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Modeling OECD energy demand: An international panel smooth transition error-correction model

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ABSTRACT

This study is the first to apply a newly developed panel smooth transition regression model with the error-correction term (PSECM) to estimate the non-linear relationship among energy consumption, real income and real energy prices for 24 OECD countries. Unlike the existing literature on non-linear estimation, we consider five "candidates" for the threshold variable including per capita real GDP, real energy prices, energy intensity, the ratio of gross capital formation to GDP, and error-correction term to explore which threshold variable is suitable for the non-linear energy demand model. Our empirical results demonstrate that energy consumption, real income and real energy prices can be cointegrated, and are in favor of the non-linearity for energy demand when the energy intensity and the ratio of gross capital formation to GDP are considered as the threshold variables. Furthermore, the results indicate that the adjustment speed toward long-run equilibrium of PSECM is small and approximately 7–17% in 1 year.

1. Introduction

The assessment of energy demand has always been an important issue in the global economy, especially in the current context of energy insecurity and global warming. As the World Bank (1996) notes that "no country in the world has succeeded in shaking loose from a subsistence economy without access to the services that modern energy provides", energy is an important factor in economic development and industrialization for many developed and developing countries. However, fossil fuels including coal, oil, and gas nowadays provide 85% of energy needs, and fossil-fuelled economic growth is the main factor for global warming through the release of carbon dioxide (CO_2) into the atmosphere (Huang, Hwang, & Yang, 2008a). Recently, many countries have started to pay attention to the problems of increasing greenhouse gas emissions and global warming. In December 1997, the United Nations Framework Convention on Climate Change (UNFCCC) adopted the Kyoto Protocol. Annex I countries agreed to reduce their collective greenhouse gas emissions by 5.2% from the 1990 level by 2008 to 2012. As the energy-dependent countries develop their economy, they should notice the great impact of greenhouse gas emissions on the environment. Thus, it is important to investigate the determinants of energy demand and clarify what factors will influence the energy–economic growth nexus.

Many recent studies have also found that energy consumption and real income are cointegrated and use the error-correction model to analyze the energy–economic growth nexus (Hunt & Manning; 1989; Athukorala, Gunatilake, Dharmasena, Gunaratne, & Weerahewa, 2009; Belloumi, 2009; Belke, Dreger, & de Haan, 2010; Ouédraogo, 2010; Athukorala & Wilson, 2010, and so on). However, these studies share common ground: they assume that the cointegration relationship of energy demand model takes a

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linear functional form. In other words, they have considered only linear cointegration framework. Specifically, ignoring the case of non-linear cointegration may lead to the misleading conclusion that no cointegration exists between energy demand and the determinants.

In this paper we argue that, contrary to the existing literature, adopting a panel smooth transition regression model with instrumental variables (González, Teräsvirta, & van Dijk, 2005; Colletaz & Hurlin, 2006; Fouquau, Hurlin, & Rabaud, 2008) to re-examine the relationship among energy consumption, real income, and own energy price in a cointegrating framework is a more efficacious approach.[1] In contrast to other studies concerning the energy–economic growth nexus, our approach is to ask a different question: which economic variables could possibly explain the transition of the energy–income–price nexus from one regime to another? If we can identify the conditions under which a significant relationship exists or does not exist for the energy demand function, more relevant energy or macroeconomic policies can be formed. Thus, our principal aim is to explore empirically the relative contribution of several "candidates" based on energy-related variables for inducing non-linear dynamic behavior in the energy demand function. Five broad threshold variables are delved into in this paper. The investigation on the impact of these conditions here has profound implications as far as policy goes since it may reveal that a country should not just "blindly" follow the general consensus.

While numerous contributions have applied this non-linear cointegration methodology in time series (Esso, 2010; Hu & Lin, 2008), this has not been done so far in the panel data context.[2] Based on the panel smooth transition regression model with the error-correction term (hereafter PSECM) specifications, we can consider the variation of energy demand's elasticity across countries and over time,[3] and it allows for a continuously smooth transition from one regime to another depending on a threshold variable. Indeed, if the candidates for threshold variables play an important role in influencing the elasticities of energy demand, then one can expect countries with the same level of economic conditions to have very different outcomes in terms of energy demand.

The investigation procedures of this study are first, to examine whether the variables follow I(0) or I(1) process[4]; second, to examine whether the energy consumption, real income, and real energy prices can be cointegrated; third, to analyze the long-run among energy consumption, real income and real energy prices, and use the estimated residual as the values of error-correction term (ECM) to set up the panel smooth transition regression model with the ECM[5]; fourth, to demonstrate which factors are the potential threshold variables for the PSECM of the energy demand; fifth and finally, to use these potential threshold variables to explore the short-run elasticities of energy demand with asymmetric adjustment.

The main purposes of this study are to explore the causes of the change in energy demand by considering five potential threshold variables based on energy-related variables, i.e. per capita real GDP, real energy prices, energy intensity, the ratio of gross capital formation to GDP and error-correction term, as the possible threshold variables and to estimate the non-linear relationship among energy consumption, real income and real energy prices in 24 Organization for Economic Cooperation and Development (OECD) countries from the period 1978–2004.

The remainder of this study is organized as follows. The next section provides a literature review and discusses the reason of nonlinear structure of the energy demand model. Section 3 introduces the PSCEM with instrumental variables. Section 4 illustrates the definitions and sources of data as well as provides the empirical results, and a conclusion is offered in Section 5.

2. Why does non-linearity matter?

Recent studies on the energy–income nexus have found the existence of the non-linear effect and structural breaks, and they also propose that the non-linear energy demand model provides a fair discussion in line with the relationship. Soytas and Sari (2006) indicate that the energy–growth nexus could be affected by the omission of countries' specific characteristics. Thus, if we neglect the possibility that the energy demand function could be non-linear, then the results obtained by using linear specifications often lead to a bias due to a false estimation method. Gabreyohannes (2010) shows that the explanatory powers of the model for energy consumption can be improved when non-linear effect is included. It means that accurately assessing and

[1] The unidirectional causality from energy consumption to macroeconomic variables and/or from macroeconomic variables to energy consumption has commonly been found in existing studies (see Yang, 1999, 2000; Jin, Choi, & Yu, 2009; Wolde-Rufael, 2009; Ozturk, 2010), implying the existence of potential endogeneity between energy consumption and macroeconomic variables. Thus, we need to use instrumental variable approach to overcome the possible problem of endogeneity.

[2] The panel data approach has a number of advantages over the analysis of individual time series or cross-sectional data. It provides more information and less co-linearity among the variables, more degrees of freedom and more efficiency, and it can control for individual heterogeneity that resulted from the cross-sectional data (Baltagi, 2008). Focusing on a panel of countries rather than on a single country permits us to investigate an individual's performance by observing the behavior of others. Wahab (2011) notes that there are some limitations in a time-series estimation since it requires an adequate number of observations to maintain enough degrees of freedom, and that a cross-section estimation will exhaust degrees of freedom with a limited number of cross-section units since it uses data-averaged over time to abstracts from business cycle effects. However, a panel-data estimation can improve these problems of the time-series and cross-section estimations.

[3] Karagianni, Pempetzoglou, and Saraidaris (2012) note that researchers should be conscious of the fact that the macroeconomic characteristics of countries determine the content of the tested variable data, letting it change across countries and over time.

[4] The variables follow the I(0) process, meaning that the variables are stationary in levels. The variables follow the I(1) process, meaning that the variables are first difference stationary.

[5] As global issues are being targeted and global datasets are established, we should apply panel data to analyze the issues on energy demand in order to improve the shortcomings resulting from using time-series and cross-sectional datasets (Lee & Lee, 2010).