Energy Economics 32 (2010) 1398–1410

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneco

Economic growth and energy consumption causal nexus viewed through a bootstrap rolling window

Mehmet Balcilar [a,1], Zeynel Abidin Ozdemir [b,*], Yalcin Arslanturk [c,2]

[a] Department of Economics, Eastern Mediterranean University, Famagusta, Turkish Republic of Northern Cyprus, via Mersin 10, Turkey
[b] Department of Economics, Gazi University, Besevler, 06500, Ankara, Turkey
[c] Gazi University, Teknikokullar, 06500, Ankara, Turkey

ARTICLE INFO

Article history:
Received 20 December 2009
Received in revised form 17 May 2010
Accepted 29 May 2010
Available online 4 June 2010

JEL classifications:
C22
Q43
Q48

Keywords:
Economic growth
Energy consumption
Bootstrap
Time-varying causality

ABSTRACT

One puzzling results in the literature on energy consumption-economic growth causality is the variability of results particularly across sample periods, sample sizes, and model specification. In order overcome these issues this paper analyzes the causal links between energy consumption and economic growth for G-7 countries using bootstrap Granger non-causality tests with fixed size rolling subsamples. The data used includes annual total energy consumption and real Gross Domestic Product (GDP) series from 1960 to 2006 for G-7 countries, excluding Germany, for which the sample period starts from 1971. Using the full sample bootstrap Granger causality test, we find that there is predictive power from energy consumption to economic growth only for Canada. However, parameter instability tests show that none of the estimated models have constant parameters and hence the full sample results are not reliable. Analogous to the full sample results, the results obtained from the bootstrap rolling window estimation indicate no consistent causal links between energy consumption and economic growth. We, however, find that causal links are present between the series in various subsamples. Furthermore, these subsample periods correspond to significant economic events, indicating that the findings are not statistical artefacts, but correspond to real economic changes. Our results encompass previous findings and offer an explanation to varying findings.

1. Introduction

The linkage between energy consumption and economic growth has been a topic studied in depth in the field of energy economics because of the importance it has in the present-day economies, ranging from small developing economies to the developed ones. Most of these studies used the Granger causality test to investigate the direction of the link between energy consumption and real GDP. The main motivation behind testing whether energy consumption Granger causes real GDP or not is rooted in energy conservation policies. It has been well-established that a positive long-run link between energy consumption and real GDP exists. Then, if the direction of the causality runs from energy consumption to real GDP, energy conservation policies will have a negative effect on real GDP growth.

A number of studies followed the pioneering paper appeared in 1978 by Kraft and Kraft. Ozturk (2010) provides an extensive survey of this literature on causal nexus between energy consumption and economic growth. Using the US annual data over the period 1947–1974 and applying Granger causality test, they found a unidirectional causality from economic growth to energy consumption. In the following year, Akarca and Long (1979), using the US monthly data from 1973 to 1979, found a unidirectional causality from energy consumption to employment, which is used as a proxy for economic growth. Besides, just a year later, Akarca and Long (1980), using monthly data from 1973 to 1979, which was shorter compared to the study of Kraft and Kraft (1978), found bidirectional causality between energy consumption and GDP, implying that temporal instability was not taken into consideration in the study of Kraft and Kraft (1978).

Since the early 1980s, a number of studies, using different time periods and different techniques, on the linkages between energy consumption and economic growth appeared in the literature. Using different techniques and the time periods these studies obtained surprisingly different results, with one contradicting another. Despite the fact that the linkage between the energy consumption and economic growth is well-studied, the findings are still controversial. To illustrate, some studies found unidirectional Granger causality from energy consumption to economic growth for the Philippines (Yu and Choi, 1985), India (Masih and Masih, 1996), Singapore (Glasure and Lee, 1997), and for France, West Germany, Japan, and Turkey

* Corresponding author. Tel.: +90 312 216 11 15; fax: +90 312 213 20 36.
E-mail addresses: mehmet.balcilar@emu.edu.tr (M. Balcilar), zabidin@gazi.edu.tr (Z.A. Ozdemir), arslanturk@gazi.edu.tr (Y. Arslanturk).
[1] Tel.: +90 392 630 1548; fax: +90 392 365 1017.
[2] Tel.: +90 312 212 68 40; fax: +90 312 221 32 02.

0140-9883/$ – see front matter © 2010 Published by Elsevier B.V.
doi:10.1016/j.eneco.2010.05.015

(Soytas and Sari, 2003). On the other hand, there are studies, where Granger causality is from economic Growth to energy consumption, such as those by Yu and Choi (1985) and Soytas and Sari (2003) for South Korea, and Cheng and Lai (1997) for Taiwan. There are also studies, where causality is in both directions and supports the neutrality hypothesis, such as for the US by Stern (1993, 2000) and Cheng (1995), for Thailand and the Philippines by Asafu-Adjaye (2000), and for Taiwan by Yang (2000).

Some studies employed a multivariate cointegration test to examine the relationship between economic growth and energy consumption, such as Stern (2000), and Ghali and El-Sakka (2004). Yu and Jin (1992), using cointegration tests, analyzed the long-run linkage with the level of energy consumption and employment for the US and found no evidence of a cointegrating relationship. On the other hand, using Engle-Granger cointegration test for a group of six Asian economies Masih and Masih (1996) found no cointegration between energy consumption and economic growth for Malaysia, Singapore, and the Philippines but significant cointegration for India, Pakistan, and Indonesia.

Using panel data of energy consumption and GDP for 82 countries from 1972 to 2002 and GMM (Generalized Method of Moment), Huang et al. (2008) found no evidence in favour of the hypothesis that energy consumption leads to economic growth. Chiou-Wei et al. (2008), using both linear and non-linear Granger causality tests, found evidence supporting the neutrality hypothesis for the US, Thailand and South Korea, while they found a unidirectional causality from economic growth to energy consumption for the Philippines and Singapore. Bowden and Payne (2009) examined the casual relationship between energy consumption and real GDP using aggregate and sectoral primary energy consumption measures within a multivariate framework. They found evidence that industrial energy consumption Granger causes real GDP.

The results in the literature on the energy consumption-growth causality are at large variability, particularly with respect to the sample period covered. The subsample variability is particularly evident in papers using data that sets that includes 1980s. There are two important issues relating to the data used in these studies. First is the small sample size and second one is the structural changes or regime shifts. A further variability in the results is due to the handling of the trending properties of the data. The results using cointegrated models are mostly different than results of those ignoring the integration-cointegration properties of the data. This paper takes these three major issues into account by using bootstrap tests and rolling window estimation. In order to be robust against small sample and integration-cointegration properties of the data we use bootstrap causality tests. In order to show the subsample variability of the Granger causality tests and bring an explanation to variability we use subsample rolling bootstrap tests.

The main objective of this paper is to investigate causal nexus between energy consumption and economic growth using a bootstrap causality test, applied to both full sample and rolling window subsamples, for G-7 countries. By causality, we mean causality in the Granger's sense (Granger, 1969). As we discussed above the previous literature on causality between energy consumption and GDP all tested for Granger causality in the full sample using several variants of the Granger causality test. In this study, we adopt a different approach and investigate the causality in a time-varying fashion using bootstrap Granger causality test. All type of Granger causality tests assumes (non)existence of one "causal" relationship for the whole sample. However, the causal relationship might be time-varying where a variable may be Granger causing the other in some periods and not in others, or there may be bidirectional causality in some periods. The results of the previous literature discussed above on the relationship between energy consumption and GDP seems sensitive with respect to changes in the sample period. When the causal relationship between two variables is not stable and the non-causality is not rejected, then it is not clear what has been rejected. Due to policy changes and the significant changes in the level energy consumption in response to changes in energy prices the causal relationship between energy consumption and economic growth may shift in time. Volatile periods during recessions may also be radically different than other periods. Ozturk (2010) points out to the conflicting results in the literature and need to consider alternative methods for analyzing the causal links between energy consumption and economic growth. Our results complement this conclusion.

To investigate whether the causal relationships between energy consumption and economic growth is stable over the sample period, we consider bootstrap Granger non-causality tests computed from rolling subsamples of a fixed size (Thoma, 1994; Swanson, 1998; Psaradakis et al., 2005). Using bootstrap rolling window approach, we analyse the time-varying causal links between economic growth and energy consumption, which is the main empirical contribution of this paper. The data used in this study are annual time series from 1960 to 2006 of total energy consumption and real GDP for G-7 countries, except Germany, for which the sample period covers 1971-2006. Total Energy Consumption is measured in kilotons of oil equivalency.

We use parameter constancy tests to establish the stability of the estimated vector autoregressive (VAR) models. The evidence obtained from the stability tests show that energy consumption and GDP do not maintain a stable dynamic relationship for none of the G-7 countries. Therefore, the causality inference based on full sample VAR estimates is not reliable. When the full sample bootstrap Granger causality test is used, results of this paper indicate that there is only predictive power from energy consumption to economic growth for Canada. Excluding this finding, the findings from full sample estimation results indicate that there is no predictive content between the series for G-7 countries. Similar to the full sample results, results of the rolling window bootstrap tests show no evidence of consistent causal links between energy consumption and economic growth.

The paper is organised as follows: Section 2 explains the methodology employed, Section 3 provides empirical results and the last section presents the conclusion.

2. Methodology

A variable is said to be Granger non-causal for another variable, if including the first variable in the information set will not improve the forecast of the second variable. In the VAR framework, commonly used test statistic, such as the Wald, likelihood ratio (LR) and Lagrange multiplier (LM) test, for testing the Granger-causality may have non-standard asymptotic properties, if the variables considered in the VAR are integrated or cointegrated. Difficulties arising in the levels estimation of such VAR models have been illustrated by Park and Phillips (1989), and Toda and Phillips (1993, 1994), among others.

Toda and Yamamoto (1995) and Dolado and Lütkepohl (1996) proposed a solution that guarantees standard asymptotic distribution for the Wald tests performed on the coefficients of VAR(p) processes with I(1) variables. Their solution requires at least one coefficient matrix be unrestricted under the null hypothesis. Furthermore, they showed that adding one extra lag to the process and performing the Wald tests on the coefficient matrices relating to first p lags obtains standard asymptotic distribution. Shukur and Mantalos (1997b) have studied the size and power properties of several standard and modified, as suggested by Dolado and Lütkepohl (1996), generalizations of Granger-causality tests in integrated-cointegrated VAR systems. Eighth versions of Granger causality tests in standard and modified forms are evaluated by Monte Carlo simulations by the authors. The authors found that the Wald test did not exhibit correct size in small, or even in medium-sized samples. Additionally, Shukur and Mantalos (1997a) showed that the critical values can be improved by using the residual-based bootstrap technique (RB), so that the true size of the RESET test, in systems ranging from 1–10 equations, approaches its