The Long-term Impacts of Energy Prices on Economic Growth

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(1) Overview

The research interest of growth economists has never been substantial on the impact of (rising) energy prices, as perhaps it has been perceived as a short to medium run issue. In accordance with this argument, a plethora of empirical literature, since the pioneering study of Hamilton (1983), on the short-term or mid-term interactions between energy, especially oil, prices and macroeconomic indicators has suggested that the impact would rather be temporary. Yet, the stylized facts on US data for the period 1951–2010 points out that the growth rate of energy prices would have a negative effect on energy demand growth and GDP growth. We, for this purpose, have studied a stylized economy, in which energy price-economic growth nexus is developed and tested.

In the theoretical part of the paper, we develop a two-sector market economy à la Rebelo (1991). In our setup the investment goods sector, the source of endogenous growth in the economy, uses only physical capital while the consumption goods sector uses energy and capital as inputs. The reasoning behind this setup is that consumption goods sector has been responsible for the majority of energy consumption. In 2009, for example, energy consumption in transportation and residential sectors constituted 51.7% of 8.35 billion toe of total consumed energy worldwide (Birol, 2010). Our model, further, presumes that the price of energy, without considering the nature of it, i.e., whether it is renewable or non-renewable, is growing at a constant rate and that it is exogenously given à la van Zon and Yetkiner (2003). While van Zon and Yetkiner (2003), considering a three-sector model, have already shown the negative impact of rising energy price on economic growth, in their paper they have included energy as an input in the intermediate goods sector. Thus, our study complements van Zon and Yetkiner (2003) by using energy in consumption goods sector.

The relationships derived in the theoretical part have, then, been tested empirically by using error-correction based panel cointegration test and panel Autoregressive Distributed Lag (ARDL hereafter) estimation for group of countries, consisted of Australia, Austria, Belgium, Canada, Denmark, France, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, United Kingdom and United States. The data on real GDP per capita, energy consumption per capita and composite energy prices covers the period from 1978 to 2011.

(2) Methods

The theoretical model developed in this article is based on a closed economy with no government. We define overall utility of the representative consumer in the economy as $U(C_t) = \int_0^\infty e^{-\rho \cdot t} \cdot u(C_t)dt$, where felicity function is $u(C) = \frac{C^{1-\theta}-1}{1-\theta}$. We presume that there are two types factors of production in the model: broader interpretation of physical capital, K, and energy, E. We, further, presume that there are also two sectors in the economy, namely investment goods sector and consumption goods sector. Following Rebelo (1991), we define production technology of the investment goods sector as follows:

$$Y_I = A \cdot K_I \tag{1}$$

In (1), Y_I represents output in investment good sector, A is overall factor productivity, and K_I, a flow variable, is broader interpretation of physical capital used in investment good production. Consumption good is produced via flow variables physical capital (K_C) and energy (E) under constant returns to scale production technology defined as:

$$Y_C (\equiv C) = K_C^{\alpha} \cdot E^{1-\alpha} \tag{2}$$

We assume that total physical capital stock $K = K_I + K_C$ is fully employed. Theoretical part of this paper is based on solving the above described general equilibrium model. As stated above derived theoretical relationships have then been tested empirically by using error correction based panel cointegration test (Eq. 3) following Westerlund (2007):

$$\Delta y_{i,t} = \delta'_i d_t + \alpha_i y_{i,t-1} + \lambda'_i x_{i,t-1} + \sum_{j=1}^{p_i} \alpha_{i,j} \Delta y_{i,t-j} + \sum_{j=-q_i}^{p_i} \gamma_{i,j} \Delta x_{i,t-j} + \varepsilon_{i,t} \tag{3}$$

where, $y_{i,t}$ is dependent variable, which in our case is either $\ln(gdp)$ or $\ln(ec)$ and $x_{i,t}$ is the independent variable, which is $\ln(q)$ for our application, for country i at time t. Moreover, while d_t represents the deterministic components, λ_i is defined as $-\alpha_i \beta'_i$ with α_i capturing the seed at which the system $y_{i,t-1} - \beta'_i x_{i,t-1}$ adjusts back to the equilibrium after an unexpected shock. Therefore, if $\alpha_i < 0$ model implies a cointegration between variables and thus the null hypothesis tested is $H_0: \alpha_i = 0$ for all i. We moreover employed panel ARDL methodology (Eq. 4 and 4) following Pesaran et al. (1999) to estimate long-term effects of energy prices on GDP and energy consumption:

$$y_{it} = \lambda_i y_{it-1}\mu_i + \delta_{10i}x_{it} + \delta_{11i}x_{it-1} + \delta_{20i}t + \varepsilon_{it} \quad (4)$$

and the error-correction parameterization as:

$$\Delta y_{it} = \phi_i(y_{it-1} - \theta_{0i} - \theta_{1i}x_{it} - \theta_{2i}t) + \delta_{11i}\Delta x_{it} + \varepsilon_{it} \quad (4')$$

where; $\phi_i = -(1-\lambda_i)$ is the error-correction term (ECT) speed of adjustment, $\theta_{0i} = \frac{\mu_i}{1-\lambda_i}$ is the non-zero mean of cointegration relationship, $\theta_{2i} = \frac{\delta_{20i}}{1-\lambda_i}$ and $\theta_{1i} = \frac{\delta_{10i}+\delta_{11i}}{1-\lambda_i}$ is the coefficient of interest, i.e. long-run estimates of elasticity.

(3) Results

The resulting steady-state equilibrium derived in the theoretical part for each variable under consideration is as follows: $\hat{E} = \frac{1}{\theta}\left(A - \delta - \rho - \frac{(1-\alpha+\alpha\theta)}{\alpha}\hat{q}\right) \equiv g'$, $\hat{K}_C = \frac{1}{\theta}\left(A - \delta - \rho - \frac{(1-\alpha)(1-\theta)}{\alpha}\hat{q}\right) \equiv g$ and $\hat{Y}_C = \frac{1}{\theta}\left(A - \delta - \rho - \frac{(1-\alpha)}{\alpha}\hat{q}\right) \equiv \alpha g + (1-\alpha)g'$, which in summary state that energy price growth $\hat{q}$ has negative impact on energy consumption growth, $\hat{E}$, capital growth, $\hat{K}_C$, and total output growth, $\hat{Y}_C$.

Table 1. Panel Cointegration Test Results

Relationship Tested	G_τ	G_α	P_τ	P_α
$\ln(gdp)$ vs. $\ln(q)$	-2.753**	-29.554***	-9.871**	-24.351***
$\ln(ec)$ vs. $\ln(q)$	-3.488***	-26.337***	-12.562***	-22.376***

Notes: ***, **, * represent significance at 1%, 5%, 10% levels, respectively. Optimal lag and lead lengths selected via AIC are both 1 and optimal Bartlett kernel window width is set to be 3.

Table 2. Panel ARDL(1,1) Model – Long Run and ECT Estimates

	$\ln(gdp)$		$\ln(ec)$	
	MG	PMG	MG	PMG
Long-Run Estimates				
$\ln(q)$	-0.4488***	-0.5120***	-0.4779***	-0.6477***
	(0.0944)	(0.1080)	(0.0986)	(0.0590)
t	0.0188***	0.0109***	0.0068***	0.0026***
	(0.0031)	(0.0016)	(0.0018)	(0.0008)
ECT	-0.1932***	-0.0750***	-0.4850***	-0.1640***
	(0.0327)	(0.0125)	(0.0577)	(0.0357)

Notes: Figures in parenthesis are standard errors. ***, **, * represent significance at 1%, 5%, 10% levels, respectively.

Empirical results provided on Tables 1 and 2, moreover, reveal that energy prices have significant cointegration relationship with real GDP per capita as well as with energy consumption per capita. Moreover, we have found that the energy prices have negative and significant long-run effect on both variables. The results support the derived theoretical relationships not only of this article but also of van Zon and Yetkiner (2003).

(4) Conclusions

In this paper we have presented a two-sector endogenous growth model, following Rebelo (1991). Including energy as an input in consumption good sector we have shown that the endogenous growth rate of both output and energy consumption depends negatively on the rate of growth of energy price. These findings are consistent with the very same argument proposed by van Zon and Yetkiner (2003), who have studied a three-sector model by identifying energy as an input in the intermediate good sector.

We have tested the theoretical relationships that has been derived by employing error-correction based panel cointegration and panel ARDL methodologies and found out that energy prices have negative and significant impact on both real GDP per capita and energy consumption per capita in the long-run. Thus, the empirical regularity represented here supports the theoretical findings not only of this article but also of van Zon and Yetkiner (2003).

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