Crude Oil Consumption and Economic Growth: Empirical Evidence from Japan

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ABSTRACT

This article establishes a long-run equilibrium relationship among quantity of crude oil import, price of the imported crude and income in Japan for the time span 1992:Q1 to 2006:Q4 employing autoregressive distributed lag (ARDL) bounds testing approach of cointegration. Empirical results show that (1) the long term price elasticity and income elasticity of imported crude oil in Japan is -0.08 and 1.35, respectively and (2) the existence of long-run causality running from economic growth and price to crude oil import. These indicate that the reduction of crude oil demanded will not affect the future economic growth and price in Japan in the long-run.

Keywords: Crude oil, GDP, Price, ARDL, Granger Causality

Introduction

With around USD 4.5 trillion of nominal GDP, Japan is the second largest economy in the world, after the United States. As of 2005, half of the energy in Japan is produced from petroleum, a fifth from coal, and 14% from natural gas. As the third largest oil consumer in the world after United States and China, Japan import 100% of its crude oil requirement and mainly are from the Middle East. The history of imported demand for crude oil consumption started in 1960, whereby the structure of energy demand and supply has changed drastically in Japan when the government allowed imported oil to compete with domestic coal as a prime source of energy. During that time, the Japanese coal was more expensive compared to Europe and United States. After some years, this situation changed drastically because of the abundant supply of low price crude oil from Middle East. Therefore, the consumers and Japanese industry could enjoy an inexpensive supply of energy.

Table 1 shows the Japanese crude oil import data in kilolitre. From the table, we can see that the top 5 imported crude oil countries are from the Middle East which contributed to almost 82% from the overall quantity imported. This indicates that Japan's dependence of imported crude oil from the Middle East countries has little change until today. The first oil crisis in 1973, had a serious impact on the Japanese economy and society. A rapid increase in the commodity price caused substantially economic confusion and a panic-like atmosphere prevailed in some places. The second oil crisis in 1978, also had a substantial impact on the Japanese economy but the response of the public were much more rational because of the previous experience. From these two scenarios, it's clearly show that there is a strong relationship between crude oil price, quantity demanded and Japan economic growth.

Hence, this article tries to investigate the relationship amongst the demand for imported crude oil, gross domestic product (GDP), as a proxy of economic activity and the price of the imported crude oil in Japan by using autoregressive distributed lag (ARDL) bounds testing approach of cointegration proposed by Pesaran *et al.* (2001). The short- and long-run income and price elasticities obtain from this model will reveal the responsiveness of import demand for crude oil due to the change in income and price. This study also attempts to establish Granger causality among these variables, which has important policy implications. For example, there is unidirectional Granger causality running from crude import to economic growth,

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reducing crude import could lead to a fall in national income. On the other hand, presence of unidirectional Granger causality running from economic growth to crude import means that reducing crude oil import would not affect the economic growth.

Table 1: Japanese crude oil import data in kilolitre (2008)

	2008	Change from 2007
Overall	242,948,719	1.80%
Saudi Arabia	67,587,589	5.40%
UAE	58,003,400	-0.90%
Iran	28,771,314	-0.70%
Qatar	26,305,133	6.30%
Kuwait	18,524,681	7.50%
Russia	8,170,320	-2.60%
Indonesia	7,767,923	7.90%
Sudan	5,754,433	-3.50%
Oman	5,119,380	0.50%
Neutral Zone	3,888,729	-20.60%
Vietnam	3,562,560	73.90%
Australia	2,840,480	21.00%
Iraq	2,495,466	1.30%
Malaysia	838,192	-24.50%
Yemen	702,070	-20.10%
Gabon	623,462	149.50%
China	605,785	136.90%
Brunei	486,590	-45.90%
Chad	295,995	5.80%
Nigeria	169,657	-70.20%
Algeria	158,502	NA
Guinea	150,797	-86.10%
Ecuador	70,175	-44.80%
Thailand	56,086	67.20%

Source: METI Preliminary Monthly Oil Statistics[1]

Krichene (2002) investigates the world markets for crude oil and natural gas from 1918 to 1999. He reveals that demand price elasticities and supply price elasticities are too low, but income elasticities are high. These elasticities will help to explain the market power of the oil producers and the price volatility in response to shock. Alves *et al*. (2003) extend previous studies by estimating the cross price elasticity between gasoline and alcohol. They show that alcohol is an imperfect substitute for gasoline even in the long-run. Hence, the need for a new fuel substitution must be initiated long before petroleum reserves vanish.

1 available online at http://www.meti.go.jp

Altinay (2007) estimates the short-run and the long-run elasticities of demand for crude oil in Turkey from 1980 to 2005. There is a long-run cointegration relationship exists between the crude oil import, nominal price and income. The findings also show that the income and price elasticities of import demand for crude oil are inelastic both in the short-run and in the long-run. Nicholas (2009) studies the intertemporal causal relationship between economic growth and energy consumption in Tanzania during 1971- 2006. He finds a stable long-run relationship between energy consumption and economic growth Based on the causality test, there is a unidirectional causal running from total energy consumption to economic growth.

Narayan and Smyth (2007) apply univariate and panel data unit root tests to examine the stationarity properties of per capita energy consumption for 182 countries over the period 1979 to 2000. The univariate unit root test can only reject the unit root null for 56 countries of the sample at the 10% level or better. They find overwhelming evidence that energy consumption is stationary when they employed the panel data unit root test. Another article written by Narayan and Smyth (2007) is used the panel unit root and panel cointegration to estimate the long-run income and price elasticities for oil in the Middle East. The results for the panel reveal that demand for oil is highly price inelastic and slightly income elastic in the Middle East. As a conclusion, the demand for oil in the Middle East is being driven largely by strong economic growth, while consumers are largely insensitive to price changes.

Data and Methodology

Data Description

Quarterly data on quantity and price of imported crude oil (in kilolitre and yen/kilolitre, respectively) have been collected from the Ministry of Finance of Japan from 1992 to 2006. Real GDP (in billion yen) data for the same period has been collected from the International Financial Statistics CD-ROM 2007. Let *Limp, Lrgdp* and *Lpri* represent the crude oil import, real GDP and price of crude oil, respectively, after their logarithmic transformation.

Cointegration

ARDL bounds testing approach has been employed to examine long-run equilibrium relationship among the variables. An ARDL model is a general dynamic specification, which uses the lags of the dependent variable and the lagged of independent variables, through which the short-run effects can be directly estimated, and the long-run equilibrium relationship can be indirectly estimated. ARDL technique involves estimating the following unrestricted error correction model:

$$\Delta Limp_t = \gamma_0 + \sum_{i=1}^{\rho} \gamma_1 \Delta Limp_{t-i} + \sum_{i=1}^{\rho} \gamma_2 \Delta Lrgdp_{t-i} + \sum_{i=1}^{\rho} \gamma_3 \Delta Lpri_{t-i} + \lambda_1 Limp_{t-1} + \lambda_2 Lrgdp_{t-1} + \lambda_3 Lpri_{t-1} + \varepsilon_{1t} \quad (1)$$

$$\Delta Lrgdp_t = \xi_0 + \sum_{i=1}^{\rho} \xi_1 \Delta Lrgdp_{t-i} + \sum_{i=1}^{\rho} \xi_2 \Delta Limp_{t-i} + \sum_{i=1}^{\rho} \xi_3 \Delta Lpri_{t-i} + \psi_1 Lrgdp_{t-1} + \psi_2 Limp_{t-1} + \psi_3 Lpri_{t-1} + \varepsilon_{2t} \quad (2)$$

$$\Delta Lpri_t = \theta_0 + \sum_{i=1}^{\rho} \theta_1 \Delta Lpri_{t-i} + \sum_{i=1}^{\rho} \theta_2 \Delta Limp_{t-i} + \sum_{i=1}^{\rho} \theta_3 \Delta Lrgdp_{t-i} + \varpi_1 Lpri_{t-1} + \varpi_2 Limp_{t-1} + \varpi_3 Lrgdp_{t-1} + \varepsilon_{3t} \quad (3)$$

where is the first difference operator.

There are several advantages of ARDL approach over alternative such as Johansen and Juselius (1990) procedure. Here, it is not pre-requisite to examine the non-stationarity property and order of integration of the variables. This procedure can be employed regardless of whether the underlying variables are integrated of order zero i.e. *I*(0), integrated of order one i.e. *I*(1) or fractionally integrated. *F*-test is used to examine whether a cointegrating relationship exists among the variables.

The null hypothesis of no cointegration among the variables in Eq. (1) is H_0: $\lambda_1 = \lambda_2 = \lambda_3 = 0$ against H_1: $\lambda_1 \neq \lambda_2 \neq \lambda_3 \neq 0$, which is denoted as F_{Limp} (*Limp|Lrgdp,Lpri*) and so on. The *F*-test has (a) non-standard distribution which depends upon whether variables included in the ARDL model are *I*(0) or *I*(1); (b) the number of regressors; (c) whether the ARDL model contains an intercept and/or a trend; and (d) the sample size. Two sets of critical *F*-values have been provided by Pesaran *et al*. (2001) for large samples and by Narayan (2005) for sample size ranging from 30 to 80, where one set assuming that all variables in ARDL model are *I*(1) and another assuming that all variables are *I*(0) in nature. If computed *F*-statistics falls outside the band, a conclusive decision can be taken without needing to know whether the underline variables are *I*(0) or *I*(1). Inference remains inconclusive if the computed *F*-statistics falls within the critical band. Under such situations, one should check the order of integration of the concerned variables followed by Johansen and Juselius (1990) procedures to detect cointegration.

Apart from the advantages of ARDL as mentioned earlier, over other cointegration procedures, this study particularly prefers ARDL model because of two major reasons; (1) bounds test produces robust results in a small sample size (Pesaran and Shin, 1999) and (2) empirical studies have established that energy market-related variables are either *I*(1) or *I*(0) in nature (Narayan and Smith, 2007a,b), justifying the application of ARDL model in energy market analysis.

Granger causality

Engle and Granger (1987) showed that if the series X and Y (for example) are individually *I*(1) and cointegrated then there would be a causal relationship at least in one direction. However, the direction of causality can be detected through the Vector Error Correction model (VECM) of long-run cointegrating vectors. Granger causality test is a convenient approach for detecting causal relationship between two or more variables. A time series (Y) is said to Granger-cause another time series (X) if the prediction error of current X decline by using past values of Y in addition to past values of X. In our case, tests for Granger causality can be done through following equations"

$$\Delta Limp_t = \varphi_0 + \sum_{i=1}^{\rho} \varphi_1 \Delta Limp_{t-i} + \sum_{i=1}^{\rho} \varphi_2 \Delta Lrgdp_{t-i} + \sum_{i=1}^{\rho} \varphi_3 \Delta Lpri_{t-i} + \varphi_4 \varepsilon_{t-1} + \mu_{1t} \quad (4)$$

$$\Delta Lrgdp_t = \beta_0 + \sum_{i=1}^{\rho} \beta_1 \Delta Limp_{t-i} + \sum_{i=1}^{\rho} \beta_2 \Delta Lrgdp_{t-i} + \sum_{i=1}^{\rho} \beta_3 \Delta Lpri_{t-i} + \beta_4 \varepsilon_{t-1} + \mu_{2t} \quad (5)$$

$$\Delta Lpri_t = \delta_0 + \sum_{i=1}^{\rho} \delta_1 \Delta Lpri_{t-i} + \sum_{i=1}^{\rho} \delta_2 \Delta Lrgdp_{t-i} + \sum_{i=1}^{\rho} \delta_3 \Delta Limp_{t-i} + \delta_4 \varepsilon_{t-1} + \mu_{3t} \quad (6)$$

where φ's, β's and δ's are parameters to be estimated, μ_t's are the serially uncorrelated error terms and ε_{t-1} is the error correction (ecm_{t-1}). The coefficient of the ecm_{t-1} indicates the speed of adjustments and the significance of the long-run causal effect.

Empirical results

The results of the bound test for cointegration, are reported in Table 2. The result indicates that cointegration is only present when *Limp* is the dependent variable. This is because F_{Limp} (*Limp|Lrgdp,Lpri*) is higher than the upper bound critical value at the 5% critical value. However, the bounds test indicates that when *Lrgdp* and *Lpri* are the dependent variable F_{Lrgdp} (*Lrgdp|Limp,Lpri*) and F_{Lpri} (*Lpri|Limp,Lrgdp*) are lower than lower bound critical value at the 5% level. Hence, there is no cointegration relationship when these variables are treated as the dependent variable. As conclusion, there is only one cointegrating relationship when *Limp* has been treated as a dependent variable.

Table 2: Bounds tests for cointegration

F-statistics	5% critical value bounds	
	I(0) 3.288	I(1) 4.070
F_{Limp} (Limp|Lrgdp,Lpri) = 4.5918^{V}		
F_{Lgdp} (Lrgdp|Limp,Lpri) = 1.2798		
F_{Lpri} (Lpri|Limp,Lrgdp) = 1.0807		

Notes: Critical values for the bounds test: Case II: restricted intercept and no trend with k = 2 and n = 60. Superscript V denotes significant at 5% level.

Once a long term relationship has been identified, in the next step, a further two-step procedure is carried out. In the first step, the optimal order of lags in the model are selected based on Schwarz-Bayesian criterion (SBC) and/or Akaike information criterion (AIC) as suggested by Pesaran *et al.* (2001) and in the second step, the selected model is estimated through ordinary least square (OLS) technique,

It has been found that optimum lag length is 3 on the basis of Akaike criterion. Estimated long-run coefficients along with the standard errors and acceptance probabilities, based on ARDL (3,2,2) model, is shown in table 3. Long-run price elasticity appears to be -0.08 with correct (negative) sign and significant at 1% level. It shows that 1% increase in the crude oil price only affect quantity demanded drop by 0.08%. Since crude oil is essential in manufacturing industries, we still need the crude oil even though the price increased. Long-run income elasticity is 1.35 and statistically significant at 5%. It means that 1% increase in real GDP, we need 1.35% increase in crude oil import. Short-run price and income elasticities estimated by the error correction representation of ARDL (3,2,2) model also appear to be statistically significant at least 5%. For the diagnostic tests, which includes testing for serial correlation, normality of the residuals, miss-specification of functional form and heteroscedasticity, did not find any significant evidence of departures from standard assumptions.

Table 3: Estimated long-run coefficient along with standard errors and acceptance probabilities based on ARDL (3,2,2) model

Dependent Variable: Limp			
Regressor	Coefficient	Standard error	Probability
Lrgdp	1.3509^{V}	0.6542	0.044
Lpri	-0.0841^{I}	0.0236	0.001
Constant	27.0564	18.8945	0.159

Note: Superscripts I and V denote significant at 1% and 5% levels, respectively.

Results of the short-run elasticities and long-run Granger causality tests are shown in Table 4. Beginning with the short-run effect, there are two regressors in crude import equation are found to be statistically significant at 5% for Δ*Lrgdp* and 5% for Δ*Limp*, respectively. This indicates that the absence of short-run causality from the Δ*Lrgdp* and Δ*Lpri* to Δ*Limp.* Turning to the long-run causality result, the coefficient of the ecm_{t-1} in Δ*Limp* equation is statistically significant at 1% level with correct sign implying that the series in non-explosive and long-run equilibrium is attainable. The ecm_{t-1} also measures the speed of adjustment at which the endogenous variable adjusts to change in the explanatory variables before converging to its equilibrium level, the coefficient of -0.91 suggests that convergence to equilibrium after a shock in quantity in crude import takes slightly one-quarter. As a conclusion, long-run price and income elasticities are found to be smaller than the short-run elasticities.

Table 4: Estimated error-correction based on ARDL (3,2,2) model

Dependent variable	C	Δ *Limp*	Δ *Lrgdp*	Δ *Lpri*	ecm_{t-1}
Δ *Limp*	-24.7173	0.3200^{V}	1.7818^{V}	-0.0617	-0.9136^{I}
	(18.9255)	(0.1582)	(0.8421)	(0.0671)	(0.2360)

Notes: Figures in parenthesis are standard error. Superscripts I and V denote statistically significant at 1% and 5% levels, respectively.

Finally, the stability in the coefficients of the estimated model is checked by using the cumulative sum of square (CUSUMSQ) stability test that employ recursive residuals. The plots of CUSUMSQ statistics, presented in Figure 1 is within the 95% critical bounds, indicating that all coefficients in the estimated ECM model are stable over the sample period.

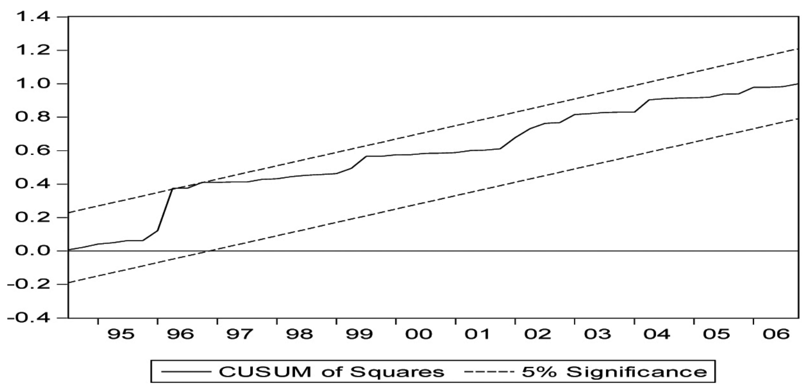

Figure 1: Plots of CUSUMSQ for the estimated ECM model

Conclusion

This study investigates a long-run equilibrium relationship among income, quantity and price of the imported crude oil in Japan for the time span from 1992 to 2006 (quarterly) using autoregressive distributed lag (ARDL) bounds testing approach of cointegration. Empirical results show that the long term income elasticity of imported crude oil quantity and price in Japan is 1.35 and -0.08, respectively. Results of short-run elasticities show that income elasticity and price elasticity in Japan is 1.78 and -0.06. As a comparison, short-run elasticity for both independent variables is higher than long-run elasticity. The significance of ecm_{t-1} suggests that reduction of crude oil import will not affect the future economic growth and the price of imported crude oil in Japan in the long-run. This is very important because of various energy efficiency can be used as an alternative of crude oil could significantly reduce the demand of imported crude oil such as diesel which is cheaper than crude oil. As we know that, crude oil is one of the limited resources in this world. In the future, the supply of crude oil will be uncertain. If the crude oil is exhausted, we have to depend on other alternative resources to continue the economic activity. In these circumstances, the Ministry of Economy, Trade and Industry (METI) has published a new "Long-term Energy Supply and Demand Outlook". In order to promote energy conservation especially in the Residential & Commercial and Transportation sectors, government regulatory and financial assistance measures will be further expanded and strengthened in the future. These measures include the strengthened restriction on energy consumption on the demand side and introduction of incentives aimed at encouraging the use of energy-efficient household appliances and automobiles.

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