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Modelling UK sub-sector industrial energy demand

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ABSTRACT

The importance of considering homogenous economic agents when estimating energy demand functions is recognized in the literature, but so far data availability problems have explained the prevalence of empirical analyses only at an aggregate level. Motivated by the goal of developing the new industrial module to be adopted by the UK government Department of Business, Energy and Industrial Strategy (BEIS) for their econometric Energy Demand Model, we propose the first cointegration analysis that provides evidence on energy demand elasticities with respect to economic activity and energy price at a disaggregated industrial level. While the average of our estimates are comparable to those of the existing literature on the industrial sector as a whole, we find that there is considerable heterogeneity in relation to the long-run impact of economic activity and energy price on energy consumption, as well as to the speed with which firms re-adjust their equilibrium demand of energy in response to economic shocks. Finally, we learn that long-run disequilibria are tackled through altering the level of energy consumption rather than economic activity, a conclusion that has important implications for policy analysis.

1. Introduction

The amount of energy used in industrial sectors constitutes an important share of national energy balances. Despite decreasing in some OECD countries, industrial energy consumption has accounted for a surprisingly constant share of world energy consumption, fluctuating between 33% in 1971 and 27% in 2013 (IEA, 2016). While the 2007 special issue of Energy Economics devoted to modelling industrial energy demand (Greening et al., 2007) testifies the academic interest for this subject, econometric studies on industrial energy demand are surprisingly scarce, as argued in Bernstein and Madlener (2015). A somewhat plausible explanation for this lack of published studies could be related to the perception that the industrial sector is one of the hardest end-uses to analyse, model and forecast (Greening et al., 2007), a perception which might be imputed to aggregation problems, i.e. the high heterogeneity of industrial firms, lumpy and sunk nature of investments, lags between the time when investments are made and when their impact on energy consumption unfolds, and the diversity in the energy price faced by industrial firms.

Existing data and tools available in standard econometric toolkits, however, are able to tackle these issues to a reasonable extent. In the spirit of Pesaran et al. (1999), who advocated estimation of energy demand functions on a set of consumers that is as homogeneous as possible, the increasing availability of data disaggregated at two-digit SIC level for a sufficiently long time span should help overcome aggregation issues. The impact of the lumpy nature of energy investments can manifest itself as structural breaks in the coefficients of energy demand models but rigorous econometric tests, like the one adopted in this study, can easily be employed to ascertain and control for these changes. Modelling the impact of economic variables on energy-using stock while taking into account the lag between the time investments are made and when their impact on energy consumption unfolds is more problematic. The capital measurement framework and the dynamic factor demand model of Pindyck and Rotemberg (1983) can be used to take into account different vintages of capital and price-induced improvements in the energy efficiency of capital stock, as recently implemented in Steinbuks and Neuhoff (2014), but comprehensive data are rarely available.[1] Finally, the difference in energy price levels faced by industrial firms is also difficult to incorporate in econometric studies. In some cases data are available, e.g. Department for Business, Energy and Industrial Strategy (BEIS) (2016a) publishes data on fuel prices paid by firms of different sizes, but similarly disaggregated information on energy consumption and GVA is not accessible, therefore hindering any econometric analysis. Microeconometric approaches like the one

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[1] As an example, the EU KLEMS database used in Steinbuks and Neuhoff (2014) ends in 2009.

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implemented in Bjørner and Jensen (2002) are however able to address this problem.

The aim of this paper is to estimate the industrial energy demand in the UK by examining its dynamics within the different subsectors. In this respect we make two substantial contributions to the existing literature. First of all, we highlight that our paper is the first cointegration study that provides evidence on energy demand elasticities at a disaggregated industrial level. Our review of the literature identifies only three studies estimating industrial energy demand at a comparable level of disaggregation, none of which takes into account the time series characteristics of the variables.[2] Our choice to explicitly estimate the long-run equilibrium relationship between energy consumption and its main determinants enables us to investigate a number of key questions related to: 1) the impact on energy price and economic activity of disequilibria in energy consumption; 2) the speed of the adjustment process originated by any disequilibrium; 3) the role of trends in the long-run energy consumption; 4) the structural stability of the estimated relationships.

Our second contribution consists in providing new evidence about the relative importance of economic activity and energy price in determining the energy consumption level. No general consensus could be found in the existing literature on the industrial sector of the economy, a problem that might be due to the fact that industrial sectors have rarely been subject to systematic investigation. A rare exception is the UK, but unfortunately estimated elasticities differ significantly among studies. In some cases, such as in Dimitropoulos et al. (2005) and Hunt et al. (2003), elasticities of economic activity is higher than that of energy price, whereas a more balanced view can be found in Agnolucci (2009) and Agnolucci (2010). Therefore, by looking at the dynamics of energy consumption at the subsectoral level we hope to cast new light on the current debate about the value of energy demand elasticities. Our conclusions are important not only from an academic perspective, but also, and probably more tangibly, for policy-making purposes as, for instance, a very low value of the elasticity with respect to price questions the very rationale of policies that rely on price signals, e.g. the EU ETS or the UK climate change levy, to achieve climate and energy goals. As a matter of fact, the analysis developed in this paper has been motivated by the very goal of developing the new industrial energy demand model adopted by the UK government Department of Business, Energy and Industrial Strategy (BEIS), as part of their wider Energy Demand Model.

The structure of the paper is as follows. In Section 2 we discuss the existing literature and assess its conclusions. Reflecting our two lines of contribution we mentioned above, we discuss two sets of studies, with the first focused on the estimation of industrial energy demand at the subsectoral level, and the other focused on the UK industrial sector as a whole. After setting out our methodological approach in Section 3, we provide details on the data we use in Section 4. In Section 5, after assessing the outcome from the unit root tests, we present our main results in terms of cointegration analysis and estimation of energy demand equations. These results are then discussed in Section 6, followed by a summary of our findings in Section 7.

2. Literature review

In the energy literature, consumption of energy in the industrial sector is posited to be positively related to economic activity and negatively related to relative energy price (when modelling energy demand) or relative fuel prices (when modelling demand for a specific fuel).[3] The methodologies that have been applied to the study of energy and fuel consumption in the industrial sector include:

1) Time series analysis based on cointegration, e.g. Polemis (2007), sometimes allowing for time-varying parameters, e.g. Chang et al. (2014);
2) Panel cointegration studies focused on the time component, e.g. El-Shazly (2013), or the cross-section component of the panel, e.g. Bjørner and Jensen (2002);
3) Input factor and fuel substitution models based on translog and linear logit specifications, which are normally static models applied to one single (Kim and Heo, 2013) or several industrial subsectors (Frondel and Schmidt, 2002), although dynamic specifications can also be found (Christopoulos, 2000, Urga and Walters, 2003);
4) Approaches focusing on the asymmetric impact of economic variables, mainly implemented with regard to energy price, normally based on the decomposition methodology introduced by Dargay and Gately (1995) – see Adeyemi and Hunt (2007) and Adeyemi and Hunt (2014) for two recent applications of this methodology in the industrial sector;
5) Implementations of the Structural Time Series Model of Harvey (1989), an approach introduced in the energy literature through the Underlying Energy Demand Model (UEDM) of Hunt et al. (2003) – see Dilaver and Hunt (2011) and Adeyemi and Hunt (2014) for two recent applications in the industrial sector.

As noticed by Bernstein and Madlener (2015), disaggregated analyses of energy consumption of industrial subsectors have rarely been undertaken. In their literature review these authors cite five studies that use two-digit industrial data: Agnolucci (2009), Calogirou et al. (1997), Christopoulos (2000), Christopoulos and Tsionas (2002), and Floros and Vlachou (2005). All these papers, with the exception of Floros and Vlachou (2005), use two-digit industrial data to create a panel dataset, i.e. Agnolucci (2009) and Calogirou et al. (1997), or to build a series for the manufacturing sector as a whole, i.e. Christopoulos (2000), and Christopoulos and Tsionas (2002). In other words, four out of the five mentioned papers are not interested in producing estimates of elasticities at the two-digit industrial subsector level.

In addition to Floros and Vlachou (2005), we identified two other studies estimating energy price and economic activity elasticities in industrial subsectors. Bjørner and Jensen (2002) compute these elasticities by using a fixed effects static model estimated on data from 8 surveys of firms collected in Denmark between 1983 and 1997. Price elasticities vary between −0.69 and −0.21 with the average for the whole industry being −0.44. Statistically significant energy demand elasticities with respect to economic activity vary between 0.44 and 0.65, with the average for the whole industry being 0.54. Floros and Vlachou (2005) model consumption of energy and energy fuels in the Greek two-digit industrial subsectors by using a two-stage translog model, where the first stage assesses the substitution between energy, capital and labour, while the second stage captures the substitution between energy fuels. The model is estimated using time series data over the period 1982–1998. Price elasticities vary considerably between −1.13 and −0.02, with the upper bound decreasing to −0.04 when non-statistically significant elasticities are discarded.

Steinbuks and Neuhoff (2014) assess the impact of energy price on energy consumption by modelling price-induced and autonomous changes in the energy efficiency of capital stock. These authors analyse 5 industrial subsectors in 19 OECD countries over the period 1990–2005 by means of two models: a Vintage Capital model and a restricted version where the input efficiency of capital stock does not change, as in Pindyck and Rotemberg (1983). Their results indicate that higher energy prices decrease energy use through improved energy efficiency of capital stock and reduced demand for energy inputs. Price elasticities of energy demand obtained from the Vintage Capital model estimated for the UK industrial subsectors vary between −0.87 and −0.26,

[2] Bernstein and Madlener (2015) undertake an analysis similar to ours but concentrating on electricity rather than energy demand.

[3] This simply implies that energy is assumed to be a normal good with respect to income and an ordinary good with respect to price.