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Energy consumption and output: Evidence from a panel of 14 oil-exporting countries☆

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ABSTRACT

We examine the long-run relation and short-run dynamics between energy consumption and output in a panel of 14 oil-exporting countries over 1980–2007. Panel unit root tests, which account for common cross-sectional factors, fail to reject non-stationarity in both variables. Thus, we explore their long-run relation and short-run dynamics using three alternative panel estimation techniques — dynamic fixed effect, pooled and mean-group estimators before and after accounting for common cross-sectional factors. These estimators allow for various degrees of heterogeneity in long-run parameters and short-run dynamics. The results based on the mean group estimator with common correlated effects suggest (a) a stable relation between energy consumption and output; (b) bi-directional causality in both long- and short-run; and (c) the robustness of the long-run causality results to the inclusion of additional variables. As such, environmental policies designed to curtail energy may have significant long-run ramifications for economic growth, and policies designed to promote economic growth may have adverse environmental consequences.

1. Introduction

What are the long-run relation and short-run dynamics between energy consumption and economic growth in oil exporting countries? This question merits investigation for at least four reasons: First, theoretical examination of the subject is not conclusive. Supply-side studies that treat energy as a factor of production, similar to labor and capital, suggest that energy use has a direct and positive effect on economic activity. In contrast, demand-side studies that model energy use in terms of economic activity and prices, assume a direct impact from economic activity to energy consumption. Thus, economic theory does not identify a unique direction for the relationship between energy consumption and economic growth. As such, Ozturk (2010) and Apergis and Payne (2011) organize the energy–growth nexus in terms of four alternative hypotheses: (a) the 'neutrality hypothesis' which suggests no causal relations between the two variables; (b) the 'conservation hypothesis' which based on the demand-side approach, assumes unidirectional causality from economic growth to energy consumption; (c) the 'growth hypothesis' which based on the production approach, assumes unidirectional causality from energy consumption to economic growth; and (d) the 'feedback hypothesis' which suggests bidirectional causality between energy use and economic activity.

Second, the direction of causality between energy use and output has important policy implications. Under the neutrality and conservation hypotheses, changes in energy policies have no significant effects on economic growth. In contrast, energy serves as a limiting factor under the growth hypothesis, and policies designed to curtail energy consumption will have an adverse effect on economic growth. Finally, the feedback hypothesis implies that energy conservation polices will affect economic growth, which in turn affect energy consumption.

Third, available empirical evidence on energy consumption–growth relation is inconclusive, and the findings are sensitive to the sample period, econometric methodology, data structure and sample of countries under investigation. As Ozturk (2010) points out, "… the literature produces conflicting results and there is no consensus neither on the existence nor on the direction of causality between energy consumption and economic growth." Using their empirical methods, Mehrara (2007) organizes the sequence of previous literature into four generations: The first-generation of studies assumes stationary data and relies on traditional VAR and Granger's causality tests (e.g. Abosedra and Baghestani, 1989; Erol and Yu, 1987; Kraft and Kraft, 1978; Yu and Wang, 1984). The second-generation assumes non-stationary variables and examines the potential long-run relation and its short-run dynamics using Granger's (1988) two-step cointegration procedure and its

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corresponding error correction model (e.g. Cheng and Lai, 1997; Glasure and Lee, 1997; Nachane et al., 1988). The third-generation uses Johansen's (1991) maximum likelihood procedure (e.g. Ghosh, 2002; Ho and Siu, 2007; Lee and Chang, 2005; Soytas and Sari, 2007); and the fourth-generation applies recent advances in panel cointegration and error correction techniques (e.g. Ciarreta and Zarraga, 2010; Lee, 2005; Lee and Chang, 2008; Narayan and Smyth, 2008; Sadorsky, 2011).

Fourth, the relation between energy consumption and economic activity in oil-exporting countries merits further investigation for at least four reasons: First, energy consumption in many of these countries has historically enjoyed generous government price subsidies, thus raising the possibility of over-consumption and resource misallocation. Second, the availability of cheap energy has downplayed the need for energy conservation (Al-Iriani, 2006; Narayan and Smyth, 2009). As such, many of these countries have witnessed sharp increases in their carbon dioxide emissions. Third, many of these countries rely on oil exports and foreign exchange earnings to finance government budget as well as large infrastructural and development projects. Thus, changes in world oil prices have major consequences for their foreign exchange earnings and growth prospects.

A limited body of literature has examined the relation between energy consumption and economic activity in this group of countries. However, the findings have varied depending on the choice of countries, the sample period, and the empirical method. Al-Iriani (2006) finds unidirectional causality from output to energy consumption in a sample of six countries in *Gulf Cooperation Council* (GCC) over 1970–2002. Mehrara (2007) reports similar results for a sample of 11 oil-exporting countries over 1971–2002. These findings are consistent with the view that energy conservation policies do not adversely affect economic growth. Both studies apply Pedroni's (1999, 2004) bivariate heterogeneous panel cointegration framework. In contrast, Narayan and Smyth (2009) report long-run bidirectional and short-run unidirectional causality from energy consumption to output in a sample of six Middle Eastern countries over 1974–2002. This finding suggests that energy conservation policies may adversely affect economic growth in both long- and short-run. Narayan and Smyth (2009) apply the panel cointegration test of Westerlund (2006), which allows for multiple structural breaks, and also incorporates exports as an additional variable in the multivariate framework. Sadorsky (2011) reports bi-directional long-run and short-run relations between energy consumption and output in a sample of 8 Middle Eastern countries over 1980–2007, a finding that is broadly consistent with Narayan and Smyth (2009). His study uses a multivariate heterogeneous panel cointegration framework which incorporates energy prices and trade as additional variables.

A common shortcoming in previous studies with conventional panel estimation techniques is lack of attention to the possibility of cross sectional correlations. As Andrews (2005) points out, such estimators are inefficient, and their estimated standard errors are biased. Further, their least squares estimators are biased if regressors are correlated with the source of interdependence. Therefore, taking cross-sectional dependency into account provides new insights on the debate over the relationship between energy consumption and economic growth.

This paper will re-examine the relationship between energy consumption and output in oil-exporting countries. In particular, it makes the following contributions to the literature: (1) it compiles the largest panel data set available by incorporating 14 oil-exporting countries over 1980–2007. (2) It examines the energy–growth nexus using three alternative panel estimation techniques proposed by Pesaran et al. (1999) – the dynamic fixed effect, pooled mean group, and mean-group estimators – which allow for various degrees of heterogeneity in long-run parameters and their short-run dynamics. The dynamic fixed effect allows for differences in intercepts across groups but other coefficients and error variances are assumed to be the same. The pooled mean group estimator allows heterogeneity in the intercept, short-run coefficients and error variances across groups but assumes homogeneity in the long-run coefficients. The mean-group estimator allows heterogeneity in coefficients and error variances in both short- and long-run. A potential short-coming of these procedures is that they do not account for the possibility of cross-sectional dependency. To address this issue, we also re-estimate the models by applying Pesaran's (2006) common-correlated-effects estimators. (3) A number of studies (Narayan and Smyth, 2009; Sadorsky, 2011) have argued that the two-variable specification of energy consumption–output relationship is subject to omitted variables bias, and the results may be driven by the omission of an important third variable. To address this possibility, we also estimate three-variable models which include urbanization, per capita values of CO_2 emissions or exports as additional regressors.

The remainder of the paper is structured as follows. Section 2 presents the empirical model and the econometric methods; Section 3 describes the data; Section 4 reports the empirical results; and Section 5 concludes.

2. Empirical model and econometric methods

We assume the long-run relation between economic activity and energy consumption follows a linear heterogeneous panel regression model,

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

Where Y_{it} and E_{it} are logarithms of real per capita income and per capita energy use in the ith country at time t, respectively; α_i is a country-specific intercept; d_t is a time dummy; β_i is the long-run elasticity of energy consumption with respect to income, and u_{it} is the composite error term.

Following Pesaran (2006), Moscone and Tosetti (2010); Pesaran and Tosetti (2011), we introduce cross-sectional correlation in Eq. (1) through two channels. One is through the composite error, which is assumed to follow a multifactor structure,

$$u_{it} = \delta_i' f_t + v_{it} \tag{2}$$

where f_t is the $m \times 1$ vector of m unobserved common factors; δ_i is the corresponding vector of parameters associated with the m common factors and the ith country; and v_{it} is a country-specific error. Thus, each country is allowed responding to common shocks with different degrees of intensity.

The other is the possibility of cross-sectional correlation between E_{it} and common factors as,

$$E_{it} = c_i + \theta_i' f_t + \varepsilon_{it} \tag{3}$$

where θ_i is the $m \times 1$ vector of factor loadings, and the error term ε_{it} is distributed independently of f_t and v_{it}. Thus, common factors can impact economic activity directly via the factor structure (2) as well as indirectly through energy consumption via Eq. (3).

Estimation of Eq. (1) subject to restrictions (2) and (3) can be carried out using the common correlated effects (CCE) approach proposed by Pesaran (2006). This method accounts for the unobservable factors by including cross-sectional averages of all variables as additional regressors in Eq. (1). That is,

$$Y_{it} = \alpha_i + d_t + \beta_i E_{it} + g_i' \bar{z}_t + u_{it}, \quad i = 1, \ldots N; \quad t = 1, \ldots, T; \tag{4}$$

where $\bar{z}_t = \left(\bar{Y}_t, \bar{E}_t\right)'$. The CCE estimator for the ith country's slope coefficient, proposed by Pesaran (2006) is,

$$\hat{\beta}_{CCE,i} = \left(E_i' \overline{M} E_i\right)^{-1} E_i' \overline{M} Y_i \tag{5}$$

with $\overline{M} = I_T - \overline{H}\left(\overline{H}'\overline{H}\right)^{-1}\overline{H}'$, and $\overline{H} = (\tau, \overline{Z})$, where $\tau = (1, \ldots, 1)'$ and $\overline{Z}$ is