Demand for Imported Crude Petroleum: The Case of the United States

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I. Introduction

A firm dependence of the oil-consuming nations on petroleum imported from the oil-producing countries was clearly evidenced by the enormous impact of the escalation of oil prices by OPEC during 1973-74 on the global economy, and is expected to be high in the future, unless alternative energy sources can be developed. A growing number of economists have recently focused attention on the problem related to demand for petroleum, or energy in general. However, a survey of literature indicates that the demand for imported crude petroelum in a specific oil-consuming country has not been explored in detail. In the case of the United States, which is the western world's largest single producer, consumer and importer of petroleum, it is important for the formulation of energy policy to have an insight into the nature of crude petroleum imports. Yet, a difficult methodological problem has deterred economists from investigating this area in detail.(1) The quotas imposed on imports of crude petroleum until 1973 was the major obstacle

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(1) 25.6% of world total crude oil production, 37.0% of world total demand for refined petroleum products, and 20.3% of imports of total domestic demand on the average for the period of 1960-72. The figures were obtained from *Basic Petroleum Data Book*, published by the American Petroleum Institute. 1975.

to the econometric studies. But a close examination of the historical record on import controls and the actual import data by crude petroleum grade suggests that there is no clear evidence that imports into the United States have always been severely restricted. Imports had basically been subject to "voluntary" limitation, except in 1959. Indeed, there is no *a priori* reason to believe the absence of adequate data for regression analysis.

The purpose of this paper is to examine rigorously U.S. demand for imported crude petroleum for the period from 1955 to 1972 by employment of the two-level CES production function, which allows the grouping of various productive factors and crude petroleum into subsets. A theoretical model is derived and estimated to find the various elasticities and the ease of substitutability among input groups, as well as within the crude petroleum subset. In the context of the neoclassical theory of production, the derivation of the demand for the productive factors by means of the conditions of profit-maximization or cost-minimization is a well-known proposition. The demand for imported crude petroleum which is a major intermediate input for the production of refined petroleum, or energy in general, may be derived exactly the same way as the demand for capital or labor. The non-linear function is reduced to the linear form by both the Kuhn-Tucker minimization conditions and the Shephard-Samuelson theorem.

The empirical results obtained by the Cochrane-Orcutt iterative method for U.S. total imports of crude petroleum are quite satisfactory and support the postulated hypothesis. The parameter estimates are statistically significant and consistent with the expected sign. From the various estimated elasticities of imports and intra-and inter-class elasticities of substitution, many useful policy implications are derived.

This paper consists of four sections, including an introduction and an appendix. The following section is concerned with derivation of the theoretical model for crude petroleum imports. The third section presents empirical results of the various elasticities and the elasticities of substitution among the energy sources, and between domestic and imported crude petroleum. Concluding remarks are given in the last section. Finally, the sources and nature of the data are discussed in the appendix.

II. Derivation of the Basic Theoretical Model

The two-factor CES production function examined by Arrow, Chenery, Minhas and Solow[1961] has provided researchers with a major thrust for empirical studies in various fields. However, because of its theoretical limitations, there have been efforts for generalization of the original CES function to an n-factor function by Uzawa[1962] and et al. The n-factor production function stemmed from the application of functional separability of variables, which has been extensively discussed in the literature in recent years in connection with utility function analysis.(2) But these n-factor production functions retain basically the original CES properties intact. In general, such production functions restrict all productive factors to being substitutes in the Hicks-Allen sense. The own-price elasticities are restricted to the range from zero to minus unity, implying that demand for each input must be inelastic with respect to own-price, while the partial elasticities of substitution between any pair of factors are constant.

Over ten years ago Professor Sato proposed the two-level CES production function which is a special case of strongly separable function. The function may be written as

$$Q=[\sum_{s=1}^{S}\alpha_s\{\sum_{i\in n_s}\beta_i^{(s)}(X_i^{(s)})^{-\rho_s}\}^{\rho/\rho_s}]^{-\nu/\rho} \tag{1}$$

where

$$\beta_i^{(s)}>0,\ \ -1<\rho_s=(1-\sigma_s)/\sigma_s<\infty,\ \ \alpha_s>0 \text{ and } -1<\rho=(1-\sigma)/\sigma<\infty.^{(3)}$$

The n-inputs are partitioned into s-disjoint subsets such that $n_1\cup n_2\cup\cdots\cup n_s$ and $n_r\cap n_s\neq\phi$ for all $r\neq s$. Next, the input vector $\{X\}$ corresponding to each of the disjoint subsets is composed of a set of subvectors $\{X\}=\{X^{(1)}$,

(2) The concept of "separation" has been discussed by W.W. Leontief, R.H. Strotz, R. Frisch, W.M. Gorman, H.S. Houthakker, I.F. Pearce, J.M. Goldman and H. Uzawa. Over twenty years ago L.R. Klein and H. Rubin presented a set of demand relations derived from a particular separable utility function which has been known as the linear expenditures system, and was first estimated by R.D. Stone. Another separable utility function, which has been referred to as the Stone-Geary Function, was later derived by P.A. Samuelson and R.C. Geary. A detailed discussion on the properties of the separable utility function is found in A.S. Goldberger[1967].

(3) See K. Sato[1967].

$X^{(2)}, \cdot\cdot\cdot, X^{(s)}\}$ for $X_i \in X^{(s)}$ and $i \in n_s$. The parameter $\beta_i^{(s)}$ represents the factor-intensity within the s-th input group, and α_s and ν represent, respectively, the factor-intensity among the input groups and the degree of homogeneity. The parameter σ_s represents the elasticity of substitution within the s-th input group (the intra-class elasticity of substitution), while the parameter σ is the elasticity of substitution among input groups (the inter-class elasticity of substitution). The nature of the above two-level production function is less restrictive than Uzawa's generalization. It allows not only for substitutes in the Hicks-Allen sense, but also complementary and independent relationships between the inputs demanded. The own-price elasticity can be anywhere in the range from zero to minus infinity. In addition, the partial elasticity of substitution varies among different groupings.

In this paper, the two-level production function is applied to the hypothetically aggregated industry producing the entire spectrum of energy in the United States. The input vector for this particular two-level function may therefore include all energy sources used currently in this country. These sources, ignoring nuclear, are coal, natural gas, petroleum, hydropower and geothermal. One of the lower level functions is assigned to petroleum in which its inputs are decomposed into domestically produced crude petroleum and imported crude petroleum, in addition to the conventional variables, capital and labor. Then the cost-minimization can be accomplished by the two-stage process.(4) For the first process, we derive the demand equations by minimization of the low-level costs subject to the corresponding productions. The demand function for imported crude petroleum is

$$M_2^{(s)} = \left(\frac{\beta_{m2}^{(s)}}{p_{m2}^{(s)}}\right)^{\sigma_s}\left[\sum_{j\epsilon s}^{n_s}\left(\frac{\beta_j^{(s)}}{p_j^{(s)}}\right)^{\sigma_s} p_j^{(s)}\right]^{-1} M^{(s)}, \tag{2}$$

where M_2=imported crude petroleum,

M=refined petroleum product,

p_{m2}=price of imported crude petroelum, and

(4) The two-stage process of optimization was originally shown by Strotz and Gorman, and was recently applied by M. Brown[1972] and many others with regard to the s-branch utility function, which subsumes the Stone-Geary linear-expenditure system as a special case. The process for derivation of the demand function for imported crude petroleum in this paper is similar to those two-stage optimization processes.

p_j=prices of material costs (both domestic and imported crude petroleum), wages and rental cost involved in the low-level production function.

Next, demand equations (2) obtained by the first process of cost minimization are substituted into the global production function for energy (1). Minimization of the total cost for production of energy accrued from each low-level subject to the global production function provides us with the optimum values for $M^{(s)}$, which are now substituted into equation (2) to obtain the following complex non-linear global demand function for imported crude petroleum:

$$M_2^{(s)}=\left(\frac{\beta_{m2}{}^{(s)}}{p_{m2}{}^{(s)}}\right)^{\sigma_s}\alpha^{(s)\sigma}\left[\sum_{j\epsilon s}^{n_s}\left(\frac{\beta_j{}^{(s)}}{p_j{}^{(s)}}\right)^{\sigma_s}p_j^{(s)}\right]^{\left(\frac{\sigma-1}{\sigma_s-1}\right)-1}\left[\sum_{r=1}^{s}\alpha_r^{\sigma}\left\{\sum_{j\epsilon r}^{n_r}\left(\frac{\beta_j{}^{(r)}}{p_j{}^{(r)}}\right)^{\sigma_r}p_j^{(r)}\right\}^{\left(\frac{\sigma-1}{\sigma_r-1}\right)}\right]^{-1}Q^{\frac{1}{v}}. \quad (3)$$

Assuming that the (n_s-1) disturbance terms within each branch have a joint normal distribution, a nonlinear full information maximum likelihood procedure may be applied to the above equation, and was frequently employed to estimate the conventional linear expenditure system in the theory of utility. However, in the context of the theory of production, the above demand equation (3) can be conveniently reduced to the linear form in logarithms by employment of the well-known Kuhn-Tucker minimization conditions and the Shephard-Samuelson theorem. Therefore, the application of algorithms developed by Eisenpress and Greenstadt-Bard-Chow is not necessary here.

By the Kuhn-Tucker minimization conditions, the second and third bracket terms in equation (3) are respectively related to the Kuhn-Tucker Largrangian multipliers (λ's), which imply the imputed minimum costs of producing a unit each of M and Q. They are, respectively,

$$\lambda^{(s)\,(\sigma_s-\sigma)}=\left[\sum_{j\epsilon s}^{n_s}\left(\frac{\beta_j{}^{(s)}}{p_{sj}}\right)^{\sigma_s}p_{sj}\right]^{\left(\frac{\sigma-1}{\sigma_s-1}\right)-1} \quad (4)$$

and

$$\lambda^{(\sigma-1)}=\sum_{r=1}^{s}\alpha^{(r)\sigma}\left\{\sum_{j\epsilon r}^{n_r}\left(\frac{\beta_j{}^{(r)}}{p_j{}^{(r)}}\right)^{\sigma_r}p_j^{(r)}\right\}^{\left(\frac{\sigma-1}{\sigma_r-1}\right)}]^{-1} \quad (5)$$

by the Shephard-Samuelson theorem, the relations between λ's and the corresponding prices are established. Since λ's$=AC$'s$=MC$'s$=p$'s, we have

$$\lambda^{(s)\,(\sigma_s-\sigma)}=p_m^{(s)\,(\sigma_s-\sigma)} \quad (6)$$

and

$$\lambda^{(\sigma-1)}=p_q^{(\sigma-1)} \tag{7}$$

where

p_m=price of refined petroleum

p_q=price of energy.

However, under imperfect competition, it is plausible, particularly for the industry producing energy, to have the factor representing any constant economy-wide tendency to move to an imperfectly competitive position. Therefore, a parameter ζ is inserted into the relation between the λ's and p's. Substituting equations (4), (5), (6), and (7) into equation (3), the simplified demand function is obtained as follows:

$$M_2^{(s)}=\Omega p_{m2}^{(s)-\sigma_s} p_m^{(\sigma_s-\sigma)} p_q^{(\sigma-1)} Q^{1/v}, \tag{8}$$

where

$$\Omega=(\zeta\alpha^{(s)\sigma}\beta_{m2}^{(s)\sigma_s}).$$

The difficulty is that parameters $\alpha^{(s)}$, $\beta_{m(2)}^{(s)}$ and ζ are indistinguishable in the intercept of the logarithmic relation, i.e., they are under-identified. However, since estimation of the import-elasticity with respect to each explanatory variable and the intra-and inter-class elasticities of substitution is the primary objective of this paper, equation (8) may be directly estimated.

III. Empirical Results

The basic theoretical model is transformed into a more manageable logarithmic form for the empirical estimation. The conventional assumptions on a specification of the probability distribution of the stochastic disturbance term and regressors (i.e., normality, zero mean, homoskedasticity, non-auto-regression, and non-stochastic regressors) are imposed. The rates of change in refined petroleum price (Δp_{mt}) and output of energy (ΔQ_t) are added as regressors on the postulated hypothesis that the importers actually decide their imports by reference to the price and output levels this year, as well as the rates of change of those variables. The argument here is that recent increases in the refined petroleum price and output of energy caused importers to expect higher future refined petroleum prices and energy output, thus increasing the import of crude petroleum.[5] In addition, the changes in inventory (ΔV_t) were also inserted on the obvious ground that the importers may frequently adjust their imports to stocks left in their depository tanks.

Equation (8) with Δp_{mt}, ΔQ_t and ΔV_t was fitted to the U.S. annual time series covering the period from 1955 to 1972, with and without the change in inventory. The regressors p_{mt-1} and Q_{t-1} were deleted from the regression equation, because of their poor performance. The overall results on the regression coefficients for two models estimated by the Cochrane-Orcutt iterative method and their summary statistics on the goodness of fit are in general quite satisfactory. The regression equations exhibited expected signs and the magnitudes of the coefficients are consistent with the postulated hypothesis in the reasonably acceptable range. Since the regression with the inventory variable had turned out to be slightly better, the model with the changes in inventory will only be discussed in this paper. $\bar{R}^2$ exceeded 0.962, and d-statistic ($=3.097$) was greater than the critical value. The individual tests for five out of seven parameter estimates reject the null hypothesis (H_0 : coefficient$=0$ against H_A : coefficient$\neq 0$) at the five per cent level of significance. These five parameters are the import price of crude petroleum, the rate of change in the price of refined petroleum, the total output of energy, the rate of change in total output of energy, and changes in inventory. The parameter with respect to the price level of refined petroleum was statistically insignificant, while the price of energy did not quite meet the critical value for the five per cent level of significance by a slight difference. While the separate influences of these two explanatory variables on the dependent variable are weak, the joint test suggests that their joint influence with other explanatory variables is quite strong. The Durbin-Watson statistic from the ordinary least-squares exhibited an inconclu-

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(5) The inclusion of Δp_{mt} or ΔQ_t is theoretically justified as follows:

Given

$$\ln y_t = \alpha \ln x_t + \beta \ln x_{t-1},$$

we can have

$$\ln y_t + \gamma \ln \Delta x_t = \alpha \ln x_t + \beta \ln x_{t-1} + \gamma \ln \Delta x_t,$$

which is rewritten as

$$\ln y_t = (\alpha - \gamma) \ln x_t + (\beta + \gamma) \ln x_{t-1} + \gamma \ln \Delta x_t.$$

sive situation, and, therefore, the Cochrane-Orcutt iterative technique was applied to remove the autocorrelation.

Although there are not any theoretical deficiencies in the formulation of the model or conceptual flaw in the variables, we went to considerable lengths to detect the possible existence of multicollinearity between the price of refined petroleum and the price of energy. One test statistic which is roughly applicable to identify multicollinearity between these two regressors has a chi-square distribution.(6) The χ^2-statistic indicates that multicollinearity was not present at the 5 per cent significance level. We were also concerned with the specification error which might have originated due to the addition of the explanatory variables (rates of changes and changes in inventory) to the basic equation. If the maintained hypothesis is such that the correctly specified model should include only basic explanatory variables, the possible existence of specification error should be tested. The null hypothesis (H_0 : coefficients of Δp_{mt} and $\Delta Q_t=0$ against H_A : coefficients of Δp_{mt} and $\Delta Q\neq 0$) tested by the F-statistic was rejected at the 1 per cent level of significance.(7) Finally, the hypothesis concerning the first and second order lag derived from the Koyck-Nerlove adjustment mechanism was examined. The lag structures were not upheld, and therefore not reported herein. The Almon lag, another very popular alternative from of lag distribution, was not tested, primarily because of the relatively short sample period.

The regression result is as follows:

$$\begin{aligned}\ln M_{2t}^{(s)} = \underset{(5.980)}{21.418} \underset{(-3.533)}{-2.257} \ln p_{m2t}^{(s)} + \underset{(0.395)}{0.205} \ln p_{mt} + \underset{(5.222)}{1.016} \ln \Delta p_{mt} + \underset{(1.709)}{0.221} \ln p_{qt} \\ + \underset{(8.676)}{0.857} \ln Q_t + \underset{(2.260)}{0.127} \ln \Delta Q_t \underset{(-3.223)}{-0.0034} \Delta V_t + u_t,\end{aligned}$$

(6) The χ^2-statistic is given by $\chi^2 = -[N-1-(1/16)(2K+5)]\ln(1-|r|)$, where N=the sample size, K=the number of regressors, $|r|$=the determinant of the simple correlation coefficient matrix. See J.L. Murphy, *Econometrics*, Homewood, Richard D. Irwin, Inc., 1973, pp.379-380.

(7) The F-statistic is given by $F_{(J-K,\ N-J)} = [(R_J^2 - R_K^2)/(1-R_K^2)][(N-J)/(J-K)]$ where N= the sample size, K=the number of explanatory variables included in the model without Δp_t, ΔQ_t and ΔV_t, J=the number of explanatory variables included in the model with Δp_t, ΔQ_t, ΔV_t, R_K^2 and R_J^2=the coefficients of determination of the models containing, respectively, K and J number of explanatory variables. $J-K$ and $N-J$ in parenthesis are the degrees of freedom for numerator and denominator. See J. Kmenta, *Elements of Econometrics*, New York, The Macmillan Company, 1971, pp.370-371.

where

$\bar{R}^2=0.962$,

$d=3.097$,

$\rho^{(4)}=-0.857^{(8)}$,

$SE=0.029$, and

the t-statistic in parenthesis.

The individual elasticities are as follows:[9]

$\varepsilon_{p_{m2}^{(s)}}=\sigma_s=-2.257$,

$\varepsilon_{p_m}=[(\sigma_s-\sigma)-\eta]=0.000$,

$\varepsilon_{\Delta p_m}=\eta=1.016$,

$\varepsilon_{p_q}=(\sigma-1)=0.221$,

$\varepsilon_Q=[(1/\nu)-\mu]=0.857$,

$\varepsilon_{\Delta Q}=\mu=0.127$, and

$\varepsilon_{\Delta V}=-0.034$.

We also obtain the intra-class elasticity $\sigma_s=2.257$ from the elasticity of the import price of crude petroleum, while the inter-class elasticity $\sigma=1.221$ is computed from the elasticity of the output price of energy. It should be observed that the elasticity of the price of refined petroleum $\varepsilon_{p_m}=[(\sigma_s-\sigma)-\eta]$ turns out to be close to zero if we substitute the estimated parameters σ_s, σ, and η in that formula.

Among the individual elasticities, those with respect to the import price of crude petroleum and changes in the price of refined petroleum are elastic, indicating that the domestic consumption of energy may be successfully manipulated by means of the pricing policy. This result is contradictory to the existing view, in the light of the American mode on the consumption of petroleum, that crude petroleum is an "essential resource" and thus the demand for imported crude petroleum may be highly inelastic with respect to the corresponding price. Instead of the price level of refined petroleum, the U.S. import of crude petroleum was much more sensitive to its rate of change. The implication of this result is that importers are concerned more with their expectations on future prices. The degree of reaction of imports to the price and output of energy was not quite substantial. Here we can see the dynamic and speculative elements involved with the decision of the importers. The paramater value of output yields $\nu=1.016$, suggesting that

(8) Autoregressive coefficient. The number of iteration is stated in the parentheses.

(9) The elasticities with respect to p_{mt}, Δp_{mt}, Q_t and ΔQ_t are referred to footnote (5).

the industry producing energy experienced constant returns to scale. The outcome is consistent with the view that the assumption of linear homogeneity in production is appropriate in the realm of American manufacturing.[10] It is interesting to note that changes in inventory did not exhibit a significant quantitative effect on the import. This result supports the most widely held conjecture that importers may not smoothly adjust their imports with respect to their stocks.

Turning to the intra-class elasticity of substitution, there exists substantial evidence that domestically produced crude petroleum and imported crude petroleum are easily substituted for each other. Drilling and pipeline construction should therefore be continued as long as its opportunity cost is

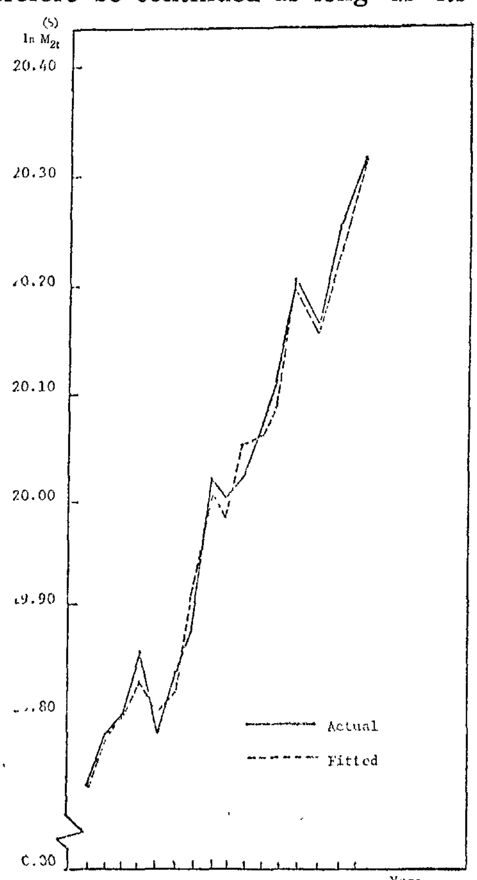

Fig. 1. Actual and Fitted Values of Crude Petroleum Imports

(10) See J.R. Moroney, *The Structure of Production in American Manufacturing*, Chapel Hill The University of North Carolina Press, 1972, pp.11-35.

smaller. On the other hand, the effort to divert the consumption pattern of energy in the United States from petroleum to some other existing sources, such as coal and hydropowcr, appears to be possible, but the speed of transfer must be very sluggish. The magnitude of inter-class elasticity of substitution, which is very close to unity, suggests that the upper-level production function is not much different from the Cobb-Douglas form.(11)

Finally, figure 1 compares the actual and fitted values of crude petroleum imports. The variables are expressed on the vertical axis for the entire sample period. It can be seen that the model reproduces the import behavior quite accurately. Turning points in imports between the actual and computed values are remarkably good. The fitted value is somewhat above the actual values during 1960 and 1965, but the discrepancies are generally small and become zero quite frequently.

IV. Concluding Remarks

By employment of the two-level production function, the U.S. import function of crude petroleum was rigorously examined. The empirical results exhibit considerable evidence that the postulated hypothesis is significantly and consistently upheld.

However, the results are based on relatively short annual time series. Because of the data, the U.S. imports of crude petroleum by region and by individual exporting country were not examined. While the findings are, as such, partial, they do shed light on the further rigorous study of the demand for imported petroleum.

The principal findings of this study are summarized as follows:

(1) The elastic import of crude petroleum with respect to the price of imported crude petroleum suggests a possibility of effective regulations by pricing policy as a policy measure, instead of direct control or some other options.

(2) The dynamic and speculative elements, such as future expectations of importers about the price of refined petroleum, played very significant roles in determining the amount of imports.

(3) The importers are not much concerned with their inventories.

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(11) $Q=\prod_{s=1}^{S}[\sum_{j\epsilon s}^{n_s}\beta_j^{(s)}(X_i^{(s)})^{-\rho_s}]^{\rho/\rho_s}$.

(4) Domestic crude petroleum is easily substituted for imported crude petroleum, while substitution between refined petroleum and coal, natural gas, and hydropower is difficult. The efforts of exploration of domestic sources of crude oil must be more actively implemented as a short-run measure on one hand, particularly at a time when there is no hope for lower import price of crude petroleum in the foreseeable future. On the other hand, a constant search for alternative energy sources, such as solar energy and nuclear power, also must be strongly initiated as a long-run measure.

Appendix—Sources and Nature of Data

The sources of data and specification of each variable will be briefly discussed below. The recent period from 1973 to 1976 was omitted from the regression because the oil embargo in late 1973 seriously distorted the data. The sample period of 1959 was also excluded, because mandatory import quotas became effective. However, there is ample evidence and a widely held view that imports into the United States were only restricted in 1959.

(1) M^2=The custom value of U.S. imports for consumption of crude petroleum, both crude shale oil, testing under 25 degrees API (sic), and 25 degrees API or more, from the petroleum producing countries. The custom value is defined as the market value in the foreign country and therefore excludes U.S. import duties, ocean freight, and marine insurance. Imports for consumption (a combination of entries for immediate consumption and withdrawals from warehouses for consumption) were used, because the data for the general imports are available only after 1968. The data sources for the imports for consumption are various issues of *U.S. Imports of Merchandise for Consumption, Commodity by Country of Origin, FT 110* and *FT 125, Imports, Commodity by Country, FT 135* and *U.S. Imports for Consumption and General Imports, TSUSA Commodity by Country of Origin, FT 246.*

(2) M=Petroleum refining. The index of production was obtained from *Industrial Production,* 1971 edition and various recent issues, published by the Board of Governors of the Federal Reserve System. (Seasonally adjusted, 1967=100.)

(3) Q=Gross energy production. The data source is U.S. Department of Interior, *Energy Perspectives 2,* June 1976.

(4) p_{m2}=Price index of imported crude petroleum (1967=100). The import price was calculated by the sum of the weighted averages of unit prices of two major imports (25 degrees and above 25 degrees of API) per barrel, the tariff per barrel on the above particular grades of imported crude oil, and transportation costs per barrel. It was then transformed into the index in terms of the 1967 price to maintain consistency with other prices. The unit price per barrel was computed by division of the imported value for consumption by the corresponding quantity. The sources for the values and quantities are the same as those for (1). The sources for the tariff(τ) and transportation cost(T) are stated below.

(5) p_q=Wholesale price index of fuels and related products, and power (1967=100). Data were obtained from U.S. Department of Commerce, *Business Statistics*, 1975.

(6) τ=Tariffs on crude petroleum including reconstituted and crude shale oil, testing under 25 degrees API, and 25 degrees API or more. The data for the period of 1963 through 1972 were obtained from *Tariff Schedules of the United States Annotated*, published by the U.S. Tariff Commission (currently the U.S. International Trade Commission). Under the provisions of the Tariff Classification Act of 1962, replacing the U.S. Tariff Act of 1930, the U.S. Tariff Commission published the first issues in 1963. The import of crude petroleum before 1963 was free of duty by Title II—Free List under the Tariff Act of 1930. The sources are the various issues of *United States Import Duties*, published by the U.S. Tariff Commission, and *U.S. Import Duties Annotated*, published jointly by the U.S. Department of Treasury, Bureau of Custom, the U.S. Department of Commerce, Bureau of Census and the U.S. Tariff Commission.

(7) T=Transportation costs of crude oil to Philadelphia (or the U.S. East Cost) or Houston from the various petroleum exporting countries. Data before 1967 (by Intascale) and for 1969 (Worldscale) were obtained from, Morris A. Adelman, *The World Petroleum Market*, Baltimore, The Johns Hopkins University Press.[12] Data for 1973 were obtained from the

(12) Worldscale is a reference book which contains transport rates between most major ports for delivery of a long ton (2,240 lbs) of bulk oil. Worldscale rates are computed by Association of Ship Brokers and Agents of New York and the London-based International Tanker Normal Freight Rate Association. It respresents the cost of transporting crude petroleum in a hypothetical 19,500 DWT tanker between various ports. The hypothetical tanker has a fixed daily charge of $1,800, a speed of 14 knots and consumes 28 tons of fuel per day at sea,

sample computation of shipping costs at Worldscale-100 for the selected crude oils and ports by Sun Oil Company, published in *Analysis of World Tank Ship Fleet*, December 1974.

References

[1] Adelman, A., *The World Petroleum Market*, Baltimore, The Johns Hopkins University Press, 1972, pp.148-186.

[2] Arrow, K.H., B. Chenery, S. Minhas and R.M. Solow, "Capital-Labor Substitution and Economic Efficiency," *Review of Economics and Statistics*, Vol. 45, August 1961, pp.225-250.

[3] Bohi, D.R., M. Russel and N.M. Snyder, U.S. Congress, House of Representatives, Committee on Banking, Currency and Housing, *The Economics of Energy and Natural Resource Pricing*, A Compilation of Reports and Hearings, 94th Congress, 1st Session, Part 1 and 2, March 1975, pp.1-230.

[4] Brown, M., "The *S*-Branch Utility Tree: A Generalization of the Linear Expenditure System," *Econometrica*, Vol. 40, No. 4, July 1972, pp.737-747.

[5] Dam, K.W., "Implementation of Import Quotas: The Case of Oil," *Journal of Law and Economics*, April 1971, pp.1-60.

[6] Fried, R. and C.L. Schultze, "Overview," Edward R. Fried and Charles L. Schultze, eds., *Higher Oil Prices and the World Economy*, Washington, D.C., The Brookings Institution, 1975, pp.1-69.

[7] Goldberger, A.S., "Functional Form and Utility: A Review of Consumer Demand Theory," Social Systems Research Institute, University of Wisconsin, Systems Formulation, Methodology, and Policy Workshop Paper 6703, 1967, pp.1-121.

[8] Houthakker, H.S., *The World Price of Oil*, Washington, D.C., American Enterprise Institute, 1976.

[9] Hudson, A. and D.W. Jorgenson, "Tax Policy and Energy Conservation," Dale W. Jorgenson, ed., *Econometric Studies of U.S. Energy Policy*, New York, American Elsevier Publishing Company, Inc., 1976, pp.7-94.

[10] Kennedy, M., "A World Oil Model," Dale W. Jorgenson, ed., *op. cit.*, pp.97-175.

[11] Nordhaus, W.D., "The Allocation of Energy Resources," *Brookings Papers on Economic Activity*, 3, 1973, pp.529-576.

[12] Perry, G.L., "The United States," Edward R. Fried and Charles L. Schultze, eds., *op. cit.*, pp.71-104.

[13] Sato, K., "A Two-Level Constant-Elasticity-of-Substitution Production Function," *Review of Economic Studies*, Vol. 34, 1967, pp.201-218.

[14] Sun Oil Company, Planning and Industry Affairs, "Basic Tank Ship Economics,"

Analysis of World Tank Ship Fleet, December 1974, pp.1-11.

[15] Uzawa, H., "Production Functions with Constant Elasticities of Substitution," *Review of Economic Studies*, Vol. 29, 1962, pp.291-299.

[16] Zannetos, Z.S., *The Theory of Oil Tankship Rates*, Cambridge, MIT Press, 1966.

Data

[1] U.S. Department of Commerce, Bureau of the Census, *U.S. Imports of Merchandise for Consumption, Commodity by Country of Origin, FT 110* (for the period of 1955-63) and *FT 125* (for the period of 1964-66).

[2] ________________, *Imports, Commodity by Country, FT 135* (for the period of 1967-72).

[3] American Petroleum Institute, *Basic Petroleum Data Book*, 1975-1977.

[4] U.S. Department of Labor, Bureau of Labor Statistics, *Wholesale Prices and Price Indexes*, various issues.

[5] Board of Governors of the Federal Reserve System, *Industrial Production*, 1971 edition and various recent issues.

[6] U.S. Tariff Commission (U.S. International Trade Commission since 1974), *Tariff Schedules of the United States Annotated*, 1963-1972.

[7] ________________, *United States Import Duties*, 1950, p.158.