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Energy consumption and economic growth for selected OECD countries: Further evidence from the Granger causality test in the frequency domain

Seref Bozoklu [a,*], Veli Yilanci [b,1]

[a] Istanbul University, Faculty of Economics, Department of Economics, 34452 Beyazit, Istanbul, Turkey
[b] Sakarya University, Faculty of Economics and Administrative Sciences, Department of Financial Econometrics, 54187 Serdivan, Sakarya, Turkey

HIGHLIGHTS

- This study reexamines the causal relationship between energy consumption and economic growth.
- We employ frequency causality analysis to determine temporary and permanent causality.
- The results provide evidence of both temporary and permanent causality relationships for countries examined.
- Energy policies should consider whether the causality is temporal or permanent.

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ABSTRACT

This paper aims to reexamine the causal relationship between energy consumption and economic growth for 20 OECD countries. To that end, we employ a Granger causality test in the frequency domain which allows us to distinguish short (temporary) and long-run (permanent) causality. The empirical results could be summarized as following. First, in terms of causality running from GDP to energy consumption, there is a temporary relationship for Australia, Austria, Canada, Italy, Japan, Mexico, the Netherlands, Portugal, the UK, the USA, and a permanent relationship for Austria, Belgium, Denmark, Germany, Italy, Japan, the Netherlands, Norway, and the USA. Second, in terms of causality running from energy consumption to GDP, there is a temporary relationship for Austria, Denmark, Italy, the Netherlands, Norway and Portugal, and a permanent relationship for Belgium, Finland, Greece, Italy, Japan, and Portugal. The main implication of our finding is that the energy policies should take into consideration not only the causality direction between economic growth and energy consumption but also whether it is temporal or permanent and furthermore authorities must design policy actions accordingly.

1. Introduction

The two energy crises of the 1970s, which hampered economic growth due to the high energy prices, required governments to implement conservative energy policies. However, reduction in energy consumption may have impacts on economic growth, if energy consumption causes economic growth, then reducing energy consumption could lead to a fall in output and employment. On the other hand, if the causality runs in the opposite direction, then energy conservation policies may be implemented without detrimental effects on output and employment. The current debate about global warming and climate change requires policy makers to take some precautions against the high level of greenhouse gas emissions, such as reducing fossil energy consumption and increasing usage of renewable energy. Some industrialized countries committed themselves to reducing greenhouse gas emission by restricting fossil fuel consumption due to the Kyoto Protocol. Nevertheless, it is argued that decreasing energy consumption may reduce economic growth and increase unemployment since energy is considered an essential factor of production (Stern, 2000). Hence, an examination of the relation between energy consumption and economic growth not only helps to understand the role of energy consumption in sustainable economic growth but also sets a framework for discussion of energy and environmental policies. Consequently, it is important to reveal the direction of causality between these variables.

The literature suggests four possible connections between energy consumption and economic growth (Squalli, 2007). *The growth hypothesis* implies that energy consumption contributes to

* Corresponding author. Tel.: +90 2124400000; fax: +90 2125208286.
E-mail addresses: sbozoklu@istanbul.edu.tr (S. Bozoklu), yilanci@sakarya.edu.tr (V. Yilanci).
[1] Tel.: +90 2642956231; fax: +90 2642956233.

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economic growth both directly and indirectly as a compliment factor to labor and capital in the production process. In addition, it claims that energy conservation policies could make the real GDP to reduce. On the other hand, *the conservation hypothesis* implies that energy conservation policies have no adverse effects on real GDP. While uni-directional causality running from real GDP to energy consumption supports the conservation hypothesis, the reverse direction of causality supports the growth hypothesis. *The feedback hypothesis* suggests that there is an interdependency causal link between energy consumption and real GDP and is valid if there is a bi-directional causality. If this is the case, an energy policy aiming at improvements in energy consumption efficiency will not adversely affect real GDP. Finally, *the neutrality hypothesis* suggests that energy consumption has a little or no impact on real GDP and therefore conservative energy policies will not reduce real GDP. The neutrality hypothesis is valid if there is no causality between energy consumption and economic growth. If energy consumption has no significant effect on the real output, then it would be reasonable for governments to adopt conservative and environment friendly policies. Energy conservation policies aimed at reducing energy consumption must create some methods to reduce consumer demand, such as an appropriate combination of energy taxes and subsidies, to eliminate or at least to mitigate unfavorable effects on economic growth. Policy makers should also encourage industries to adopt technology that reduces pollution.

This paper contributes to the energy-growth literature by employing the Granger causality in the frequency domain to analyze both short- and long-run causality and aims to indicate whether there is a change in causality direction over time. To the best of our knowledge, this is the first study investigating causality between these two variables in high and low frequencies. Our analysis of the relationship between energy consumption and economic activity is based on a sample of 20 OECD countries. The remainder of the paper is organized as follows: Section 2 introduces the selected literature, Section 3 presents econometric methodology with empirical results in Section 4, and Section 5 presents our conclusions.

2. Selected literature

The literature offers inconsistent results on the relationship between energy consumption and economic growth after the pioneering work of Kraft and Kraft (1978). As pointed out by Toman and Jemelkova (2003), the lack of consensus may be due to the heterogeneity in climate conditions among countries, the changing energy consumption patterns, the structure and stages of economic development within a country and among countries, the alternative econometric methodologies employed, the presence of omitted variable bias, and varying time horizons of the studies conducted.

Lee and Chang (2008) and Lee et al. (2008) employed panel cointegration technique to examine the relationships among energy consumption, GDP, and capital in 16 Asian and 22 OECD countries over 3 and 4 decades, respectively. Lee and Chang (2008) found a long-run causal relationship from energy consumption to GDP while Lee et al. (2008) suggested a bidirectional relationship in the OECD sample. Taken together, the inconclusive results of these studies are possibly due to the omission of non-energy inputs. By contrast, in a recent bivariate panel data study, Joyeux and Ripple (2011) found causality flowing from output to energy consumption for 56 developed and developing economies and Chontanawat et al. (2008) found causality running from energy consumption to GDP and stated that this result is more valid in the developed OECD countries compared with the developing non-OECD countries in a group of 100 countries. Through a panel vector error correction model consisting of GDP, energy consumption, and energy prices for 26 OECD countries, Costantini and Martini (2010) found that in the short run, there is bidirectional causality found between energy consumption and real GDP. However, in the long run, they found that real GDP growth drives energy consumption.[2] Belke et al. (2001) indicated the presence of a bidirectional causal relationship between energy consumption and economic growth for 25 OECD countries. Recent studies of Chiou-Wei et al. (2008), Huang et al. (2008) and Fallahi (2011), among others, imply that the interrelationship between energy consumption and economic variables might be inherently nonlinear. The irreconcilable findings of empirical studies make it troublesome to suggest a certain policy recommendation for OECD countries. Most previous studies did not consider the changing of causality direction, which may be due to such as business cycles, wage rates, energy crises, and structural reforms as stated by Fallahi (2011) and this creates room for a frequency-based rather than a conventional causality analysis between energy consumption and economic growth.

3. Econometric methodology

If the predictability of a time series can be improved by the incorporation of a second time series, it can be stated that the second time series has a causal effect on the first one. Wiener (1956) introduced the idea of Granger causality, and Granger (1969, 1980) formulated this idea by employing linear regression models. The process of Granger causality test essentially consists of estimating a bivariate linear model, determining the optimal lag length, and testing the significance of the lags of the exogenous variable(s). Although the Granger causality test has been one of the most popular econometric techniques employed by academicians, it has some drawbacks. For instance, this test ignores the possibility that the strength/direction/existence of the Granger causality could vary over different frequencies as mentioned by Lemmens et al. (2008), and in the case of nonstationary variables, we should take differences to make them stationary which cause to loss of long-run information. Therefore, in this study we employ the Granger causality test in the frequency domain introduced by Breitung and Candelon (2006), which allows us to test causality over the different frequencies to overcome the first drawback, and we follow the suggestion of Dolado and Lütkepohl (1996) by augmenting the vector autoregressive model (VAR) with one lag to eliminate the need for pretesting the unit root characteristics of the variables and also to avoid taking the differences of the nonstationary variables..

A finite-order VAR representation of order can be illustrated as follows:

$$\begin{aligned} Y_t &= \theta_{11,1}Y_{t-1}+\theta_{11,2}Y_{t-2},\dots,+\theta_{11,p}Y_{t-p}+\theta_{12,1}X_{t-1}+\theta_{12,2}X_{t-2},\dots,+\theta_{12,p}X_{t-p} \\ X_t &= \theta_{21,1}Y_{t-1}+\theta_{21,2}Y_{t-2},\dots,+\theta_{21,p}Y_{t-p}+\theta_{22,1}X_{t-1}+\theta_{22,2}X_{t-2},\dots,+\theta_{22,p}X_{t-p} \end{aligned} \quad (1)$$

This model can be presented in matrix notation using the lag operator (L) as follows:

$$\theta(L)\begin{pmatrix} Y_t \\ X_t \end{pmatrix} = \begin{pmatrix} \theta_{11}(L) & \theta_{12}(L) \\ \theta_{21}(L) & \theta_{22}(L) \end{pmatrix}\begin{pmatrix} Y_t \\ X_t \end{pmatrix} = \varepsilon_t \quad (2)$$

where $\theta(L)=I-\theta_1 L-\theta_2 L^2-\ldots-\theta_p L^p$ is a 2×2 lag polynomial, and $\theta_1-\theta_2-\theta_3-\ldots-\theta_p$ are 2×2 autoregressive parameter matrices. The error vector ε_t is white noise with zero mean and $E(\varepsilon_t\varepsilon'_t)=\Sigma$

[2] We did not do a complete literature review. For recent surveys, please see Ozturk (2010), Payne (2010), and Yildirim and Aslan (2012).