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Renewable and non-renewable energy consumption and economic activities: Further evidence from OECD countries

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ABSTRACT

This article examines the dynamic relationship between renewable and non-renewable energy consumption and industrial output and GDP growth in OECD countries using data over the period of 1980–2011. The panel cointegration technique allowing structural breaks is used for empirical investigation. The results show that there is a long-term equilibrium relationship among non-renewable and renewable energy sources, industrial output and economic growth. The panel causality analyses show bidirectional causality between industrial output and both renewable and non-renewable energy consumption in the short and long run. However, there is evidence of bidirectional short-run relationship between GDP growth and non-renewable energy consumption while unidirectional causality between GDP growth and renewable energy consumption. These results indicate that OECD economies still remain energy-dependent for their industrial output as well as overall economic growth. However, expansion of renewable energy sources is a viable solution for addressing energy security and climate change issues, and gradually substituting renewable to non-renewable energy sources could enhance a sustainable energy economy.

1. Introduction

Energy is a fundamental driver of output growth in OECD (Organization of Economic Cooperation and Development) countries. The average output growth remains at approximately 1.2% per annum, whereas energy consumption jumped from 197 quadrillion Btu in 1990 to 254 quadrillion Btu in 2010 (EIA, 2013) in these economies. The vast majority of this energy is generated from conventional sources, especially oil, coal, and gas. However, given concerns about climate change and global warming and political and social pressure to curb carbon dioxide gas emissions, OECD economies have demonstrated growing interest in renewable energy sources to both secure the energy supply and diversify the energy mix. This interest has been supported by various government policies, such as tax benefits, rebates, feed-in tariffs, and markets for renewable energy. As a result, the total investment in renewable energy has amounted to more than 1 trillion US dollars in OECD economies since 2002, and renewable energy represents approximately 20% of the total energy supply in these economies (IEA, 2012).

In any economy, both renewable and nonrenewable energy use are strongly connected to the level of economic activity and economic growth. However, among the various sectors of the economy, the industrial sector dominates economic activities in OECD economies, consuming the largest portion of energy and producing a significant amount of carbon dioxide emissions. A number of studies have investigated these relationships between energy consumption, pollutant emissions, and economic growth. However, their findings are rather diverse, and there is a lack of consensus among economists. Most previous studies are aggregated analyses in which total energy consumption, pollutant emissions, and economic growth are evaluated. Exceptions to this approach are the studies of Apergis and Payne (2011, 2012) and Tugcu et al. (2012), who provide disaggregated analyses and contribute substantially to the literature. However, no study thus far has investigated the link between renewable and nonrenewable energy consumption and industrial output. Given the dominance of the industrial sector in the economic activities of the OECD economies, it is important to identify the links between renewable and nonrenewable energy consumption

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that are responsible for the dynamic industrial output growth as well as the steady economic growth of these mature economies.

This paper aims to analyze the relationship between renewable and non-renewable energy consumption and GDP growth in 29 OECD countries over the period of 1990–2012. It also seeks to contribute to the literature on the dynamic nexus between renewable and non-renewable energy consumption and industrial output of these matured economies. We use the Common Correlated Effects Mean Group (CCEMG) estimator, proposed by Pesaran (2006) to examine long run relationship between dependent and independent variables. Following Liao et al. (2010) and Arbex and Perobelli (2010) we utilize a production function framework accounting for renewable and non-renewable energy consumption in addition to usual inputs: capital and labor. We also test for structural breaks in the data and examine the possibility of cross-sectional dependence (CSD) by following Carrión-i-Silvestre et al. (2005) and Pesaran (2004) respectively. The empirical results show that both renewable and non-renewable energy positively impacts GDP and industrial output. We also find the possibility of substitution of renewable energy for non-renewable energy. Using the Pooled Mean Group (PMG) model of Pesaran et al. (1999) after time demeaning of variables to control for CSD, we find evidence of a bidirectional short-run relationship between GDP growth and non-renewable energy consumption while unidirectional causality between GDP growth and renewable energy consumption. The later finding is contradictory with those of Apergis and Payne (2011) who find unidirectional causality from GDP to renewable energy use. We also find bidirectional causality between industrial output and renewable and non-renewable energy consumption.

The remainder of the paper is organized as follows. Section 2 presents a review of the existing literature. The methodology is described in Section 3, followed by the empirical results in Section 4. Lastly, conclusions and policy implications are provided in Section 5.

2. Review of the existing literature

An impressive body of literature developed on the causal link between energy consumption, economic growth, and pollutant emissions after the seminal work by Kraft and Kraft (1978). There is no theoretical guide from the neoclassical school on the direction of this relationship, and the findings from the empirical literature are mixed. Some studies find that energy consumption leads to economic growth (*growth hypothesis*). These studies include Chontanawat et al. (2008), Narayan and Smyth (2008), Apergis and Payne (2009), Bowden and Payne (2009), Apergis and Payne (2010a,b,c,d), and Yildirim and Aslan (2012). In a very recent paper, Apergis and Tang (2013) investigate the validity of the energy-led growth hypothesis using a different model specification and different stages of economic development for 85 selected countries. Overall, these authors find a systematic pattern, although the causality results for different countries are mixed. In particular, their results provide support for the energy-led growth hypothesis comparing less-developed or low-income countries to developed countries.

Another group of empirical studies demonstrates a bidirectional causal relationship (*feedback hypothesis*) between these variables. These studies include Apergis and Payne (2010a), Belke et al. (2011), Eggoh et al. (2011), Fuinhas and Marques (2012), and Kaplan et al. (2011). These authors argue that energy consumption drives economic growth, and economic growth contributes to energy consumption and pollutant emissions. However, Lise and Montfort (2007) and Huang et al. (2008) find unidirectional causality from economic growth to energy consumption (*conservation hypothesis*), whereas Soytas et al. (2007) did not find any causality (*neutrality hypothesis*) between these variables.

Recently, a new line of standard research has focused on the link between renewable energy consumption and economic growth. For instance, Payne (2011) demonstrated the validity of the growth hypothesis; Apergis and Payne (2010c, 2011), proved the validity of the feedback hypothesis; and Menegaki (2011) demonstrated the validity of the neutrality hypothesis. Furthermore, Chien and Hu (2007) and Fang (2011) showed that an increase in the consumption of renewable energy sources positively contributes to economic growth, whereas Sadorsky (2009a) verified that the larger an economy grows, the more renewable energy sources are consumed.

Most recently, another line of standard research has decomposed the effects of energy consumption into renewable and non-renewable energy based on economic growth. Very few studies have been conducted in this line of research, including Sari and Soytas (2004), Payne (2009), Sadorsky (2009b), Apergis et al. (2010), Apergis and Payne (2012), and Tugcu et al. (2012). Using time series data over the period of 1946–2006 from the US, Payne (2009) finds an absence of Granger causality between renewable and non-renewable energy consumption and real GDP and thus supports the neutrality hypothesis. However, analyzing the causal relationship between CO_2 emissions, nuclear energy consumption, renewable energy consumption, and economic growth for a group of 19 developed and developing countries, Apergis et al. (2010) find bidirectional causality between renewable energy consumption and economic growth, supporting the feedback hypothesis. Similar findings are obtained by Apergis and Payne (2010d) for a panel of 20 OECD countries and by Sadorsky (2009a) for a panel of 18 emerging countries, in line with the short- and long-run bidirectional causality found by Apergis and Payne (2012) for a panel of 80 countries. These findings of bidirectional causality between renewable and non-renewable energy consumption and economic growth lend support to the feedback hypothesis, implying that renewable and non-renewable energy consumption and economic growth are interdependent.

The empirical literature on the relationship between energy consumption and economic growth is extensive, and the findings are diverse. However, surveying the existing studies on the energy consumption-economic growth nexus, Ozturk (2010) concludes, "There is no consensus, neither on the existence nor on the direction of causality between these variables in the literature" (P: 347). Therefore, the literature on this issue continues to grow. Few studies on OECD countries provide a disaggregated analysis of renewable and non-renewable energy consumption and economic growth. Therefore, the present study aims to contribute to the literature by identifying the impacts of renewable and non-renewable sources of energy on the real gross domestic product and on the industrial sector in OECD countries.

3. Methodology

3.1. Theoretical framework

Recent literature concerning economic growth indicates that capital, labor, technological progress, and energy are the basic elements of economic growth in developed countries. The analytical framework used here is developed by Liao et al. (2010) and justified by Arbex and Perobelli (2010). Accordingly, this study augments the neoclassical Cobb–Douglas production function by incorporating renewable and non-renewable energy consumption in addition to capital and labor employment in estimating the long-run relationship between variables. Although the mainstream neoclassical growth models do not include energy as a factor in the production function that could constrain or enable economic growth the recent literature pays attention to this for substitution of other inputs for energy particularly renewable energy due to high oil price and the fear of so called 'peak oil'. Thus, optimum adjustment of fuel mix has never been more important than now and the economic outcome of decisions regarding energy policy often hinges on substitution between energy sources and other factors of production. Hence, accurately estimating and analyzing the linkages between renewable and non-renewable energy consumption and industrial output as well as GDP growth can provide some information