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Long-run relation and short-run dynamics in energy consumption–output relationship: International evidence from country panels with different growth rates☆

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ABSTRACT

The long-run relation and short-run dynamics between output and consumption of energy (electricity) are examined in panels of countries with different growth rates. Seventy nine countries over 1971–2011 are grouped into high-, low- and negative-growth categories based on exponential growth rate of their per capita output. Tests of cointegration suggest the existence of long-run relation between energy (electricity) consumption and output in high- and low-growth panels but its absence in the panel with negative growth. Accounting for cross-country dependency strengthens the findings. Estimates of long-run elasticity of output with respect to energy (electricity) are significant in panels with positive growth rates. The common correlated effect mean-group estimators of the error-correction model suggest (1) long-run bidirectional causality between output and energy (electricity) in all three groups of countries, (2) short-run bidirectional causality in output-energy relation for the full sample as well as in the low-growth category; and (3) unidirectional causality from output to energy in the negative-growth category. The finding of long-run bidirectional causality is robust to inclusion of carbon emission, urbanization, exports, and foreign direct investment as control variables.

1. Introduction

What role does energy and electricity play in economic development? Do countries with higher energy use have better opportunities for development and countries with lower energy consumption experience slowdowns in their development efforts? To what extent the relation between output and energy use is influenced by the country's stage of economic development and its growth prospects? A critical review of the literature suggests that empirical evidence on these questions vary significantly across countries, over different sample periods, and across alternative methodologies (Apergis and Payne, 2011). Nevertheless, a better understanding of this relationship is important from a theoretical, policy, and empirical perspectives.

Theoretically, the energy–output relation has been modeled using both demand- and supply-side approaches. The demand-side approach is based on a derived demand function for energy, which depends on the level of economic activity, price of energy and the state of technology. Thus, according to this approach, energy consumption is caused by the level of economic activity. In contrast, the supply-side approach treats energy as an input in the production process. Thus, energy consumption is the underlying cause of economic activity.

To emphasize their policy implications, a number of studies (Apergis and Payne, 2011; Mehrara, 2007; Ozturk, 2010) have organized the causal relation between energy consumption and output in terms of four alternative hypotheses. First, the "growth hypothesis" suggests that energy contributes to economic activity as an important input in the production process. Thus, conservation policies which limit energy consumption may have an adverse effect on economic activity. Second, "conservation hypothesis" assumes economic activity plays a critical role in demand for energy, which is consistent with the demand-side approach. Thus, policies that curtail energy consumption may not have an adverse effect on economic activity. Third, the "feedback hypothesis" suggests that both energy and output are endogenous, and there is a bidirectional causal relation between them. Thus, energy conservation policies will reduce economic activity, which results in further slowdown in energy consumption. Finally, the "neutrality hypothesis" suggests lack of causal relations between output and energy consumption. Thus, energy conservation polices play a minor role in economic activity.

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Empirically, a large body of literature has examined the relation between output and energy. Most early works are time series although recently there has been a shift to panel analyses. Three of these studies (Apergis and Payne, 2011; Omri and Kahouli, 2014; and Ozturk, et al., 2010) have examined the output–energy relation in subpanels of countries at different stages of economic development. These studies differ in their choice of countries, sample periods, panels, and empirical methodology. However, their findings broadly support long-run bidirectional causality between energy and output in all subpanels except those at the lowest stage of development. However, evidence of short-run causality is rather mixed.

This study will re-examine the energy consumption–output nexus. The primary purpose of our investigation is to explore the possibility that the elasticity of output with respect to energy (and electricity) is sensitive to the country's growth rate rather than its level of development. In particular, we postulate that countries in a higher growth category command a higher elasticity of output with respect to energy and electricity. To address this issue, we organize data for 79 countries over 1971–2011 into three subpanels of high-, low- and negative-growth categories based on the countries' exponential growth rates over the sample period. For each subpanel, we (a) test for cointegration between output and energy (electricity) consumption using the residual-based procedure proposed by Pesaran (2006), (b) estimate the long-run elasticity of output with respect to energy (electricity) using the common correlated mean-group estimator also proposed by Pesaran (2006), and (c) test for long-run and short-run causality using the corresponding vector-error-correction model. As Pesaran (2006) shows, this procedure allows for cross-country heterogeneity and also accounts for cross-sectional correlation due to common shocks. Finally, given the possibility of omitted variable bias in bivariate models (Narayan and Smyth, 2009; Sadorksy, 2011), we re-examine the robustness of our findings by estimating trivariate models, which include CO_2 emission, urbanization, exports, and foreign direct investment as additional control variables.

The remainder of the paper is organized as follow: Section 2 provides a brief review of relevant empirical literature. Section 3 explains the empirical model as well as the estimation method. Section 4 describes the construction of our data sets and highlights the simple statistics of the variables. Section 5 reports the empirical results based on the bivariate model. Section 6 reports the results of the tests of robustness of from the trivariate models. Finally, Section 7 provides a summary of the results and major conclusions.

2. Previous literature

A large and growing body of literature has empirically examined the relation between output and energy (electricity). Most early work is time series although recently there has been a shift to panel analyses. Mehrara (2007) divides the existing literature into four generations based on the estimation techniques. The first-generation literature consists of studies based on the traditional vector autoregressive (VAR) model introduced by Granger (1969) and Sims (1972), which assumes stationarity of variables (Kraft and Kraft, 1978; Murry and Nan, 1996; Stern, 1993). The second-generation studies introduce tests of unit roots and cointegration. Typically, these studies use the Engle and Granger's (1988) residual-based test of cointegration and its corresponding error-correction model (ECM) for tests of causality (Altinay and Karagol, 2004; Cheng, 1998; Nachane et al., 1988). The third-generation studies utilize the maximum likelihood cointegration analysis introduced by Johansen and Juselius (1990) and the corresponding vector error-correction model (VECM), or autoregressive distributed lag (ARDL) model to examine the long-run and short- run causality among the variables (Acaravci and Ozturk, 2010b; Chang, 2010; Masih and Masih, 1996; Mensah, 2014; Narayan and Prasad, 2008; Ozturk and Acaravci, 2011; Soytas and Sari, 2003). The fourth-generation studies use panel cointegration tests and panel-based VECM that accommodate cross-sectional heterogeneity, thereby yielding more robust results relative to time series analysis (Acaravci and Ozturk, 2010a; Apergis and Payne, 2010; Chen et al., 2007; Mohammadi and Parvaresh, 2014; Narayan and Smyth, 2009; Yıldırım et al., 2014). Panel studies also benefit from a larger sample size, higher degrees of freedom, and potential reductions in collinearity among explanatory variables (Yoo, 2005).

Three recent studies relevant to our work (Apergis and Payne, 2011; Omri and Kahouli, 2014; and Ozturk, et al., 2010) have examined the energy–output relationship in subpanels of countries at different stages of economic development. These studies differ in their choice of countries, sample periods, subpanels, and empirical methodology. However, their findings are broadly similar. Ozturk, et al. (2010) organize 51 countries over 1971–2005 into three subpanels of upper-, lower- and low-income groups; Omri and Kahouli (2014) organize 65 countries over 1990–2011 into three subpanels of high-, middle-, and low-income groups; and Apergis and Payne (2011) organize 88 countries over 1990–2006 into four subpanels of high-, upper-middle-, lower-middle-, and low- income panels. The empirical methodology varies from panel cointegration tests of Pedroni (1999, 2004) in Ozturk, et al. (2010), to panel cointegration tests of Larsson et al. (2001) in Apergis and Payne (2011), and to the GMM estimation in Omri and Kahouli (2014). Ozturk, et al. (2010) report cointegration between output and energy consumption across all three income categories while Apergis and Payne (2011) find cointegration in all but the lowest-income category. Ozturk, et al. (2010) finds long-run bidirectional causality for upper- and lower-income panels but unidirectional causality from output to energy consumption in the low-income panel. Omri and Kahouli (2014) report bidirectional causality between income and energy consumption in all three subpanels. In contrast, Apergis and Payne (2011) report long-run bidirectional causality in high-, upper-middle-, and lower-middle-income panels; short-run bidirectional causality in high- and upper-middle-income panels and unidirectional causality from electricity to output in lower-middle- and low-income panels. Thus, while there is more support for bidirectional long-run causality between energy and output for countries in almost all stages of economic development, evidence on patterns of short-run causality is rather mixed.

3. Empirical model

Our modeling of the relationship between output and energy consumption is based on the production function approach. Following Mohammadi and Parvaresh (2014), we model the bivariate long-run relation between output and energy consumption as a linear heterogeneous function represented by Eq. (1),

$$Y_{it} = \alpha_i + d_t + \beta_i E_{it} + e_{it}, \quad i = 1, \ldots N; \quad t = 1, \ldots T; \tag{1}$$

where Y_{it} and E_{it} are natural logs of real per capita output and per capita energy consumption in the ith country at time t, α_i is country-specific intercept, d_t is time dummy, β_i is the long-run elasticity of output with respect to energy use, and e_{it} is the idiosyncratic error term.

As Pesaran (2006) and Chintrakarn et al. (2012) note, three specification issues must be addressed in estimating the parameters of model (1). First, tests of cointegration require income and energy consumption variables to be non-stationary in level, stationary in first-difference, and have a stationary linear combination (i.e., the error term must be stationary). A stationary error term implies that no relevant non-stationary variable is omitted from the model. If the true cointegrating model includes other non-stationary variables, then their omission would produce a non-stationary error term and makes detection of cointegration difficult. Second, countries vary in size, income level, macroeconomic and trade policies, geographical location, resources, etc. This implies that α_i and β_i parameters may vary significantly across countries, and treating them equal might produce inconsistent and potentially misleading estimates (Pesaran et al., 1999). Thus, estimation of Eq. (1) requires proper account of cross-country parameter heterogeneity. Third, output and energy consumption across countries may be