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Energy consumption and economic growth: New insights into the cointegration relationship

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ABSTRACT

This paper examines the long-run relationship between energy consumption and real GDP, including energy prices, for 25 OECD countries from 1981 to 2007. The distinction between common factors and idiosyncratic components using principal component analysis allows to distinguish between developments on an international and a national level as drivers of the long-run relationship. Indeed, cointegration between the common components of the underlying variables indicates that international developments dominate the long-run relationship between energy consumption and real GDP. Furthermore, the results suggest that energy consumption is price-inelastic. Causality tests indicate the presence of a bi-directional causal relationship between energy consumption and economic growth.

1. Introduction

The question of whether or not energy conservation policies affect economic activity is of great interest in the international debate on global warming and the reduction of greenhouse gas emissions. Although the causal relationship between energy consumption and economic growth has been widely studied, no consensus regarding this so-called energy consumption-growth nexus has yet been reached. The direction of causality is highly relevant for policy makers. For instance, if causality runs from energy consumption to economic growth, energy conservation policies that have the aim of reducing energy consumption may have a negative impact on an economy's growth. The literature proposes four different hypotheses regarding the possible outcomes of causality (Apergis and Payne, 2009a,b).[1] The growth hypothesis suggests that energy consumption is a crucial component in growth, directly or indirectly as a complement to capital and labour as input factors of production. Hence, a decrease in energy consumption causes a decrease in real GDP. In this case, the economy is called 'energy dependent' and energy conservation policies may be implemented with adverse effects on real GDP. By contrast, the conservation hypothesis claims that policies directed towards lower energy consumption may have little or no adverse impact on real GDP. This hypothesis is based on a uni-directional causal relationship running from real GDP to energy consumption. Bi-directional causality corresponds with the feedback hypothesis, which argues that energy consumption and real GDP affect each other simultaneously. In this case, policy makers should take into account the feedback effect of real GDP on energy consumption by implementing regulations to reduce energy use. Finally, the neutrality hypothesis indicates that reducing energy consumption does not affect economic growth or vice versa. Hence, energy conservation policies would not have any impact on real GDP.

In consideration of such a pure statistical causality analysis with a few variables it should be noted that the policy implications of causality between energy consumption and real GDP are not straightforward. Energy conservation policies cannot sensibly be constituted without considering economic or environmental factors such as energy supply

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[1] The different directions of causality between energy consumption and economic growth have been described in many previous studies. Also, the phrase 'neutrality hypothesis' has often been used. The denotations of the other causal relations were proposed by Apergis and Payne (2009a,b).

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infrastructure, energy efficiency considerations or institutional constraints (Mahadevan and Asafu-Adjaye, 2007). Hence, the formulation of an efficient energy policy is more complicated than empirical results might suggest. For instance, energy conservation policies accomplishing a reduction in energy consumption due to an improved energy efficiency may raise the productivity of energy consumption, which in turn may stimulate economic growth. Thus, a shift from less efficient energy sources to more efficient and less polluting options may establish a stimulus rather than an obstacle to economic growth (Costantini and Martini, 2010). The other way around, bad energy supply infrastructure or other supply side disruptions decreasing energy consumption could indeed induce an adverse impact on economic growth. Further, high substitutability between energy and other input factors on the production side can explain possible economic growth without a considerable increase in energy consumption. Therefore, the empirical results of causality analyses should be interpreted with caution.

Our analysis of the relationship between energy consumption and economic activity is based on a sample of 25 OECD countries from 1981 to 2007 and uses recently developed panel-econometric methods. We explore an additional channel of causality by introducing energy prices. As energy prices have been neglected in many previous studies, the long-run parameters and the evidence of causality may be biased, see Masih and Masih (1997) and Asafu-Adjaye (2000). But in contrast to these two studies, we examine the original energy price index rather than the consumer price index (CPI) as a proxy. Income and price elasticities provide policy makers a suggestion of the extent to which prices need to increase, in the form of energy taxes, in order to reduce energy consumption and the potential for the market to conserve energy (Lee and Lee, 2010). Additionally, energy companies need this information to design their demand management policies. But only a few papers have estimated income and price elasticities for energy consumption in a panel framework. Furthermore, the long-run equilibrium relationship is studied in both directions, i.e. with either energy consumption or real GDP as a dependent variable (Costantini and Martini, 2010).

The innovative contribution of our paper is to determine the long-run relationship between energy consumption, real GDP and energy prices in more detail. In contrast to other studies concerning the energy consumption-GDP growth nexus, we distinguish between national and international trends as potential drivers of the long-run equilibrium between energy consumption, real GDP and energy prices. To analyse these issues, each variable is decomposed into common and idiosyncratic components. The idiosyncratic component is the part of a variable that is driven by national developments, whereas the common component represents international trends in the evolution of the variables. These might, however, have a different relevance for individual countries. Taking this decomposition as a starting point, cointegration between the common components means that the common components of energy consumption, real GDP and energy prices move together in the long run and do not deviate permanently from one another. Hence, cointegration between the common components suggests that the relationship between these variables depends to a great extent on international developments. Instead, cointegration between idiosyncratic components refers to developments relevant exclusively on the national level (Dreger and Reimers, 2009). Depending on the results of the cointegration tests, this distinction has important implications for policy makers. If the common components cointegrate, national energy policies may not have a large impact on economic growth. Indeed, this paper delivers empirical evidence that energy consumption, real GDP and energy prices are cointegrated in their common factors, but not in their idiosyncratic components.

The remainder of this paper is organised as follows. Section 2 briefly reviews the literature related to the causal relationship between energy consumption and economic growth. Section 3 presents the data, discusses the econometric methods and presents the empirical results. Section 4 provides conclusions and policy implications.

2. Literature review

The empirical literature provides mixed and conflicting evidence with respect to the energy consumption-growth nexus. This discrepancy in results is due largely to the use of different econometric methods and time periods, besides country-specific heterogeneity in climate conditions, economic development and energy consumption patterns, among other things. From a methodological perspective, four generations of contributions can be identified. First generation studies applied a traditional vector autoregression (VAR) model in the tradition of Sims (1972). For example, the seminal work of Kraft and Kraft (1978), using a VAR model, found evidence in favour of causality running from income to energy consumption in the United States for the period 1947–1974. Further, studies of the first generation examined the direction of causality assuming stationarity of the underlying variables. By contrast, second generation studies accounted for non-stationarity in the data and performed cointegration analysis to investigate the long-run relationship between energy consumption and growth. This literature, based on the Engle and Granger (1987) two-step procedure, studied pairs of variables to check for cointegration relationships and used estimated error-correction models to test for Granger causality. Third generation studies used multivariate estimators in the style of Johansen (1991). Johansen's multivariate approach also allows for more than two variables in the cointegration relationship. Finally, fourth generation studies employ recently developed panel-econometric methods to test for unit roots and cointegration relations. This literature estimates panel-based error-correction models to perform Granger causality tests.[2] According to our analysis of 25 OECD countries Table 1 summarises preferably all studies of the last five years on developed countries and their empirical results.[3] The ambiguous evidence of the empirical literature on the causal relationship between energy consumption and economic growth can already be seen from this recent studies on developed countries. Panel data analyses of OECD countries, however, all indicate bi-directional causality.

Most of the studies dealing with the energy consumption-growth nexus focus on production side models, which often include capital stock and labour in addition to energy consumption and GDP. If one concentrates on energy demand, trivariate models with energy prices as an additional variable should be used (see Oh and Lee (2004b)). The studies by Masih and Masih (1998), Asafu-Adjaye (2000), Fatai et al. (2004) as well as Mahadevan and Asafu-Adjaye (2007) take the consumer price index (CPI) as a proxy of the energy price. However, as the CPI is known not to capture the energy price very well, we employ the real energy price index, such as Lee and Lee (2010) and Costantini and Martini (2010). Masih and Masih (1998) and Asafu-Adjaye (2000) previously used the vector error-correction model (VECM); Fatai et al. (2004) applied the autoregressive distributed lag (ARDL) approach; and Mahadevan and Asafu-Adjaye (2007), Lee and Lee, (2010) as well as Costantini and Martini (2010) used a panel vector error-correction specification for the trivariate model.

In this paper, we study the cointegration property in more precise terms within a panel-econometric framework. Firstly, in order to distinguish between national and international trends that might drive the overall cointegration relationship, each variable is separated into common and idiosyncratic components by a principal component analysis. As a second step, we test common and idiosyncratic components

[2] For a detailed overview of the empirical literature on the causal relationship between energy consumption and economic growth see the recent surveys by Ozturk (2010) and Payne (2010).

[3] Although many of the listed studies also report results for developing countries, we only show their results with respect to developed countries to save space.