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Regional impact of changes in disposable income on Spanish electricity demand: A spatial econometric analysis

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A B S T R A C T

This paper presents an empirical analysis of residential electricity demand considering the existence of spatial effects. This analysis has been performed using aggregate panel data at the province level for 46 Spanish provinces for the period from 2001 to 2010. For this purpose, we estimated a log–log demand equation using a spatial autoregressive model with autoregressive disturbances (SARAR). The purpose of this empirical analysis is to determine the influence of price, income, and spatial spillovers on residential electricity demand in Spain. We are particularly interested in analyzing the impact of household disposable income variation across provinces observed during the economic crisis period 2009–2010. The estimation results show relatively low income elasticity and an inelastic demand to prices. Furthermore, the results show the presence of spatial effects in Spanish residential electricity consumption.

1. Introduction

Since the publication more than 30 years ago of the book by Paelinck and Klaassen (1979) on spatial econometrics, several empirical studies considering spatial issues have been published.[1] Generally, these studies explicitly consider spatial interdependences between cross-sectional units due to spillovers, externalities, copycat policies, copycat behaviors or social networks. These spatial interdependences appear when the dependent variable of a cross-sectional unit depends on a weighted average of the dependent variables of the neighboring cross-sectional units or when the error terms are spatially correlated (Anselin et al., 2008).

Due to the socioeconomic relations between cross-sectional units such as provinces or regions, we can also hypothesize the presence of spatial spillovers and spatial clusters in electricity consumption. For instance, the electricity consumption in one region can be influenced by the lifestyle of the households in neighboring provinces. One might imagine a phenomenon of imitating neighbors that can produce spatial spillovers in electricity consumption behavior as well as in the adoption of more electrical appliances or of new energy-efficient appliances. This behavior can create spatial clusters in the adoption and use of electrical appliances, and therefore, in electricity consumption. From a theoretical point of view, these types of behaviors assume that consumption preferences are not separable across households.[2] Another spatial economic effect could arise from the presence of workers living in one region but working in adjacent or nearby provinces. This effect could also develop from those who have a strong economic dependence on what occurs in bordering territories, even though they do not work there. In this case, a change of the economic situation in one province would also have an impact on the socioeconomic situation in neighboring provinces and, therefore, on electricity consumption. Finally, energy policies are partially implemented at the regional level; thus one could suppose that policy measures taken in one province have certain influence in the surrounding territories.[3]

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[1] See Anselin (2010) for a discussion on the development of spatial econometrics during recent decades.

[2] For a discussion and review of the literature on the separability and non-separability assumption of the preferences across households see Varian (1974), Ravina (2008) and Alvarez-Cuadrado et al. (2012). Ravina (2008) and Alvarez-Cuadrado et al. (2012), using micro-data, based the construction of their reference group on a purely geographical criterion as long as the reference group of any given household is compared with the other households that live in the same census tract. Both works find that households derive around one fourth of their consumption services from comparison between their consumption and that of their neighbors.

[3] See LeSage and Pace (2009) for a detailed overview on the different types of spatial effects (spillovers).

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In this paper we argue that due to the presence of spatial spillover effects in electricity consumption it is important to use a spatial econometric approach in the empirical analysis. In fact, unobservable variables may be spatially correlated and consumption patterns observed in neighboring provinces may also be correlated with local consumption. As a consequence, standard estimation procedures like Ordinary Least Squares (OLS) for cross-sectional data or fixed effects (FE) for panel data can lead to biased and inefficient estimates (see, for example Anselin, 2010; Anselin et al., 2008; LeSage and Pace, 2009). Furthermore, the use of spatial econometric models allows for breaking down the effect of a change in an independent variable across the regions into a direct and indirect effect (spatial spillovers).

From an energy economics point of view, the presence of possible spatial effects in electricity consumption has been so far neglected. Since the pioneer work by Houthakker (1951), a relatively high number of studies on estimating residential demand for electricity have been published.[4] Most of the published works focus on calculating short and long-run price and income elasticities. Many of these estimations use aggregate regional panel data sets and static as well as dynamic specifications of the electricity demand model (e.g., Alberini and Filippini, 2011; Bernstein and Griffin, 2006; Houthakker, 1980; Hsing, 1994; Maddala et al., 1997 and Paul et al., 2009). Most of these studies are for the US and provide an estimation of the price and income elasticities that does not vary across regions. One exception is the study by Bernstein and Griffin (2006), who found significant regional differences in price elasticity values. To our knowledge, none of the studies published on residential electricity demand using aggregate regional data has taken into account spatial effects. An exception is the study by Noonan et al. (forthcoming), which, by using household data, analyzed the adoption of energy-efficient residential and air conditioning systems in the Greater Chicago area from 1992 to 2004. They apply a spatial lag model (without considering the spatial error effect) and find a significant spatial multiplier effect that magnifies the effect of other factors affecting adoption rates.

In this respect, this paper seeks to explore the application of spatial econometric methods to the estimation of static electricity demand models which use aggregate regional panel data. From an econometric point of view, in this paper we implement a GMM estimator in STATA for the estimation of a spatial autoregressive model with autoregressive disturbances using panel data. In fact, the few published studies that consider the estimation of these types of models have used maximum likelihood estimators. In particular, we analyze the case of residential electricity consumption in Spain for the period from 2001 to 2010, which is characterized by variability across its provinces. Therefore, the use of these relatively new econometric approaches is very well suited. To our knowledge, this is one of the first applications of this GMM estimator for panel data in spatial econometric literature.[5]

The evidence on residential electricity demand for Spain is fairly limited (e.g. Labandeira et al. (2006) and Labandeira et al. (2011) using household disaggregate data), and the only study estimating residential electricity demand using aggregate panel data is the one by Blázquez et al. (2013). These authors have estimated a demand model using aggregate panel data at the province level for 47 Spanish provinces for the period from 2001 to 2008. For this purpose, they estimated a log–log demand equation for electricity consumption using a dynamic partial adjustment approach and using the two-step system GMM estimator proposed by Blundell and Bond (1998). Therefore, this paper aims to complement the previous by Blázquez et al. (2013) in three respects: a) the use of a spatial econometric approach; b) the use of an enlarged data set and c) the analysis of the direct and spatial effects of disposable income variation.[6]

[4] For a systematic review of these papers see Heshmati (2012).

[5] See for instance Egger et al. (2005).

[6] The estimation of a dynamic spatial econometric model using a GMM estimator implies several relatively complicated econometric issues. For this reason we decided to estimate a static model.

The specific goal of this paper is to estimate price and income elasticities for Spanish residential electricity demand by considering the presence of spatial effects. Additionally, we intend to analyze the impact of the change in household disposable income observed during the economic crisis period – specifically from 2009 to 2010 – on electricity consumption in Spanish provinces. We are particularly interested in estimating the effects in each province of the spatial spillovers derived from the change of the disposable income. In order to do this, as discussed previously, we will apply a spatial autoregressive model with autoregressive disturbances (SARAR) to a panel data set that considers 46 Spanish provinces for the period 2001 to 2010.

The paper is organized as follows: Section 2 presents the empirical model. In Section 3, the econometric approach is explained. In Section 4 the empirical results are discussed. Some concluding remarks appear in Section 5 of the paper.

2. Model specification and data

Residential electricity demand can be specified using the basic framework of household production theory (Alberini and Filippini, 2011; Filippini and Pachauri, 2004; Flaig, 1990). According to this theory, households purchase inputs to produce "commodities" that appear as arguments in the household's utility function. In our specific case, a household combines electricity with electrical appliances to produce energy services such as heated rooms, lighting and hot water. Following this theoretical framework, the electricity demand function should include the following explanatory variables: i) the price of electricity; ii) the price of substitutes, with natural gas being the main substitute for electricity; (iii) the capital price (electrical appliances), which may have an influence on how well equipped a household is; iv) household disposable income; v) some socioeconomic variables, such as population and household size, which determine the number of houses and the presence of possible economies of scales in electricity consumption at home; and vi) climate variables. It should be highlighted that due to missing information, the empirical studies on electricity demand generally do not include the capital price as an explanatory variable in the model. Neither is this information available for the Spanish provinces. However, in general the regional variation of the price for appliances is relatively low. Therefore, the impact of this variable should be captured by the constant term.

Based on previous studies and on the available data, we specified the following static residential electricity demand model:

$$el_{it} = f(y_{it}, pel_{it},\ \ pengas_{it},\ \ pop_{it}, hs_{it}, hcdd_{it}, time) \tag{1}$$

where el_{it} is the aggregate electricity consumption for province i in period t; y_{it} is the net real disposable income of the household sector in Euros (Base: 2006 = 100); pel_{it} is the real average price of electricity[7] in Euros (Base: 2006 = 100); pop_{it} is the population; and $pengas_{it}$ is the percentage of households that have access to gas. This variable is used as a proxy for the price of gas that, unfortunately, is not available at the province level. Generally, electricity and gas are substitute fuels for many appliances in Spanish households (e.g. heating, hot water). Of course, the gas penetration level in the residential sector of a province also depends on the level of electricity consumption. Therefore,

[7] The Spanish tariff scheme for domestic electricity consumption is a two-part tariff system, regulated in the majority of cases. This tariff is composed of two elements: a fixed monthly charge (or power term), which is based on the level of contracted power and the (regulated) price per kWh. In this case, the level of the average electricity price depends both on the amount of electricity consumed and on the level of power contracted and this could create an endogenous problem. Nevertheless, Bernstein and Griffin (2006), Paul et al. (2009), Alberini and Filippini (2011), and Blázquez et al. (2013) argue that, at the aggregate level, the potential for the price to be endogenous with consumption is mitigated by the presence of many different regulated block pricing levels, in our case many power block pricing levels. In order to verify the endogeneity of price, we performed the Davidson–MacKinnon test. The result of this test indicates that this variable should be considered exogenous (p-value = 0.16).