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The causality between energy consumption and economic growth: A multi-sectoral analysis using non-stationary cointegrated panel data

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ABSTRACT

The increasing attention given to global energy issues and the international policies needed to reduce greenhouse gas emissions have given a renewed stimulus to research interest in the linkages between the energy sector and economic performance at country level. In this paper, we analyse the causal relationship between economy and energy by adopting a Vector Error Correction Model for non-stationary and cointegrated panel data with a large sample of developed and developing countries and four distinct energy sectors. The results show that alternative country samples hardly affect the causality relations, particularly in a multivariate multi-sector framework.

1. Introduction

The increasing attention given to global energy issues and the international policies needed to reduce greenhouse gas (GHG) emissions have given a renewed stimulus to research interest in the linkages between the energy sector and economic performance at country level. The empirical analyses and the adopted models for investigating these linkages highly depend on the development level and economic structure of the countries considered.

Toman and Jemelkova (2003) argue that most of the literature on energy and economic development discusses how development affects energy use rather than vice versa. This strand of literature considers economic growth as the main driver for energy demand and only advanced economies with a high degree of innovation capacity can decrease energy consumption without reducing economic growth.

Stern and Cleveland (2004), on the other hand, have stressed the importance of considering the effect of changes in energy supply on economic growth in both developed and developing countries. When energy supply is considered a homogenous input for the production function, economic development is harmed if policy constraints affect energy supply. When energy services are differentiated, emphasizing the existence of higher and lower-quality forms of energy, society should make a choice in terms of an optimal energy mix, considering that higher-quality energy services could produce increasing returns to scale. This means that energy regulation policies could provide impulse to economic growth rather than be detrimental to the development process, since they support the shift from lower-quality (typically less efficient and more polluting) to higher-quality energy services.

If we consider energy consumption as a function of economic output, regulation and technical innovation, a suitable representation is the formalization provided in Medlock and Soligo (2001) as expressed in Eq. (1):

$$EC_{tj} = f(Y_{tj}, p_{tj}, \tau(Y_{tj}, p_{tj})) \quad (1)$$

where energy consumption (EC) at time t for each j-th end-use sector is a function of economic output (Y), energy prices (p) and technology (τ). In this specification, public regulation in the energy sector is modelled through energy prices, whereas endogenous technical change (τ) is expressed as a function of output level and energy prices.

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The opposite relation is adapted from Lee and Chang (2008) and Stern (2000a,b), as expressed in Eq. (2):

$$Y_{tj} = f(K_{tj}, L_{tj}, EC_{tj}(p_{tj})) \quad (2)$$

where economic output (Y) is a function of the capital stock (K), labour (L) and energy inputs (EC), here modelled as being strictly dependent on energy prices (p).[1]

These alternative views have important policy implications concerning, for example, aspects such as the development level of the considered country or the distributive effects related to the introduction of stringent energy (and environmental) regulations.

If we consider highly industrialized countries, total energy use has increased, energy efficiency has improved and energy intensity has steadily fallen, especially in the industrial sector. Stabilization of greenhouse gas concentrations requires reductions in fossil fuel energy use which is a major essential input throughout all modern economies. If energy conservation and a switch from fossil fuels to alternative energy sources can be affected using new energy-efficient technologies, the trade-off between energy and growth becomes less severe.

Moreover, if the development process is in the deindustrialization phase, the increasing importance of value-added produced by the service sector could lead to a global reduction in energy consumption due to a minor weight represented by energy-intensive industrial sectors.

Nonetheless, empirical analysis has shown that energy regulations and the shifting in production structure do not necessarily lead to a consistent reduction in global energy consumption. This evidence is explained as a "rebound effect", postulated first by Brookes (1990) and Khazzoom (1980). In some cases, energy-saving technical innovations tend to introduce more energy-using appliances to households and industries causing even more energy consumption as the money saved is spent on other goods and services which require energy to be produced. A stronger implication of the rebound effect is related to a reduction in energy prices that occurs when energy efficiency leads to a reduction in the energy demand (Binswanger, 2001). An innovation that reduces the amount of energy required to produce a unit of energy services lowers the effective price of energy services, resulting in an increase in their demand. The lower price of energy also results in an income effect that increases demand for all goods in the economy and therefore the energy required to produce them (Lovins, 1988; Newell et al., 1999; Popp, 2002). Therefore, if delinking between economic growth and energy consumption is the aim of energy policies, policy makers should consider some form of energy regulation (taxes, price cap or other) that allows cost of energy services to remain unchanged provided that technological innovation lowers effective energy prices (Bentzen, 2004).

Not many empirical studies have analysed this phenomenon by considering different economic sectors: a large part of the literature has investigated energy efficiency only at a general level. This has important policy implications. One of the most accurate contributions is the analysis by Zachariadis (2007) for G-7 countries where energy–economy causality for four sectors (industry, service, residential and transport) is analysed, using alternative estimation methods for each country. If declining energy intensity is observed only for specific sectors and not for the whole economy, differentiated policy measures are required in order to obtain the best results in terms of decoupling economic growth from energy consumption.

[1] This simple assumption is required if we consider that energy supply is often affected by exogenous elements such as international energy prices and public regulation, assuming that public regulation can be fully expressed by domestic energy prices. We are aware that this is a simplification but we also know that, in many cases, energy taxes in OECD countries constitute the largest part of energy prices.

There are many studies that investigate the strength of the structural linkage between energy and growth using time series analysis for single countries and, more recently, panel datasets, but at the best of our knowledge there are no contributions which adopt a panel approach for analysing energy–economic growth causality at the sectoral level. The purpose of this paper is to provide empirical evidence on the better performance of panel sectoral datasets in explaining the causal linkages between the economy and energy consumption. Moreover, by using energy prices for each specific sector, we can estimate the elasticity parameters related to energy demand changes induced by public regulation, expressed as energy taxes and empirically represented by energy prices.

This paper is different from previous contributions in several aspects. The sample adopted for the dataset is rather wider than other contributions based on the panel approach and includes 71 countries, thus allowing a number of considerations on different results emerging from alternative sub-samples consisting of developed and developing countries. The analysis is carried out on the whole economy and on four distinct end-use sectors, industry, service, transport and residential, allowing for specific considerations to be made for each sector divided into the sub-samples examined in this paper. Comparing results from different sectors reinforces the need for a multivariate model that accounts for structural peculiarities of both sectors and countries. A first attempt is provided by including specific energy prices for each end-use sector for OECD countries and the results offer strong advice in favour of multivariate multi-sector models.

The rest of the paper is structured as follows. Section 2 provides the methodological strategy for addressing Granger causality in the energy sector with particular emphasis on contributions dealing with non-stationary and cointegrated panel dataset, Section 3 gives a description of the data used in the empirical analysis, Section 4 describes the econometric strategy and presents the empirical results and Section 5 concludes with some policy implications.

2. Econometric models for an analysis of causality between energy and economic growth

To date, empirical findings on the causal relationship between energy consumption and economic growth have been mixed, depending on the functional form adopted, the econometric approach used, the time periods and the sample of countries analysed. Based on the methodology used, the literature on the relationship between energy use and economic growth can be divided into four generations. Interest in the subject dates back to a pioneering study by Kraft and Kraft (1978) that examined the energy use and economic growth relationship in the USA and found evidence of causality running from income to energy consumption. Several studies on the USA followed (for example, Akara and Long, 1980; Yu and Wang, 1984), and also on other developed countries (Yu and Choi, 1985). First-generation studies assumed that the time series examined were stationary and they were based on a traditional VAR methodology (Sims, 1972) and Granger causality testing (1969). Subsequent studies recognized the non-stationarity of the data series and they therefore performed cointegration analysis in order to investigate the energy use and economic growth relationship. Second-generation studies, based on the Granger's two-stage procedure (Granger, 1988), tested pairs of variables for cointegrating relationships and used estimated Error Correction Models (ECM) to test for Granger causality, concentrating their attention mainly on transition economies (Cheng and Lai, 1997) and developing countries (Nachane et al., 1988). Third-generation literature used multivariate estimators (Johansen, 1991), facilitating the estimation of systems where restrictions on cointegrating relations can be tested and, at the same time, the possibilities of short-run adjustment can be investigated. Johansen's approach also allows for more than two variables in the cointegrating relationship (see, among others, Masih and Masih, 1996; Stern, 2000a,b; Asafu-Adjaye, 2000; Oh and Lee, 2004). Fourth-generation studies