204	-0.514
Model			
Aggregate data	1139	-0.158	-0.456
Aggregate data and cointegrated (or ECM)	364	-0.181	-0.452
Demand system	213	-0.270	-0.790
Microeconomic model	83	-0.358	-0.679
Continuous-discrete micro model	45	-0.293	-0.880
Sample period			
Pre-1973	101	-0.224	-0.634
Post-1973	1743	-0.183	-0.518
Pre-1979	354	-0.191	-0.551
Post-1979	1490	-0.184	-0.518
Pre-2008	1817	-0.186	-0.526
Post-2008	27	-0.175	-0.323
Publication			
Peer-review journal	1461	-0.193	-0.567
Other	383	-0.151	-0.382
Estimation method			
Least squares	1151	-0.188	-0.458
Instrumental variables	265	-0.184	-0.559
Other methods	428	-0.180	-0.641

[2] A description of most of the above-mentioned estimation methods can be found in Wooldridge (2002). For non-parametric methods and Bayesian procedures seminal references are respectively Härdle and Linton (1994) and Chib et al. (2008).

4. Results and discussion

4.1. Results

The model of Section 3 was estimated using GLS for both short and long-term elasticities because the elasticity figures provided by the literature, conforming a sample with two dimensions (time and type of study), could lead to heteroskedasticity and correlation of error terms given the different sample sizes of the various studies. Moreover, we attempted to control for unobserved study-specific factors with the estimation of Equation 1 by using a panel data structure in which the dimensions are the energy product under consideration and the study. It was also considered that the dimension of the sample allowed the use of random effects under the assumption of non-correlated effects. Table 4 presents the average elasticities adjusted using the above-mentioned methods, with the top (bottom) panel reporting the short-term (long-term) elasticities.[3]

Table 4. Average elasticities in the empirical literature

	GLS	**Random-effects panel**
	Short-term	
Energy	**-0.220*** **	**-0.224*** **
Electricity	-0.231***	-0.209***
Natural Gas	-0.239***	-0.216***
Gasoline	-0.249***	-0.227***
Diesel	-0.213***	-0.204***
Heating Oil	-0.242***	-0.259***
	Long-term	
Energy	**-0.600*** **	**-0.652*** **
Electricity	-0.677***	-0.686***
Natural Gas	-0.614***	-0.850***
Gasoline	-0.720***	-0.715***
Diesel	-0.620***	-0.595***
Heating Oil	-0.747***	-0.764***

Note: *** Significant at the 1% level.

Regarding the results obtained for the specification estimated using random effects panel data models, which will be later compared to alternative methodological outcomes, the short-term price elasticity of energy demand is, on average, -0.22, with diesel being the least elastic good and heating oil being the most elastic one (which reflects not only the evolution of its own price but also the substitution possibilities among energy sources for heating). In all cases, the dispersion of price elasticities is quite small: estimates from GLS are slightly higher in absolute value, with the exception of the results for energy in general and heating oil. However, these observed differences are not statistically significant.

A second relevant matter refers to the factors affecting the reported elasticities. Regarding short-term price elasticities the use of micro data generates significantly higher elasticities (in absolute value) than do aggregate models. This is, intuitively, an unexpected outcome since microeconomic models include a wide range of socioeconomic and demographic variables that could induce a reduction on price effects. Therefore, it is necessary to turn to other factors to obtain a coherent explanation for these results. Indeed, the absence of a representative consumer (and, thus, unobserved

[3] Table A1 and Table A2 in Annex I show the complete results of the estimates. Note that the alternatives presented in this section were not the only ones used: they were actually selected by rigorously contrasting their robustness, as further discussed in the paper.

heterogeneity as well as correlated heterogeneity) could affect the estimates of price effects in much the same way. The reported results also show that residential and commercial demands have a remarkably higher short-term sensitivity to prices than do the industrial or aggregate demands. In aggregate models that adjust industrial energy demand, the most important factor explaining this phenomenon is the business cycle (GDP change): actually, conditional on the business cycle, prices have a limited impact on demand.

With regard to long-term elasticities, the average value is -0.65: higher and with a greater dispersion than the reported short-term results. Significant differences among different goods, with diesel being the most inelastic product and natural gas being the most elastic one, are also found. As expected, GLS estimation results are similar to those obtained using panel data techniques. Long-term results are explained by a number of factors: the first oil crisis, type of energy consumed and type of data employed and modeling strategy of the studies (see Table A2). The meta-analysis indicates that long-term price elasticities are lower after the first oil shock (1973), probably due to the significant investments and behavioral changes brought about by the sharp increase in the price of energy goods. Moreover, price elasticities of commercial demand are significantly higher than those of residential and industrial demands. Price elasticities of energy demand from panel data are significantly smaller (in absolute terms, as in the previous comparisons) than those from cross-sections, although higher to the ones from time series. Finally, the use of complete demand systems leads to higher price elasticities than do single equations. This may indicate that only some of the models may be able to capture decisions at both the extensive and intensive margins, and also that complementary or substitution relationships may exist.

With respect to the existing meta-analyses in the energy domain (see Section 2), this paper reports lower price elasticities for electricity demand (-0.21 vs -0.35 in the short term, and -0.67 vs -0.85 in the long term). This may be related to the income effect and to the improvements in energy efficiency, as the data from the only meta-analysis on electricity (Espey and Espey, 2004) covers a much older period (1947-1997 vs 1990-2014). Similar reasons may explain the divergence between the results of this paper regarding price elasticities of car-fuels demand (-0.20 and -0.23 for respectively diesel and gasoline in the short term, and -0.60 and -0.72 in the long term) and the intervals of the other two meta-analyses (-0.25, -0.76 in the short term; -0.77, -1.16 in the long term). Yet, our results are comparable to those reported by the four meta-analyses specifically focusing on the price elasticity of gasoline demand.

Finally, this meta-analysis does not indicate differences in the price elasticities of energy demand between developing and developed countries. However, an additional estimation that includes a dummy of OECD country indicates that price elasticities of energy demand are significantly higher in developing countries. In this sense, it is possible to infer that income convergence may have important consequences on energy demand (and indirectly on environmental matters and dependence on foreign energy stocks). Therefore, economic development may restrict the capacity of countries to reduce energy consumption through higher policy-induced energy prices.

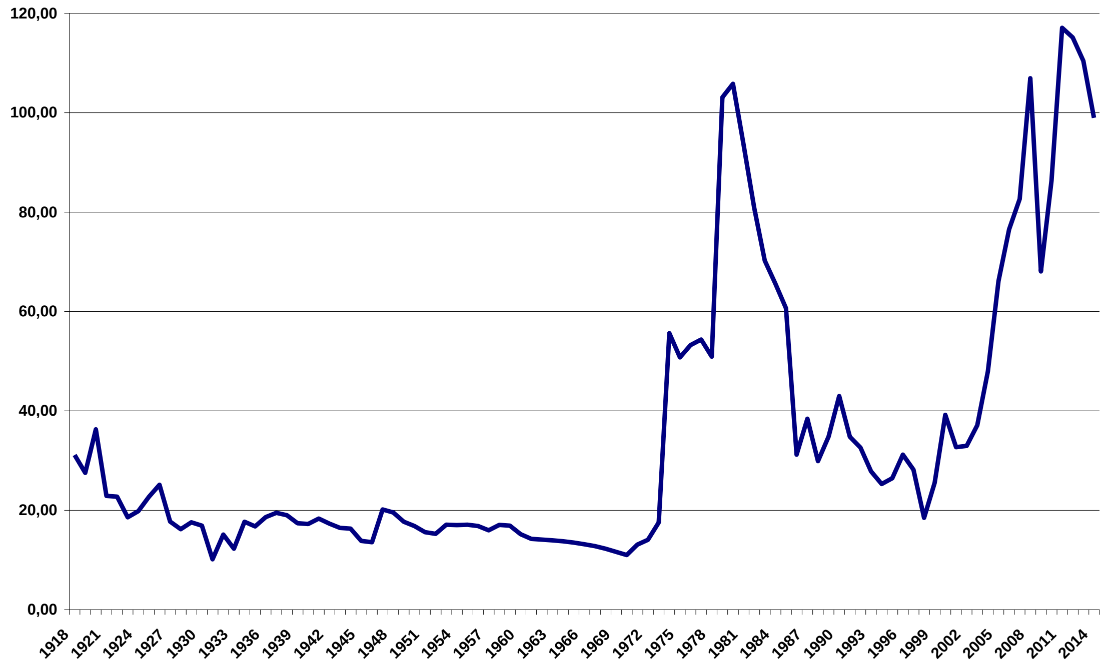
4.2. Discussion and testing

A major potential determinant of energy demand is technical progress. Given that the importance of technical progress depends on the time period under observation, an average for each of the periods was calculated in order to assign the value of the trend. The first year of data is 1945, so this new variable takes value 1 in that year and subsequently the value to the trend is assigned following the average of the calculated sample period. Note that the trend is not significant at any level in any given specification.

Another specification issue that may affect the estimates is the departure from normality in the distribution of the elasticities, as depicted in Figure 1. Yet, since the models are estimated using GLS and taking into account the presence of heteroskedasticity and autocorrelation, it is unlikely that this affects the estimation results.

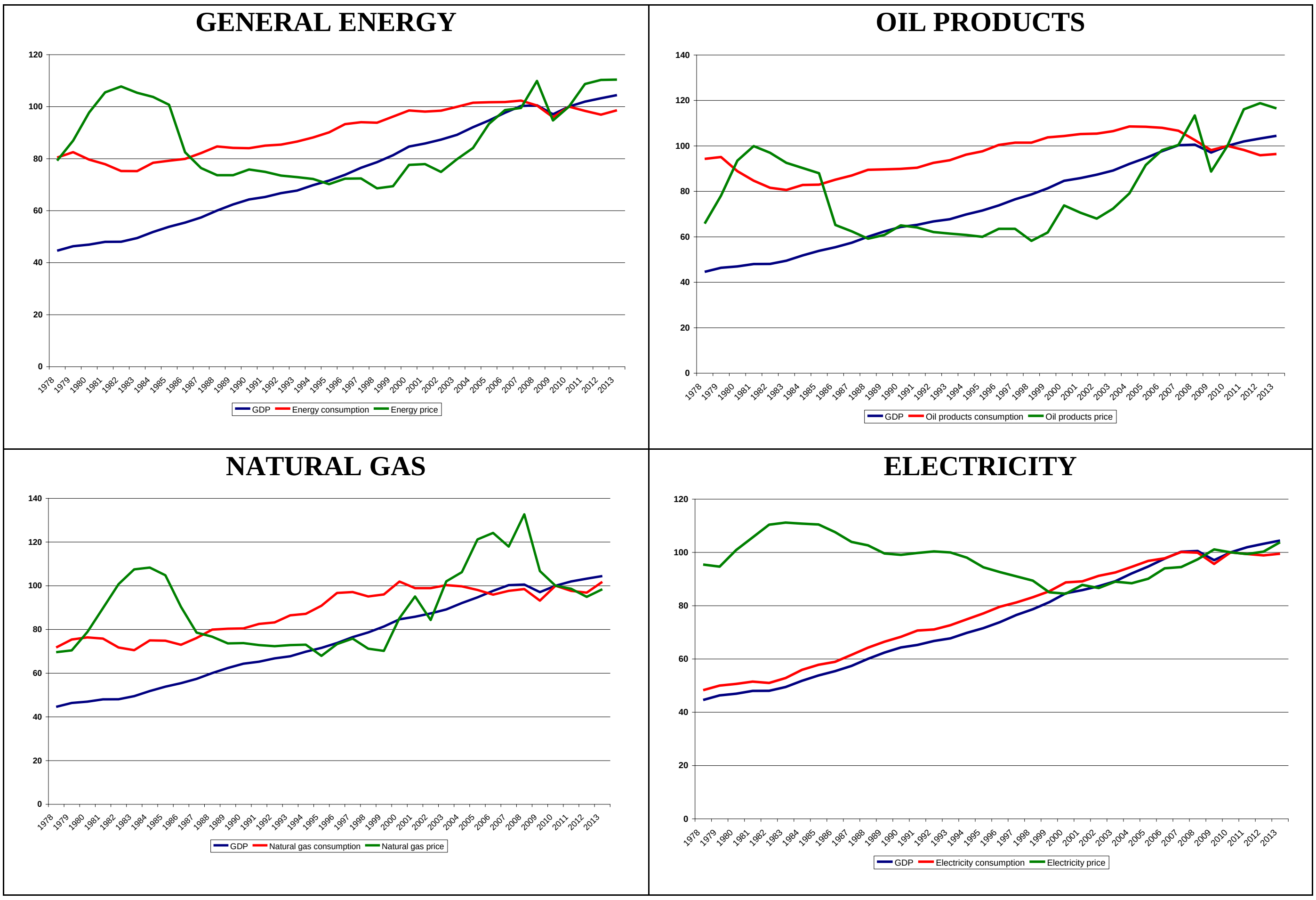
A major aim of this paper is to explain the fit of the demand for energy regarding the evolution of prices, conditioned to other determinants of the behavior of agents. In fact, merely taking look at Figure 2 or at any of the components of Figure 3, several relevant matters for the literature in this area become evident. First, energy consumers adapted to price shocks as soon as the first oil crisis took place at the beginning of the 1970s. Second, the second oil crisis a few years later affected energy demand mainly through oil products and natural gas. However, the evolution of electricity consumption closely followed the evolution of GDP and it benefited from decreases in real electricity prices for a long time. Third, even though Figure 3 does not distinguish between different types of energy consumers (available upon request), the evolution of income is the main determinant of their energy demand, particularly in industrial and commercial sectors, and therefore leaves limited possibilities for corrective pricing signals. Fourth, only the 2008 economic crisis has affected aggregate demand (and its components) and this was due to decreases in economic activity rather than to energy price movements. Finally, cross-price effects appear to have the potential to substitute polluting sources in the energy domain. Contrarily, if clean energy sources face price increases, substitution and the limited capacity of demand reduction through prices will both move in a negative environmental direction. It seems therefore that other alternatives, such as information and awareness, should play a role within corrective public policies in this area.

Figure 2. Evolution of crude oil prices 1918-2014 (US$ of 2012)



Source: BP (2015)

Figure 3. GDP, energy consumption and real energy price in the OECD, 1978-2013 (2010=100)



Source: IEA (1999; 2015)

5. Conclusions

This paper has conducted a meta-analysis of empirical studies estimating the price elasticity of demand of energy. Unlike previous studies, which particularly focused on specific energy goods (mainly gasoline), the paper considered aggregated energy as well as the demand for the most important energy products: electricity, natural gas, gasoline, diesel and heating oil. Despite the focus of this paper in recent empirical evidence, both the number of considered papers and elasticity estimates are much larger than in previous meta-analyses in the field.

It is clear that a solvent estimation of the price elasticities of energy demand is crucial if we are to understand how shocks in energy prices (policy-related or exogenous) may impact energy consumption at an individual (firm or household) level, or growth at an aggregate level, both in the short and long-terms. Besides, insights on the distributional impacts of energy price movements and the related implementation of compensatory policies, subject to an increasing debate in many countries nowadays, would largely benefit from a proper knowledge of price elasticities of energy demand.

The results from this paper show that, on average, the literature has estimated a price elasticity of demand of energy in the short term of -0.22, and of -0.65 in the long term. Several short-term elasticities of energy products range between -0.26 and -0.20, while their long-term elasticities range from -0.85 to -0.60. Except in the case of gasoline demand, already covered by most existing exercises in the area, the results of the paper depict lower short and long-term price elasticities of energy demand than in previous meta-analyses. The main factors influencing the estimates obtained from elasticities in the short term are the type of model used for the study and the type of consumer considered. Indeed, the results indicate that studies with micro models and those employing residential and commercial data lead to significantly higher price elasticities (in absolute terms) than respectively those using aggregate models and industrial data. Regarding long-term elasticities, the most important factors affecting the results are the type of data and model used for the study as well as the type of consumer considered and the fact that the data are previous or subsequent to the 1973 oil crisis. The meta-analysis shows in this case that price elasticities from panel data approaches are significantly higher (lower) than those from time series (cross sections). Moreover, price elasticities are significantly higher when using commercial data on energy demand and when complete demand models are employed, and significantly lower when post-1973 data are used.

It is possible, therefore, to conclude from the meta-analysis results that agents somewhat react to changes in the prices of energy products; this reaction is larger in the long term than it is in the short term and it is quite similar among different energy products. The average values obtained classify energy products as price inelastic, so that pricing policies (through taxation or other regulatory tools) can give rise, *ceteris paribus*, to a less than proportional reduction in the demand for these goods both in the short and long terms. It is also worth pointing out that the 1973 oil crisis influenced the energy behavior of the agents by forcing them to take steps to reduce their exposure to sharp fluctuations in the prices of energy goods. After that crisis, given the depletion of abatement possibilities, the long-term sensitivity of the agents to changes in the price of energy goods decreased.

Finally, the results of this paper allow the identification of energy goods in which consumption is more susceptible to price changes, i.e. those goods on which price shocks are likely to have most socio-economic and environmental effects or where corrective pricing policies are potentially more effective. In this sense, heating oil consumption is the most affected by price fluctuations in the short term, while in the long term it is the consumption of natural gas that is the most affected. By contrast, diesel is the least price-sensitive energy good in the short and long terms. In sum, energy and environmental policies that exclusively rely on correcting energy prices may be constrained by the limited price responsiveness shown by this exercise and thus other complementary approaches (information, nudging, etc.) are likely to be necessary in the area.

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ANNEX I

Parameter Estimates

Table A1. Parameter estimates for short-term elasticities

Regressor	GLS	Random-effects panel
$\hat{\beta}$	**-0.2196*** **	**-0.2237*** **
Electricity	-0.011	0.148
Natural gas	-0.019	0.007
Gasoline	-0.029**	-0.003
Diesel	0.007	0.020
Heating oil	-0.023	-0.036
Net energy exporter	-0.006	-0.006
Developing country	-0.008	-0.019
Post 1973	0.059**	0.030
Post 1979	0.014	0.039
Post 2008	0.013	-0.018
Residential	-0.007	-0.053**
Industrial	0.009	-0.030
Commercial	-0.076*	-0.069**
Cross-section	-0.042	-0.061
Time series	0.017	0.009
Cointegration model	-0.033**	-0.028
AIDS model	-0.085**	-0.066*
Micro model	-0.201***	-0.136***
Discrete-continuous model	-0.105***	-0.058
No journal	0.028**	0.012
Instrumental variables	-0.004	-0.010
Other estimation methods	0.015	0.028
Joint significance	F (22,880)=6.20 (p-value=0.00)	Wald χ^2(22)=75.16 (p-value=0.00)
R^2	0.134	0.125

Note: *** Significant at the 1% level; ** at the 5% level; and * at the 10% level.

Table A2. Parameter estimates for long-term elasticities

Regressor	GLS	Random-effects panel
$\hat{\beta}$	**-0.6002*** **	**-0.652*** **
Electricity	-0.077**	-0.034
Natural gas	-0.134***	-0.198***
Gasoline	-0.120***	-0.063
Diesel	-0.020	0.057
Heating oil	-0.147	-0.112
Net energy exporter	-0.024	-0.024
Developing country	-0.074***	-0.034
Post 1973	0.114*	0.152*
Post 1979	0.161***	0.031
Post 2008	0.161**	0.081
Residential	-0.085**	-0.037
Industrial	-0.023	0.022
Commercial	-0.298***	-0.152*
Cross-section	-0.116**	-0.175**
Time series	0.109***	0.132***
Cointegration model	-0.017	-0.025
AIDS model	-0.229***	-0.165**
Micro model	-0.001	-0.024
Discrete-continuous model	-0.080	-0.198
No journal	0.032	0.065
Instrumental variables	-0.061	-0.037
Other estimation methods	-0.087***	-0.001
Joint significance	F (22,916)=38.36 (p-value=0.00)	Wald $\chi^2(22)$=84.08 (p-value=0.00)
R^2	0.479	0.196

Note: *** Significant at the 1% level; ** at the 5% level; and * at the 10% level.

ANNEX II

Papers used in the meta-analysis

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Author contacts:

Xavier Labandeira

Rede, Universidade de Vigo

Facultade de CC.EE.

Campus As Lagoas s/n

36310 Vigo

Spain

and

Florence School of Regulation Climate

European University Institute

Via delle Fontanelle 19

50014 San Domenico di Fiesole

Italy

Email: Xavier.Labandeira@EUI.eu

José M. Labeaga (corresponding author)

Departamento de Análisis Económico, UNED

Senda del Rey 11

28040 Madrid

Spain

Email: jlabeaga@cee.uned.es

Xiral López-Otero

Rede, Universidade de Vigo

Facultade de CC.EE.

Campus As Lagoas s/n

36310 Vigo

Spain

Email: xiral@uvigo.es