

Price elasticity of demand for crude oil: estimates for 23 countries

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Abstract

This paper uses a multiple regression model derived from an adaptation of Nerlove's partial adjustment model to estimate both the short-run and long-run elasticities of demand for crude oil in 23 countries. The estimates so obtained confirm that the demand for crude oil internationally is highly insensitive to changes in price.

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CRUDE OIL CONTINUES to occupy a pre-eminent position at the heart of the world economy. It is the most important source of energy, accounting for some 40.6 per cent of primary energy consumption, and it is the raw material for the international petrochemical industry. Over the 30-year period from 1971 to 2000, world crude oil consumption increased by 46 per cent, from 2,412 to 3,519 million tonnes per annum. Of this total, the United States of America currently consumes just in excess of 25 per cent.

One would have expected the large oil price rises of the 1970s to have provided a very strong incentive for the more efficient use of oil, through the development and exploitation of new technology. The accompanying **table** shows the average annual rate of growth of oil consumption per capita, along with the average annual rate of growth of real GDP per capita over the period 1979–2000 for 23 economies. A comparison of these two figures provides a crude measure of any improved efficiency. More precisely, if oil consumption has grown at a slower rate than real GDP, then, *ceteris paribus*, the rate of oil consumption in the production of GDP must have declined. Of course, it may be the case that GDP growth is now being fuelled by the relatively less energy-intensive service sector, rather than the more energy-intensive industrial sector, but, with this *caveat* in mind, it is still interesting to make the comparison.

All 23 economies experienced positive real economic growth to varying degrees, and 13 of these showed negative average growth in oil consumption. Of the ten for which average growth in oil consumption was positive, seven recorded a higher rate of economic growth. Newly industrializing China is a prominent example. In only three economies, namely Greece, Korea and Portugal, did growth in oil consumption exceed economic growth. Thus, in general, as economies have substituted more energy efficient capital stock and/or have expanded their less energy-intensive service sector, their consumption of crude oil has exhibited a downward trend.

Another important quantity monitored by policy-makers is the price elasticity of demand for crude oil. This measures the responsiveness or sensitivity of oil demand to changes in price. Econometric estimates, derived from a variety of statistical procedures and covering various different periods, suggest that this price elasticity is very low in both the short and the long run. The US Federal Energy Office, for example, estimated that the long-run price elasticity of demand in consuming countries ranged from -0.2 to -0.6 , with that of the USA recorded at -0.5 (see Kalymon, 1975). *A priori*, one would expect short-run price elasticities to be even lower, given the time-lag necessary to respond to significant price changes. Thus, for example, Brown and Phillips (1989) estimated the long-run price elasticity for the USA at -0.56 , which is similar to that reported above, while the corresponding short-run elasticity was estimated at -0.08 . Given the critical importance of price elasticity of demand for pricing policy, this paper will attempt to provide both short-run and long-run estimates of this quantity for all 23 countries listed in the table.

Table
Demand for crude oil

	Oil consumption % growth per capita	Real GDP % growth per capita	Price elasticity	
			Short-run	Long-run
Australia	-0.3	1.7	-0.034	-0.068
Austria	-0.7	3.1	-0.059	-0.092
Canada	-1.3	1.6	-0.041	-0.352
China	3.6	8.6	0.001	0.005
Denmark	-2.5	1.5	-0.026	-0.191
Finland	-1.2	2.1	-0.016	-0.033
France	-1.5	1.7	-0.069	-0.568
Germany	-1.4	1.2	-0.024	-0.279
Greece	2.2	1.5	-0.055	-0.126
Iceland	0.5	2.2	-0.109	-0.452
Ireland	0.2	3.9	-0.082	-0.196
Italy	-0.4	2.2	-0.035	-0.208
Japan	-1.0	8.1	-0.071	-0.357
Korea	8.3	6.4	-0.094	-0.178
Netherlands	-0.5	1.7	-0.057	-0.244
New Zealand	-0.4	1.4	-0.054	-0.326
Norway	0.2	2.9	-0.026	-0.036
Portugal	3.0	2.9	0.023	0.038
Spain	1.3	2.1	-0.087	-0.146
Sweden	1.3	2.8	-0.043	-0.289
Switzerland	-0.7	0.9	-0.030	-0.056
United Kingdom	-1.1	2.0	-0.068	-0.182
Unites States of America	-0.7	2.0	-0.061	-0.453

The calculations for China and South Korea are based on the period 1979–2000.

Methodology

The approach used to model crude oil demand was to specify a partial adjustment equation to account for the difficulty and cost of changing technology in the short run. The theoretical underpinning for this procedure is provided in the appendix. The equation estimated took the following form:

$$\text{Ln } D_t = \text{Ln } \alpha + \beta \text{Ln } P_t + \gamma \text{Ln } Y_t + \delta \text{Ln } D_{t-1} + \varepsilon_t \quad (1)$$

where:

D_t = per capita consumption of crude oil in year t
 P_t = real price of crude oil in year t
 Y_t = real GDP per capita in year t
 ε_t = assumed random error term
 Ln = natural logarithm
 $\alpha, \beta, \gamma, \delta$ are coefficients to be estimated

An attractive feature of such a log-linear model is that the coefficient β can be interpreted as the short-run price elasticity of demand and $\beta \div (1-\delta)$ as the long-run price elasticity of demand.

The most serious estimation problem with any specification containing a lagged dependent variable is the high probability of serial correlation. Detection of serial correlation with the familiar Durbin-Watson statistic is invalid in such circumstances and, accordingly, the Breusch-Godfrey Lagrange multiplier test was used instead. Thereafter, in the presence of serial correlation, the Cochrane-Orcutt iterative procedure was employed to estimate the coefficients, using annual data for the period 1971–2000. Oil consumption and price data were supplied by British Petroleum, while real per capita GDP was computed from statistics published by the International Monetary Fund.

The estimated equation for the USA is presented below, for illustrative purposes:

$$\text{Ln } D_t = 0.62 - 0.06 \text{ Ln } P_t + 1.05 \text{ Ln } Y_t + 0.87 \text{ Ln } D_{t-1} \quad (2)$$

(3.39)
(4.06)
(6.54)

$$R^2 = 0.91 \quad F = 66.55 \quad LM = 0.89$$

t-statistics are shown in parentheses.

The adjusted R^2 figure and the overall F statistic indicate that the model fits the data very well. The estimated coefficients have the expected *a priori* signs and the associated t-statistics indicate that these coefficients are all statistically significant at the one per cent level. The estimated short-run price elasticity of demand is -0.06 , while the long-run price elasticity of demand equals $-0.06 \div (1-0.87)$ or -0.46 . Note that these values are very close to the estimates for the USA reported by other analysts.

This same model was estimated for the other 22 other countries and the estimated elasticities are presented in the table.

The results

- (a) All estimated short-run elasticities suggest that oil demand is highly price-inelastic in the short run. Only two estimates do not have the expected negative sign, namely China and Portugal, but the t-statistics (0.05 and 1.20, respectively) indicate that these two coefficients are not statistically different from zero anyway.

(b) As expected, all long-run elasticities are greater than the corresponding short-run values. Interestingly, for the G7 group of countries, namely Canada, France, Germany, Italy, Japan, the United Kingdom and the USA, the long-run elasticity falls within the range -0.18 to -0.45 . Clearly, this corresponds very closely to the range of -0.2 to -0.6 estimated by the US Federal Energy Office.

References

BP Statistical Review of World Energy, British Petroleum, various issues.

Brown, S.P.A., and Phillips, K.R., Oil Demand and Prices in the 1990s, Federal Reserve Bank of Dallas Economic Review, January 1989.

International Financial Statistics, International Monetary Fund, various issues.

Kalyon, B.A., "Economic incentives in OPEC oil pricing policy", Journal of Development Economics, Vol.12, No.4, 1975.

Appendix

Consider a hypothetical economy, which is seeking to reduce its consumption of crude oil. Suppose, for illustrative purposes, it has succeeded in reducing its oil consumption from 125 units in year $t-1$ to 110 units in year t , but, ideally, wants to reduce consumption to 100 units. Because of technical rigidities, this further reduction cannot be accomplished within a single period. Only a partial adjustment can be made each period, and the entire move to the new desired long-run level will be spread over several periods.

The following adaptation of Nerlove's partial adjustment model allows us to capture the above situation and, at the same time, to estimate long-run price elasticities from available short-run data.

Let the long-run demand function for crude oil in the economy be given by:

$$D_{tL} = a P_t^b Y_t^c e_t \quad (1A)$$

and let the gradual adjustment process be expressed as:

$$\frac{D_{tL}}{D_{tS}} = \left[\frac{D_{tL}}{D_{t-1,S}} \right]^d \quad \text{where } 0 < d \leq 1 \quad (2A)$$

where:

D_{tL} = long-run demand for oil as at year t

D_{tS} = short-run demand for oil in year t

P_t = real price of oil in year t

Y_t = real GDP per capita in year t

e = random error term

and a , b , c , d are parameters, where:

b = long-run price elasticity of demand for oil

d = coefficient of adjustment

In the simple arithmetical example above, equation (2A) becomes:

$$\frac{100}{110} = \left[\frac{100}{125} \right]^d$$

or:

$$0.9091 = (0.8)^d, \text{ from which } d = 0.4272$$

Solving for D_{tL} in equation (2A), we obtain:

$$D_{tL} = \left[\frac{D_{tS}}{(D_{t-1,S})^d} \right]^{\frac{1}{1-d}} \quad (3A)$$

Substituting this value for D_{tL} in equation (1A), we obtain:

$$\left[\frac{D_{tS}}{(D_{t-1,S})^d} \right]^{\frac{1}{1-d}} = a P_t^b Y_t^c e_t$$

from which:

$$D_{tS} = a^{(1-d)} P_t^{b(1-d)} Y_t^{c(1-d)} D_{t-1,S}^d e_t^{(1-d)} \quad (4A)$$

Taking logs of both sides of equation (4A), we obtain:

$$\begin{aligned} \text{Ln } D_{tS} &= (1-d) \text{Ln } a + b(1-d) \text{Ln } P_t + c(1-d) \text{Ln } Y_t + d \text{Ln } D_{t-1,S} \\ &+ (1-d) \text{Ln } e_t \end{aligned} \quad (5A)$$

Equation (5A) above is in the same form as equation (1) in the text and is its theoretical underpinning. The short-run price elasticity of demand is given by $b(1-d)$, which corresponds to β in equation (1). Similarly, the long-run price elasticity of demand is given by b , which is equivalent to $\beta \div (1-\delta)$ in equation (1).