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Energy consumption and economic growth: Parametric and non-parametric causality testing for the case of Greece

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ABSTRACT

The objective of this paper is to contribute towards the understanding of the linear and non-linear causal linkages between energy consumption and economic activity, making use of annual time series data of Greece for the period 1960–2008. Two are the salient features of our study: first, the total energy consumption has been adjusted for qualitative differences among its constituent components through the thermodynamics of energy conversion. In doing so, we rule out the possibility of a misleading inference with respect to causality due to aggregation bias. Second, the investigation of the causal linkage between economic growth and the adjusted for quality total energy consumption is conducted within a non-linear context. Our empirical results reveal significant unidirectional both linear and non-linear causal linkages running from total useful energy to economic growth. These findings may provide valuable information for the contemplation of more effective energy policies with respect to both the consumption of energy and environmental protection.

1. Introduction

This paper aims at uncovering the possible linear or non-linear causality between total energy supply and economic activity using annual data from the Greek economy spanning the period between 1960 and 2008. Our analysis is much broader than that of most past studies (for reviews see e.g., Dergiades and Tsoulfidis, 2011) as it includes besides electricity all other energy flows used within the Greek energy system. The characteristic difference of our study from other previous international ones is the homogenization of energy inputs in a way such that to account for their differential efficiencies, and in so doing, we end up with an altogether new data series of quality adjusted energy consumption known as total useful energy (e.g., Cleveland et al., 2000). Furthermore, our analysis for the identification of the causal linkages between economic growth and the adjusted for quality total energy consumption is carried out within a non-linear context. The later allows us to overcome the restrictive linear causality paradigm which is common in the majority of past studies. The linear causality paradigm may act as a limiting factor when the true relationship might be non-linear. Baek and Brock (1992) noticeably mentioned that the standard causality testing procedures are inadequate to identify non-linear causal relationships.

Four are the possible outcomes or testing hypotheses of the causality (linear or nonlinear) analysis, between energy consumption and economic activity: a) the growth hypothesis, b) the conservation hypothesis, c) the neutrality hypothesis and finally d) the feedback hypothesis. Each of the above mentioned hypotheses implies a different kind of economic policy. In particular, the first hypothesis deals with the presence of unidirectional causality running from energy consumption to economic growth, suggesting that disruptions or restrictions in the smooth supply of energy in the economy will exert a negative impact on economic growth. On the other hand, non-conservation energy policies, other things equal, are expected to affect favorably economic growth. By contrast, the second hypothesis implies that there is unidirectional causality running from economic growth to energy consumption. The policy implication of the conservation hypothesis is that as the economy is not entirely energy-dependent, the government may adopt energy conservation policies with minimal effects on economic growth. The third hypothesis refers to the case, where there is no causality running in either direction, and therefore, any policy with respect to the consumption of energy, conservative or expansive, is expected to have a negligible effect on economic growth. Finally, the fourth hypothesis suggests a bidirectional causal relationship between energy consumption and economic growth, thereby

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lending support to the view that a carefully designed mix of taxation and subsidization policies may exert a positive growth effect in the economy without influencing, at the same time, the effectiveness of the implemented energy conservation policies. As a consequence, the empirical findings related to the causality direction, may be extremely useful for the appraisal of the effectiveness of various energy policies.

Compared to previous efforts, the novelty of our study relies on the combination of non-linear causality techniques along with the use of a quality-weighted scheme in the construction of the total energy consumption series. Although the analysis is restricted to the Greek economy, due to data availability, nevertheless the adopted methodological framework can be straightforwardly implemented to other economies. The energy quality adjustment approach adopted in this paper is in accordance with the influential study of Cleveland et al. (2000), who argued that "aggregating different energy types by their heat units embodies a serious flaw: it ignores qualitative differences among energy vectors" as well as that "adjusting energy for quality is important as is considering the context within energy use is occurring". This view, for energy quality adjustment, is further acknowledged and supported by Zachariadis (2007), who argued that such practice has to be seriously considered in similar empirical applications. Moreover, our methodological framework is in line with the conclusion of Ozturk (2010) who noted that "it should be understood that research papers using the same methods with the same variables, just by changing the time period examined, have no more potential to make contribution to the existing energy-growth literature". In particular, apart from the usual implementation of the standard Granger causality test (Granger, 1969); we applied the well known non-parametric Hiemstra and Jones (1994) test for non-linear causality as well as its recent modification, proposed by Diks and Panchenko (2006).

In order to aggregate the various heterogeneous sources of energy particular care should be applied in accounting for their differential efficiencies. In this sense, we took into consideration the efficiency adjustments in the energy mix used in the economy over time, since by definition the total useful energy measures the capacity of the various energy flows to perform useful work. There are many approaches that can be used in order to account for energy quality, such as for example production side approaches (characterized in the literature as emergy) or end-use approaches (known as exergy or the price-based approach).[3] Ideally, one would compare the results of our analysis with those that would be derived had we followed an economically meaningful way to homogenize the energy flows, that is, through prices, the idea being that prices reflect both preferences and productivities. The trouble with such an approach is that, on the one hand, the data on prices for so many diverse energy input sources are hard to come by and, on the other hand, prices in energy markets do not necessarily reflect preferences or productivities only, simply because of government regulation of the energy industry. Fraught with a number of taxes and restrictions, they may not faithfully reflect preferences and productivities. Finally, the use of prices for the purposes of aggregation of various energy sources to a single measure is based on the implicit assumption that the substitutability among the various fuels is unaffected by the magnitude of the non-fuel inputs used (Cleveland et al., 2000), a very strong assumption in some cases.[4]

The remainder of the paper is organized as follows: Section 2 reviews briefly the literature on the nexus between energy consumption and economic growth. Section 3 continues with the presentation of the adopted methodological framework. Section 4 discusses basic data issues and at the same time conducts the necessary preliminary econometric analysis. Section 5 presents and evaluates the results of the causality analysis and finally, Section 6 summarizes and draws some broad policy conclusions.

2. Review of the literature

In the recent years, there are many studies contributing to the understanding of the nexus between energy consumption and economic growth. Detailed surveys of past studies can be found in Payne (2010), Ozturk (2010) and Pirlogea and Cicea (2012). Given the vast volume of studies in the relevant literature, the purpose of this section is twofold: on the one hand, to review past studies focusing on Greece, and on the other hand to provide a rather comprehensive review of recently published international studies. The results of these studies are mixed for reasons related to differences in estimating methods, sample periods, quality of data and model specifications. Furthermore, it is worth noting that the results in most of past studies may suffer from a certain degree of bias, as they assume linearity in the variables involved, while in effect the relations between variables is likely to be non-linear. Meanwhile, various economic shocks and regime changes, such as for example those emanating from economic environment, energy policies and variations in energy prices may give rise to substantial structural changes in energy consumption rendering this way the assumption of linearity utterly misleading. Clearly, such structural changes may be described much more accurately within a non-linear context, and therefore the non-linear modeling may be more suitable to the task at hand (Lee and Chang, 2005). The results of several recent studies are conveniently displayed in Table A1 (see Appendix 2).

Table A1 classifies chronologically studies that are concentrated on a single country (Panel *A*) as well as studies that are concentrated on a group of countries (Panel *B*). Table A1, analytically presents the country of interest (or the group of countries), the length of the period investigated, the adopted methodological framework and finally the causality inference. Our focus initially turns on the case of Greece. To the best of our knowledge there are only a few research papers that investigate the causal relationship between energy consumption and economic growth in the case of Greece. These studies are by Fuinhas and Marques (2012), Hatzigeorgiou et al. (2011), Hondroyiannis et al. (2002) and Tsani (2010). Fuinhas and Marques (2012) making use of annual time series data for the period 1965–2009, implemented the ARDL approach to cointegration and within a bivariate VECM framework established a bidirectional linear causality between energy consumption and economic growth. Hatzigeorgiou et al. (2011), for a substantial shorter time period (1977–2007) and under a similar methodological framework (Johansen cointegration and a trivariate VECM) ascertained unidirectional linear causality that runs from growth to energy intensity. Tsani (2010) using data spanning the period 1960–2006 and the Toda–Yamamoto causality test (within a bivariate framework) finds unidirectional linear causality running from energy consumption to GDP, while different causal links are identified at disaggregated levels (not shown in Table 1). Finally, Hondroyiannis et al. (2002) in their study for the period 1960–1996, (utilizing the ARDL econometric methodology) found bidirectional linear causality between energy consumption and growth.

Our study consists an extension of the abovementioned empirical studies for the Greek economy in the three following ways: a) we adjust energy consumption for energy quality through the thermodynamics of energy conversion b) we winkle out from the restrictive linear causality paradigm achieving this way to identify possible non-linear causal relationships and c) we further investigate the nature of the identified causality given that it makes an essential difference if causality is ascertained in the conditional mean or in higher order moments. It is well established in the literature that the standard Granger causality framework restricts causality inference in the

[3] Cleveland (1992) provides a comprehensive and insightful discussion of the concept of energy quality.

[4] According to Cleveland (1992) there is no single method of aggregation generally and unequivocally accepted among researchers, there are pros and cons in each research method.