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Functional form and aggregate energy demand elasticities: A nonparametric panel approach for 17 OECD countries

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ABSTRACT

This paper studies whether the commonly used linear parametric model for estimating aggregate energy demand is the correct functional specification for the data generating process. Parametric and nonparametric econometric approaches to analyzing aggregate energy demand data for 17 OECD countries are used. The results from the nonparametric correct model specification test for the parametric model rejects the linear, log-linear and translog specifications. The nonparametric results indicate that the effect of the income variable is nonlinear, while that of the price variable is linear but not constant. The nonparametric estimates for the price variable is relatively low, approximately −0.2.

1. Introduction

There has been an increased awareness and interest on the impact of human activities on the world's climate in recent years, especially through emission of greenhouse gases. A lot of focus in the discussions of curbing climate change has been on issues related to energy use and clean production. For example, there has been an intense debate among energy policy analysts on how policies can promote efficient energy use, less dependence on fossil fuels, and how these have contributed to reduce emissions of greenhouse gases. The central point in this discussion concerns the behavioral response among households and firms to various policy reforms. That is, how do households and firms change their energy consumption as a result of changes in, for instance energy taxes and/or incomes? In order to answer such questions, which are a prerequisite for designing an efficient policy, knowledge about behavioral response is needed. In other words, we need knowledge about price and income elasticities.

Most of the elasticities that are used come from econometric models of energy demand. A look at the literature on energy demand reveals that there exist numerous econometric models, of different types, starting with simple static models to more general dynamic ones. It is interesting to note that most of these models are linear or log-linear models. However, whether the assumed functional form is appropriate or not for the underlying energy demand data generating process (DGP) is usually not tested for. Hence the conclusions drawn must be viewed as conditional on the assumption that energy demand is linear. Aggregate Energy demand studies can be found in the following surveys; Hartman (1979), Bohi (1981), Bohi and Zimmerman (1984), Dahl (2005) as well as Atkinson and Manning (1995).

The consequences of a mis-specified model on the parameter estimates cannot be over emphasized, as it leads to bias and inconsistent estimates. To the best of our knowledge, only two studies exist that study the choice of functional form for energy demand models, Zarnikau (2003) and Xiao et al. (2007). Zarnikau (2003) focuses on electricity demand at the household level for the USA. He studied three functional forms for household electricity demand (linear, log-linear and trans-log) and uses a nonparametric specification test developed by Härdle and Manmen (1993) and Zheng (1996) to test the parametric models. The test results from his study reject each of the three functional forms as the correct specification for the household electricity demand (regressors used are price of electricity, price of natural gas, income and heating degree days). Xiao et al. (2007) on the other hand adopted a Bayesian model selection criterion (that of the Deviance information criterion (DIC)) proposed by Spiegehalter et al. (2002) and applied it to the same data set as in Zarnikau (2003). The result from their study indicates that the

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AIDS[1] and trans-log models are superior to the log-linear model, which in turn is better than the linear model. However, none of these studies makes extensions to panels nor uses aggregate data on energy demand using fully nonparametric modeling that allows for all possible nonlinearities and interactions among the regressors, while controlling for boundary bias at the same time. There is thus a scope for further investigations into the correct functional forms in estimating energy demand with aggregate data. Further, Zarnikau (2003) and Xiao et al. (2007) did not consider cointegration relationships between the dependent variable and the regressors and hence implicitly assume a long run relationship to exist without testing for it. In this paper we will test for cointegration in panels, using the Westerlund (2007) error-correction approach.

Getting the correct functional form is a very difficult task to do, since economic theory does not provide a guide regarding the correct functional specification. In this paper we therefore model energy demand more flexibly by applying a fully nonparametric approach. Particularly the local linear kernel estimator is used in estimating energy demand for 17 OECD countries from 1960 to 2006. Modeling energy demand in a fully nonparametric sense will avoid the issue of functional mis-specification since we do not restrict the functional form a priori.

The main objective of this paper is thus to assess the commonly used log-linear functional form for energy demand models (our focus here is on long run energy demand model) which is the appropriate functional form for such models. We applied the panel error correction model to study if there is cointegration between energy demand, real price of energy, real income per capita and the effect of climate. This paper is organised as follows: Section 2 deals with the literature review for the study; Section 3 is the modeling of aggregate energy demand for 17 OECD countries. The data and the econometric analysis are presented in Section 4, and Section 5 concludes the paper with a summary of the findings and some proposals for future research.

2. Literature review

As mentioned in the introduction, there exists a large body of empirical research in estimating price and income elasticities for energy demand. However, most of the works have an individual country time series perspective or cross-sectional dimension of countries, but few exist in estimating the elasticities using panel data. Most of the panel data research on this topic rather focuses on sub-groups of aggregate energy demand such as industrial, residential and transport, or on specific energy sources such as electricity, gasoline, coal or gas. Our focus here is to review the existing literature on aggregate energy demand that uses panel data, but we will also consider the literature that are using aggregated OECD country data using a time series approach.

Balestra and Nerlove (1966) studied the demand for natural gas for US states between the periods 1950 to 1962. In their estimation of demand for natural gas, they assumed a linear specification in a dynamic panel model. The results from their study indicate that the long run price and income elasticities for the unconstrained model are −0.63 and 0.62, respectively, and −0.63 and 0.44 for the constrained model, where the depreciation rate is assumed to be 11% for all fuel-using appliances.

Using annual data for seven European Economic Community (EEC) Countries from 1955 to 1970, Kouris (1976) adopted both a time series model and a pooled model to determine the main factors affecting energy demand in EEC areas. The author included price, income and temperature as the main determining factors of aggregate energy demand in the seven EEC countries. In the empirical analysis, Kouris favored the estimates from the pooled model compared to the estimates from the time series model. One reason for this is that the price elasticity from the time series model for four of the countries was of the wrong sign, compared with what was expected from theory. Of the three remaining countries, only the Danish price elasticity was statistically significant. The pooled model resulted in a long run price elasticity of −0.76, and an income elasticity of 0.84. The author also investigated the variation of elasticities over time by dividing the entire sample into six-year overlapping intervals. The conclusion from this is that, all elasticities do vary from period to period.

Nordhaus (1977), on the other hand, studied the demand for energy in seven different western countries over the period 1955 to 1972. In this study, both individual country estimation and pooling was done for four major sectors of the economy, namely transport, domestic, industry and energy sectors. In addition to the four sectors, he also estimated energy demand at the aggregate (over sectors) level. The results from the individual country aggregate model shows that the short run price elasticities ranges from −0.03 to −0.68, while the income elasticity ranges from 0.29 to 1.11. The long run price elasticities however were estimated to be between −1.94 and 1.45, and the long run income elasticities were ranging from 0.26 to 1.42. The estimated price elasticity from the pooled model with country dummies was −0.85, and −1.15 for the model without country dummies. The income elasticities were 0.79 and 0.87 for the model with and without country dummies respectively. All the estimations were done with the assumption of a linear specification.

The standard approach used in the literature for accounting for technological progress is to include a time trend, especially in a dynamic model. In this regard, Beenstock and Willcocks (1981) included a time trend in an error correction model for annual aggregate energy demand model for industrialised OECD countries, using aggregated annual data from 1950 to 1978. In their study they found the short run price and income elasticities to be −0.01 and 0.37, respectively, and that of the long run to be −0.06 and 1.78, respectively. The authors also estimated a model without a time trend and found the long run price elasticity to increase to −0.13, and the long run income elasticity to decrease to 0.88, a value that is consistent with the, "around unity income elasticity estimates consensus" for econometric energy demand models.

Kouris (1983) estimated price and income elasticity for OECD countries by excluding the time trend as an explanatory variable in his aggregate energy demand model. Income elasticity was restricted to only account for short run dynamics, while allowing the price variable to have both a short run and long run effects. Estimates from the various sub-samples of OECD data set from 1961 to 1981 indicate that the short run price elasticity ranges from −0.14 to −0.32, while that of the long run ranges from −0.26 to −0.84. Prosser (1985), using annual data set for seven of the most industrialised OECD countries from 1961 to 1982, found similar income elasticities as in Kouris (1983) but different price elasticities both for the short run and the long run. The long run estimated price elasticity in Prosser (1985) ranges from −0.28 to −0.42. Welsch (1989), using both a pooled and country specific annual data on eight OECD countries, found the long run price elasticity to be −0.34 and the long run income elasticity to be 0.64 for the preferred pooled dynamic model without a time trend.

Jones (1994), on the other hand, used a much longer data set than that from Kouris and Prosser on the same seven OECD Countries. The idea of the study was to access the validity of Kouris and Prosser model, which is a restricted version of a general autoregressive distributed lag model without a time trend. Results from the study indicated that the restriction imposed by Kouris–Prosser is valid. The estimated long run price elasticity from Kouris–Prosser model without trend was −1.73, while adding a time trend this reduces the long run price elasticity to a reasonable value of −0.7.

[1] Almost ideal demand system proposed by Deaton and Muellbauer (1980) and extended quadratic form by Banks et al. (1997) to handle aggregated non-linear expenditure effects.