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Energy Cost, Energy Risk and Japanese Technical Changes

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Abstract

This study assumes the existence of a short-run energy cost-driven technical application mechanism and a long-run energy risk-driven technical progress mechanism. Using the Japanese monthly data from 1988 to 2010, we perform Granger causality tests on the four time series, namely energy price, import volume of crude oil, geographical dispersion of oil imports, as well as real industrial output. The results show that for a country with tight energy constraint, energy price shocks may trigger the both mechanisms of technical application and technical progress, which facilitate the short-run and the long-run economic growth separately. Moreover, we find that the geographical dispersion of oil imports is mainly employed as a tool to control the risk of import volume, instead of energy price uncertainties.

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1. Introduction

Petroleum products have constituted a considerably large proportion of total energy consumption. As a result, the oil prices have been exerting crucial influences on the price changes of the other forms of primary energies. What is noteworthy, however, is that the increasing crude oil prices may have different effects upon the energy-abundant countries and the energy-poor countries.

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Energy-abundant countries may directly benefit from the rising energy prices, with extra oil export incomes booming their short-run GDP growth. However, the bad news is that the easy oil export revenues may effectively hurt the incentives for technological progress in a developing country, leading up to a low-productivity specialization trap [1] or the curse of natural resources [2]-[3] in the long-run; Energy-poor countries, especially the industrialized oil importing countries, often suffer from the increasing energy prices which imply higher costs. The soaring energy costs may shift the aggregate supply curve leftward and therefore generate higher prices and lower production outputs [4]-[5]. However, when there is an extremely tight energy supply constraint, the profit maximizing private firms may have more incentives to control their energy costs by means of technological and operational innovation[6], which will lead up to an endogenous cost-driven technological progress [7]-[9].

This study goes beyond the theory of energy cost-driven technical change by two related assumptions:

- The first is that a rising energy cost makes more previously expensive energy technologies applicable. This energy cost-driven technical application mechanism may offset the increasing energy cost and lead up to a short-run economic growth;
- The second is that the incentive of energy risk (measured by the geographical dispersion of crude oil imports) avoidance drives firms to make more investment in energy R&D. This energy risk-driven which may facilitate technical change and exert positive effects on long-run economic growth.

The rest of this paper is organized as follows: In section 2 we develop a basic model which contains energy imports for further econometric analysis; in section 3 we perform Johansen co-integration test as well as short-run and long-run Granger tests; concluding remarks are made in section 4.

2. Model and Data

2.1. Revenue Function

Consider a Cobb-Douglas production function:

$$Y = AL^{\alpha} K^{\beta} E^{\gamma} \tag{1}$$

where Y is the production output, L stands for labor input and K for capital input, and E is the consumption of energies; α, β and γ are the coefficients of output elasticity of L, K and E respectively; A is total factor productivity that captures the contribution of other factors, which is usually acknowledged as technological level and institutional quality of the economy [10]. At steady state, where both labor input and capital input keep constant. Let $a_0=L^{\alpha}K^{\beta}$, the production function becomes

$$Y = a_0 AE^{\gamma} \tag{2}$$

In perfect competition, there is a horizontal demand curve which implies that Y is also the revenue function when price is normalized to unity.

2.2. Cost Function

Assuming that the non-linear energy cost function is in the Cobb-Douglas form of

$$C = A^{a} P^{b} E^{c} H^{d} \tag{3}$$

where P is the energy price and H is a measurement of energy risk. The coefficients of a, b, c and d are the energy cost elasticity of the four determinants. In this study, we use Herfindahl-Hirschman-Gini coefficient of the geographical dispersion of oil imports to capture this energy risk:

$$H = \sum_{k=1}^{n} \left(\frac{M_k}{\sum_{k=1}^{n} M_k}\right)^2 \tag{4}$$

where M is oil import volume and k stands for the k-th country. A higher H implies that the oil imports are more concentrated and more risky. When assuming there is second-degree price discrimination in the world oil market, a reduction of H can diversify the risk but may generate additional transaction cost.

2.3. Equilibrium

Assume that a representative firm chooses the optimal energy consumption E to maximize the profit

$$\pi = Y - C = a_0 A E^{\gamma} - A^a P^b E^c H^d \tag{5}$$

The first-order condition gives

$$\frac{d\pi}{dE} = \gamma a_0 A E^{\gamma-1} - c A^a P^b E^{c-1} H^d = 0 \tag{6}$$

$$\gamma a_0 A E^{\gamma-1} = c A^a P^b E^{c-1} H^d \tag{7}$$

Multiplying each side of the equation by Q_t, we can derive the function at production equilibrium

$$Y = A E^{\gamma} = \frac{c}{a_0 \gamma} A^a P^b E^c H^d \tag{8}$$

By taking natural logarithm of equation and by introducing time notion t to our model (4), we have

$$\ln Y_t = \ln\left(\frac{ac}{a_0 \gamma}\right) + b \ln P_t + c \ln E_t + d \ln H_t + \mu_t \tag{9}$$

Because it is difficult to directly measure the technology, we take the part of $\ln A_t$ as in the residual μ.

2.4. Data

We employ the Japanese monthly data ranging from 1988.01 to 2010.12 to perform the time series analysis. Data of seasonal adjusted industrial production Y is compiled from IFS database with the series code of "15866...CZF...". Crude oil import price and volume are employed to capture the dynamics of the Japanese energy price and energy consumption, which are compiled form Trade Statistics of Japan Ministry of Finance (http://www.customs.go.jp/toukei/srch/indexe.htm).

Specifically, we obtain the monthly data of crude oil (HS code 2709) import quantity and amount from each country in each month. Firstly, we take the total crude oil import quantity as the proxy for the Japanese energy consumption; secondly, by dividing the total import amount by total quantity, we have the Japanese crude oil import price (in Yen/Kl); thirdly, we calculate Herfindahl-Hirschman-Gini coefficient of the geographical dispersion of Japanese oil imports.

3. Granger Causality Test

3.1. Vector Error Correction Model

The unreported ADF unit root tests show that all the variables are I(1) series and Johansen cointegration test indicates that the series are cointegrated. The optimal model contains neither intercept nor linear trend, with 3 lags. Therefore we have the optimal vector error correction model (VECM) in the form of

$$\Delta x_t = \Gamma_0 \cdot e_{t-1} + \Gamma_1 \cdot \Delta x_{t-1} + \Gamma_2 \cdot \Delta x_{t-2} \tag{7}$$

x_t=(Y_t, P_t, E_t, H_t,) and Γ_0, Γ_1, Γ_2 are the coefficient matrix. e_{t-1} stands for the error correction term which is the residual of the cointegration equation.

3.2. Short-run and Long-run Granger Causality Tests

We employ the VECM to perform both short-run and long-run Granger causality tests. The short-run effect is judged by the signs of the coefficients while the long-run effect is measured by the 24th period values of the impulse-response functions (LE). The results are reported in table 1.

Table 1. VECM based Granger causality test results

Independent variables	Short-run effects				Long-run effects							
	$\Delta\ln Y_t$	$\Delta\ln P_t$	$\Delta\ln Q_t$	$\Delta\ln H_t$	$\Delta\ln Y_t$	LE	$\Delta\ln P_t$	LE	$\Delta\ln Q_t$	LE	$\Delta\ln H_t$	LE
e_{t-1}	——	——	——	——	8.743 (0.003)	——	3.407 (0.067)	——	16.867 (0.000)	——	27.864 (0.000)	——
$\Delta\ln Y_{t-1}$, $\Delta\ln Y_{t-2}$	——	3.660 (0.160)	1.889 (0.389)	6.379 (0.041)	——	——	3.054 (0.029)	0.041	5.894 (0.001)	-0.001	12.442 (0.000)	-0.001
$\Delta\ln P_{t-1}$, $\Delta\ln P_{t-2}$	36.253 (0.000)	——	8.182 (0.017)	1.308 (0.520)	12.783 (0.000)	0.010	——	——	6.745 (0.000)	-0.005	9.653 (0.000)	0.013
$\Delta\ln Q_{t-1}$, $\Delta\ln Q_{t-2}$	4.110 (0.128)	7.130 (0.028)	——	30.057 (0.000)	4.462 (0.005)	-0.009	2.428 (0.066)	-0.027	——	——	11.984 (0.000)	0.021
$\Delta\ln H_{t-1}$, $\Delta\ln H_{t-2}$	3.507 (0.173)	2.841 (0.242)	10.380 (0.006)	——	3.215 (0.023)	0.009	2.230 (0.085)	0.028	6.555 (0.000)	0.014	——	——

Note: The first column from the left presents the independent variables to be tested, and the second line from the top lists the independent variables. For long-run Granger causality, we conduct Wald restriction test on 1) the error correction term e_{t-1}; and 2) the joint of e_{t-1} and the lagged first-differences of each independent variable. F-statistics are reported in the table with probabilities in the parentheses.

Conclusion

Short-run Granger causality tests reveal the following major results:

- $\Delta\ln P_t$ positively Granger causes $\Delta\ln Y_t$, indicating that a rising oil price facilitates the application of energy saving technologies to boom Japanese economy, which is the evidence of technical application mechanism.
- $\Delta\ln Y_t$ has negative effects on $\Delta\ln H_t$, showing Japan tends to diversify its oil imports to guarantee its energy safety when the economy is stable, and emphasizes to control the diversification cost at recession.

Long-run Granger causality tests show further thoughtful evidences:

- Both $\Delta\ln P_t$ and $\Delta\ln Q_t$ exert positive effects upon $\Delta\ln Y_t$ in the long-run, which suggest the existence of an energy-cost-driven and an energy-risk-driven technical change mechanism.
- $\Delta\ln H_t$ positively Granger causes both $\Delta\ln P_t$ and $\Delta\ln Q_t$, suggesting that a more concentrated oil imports makes the Japanese firms to afford higher prices and thus import more crude oil.
- $\Delta\ln P_t$ has positive effects on $\Delta\ln H_t$, showing that the Japanese firms are forced to give up energy security considerations when prices are high; on the other hand, $\Delta\ln Q_t$ exerts negative long-run effects on $\Delta\ln H_t$, implying that the oil import diversification strategy aims at controlling the risk of volume in the long-run.

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