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LOG-LINEAR MODELS OF PETROLEUM PRODUCT DEMAND:

AN INTERNATIONAL STUDY

by

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1. Introduction

The purpose of this work is to describe a set of log-linear models of petroleum product demand and to document the estimation results. This effort is part of an overall study to understand and model the world oil market. As results obtained here will be used to construct portions of a larger simulation model, this paper is intended to serve as a reference to the methodology employed in obtaining the results.

More encompassing and sophisticated translog models have been used to analyze total energy demand and oil's share of the demand for about ten major Western countries.[1] The relatively simple log-linear specification for demand equations is used here for two purposes. The first is to provide preliminary estimates of demand response to price and income changes in the major consuming ("primary") countries for the main product groups. The intent is to provide a starting point by constructing equations which can be used in a simulation model and can be replaced as other segments of the overall study are completed.

The second purpose is to provide "final" equations and estimates for what will be referred to as "secondary" countries. These are countries which because of data availability problems and/or relatively less significant quantities of demand are placed outside the scope of current plans for more detailed modeling.

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[1] See Pindyck [1], [2].

No explicit distinction is made between "primary" and "secondary" countries in this segment of the study. Both secondary and primary countries are pooled together to obtain joint estimates. But if sensible results were obtained using the translog formulation, efforts were more readily redirected if reasonable results could not be obtained for log-linear models.

The 20 countries represented in this work are listed below:

<u>Europe</u>

Austria
Belgium
Denmark
France
Greece
Ireland
Italy
Netherlands
Norway
Spain
Sweden
Switzerland
Turkey
United Kingdom
West Germany

<u>Asia</u>

Japan

<u>North America</u>

Canada
United States

<u>South America</u>

Brazil
Mexico

Exhibit 1 shows their relative size as oil consumers. The above 20 countries accounted for 82.3% (based on weight) of the 1974 total oil demand, excluding the U.S.S.R., Eastern Europe and China, or 68.1% of the world total including those countries with controlled economies.

Exhibit 1

World Oil Consumption 1975 and 1974

Country/Area	Million Tonnes 1975	Million Tonnes 1974	Percentage† 1975 Share of Total	Percentage† Change 1975 over 1974	Percentage† Change Annual Average 1970/1975	Thousand Barrels Daily 1975	Thousand Barrels Daily 1974
U.S.A.	764.2	782.6	28.3%	-2.3%	+1.9%	15,845*	16,150*
Canada	82.5	84.8	3.1%	-2.7%	+2.5%	1,735	1,785
Total North America	846.7	867.4	31.4%	-2.4%	+2.0%	17,580	17,935
Latin America	173.9	171.3‡	6.4%	+1.5%	+4.9%	3,660	3,595**
TOTAL WESTERN HEMISPHERE	1,020.6	1,038.7	37.8%	-1.7%	+2.4%	21,240	21,530
Austria	10.6	10.7	0.4%	-1.3%	+2.5%	215	215
Belgium & Luxembourg	27.1	28.1	1.0%	-3.4%	-0.6%	545	560
Denmark	15.5	16.0	0.6%	-3.0%	-3.6%	310	320
Eire	5.2	5.4	0.2%	-3.3%	+4.8%	105	110
Finland	11.9	11.6	0.4%	+3.3%	+2.1%	235	230
France	109.3	121.0	4.1%	-9.7%	+3.0%	2,240	2,460
Greece	10.2	9.4	0.4%	+8.7%	+8.7%	205	185
Iceland	0.6	0.6	--	-2.5%	+0.9%	10	15
Italy	95.6	100.8	3.5%	-5.1%	+1.8%	1,925	2,015
Netherlands	34.8	35.4	1.3%	-1.7%	-1.0%	710	725
Norway	8.0	7.7	0.3%	+4.3%	-0.7%	165	160
Portugal	6.8	6.5	0.2%	+5.1%	+8.2%	140	135
Spain	43.4	41.1	1.6%	+5.7%	+9.1%	880	820
Sweden	26.4	27.1	1.0%	-2.5%	-2.4%	530	540
Switzerland	12.5	13.0	0.5%	-4.4%	-0.1%	260	270
Turkey	13.6	12.5	0.5%	+9.1%	+12.1%	275	255
United Kingdom	92.1	105.9	3.4%	-13.0%	-2.0%	1,875	2,145
West Germany	128.6	134.3	4.8%	-4.3%	--	2,665	2,760
Yugoslavia	11.4	11.5	0.4%	-0.6%	+10.3%	230	235
Cyprus/Gibraltar/Malta	1.1	1.3	--	-12.8%	+1.1%	20	25
Total Western Europe	664.7	699.9	24.6%	-5.0%	+1.2%	13,540	14,180
Middle East	70.4	68.6	2.6%	+2.7%	+7.3%	1,390	1,355
Africa	51.4	50.3	1.9%	+2.2%	+4.3%	1,050	1,020
South Asia	28.5	27.7	1.0%	+2.9%	+1.0%	575	560
South East Asia	81.3	77.7	3.0%	+4.7%	+6.4%	1,615	1,540
Japan	239.8	258.9	8.9%	-7.4%	+3.8%	4,905	5,270
Australasia	35.6	36.0	1.3%	-0.9%	+3.4%	750	755
U.S.S.R.	370.0	341.5	13.7%	+8.3%	+7.1%	7,480	6,905
Eastern Europe	84.0	81.0	3.1%	+3.7%	+8.7%	1,725	1,660
China	55.5	48.5	2.1%	+14.4%	+22.6%	1,105	970
TOTAL EASTERN HEMISPHERE	1,681.2	1,690.1	62.2%	-0.5%	+4.2%	34,135	34,215
World	2,701.8	2,728.8	100.0%	-1.0%	+3.5%	55,375	55,745
WORLD (Excl. U.S.S.R., E. Europe & China)	2,192.3	2,257.8	81.1%	-2.9%	+2.5%	45,065	46,210

Differences between production and consumption are accounted for by stock changes and unknown military liftings. *U.S. processing gain has been deducted from total domestic product demand. †Based on weight. ‡Brazil 35.2, Mexico 29.1. **Brazil 855, Mexico 707. Source: BP Statistical Review of the World Oil Industry 1975 [4].

2. The Log-Log Specification

The log-log equation sets the log of the variable to be explained equal to a linear combination of the logs of the independent variables, hence its name. The basic static demand equation for fuel i is:

$$\log q_{ijt} = \alpha_{ij} + \beta_i \cdot \log y_{ijt} + \gamma_i \cdot \log P_{ijt} + \varepsilon_{ijt} \qquad (1)$$

where j is the country index and t the time index, q_i is per capita consumption of fuel i, y_j is the per capita gross domestic product in constant currency units of country j, and P_{ij} is the fuel price in real units of local currency. Adding the subscript j to the constant term (using intercept dummies) allows estimating an equation across countries with different units for the same variable. The α_{ij}'s account for scale differences because they are multiplicative terms. This is one of the conveniences of the log-log formulation, allowing pooling of various countries' time series without performing the often difficult task of conversion to a common unit of currency.

Unfortunately this same property eliminates the ability to pick up inter-country differences in estimating the elasticities. But if the true elasticities are the same in the pooled countries, pooling results in more efficient estimates. Alternative poolings can be used to test for differences in elasticities across countries.

By differentiating equation (1) with respect to P and y and multiplying by P/Q and y/Q respectfully, one obtains the price and income elasticities:

$$\eta_p = \frac{dq}{dp} \times \frac{P}{Q} = \gamma_i \qquad (2)$$

$$\eta_y = \frac{dq}{dy} \times \frac{P}{y} = \beta_i \qquad (3)$$

The elasticities can be read directly as one of the estimated coefficients and the elasticities are constant, i.e. identical for all values of q, P, and y.

If q is a "habit" level of consumption, or is consumed by a capital stock, the new equilibrium level of q after a sustained change in P or y is not reached instantaneously. This is a lagged adjustment process. One type of lagged adjustment is the Koyck or geometric lag, where the adjustment that takes place in each period is a constant portion of the difference between the current level of consumption and the equilibrium or "desired" level.

A dynamic version of equation (1) containing a Koyck lag is:

$$\log q_{ijt} = \alpha_{ij} + \beta_i \cdot \log y_{jt} + \gamma_i \cdot \log P_{ijt} + \lambda_i \cdot \log q_{ij,t-1} + \varepsilon_{ijt} \qquad (4)$$

where $1-\lambda$ $(0 < \lambda < 1)$ is the portion of adjustment between the current and equilibrium value of q that takes place in a given period. In the long-run equilibrium, which strictly speaking is reached only after an infinite number of periods, q_t equals q_{t-1}. Therefore substituting q_t for q_{t-1} in equation (4) and resolving for the log of q_t results in:

$$\log q_{ijt} = \frac{\alpha_{ij}}{1-\lambda_i} + \frac{\beta_i}{1-\lambda_i} \cdot \log P_{ijt} + \frac{\gamma_i}{1-\lambda_i} \cdot \log y_{jt} \qquad (5)$$

From this we see that the total long-run elasticities are the short-run (one period) elasticities, β_i and γ_i, divided by $(1-\lambda)$.

The fraction of the total adjustment to the new equilibrium t periods after a maintained change in P or y at t=0 is:

$$\frac{q_o - q_t}{q_o - q_{eq}} = 1 - \lambda^t \tag{6}$$

A useful measure when discussing and comparing lags is the median lag, T_m, or the value of t in equation (6) for which the fraction of the total adjustment completed equals one half.

$$.5 = 1 - \lambda^{T_m} \quad \text{or} \quad T_m = \log(.5)/\log(\lambda) \tag{7}$$

For example, if $\lambda = .7$ which implies a 30% adjustment to the long-run equilibrium in each period, the median lag is approximately 1.9 periods.

3. Data

This section provides a brief summary of the data used in estimating the previously described equations for the twenty countries. Also presented are the methods of transforming the data into the exact forms in which they were used in the estimating equations.[2]

Product Quantities:

The annual consumption by product type comes from two sources, each having a different category breakdown. They are each described below. The source of the quantity data for 18 countries (all except Brazil and Mexico) is OECD's Energy Statistics. For these countries there are nine fuel categories:

1. Aviation gasoline (AG)
2. Diesel fuel (DS)
3. Industrial fuel oil (INDFO)
4. Jet fuel (JF)
5. Kerosene (KS)
6. Liquified petroleum gases (LPG)
7. Motor gasoline (MG)
8. Other fuel oil -- other than industrial (RESFO)
9. Other petroleum products (FOPET) -- petroleum chemical feedstocks, fuel oil and LPG used to generate electricity and steam

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[2] The data employed are part of a large international data base. For complete details, see Chapter 5 of the Users Guide [3].

Fuel consumption data for Brazil and Mexico were obtained from the UN's World Energy Supplies. For these two countries there are four fuel categories:

1. Fuel oil -- consumption by all sectors, also diesel fuel
2. Gasolines -- motor and aviation gasolines
3. Kerosenes -- kerosene including jet fuel
4. LPG -- Liquified petroleum gases consumed by all sectors

The units of all of the above categories are Tcals per million capita per year. Tcals, a measure of the heat content of a fuel, is an abbreviation of teracalories or 10^{12} calories. A Tcal is the equivalent of 3.968×10^{9} BTU, or approximately 685 barrels of crude oil.

Prices:

For the nineteen countries other than the United States the prices of all petroleum products, retail price of gas, coal, and electricity and the industrial price of gas, coal, and electricity, were obtained from the international energy statistics compiled by the Federal Energy Administration.[3] In the data base the data are converted from various units to units of local currency per Tcal.

Price series for jet fuel and aviation gasolines were not available for any of the twenty countries. The price of kerosene was used as a proxy for the price of jet fuel and the price of motor gasoline was used in place of the price of aviation gasoline. Although the markets are different, the products are physically very similar. Prices for the U.S. were obtained from the Bureau of Mines and Department of Commerce. Details for each series may be found in Table 5-5 of the User's Guide [3].

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[3] With the exception of Brazil and Mexico, these data are proprietary and not described in the above mentioned User's Guide.

For the countries with an "other petroleum products" category an average of the prices of No. 2 and No. 6 fuel oils was used to approximate the price movements of those products. When used in estimating equations, all prices are deflated using the implicit gross domestic product deflator with 1970 as a base year. Therefore, the units are constant 1970 units of local currency for Tcal.

Price of Energy:

In estimating the demand for fuel oils, the products most susceptible to substitution of alternative fuels, a measure of the aggregate price of energy was needed. Translog price aggregators have been estimated for nine countries (residential price of energy) and ten countries (industrial price of energy).[4] Both groups are subsets of the 18 OECD countries included here. The coefficients estimated for these subsets were used with the prices of oil, gas, electricity, and coal in each country to generate a price index of energy for the entire group of 18 countries. Three indices were used: a four fuel residential index for European countries, a three fuel residential index for the U.S. and Canada,[5] and a four fuel index using industrial prices. The appropriate set of coefficients were used in each case, but no attempt was made to scale the index as the input prices were in each country's local currency.

The units of the price of energy indices are not defined, but since they are constructed from nominal local currency prices, the indices are deflated (using the implicit GDP deflator) when used in the estimating

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4 For a detailed description of the energy price aggregators, see Pindyck [1], [2].

5 Virtually no coal is used in the residential sectors of either the U.S. or Canada.

equations. The hope is that the indices capture the movement of the price of energy within each country.

Other Variables:

Series for gross domestic product, population, and temperature were also used. Gross domestic product data were obtained from the OECD's National Accounts and the UN's National Account Statistics. The units are 1970 local currency per capita. The implicit deflators were derived from the same sources by using the ratios of the GDP in current purchasers' values to the GDP in constant purchasers' values (1970 base year). Data for the total population of each country, used to transform fuel quantities and income to per capita bases, come from the UN Demographic Yearbook.

The temperature series represent the average temperature over the five winter months (November-March) of the major city or cities of each country. The source is the U.S. Weather Bureau's Monthly Climatic Data for the World, and the units of measurement are degrees Fahrenheit.

Table 1 shows the range of data available for the variables described above. The range of values used for estimation is only the intersection of the range for each variable included.[6] Table 2 gives the relative consumption of each fuel category for two different years. The total consumption in 1,000's of Tcals is also shown for the same years. One may observe that although the shares may differ drastically between countries, they are relatively stable over time within each country.

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[6] For some fuel categories the range includes zero values (no consumption) which can not be used in log equations.

TABLE 1

RANGE OF DATA

	Product Quantities	Petroleum Product Prices	Retail Price Other Fuels	Industrial Price Other Fuels	Income and Deflator	Temperature
All OECD except U.S.*	All 1950-1973	All 1955-1975	All 1955-1975	All 1955-1975	1955-1974	1955-1974 (varies slightly by country)
United States	All 1950-1973	Gasoline 50-75 #2 FO 56-74 #6 FO 54-57, 59-74	Coal 60-1974 Elec. 52-1972 Gas 59-1973	Coal 54-57 59-74 Elec. 56-74 Gas 54-57, 59-74	1955-1974	1955-1975
Brazil	All 1950-1974 (4 categories)	Gasolines 54-75 Fuel oils 54-75 Kerosene 54-71 LPG 56-75	N/A	N/A	1953-1974	1954-1975
Mexico	All 1950-1974 (4 categories)	Gasolines 60-75 Fuel oils 61-74 Kerosene 50-74 LPG 62-74	N/A	N/A	1958-1975	1959-1975

* Includes: Austria, Belgium, Canada, Denmark, France, Greece, Ireland, Italy, Japan, Netherlands, Norway, Spain, Sweden, Switzerland, Turkey, United Kingdom and West Germany

TABLE 2

RELATIVE PRODUCT SHARES

(% of total Tcals)

Country		Motor Gasolines	Industrial Fuel Oil	Other Fuel Oil	Diesel Fuel	Jet Fuel	LPG	Kerosene	Aviation Gasoline	Other Petroleum Products	Total (10^{15} Calories)*	
Austria	1963	19.8%	34.3%	10.7%	13.6%	.7%	1.3%	.5%	.02%	19.0%	100%	46
	1973	20.6%	28.9%	22.4%	10.9%	.5%	.7%	.1%	.03%	15.7%	100%	121
Belgium	1963	12.8%	30.6%	19.6%	9.4%	1.7%	3.5%	.5%	.3%	21.5%	100%	109
	1973	10.4%	18.0%	28.1%	7.5%	2.0%	2.2%	.1%	.04%	31.6%	100%	278
Canada	1963	36.7%	12.9%	32.2%	6.1%	2.6%	1.7%	6.3%	.6%	1%	100%	412
	1973	35.0%	17.4%	30.0%	6.3%	3.8%	2.5%	3.4%	.2%	1.4%	100%	774
Denmark	1963	15.2%	31.3%	27.6%	7.4%	3.1%	2.0%	3.4%	.5%	9.5%	100%	77
	1973	10.1%	14.8%	36.3%	10.4%	4.4%	1.7%	1.1%	.1%	21.0%	100%	181
France	1963	20.1%	27.9%	16.6%	11.5%	2.0%	3.4%	.3%	.3%	18.0%	100%	390
	1973	15.0%	21.3%	27.5%	9.2%	1.7%	2.3%	.04%	.04%	23.0%	100%	1,180
Greece	1963	5.9%	13.7%	5.1%	11.5%	4.2%	.4%	3.4%	1%	54.8%	100%	46
	1973	4.7%	9.1%	5.8%	7.4%	3.8%	.8%	.4%	.06%	67.8%	100%	203
Ireland	1963	6.2%	6.3%	3.2%	3.6%	.4%	.3%	1.6%	.07%	78.2%	100%	68
	1973	4.7%	6.7%	3.3%	2.4%	1.6%	.5%	.7%	.01%	80.1%	100%	195
Italy	1963	14.7%	34.2%	11.9%	11.6%	2.0%	3.1%	.8%	.2%	21.4%	100%	350
	1973	12.6%	23.2%	19.1%	6.6%	1.9%	2.3%	2.9%	.03%	31.3%	100%	1,000
Japan	1963	13.2%	34.1%	8.5%	6.0%	.6%	3.3%	6.1%	.2%	28.0%	100%	553
	1973	9.5%	27.3%	12.9%	5.3%	.6%	4.1%	8.8%	.05%	31.5%	100%	2,325
Netherlands	1963	11.2%	27.0%	16.7%	11.2%	2.1%	1.5%	6.0%	.2%	24.1%	100%	154
	1973	12.9%	8.2%	17.1%	9.6%	3.1%	1.8%	4.1%	.03%	43.2%	100%	309
Norway	1963	14.7%	34.7%	21.7%	16.8%	2.0%	.2%	3.0%	.8%	6.0%	100%	42
	1973	16.1%	28.7%	20.7%	16.7%	3.9%	.4%	6.5%	.1%	6.9%	100%	76

* 1,000 Tcals (10^{15} calories) ≈ 200 barrels/day

TABLE 2 -- Continued

RELATIVE PRODUCT SHARES (% of total Tcals)

Country	Year	Motor Gasolines	Industrial Fuel Oil	Other Fuel Oil	Diesel Fuel	Jet Fuel	LPG	Kerosene	Aviation Gasoline	Other Petroleum Products	Total (10^{15} Calories)*	
Spain	1963	13.1%	16.6%	7.2%	22.8%	2.4%	4.3%	5.0%	1.1%	27.5%	100%	78
	1973	11.9%	32.1%	2.8%	18.5%	5.3%	6.0%	.7%	.3%	22.4%	100%	382
Sweden	1963	13.5%	24.0%	42.9%	6.9%	2.0%	.3%	1.9%	.3%	8.2%	100%	158
	1973	11.9%	25.4%	38.9%	6.4%	2.0%	.9%	.5%	.1%	13.8%	100%	292
Switzerland	1963	20.9%	25.5%	38.9%	8.6%	3.6%	.2%	.3%	.3%	5.3%	100%	67
	1973	18.6%	20.8%	43.7%	5.9%	4.8%	.4%	.1%	.04%	5.5%	100%	151
Turkey	1963	20.7%	17.5%	1.9%	26.9%	.4%	.4%	18.1%	.07%	14.1%	100%	28
	1973	12.1%	15.6%	16.0%	24.2%	1.3%	4.1%	4.9%	Ø	21.7%	100%	124
United Kingdom	1963	18.2%	27.5%	8.0%	10.1%	4.0%	.4%	3.7%	.5%	27.5%	100%	564
	1973	17.5%	25.4%	8.1%	8.8%	4.4%	1.4%	3.3%	.06%	31.0%	100%	1,082
United States	1963	34.1%	4.7%	18.9%	6.4%	5.2%	4.3%	2.8%	2.9%	15.5%	100%	5,069
	1973	38.7%	3.5%	15.6%	6.9%	6.5%	4.7%	1.4%	.2%	22.4%	100%	8,263
W. Germany	1963	16.2%	26.1%	28.5%	11.6%	.7%	1.8%	.1%	.2%	14.7%	100%	648
	1973	14.9%	21.0%	34.6%	8.1%	1.9%	2.3%	.05%	.02%	17.1%	100%	1,420

	Year	Motor and Aviation Gasoline	Fuel Oils	LPG	Kerosene and Jet Fuel	Total (10^{15} Calories)*	
Brazil	1963	29.9%	60.3%	4.4%	5.4%	100%	161
	1973	29.4%	62.4%	3.8%	4.4%	100%	363
Mexico	1963	30.5%	49.8%	7.0%	12.7%	100%	138
	1973	31.7%	49.1%	10.5%	8.6%	100%	280

*1,000 Tcals (10^{15} calories) ≈ 200 barrels/day

4. Statistical Results

In this section we present the estimation results for the models described above. The twenty countries are pooled into five groups and alternative model specifications are explored for each product category within each group. The five groups are:

1. North America (2 countries): United States and Canada
2. Europe (12 countries): Austria, Belgium, Denmark, France, Ireland, Italy, Netherlands, Norway, Sweden, Switzerland, United Kingdom and West Germany
3. Southern Europe (3 countries): Greece, Spain and Turkey
4. Japan (1 country)
5. South America (2 countries): Brazil and Mexico

This grouping is based upon geographic proximity and broad similarity of economic characteristics, such as degree of development and growth rate. Many other possible combinations of countries exist along with valid arguments for their use. Alternative poolings have not yet been completed, as each requires a bare amount of computer work. One or two different poolings for a few of the equations should be estimated to test the validity of the selected pooling.

For each of the groups a subset of the estimated equation specifications are presented in Tables 3 through 7. All regressions were done using the ordinary least squares (OLS) program of TROLL. As opposed to a verbal description of the information contained in these tables, a general outline of the estimation work is presented. For each product type in each of the country groups the "preferred" specification is

NOTES TO TABLES 3A THROUGH 7

When a variable is indicated, the coefficient is that of the log of that variable.

The lagged dependent variable is the value of the left-hand side variable in the previous year.

The T statistic for each coefficient appears in parentheses below the coefficient.

NOB = number of observations

F = F statistic

T_m = median lag in years

MG = motor gasoline
DS = diesel fuel
KS = kerosene
JF = jet fuel
AG = aviation gasoline
LPG = liquified petroleum gases
INDFO = industrial fuel oil
RESFO = residential (other) fuel oil
FOPET = other petroleum products

* indicates preferred specification

TABLE 3A

ALTERNATIVE EQUATION SPECIFICATIONS FOR US AND CANADA

Dependent Variable	Price	Income	Lagged Dependent	NOB	R^2	F	T_m	Long Run Elasticities		Constant	
								Price	Income	Canada	US
1 MG	-.032 (-.452)	.355 (5.69)	.686 (9.61)	38	.996	2324	1.84	-.102	1.13	.277 (.274)	.283 (.280)
*2 MG	-.381 (-3.24)	.860 (13.3)	--	38	.987	832	--	--	--	5.67 (3.53)	5.75 (3.57)
3 DS	-.440 (-3.11)	.373 (3.63)	.597 (9.39)	38	.986	564	1.34	-1.09	.926	3.95 (2.22)	4.06 (2.21)
*4 DS	-1.06 (-4.52)	1.02 (7.10)	--	38	.947	202	--	--	--	8.70 (2.70)	8.98 (2.71)
*5 KS	-.314 (-1.56)	-.274 (-2.31)	.786	37	.977	344	2.88	-1.47	-1.28	6.58 (2.14)	6.42 (2.12)
6 KS	-1.13 (-3.60)	-.824 (-4.63)	--	37	.925	136	--	--	--	24.04 (5.83)	23.39 (5.73)
*7 LPG	-.899 (-2.21)	.622 (2.03)	.516 (3.19)	34	.976	301	1.05	-1.86	1.29	6.49 (1.34)	5.67 (1.27)
8 LPG	-1.85 (-5.84)	1.26 (4.73)	--	34	.968	304	--	--	--	13.4 (2.72)	11.8 (2.57)
*9 JF	-.571 (-1.46)	.831 (2.92)	.603 (6.89)	37	.982	429	1.37	-1.44	2.09	.981 (.214)	.994 (.219)
10 JF	-1.82 (-3.38)	2.25 (7.38)	--	37	.954	230	--	--	--	4.45 (.631)	4.40 (.628)

* preferred specification, see notes on preceding page.

TABLE 3B

ALTERNATIVE EQUATIONS SPECIFICATIONS FOR US AND CANADA

Dependent Variable	Price	Income	Dependent	NOB	R^2	F	T_m	Long Run Elasticities Price	Long Run Elasticities Income	Other Fuel Prices Coal	Other Fuel Prices Elec	Other Fuel Prices Gas	Constant Canada	Constant US
11 INDFO	.108 (.730)	.293 (.960)	.890 (7.53)	36	.981	208	5.95	.982	.266	.191 (.741)	-.047 (-.106)	.298 (1.19)	-3.51 (-.913)	-3.456 (-.852)
*12 INDFO	-.606 (-3.08)	1.57 (3.62)	--	36	.943	80	--	--	--	1.42 (4.19)	1.76 (2.75)	-.024 (-.058)	-12.1 (-1.93)	-13.4 (-2.04)
13 INDFO	.166 (1.63)	.243 (2.10)	.939 (14.1)	37	.979	381	11.0	2.72	3.98	--	--	--	-2.74 (-1.73)	-2.83 (-1.83)
14 INDFO	-.087 (-.32)	.551 (1.83)	--	37	.851	63	--	--	--	--	--	--	4.41 (1.11)	3.19 (0.81)
15 RESFO	-.113 (-.705)	.062 (.271)	.537 (3.14)	33	.979	200	1.11	-.244	.134	--	-.274 (-1.24)	-.260 (-1.32)	7.09 (1.37)	6.98 (1.34)
16 RESFO	-.379 (-2.48)	.268 (2.39)	.561 (4.79)	37	.970	256	1.20	-.863	.610	--	--	--	5.05 (2.51)	4.85 (2.43)
17 RESFO	-.944 (-7.56)	.644 (6.23)	--	37	.948	201	--	--	--	--	--	--	11.87 (6.49)	11.47 (6.20)
*18 RESFO	-.279 (-1.82)	.224 (2.05)	.640 (5.44)	37	.973	228	1.55	-.775	.622	Temperature -.377 (-2.09)	--	--	5.13 (2.68)	5.01 (2.64)
*19 FOPET	-.842 (-1.99)	.472 (1.16)	.475 (3.61)	30	.999	3521	.931	1.60	.900	--	-.370 (-1.87)	--	6.55	8.18
20 FOPET	-.992 (-1.94)	1.36 (3.49)	--	30	.999	2971	--	--	--	--	-.405 (-1.68)	--	2.95 (.440)	5.77 (.836)
21 AG	-.594 (-1.43)	1.23 (1.34)	.801 (7.77)	38	.957	144	3.12	2.98	6.18	Time -.069 (-1.68)				

* preferred specification, see notes on page 15.

TABLE 4A

ALTERNATIVE EQUATION SPECIFICATIONS FOR EUROPE

Dependent Variable	Price	Income	Lagged Dependent	NOB	R^2	F	T_m	Long Run Elasticities Price	Long Run Elasticities Income
*1 MG	-.214 (-5.91)	.088 (2.46)	.867 (48.59)	228	.995	3116	4.86	-1.61	.662
2 MG	-1.03 (-9.24)	1.35 (15.8)	--	228	.941	263	--	--	--
*3 DS	-.075 (-1.93)	.096 (1.85)	.878 (46.9)	228	.988	1267	5.33	-.615	.787
4 DS	.038 (.291)	2.05 (19.6)	--	228	.865	105	--	--	--
5 KS	.050 (2.08)	.082 (1.54)	.978 (46.2)	228	.993	2066	52.9	3.84	6.31
*6 KS	--	.029 (.613)	.977 (45.7)	228	.992	2190	29.8	--	1.26
*7 LPG	-.051 (-.428)	.370 (2.39)	.796 (22.7)	214	.969	447	3.04	-.250	1.81
8 LPG	-.066 (-.290)	2.86 (13.8)	--	214	.889	123	--	--	--
*9 JF	-.094 (-1.64)	.586 (3.02)	.779 (21.8)	220	.941	236	2.78	-.425	2.65
10 JF	-.325 (-3.14)	3.80 (16.5)	--	220	.806	65	--	--	--

* preferred specification, see notes on page 15.

TABLE 4A (Continued)

CONSTANT TERMS

Dependent Variable	Austria	Belgium	Denmark	France	Ireland	Italy	Netherlands	Norway	Sweden	Switzerland	UK	W. Germany
1 MG	2.93	2.99	2.80	2.76	2.43	3.39	2.67	2.77	2.75	2.69	2.40	2.68
	(4.43)	(4.17)	(4.55)	(4.61)	(5.45)	(4.01)	(4.70)	(4.52)	(4.57)	(4.64)	(5.28)	(4.68)
2 MG	6.39	5.95	6.97	7.03	8.40	5.69	7.05	6.77	6.88	6.76	7.89	6.82
	(2.79)	(2.40)	(3.29)	(3.41)	(5.66)	(1.94)	(3.62)	(3.21)	(3.33)	(3.39)	(5.17)	(3.45)
3 DS	.849	.792	.861	.875	.979	.776	.864	.874	.868	.824	.942	.885
	(1.01)	(.877)	(1.16)	(1.17)	(1.87)	(.708)	(1.27)	(1.82)	(1.15)	(1.11)	(1.72)	(1.22)
4 DS	-15.4	-17.5	-13.2	-12.8	-6.19	-21.9	-11.3	-12.7	-13.1	-12.9	-7.13	-12.0
	(-5.95)	(-6.40)	(-5.80)	(-5.51)	(-3.68)	(-6.61)	(-5.36)	(-5.54)	(-5.58)	(-5.63)	(-4.07)	(-5.30)
5 KS	-1.47	-1.54	-1.18	-1.32	-.763	-1.66	-1.03	-1.11	-1.24	-1.15	-.785	-1.21
	(-1.97)	(-1.91)	(-1.75)	(-1.99)	(-1.72)	(-1.76)	(-1.67)	(-1.66)	(-1.87)	(-1.86)	(-1.65)	(-1.89)
6 KS	-.268	-.263	-.106	-.255	-.035	-.156	-.038	-.037	-.188	-.204	-.013	-.195
	(-.559)	(-.495)	(-.241)	(-.599)	(-.128)	(-.254)	(-.096)	(-.086)	(-.435)	(-.482)	(-.042)	(-.473)
7 LPG	-2.23	-2.36	-1.82	-1.66	-.678	-3.01	-1.54	-2.06	-1.95	-2.11	-1.03	-1.59
	(-.799)	(-.798)	(-.749)	(-.690)	(-.386)	(-.852)	(-.661)	(-.790)	(-.768)	(-.859)	(-.563)	(-.662)
8 LPG	-25.2	-26.8	-21.6	-20.5	-12.2	-32.4	-19.2	-23.6	-22.6	-22.6	-14.5	-19.8
	(-5.09)	(-5.12)	(-5.01)	(-4.77)	(-3.83)	(-5.21)	(-4.64)	(-5.15)	(-5.02)	(-5.28)	(-4.43)	(-4.67)
9 JF	-4.09	-4.36	-3.22	-3.24	-1.49	-5.29	-2.86	-3.30	-3.29	-3.22	-1.73	-3.19
	(-1.82)	(-1.81)	(-1.62)	(-1.66)	(-1.19)	(-1.86)	(-1.59)	(-1.67)	(-1.68)	(-1.73)	(-1.29)	(-1.69)
10 JF	-32.3	-34.8	-27.5	-27.2	-15.5	-41.9	-24.5	-27.6	-27.5	-26.9	-16.6	-27.2
	(-9.71)	(-9.73)	(-9.17)	(-9.29)	(-7.89)	(-10.0)	(-8.97)	(-9.25)	(-9.30)	(-9.80)	(-7.89)	(-9.72)

TABLE 4B

ALTERNATIVE EQUATION SPECIFICATIONS FOR EUROPE

Dependent Variable	Price	Income	Lagged Dependent	NOB	R^2	F	T_m	Long Run Elasticities: Price	Long Run Elasticities: Income	Other Fuel Prices: Coal	Other Fuel Prices: Elec	Other Fuel Prices: Gas
11 INDFO	-.109 (-1.96)	.004 (.042)	.890 (28.9)	228	.961	304	5.95	-.991	.036	-.106 (-1.66)	.055 (.686)	.074 (1.87)
*12 INDFO	-.101 (-2.06)	-.015 (-.167)	.879 (28.5)	228	.959	361	5.37	-.835	-.124	--	--	--
13 INDFO	-.481 (-4.64)	1.71 (11.9)	--	228	.805	67	--	--	--	--	--	--
14 RESFO	-.185 (-2.49)	.166 (1.73)	.868 (35.4)	228	.989	1066	4.90	-1.40	1.26	.002 (.029)	.069 (1.56)	.008 (.179)
15 RESFO	-.171 (-2.46)	.157 (1.67)	.856 (36.9)	228	.988	1295	4.46	-1.19	1.09	--	--	--
16 RESFO	-.127 (-1.86)	.220 (2.33)	.857 (38.3)	222	.989	1246	4.49	-.888	1.54	Temperature -.690 (-4.75)	--	--
*17 RESFO	-.184 (-2.62)	.253 (2.71)	.859 (38.9)	222	.989	1207	4.56	-1.30	1.79	-.665 (-4.65)	Price Energy .152 (2.78)	
18 FOPET	-.471 (-4.43)	.211 (1.68)	.773 (23.0)	223	.978	606	2.69	-2.07	.930	--	Elec -.034 (-.537)	--
*19 FOPET	-1.47 (-8.08)	1.42 (6.59)	--	223	.921	172	--	--	--	--	-.461 (-4.01)	--
20 AG	-.413 (-1.01)	6.26 (1.34)	--	224	.820	68	--	--	--	Time -.099 (-6.33)		

* preferred specification, see notes on page 15.

TABLE 4B (Continued)

CONSTANT TERMS

Dependent Variable	Austria	Belgium	Denmark	France	Ireland	Italy	Netherlands	Norway	Sweden	Switzerland	UK	W. Germany
11 INDFO	1.78	1.88	1.75	1.66	1.45	2.16	1.60	1.75	1.74	1.67	1.43	1.73
	(1.25)	(1.20)	(1.38)	(1.36)	(1.80)	(1.14)	(1.38)	(1.43)	(1.39)	(1.39)	(1.68)	(1.45)
12 INDFO	2.28	2.40	2.21	2.12	1.79	2.68	2.03	2.20	2.21	2.12	1.84	2.14
	(1.97)	(1.90)	(2.09)	(2.10)	(2.60)	(1.76)	(2.13)	(2.09)	(2.14)	(2.10)	(2.57)	(2.18)
13 INDFO	-5.18	-6.32	-3.67	-3.67	.354	-8.73	-2.90	-3.54	-3.35	-3.61	-.161	-3.47
	(-2.09)	(-2.34)	(-1.61)	(-1.68)	(.235)	(-2.72)	(-1.41)	(-1.56)	(-1.50)	(-1.67)	(-.102)	(-1.65)
14 RESFO	.895	.722	1.01	.808	1.01	.502	.862	.919	.928	.958	.943	.931
	(.570)	(.424)	(.719)	(.595)	(1.11)	(.248)	(.681)	(.662)	(.681)	(.715)	(.983)	(.716)
15 RESFO	1.59	1.56	1.65	1.46	1.41	1.50	1.46	1.48	1.57	1.56	1.33	1.56
	(1.08)	(.998)	(1.26)	(1.16)	(1.61)	(.819)	(1.23)	(1.14)	(1.24)	(1.25)	(1.45)	(1.29)
16 RESFO	2.81	2.78	3.01	3.01	3.26	2.66	2.96	2.67	2.84	2.96	3.14	2.98
	(1.89)	(1.76)	(2.24)	(2.31)	(3.40)	(1.45)	(2.42)	(2.01)	(2.19)	(2.31)	(3.14)	(2.39)
17 RESFO	1.84	1.67	2.16	2.15	2.80	1.21	2.23	1.87	1.98	2.12	2.69	2.19
	(1.23)	(1.04)	(1.60)	(1.64)	(2.93)	(.642)	(1.81)	(1.40)	(1.51)	(1.64)	(2.70)	(1.74)
18 FOPET	3.53	3.85	3.24	3.22	3.10	4.70	3.16	2.92	3.00	2.58	2.53	3.00
	(1.72)	(1.70)	(1.75)	(1.77)	(2.54)	(1.74)	(1.87)	(1.61)	(1.67)	(1.48)	(2.01)	(1.73)
19 FOPET	9.62	10.4	8.96	9.39	10.7	12.3	9.50	7.57	8.26	6.47	8.20	8.70
	(2.52)	(2.46)	(2.60)	(2.78)	(4.86)	(2.44)	(3.03)	(2.24)	(2.47)	(1.98)	(3.53)	(2.70)
20 AG	1.51	3.20	4.72	3.57	4.07	2.10	3.76	4.50	4.44	3.79	4.57	3.07
	(.177)	(.345)	(.597)	(.466)	(.748)	(.191)	(.520)	(.572)	(.574)	(.508)	(.809)	(.417)

TABLE 5A

ALTERNATIVE EQUATION SPECIFICATIONS FOR GREECE, SPAIN, & TURKEY

Dependent Variable	Price	Income	Lagged Dependent	NOB	R^2	F	T_m	Long Run Elasticities Price	Long Run Elasticities Income	Constants Greece	Constants Spain	Constants Turkey
*1 MG	-.159 (-1.54)	.744 (6.04)	.616 (8.75)	57	.982	571	1.43	-.414	1.94	-2.99 (-1.67)	-3.37 (-1.76)	-2.03 (-1.31)
2 MG	-.333 (-2.09)	1.72 (20.9)	--	57	.956	283	--	--	--	-6.80 (-2.49)	-7.71 (-2.67)	-4.55 (-1.91)
3 DS	.121 (1.86)	.165 (1.13)	.937 (15.5)	57	.988	854	10.6	1.92	2.62	-2.67 (-1.71)	-2.92 (-1.71)	-2.30 (-1.75)
*4 DS	--	.366 (1.98)	.761 (8.80)	33 (63-73)	.984	422	2.54	--	1.53	-2.03 (-1.47)	-2.23 (-1.48)	-1.47 (-1.37)
5 KS	.163 (1.24)	-.089 (-1.18)	.764 (10.1)	57	.914	108	2.57	.691	-.377	-.055 (-.025)	-.143 (-.061)	.006 (.003)
*6 KS	--	-.177 (-3.93)	.787 (11.4)	59	.901	123	2.89	--	-.831	2.81 (4.24)	2.88 (4.28)	2.52 (4.26)
7 JF	.347 (.463)	1.49 (2.01)	.612 (6.40)	48	.944	140	1.41	.894	3.84	-17.3 (-1.09)	-18.9 (-1.13)	-15.2 (-1.08)
*8 JF	--	1.14 (1.82)	.638 (4.74)	33 (63-73)	.950	132	1.54	--	3.15	-9.47 (-1.61)	-10.6 (-1.64)	-8.28 (-1.67)

* preferred equation, see notes on page 15.

TABLE 5B

ALTERNATIVE EQUATION SPECIFICATIONS FOR GREECE, SPAIN, & TURKEY

Dependent Variable	Price	Income	Lagged Dependent	NOB	R^2	F	T_m	Long Run Elasticities Price	Long Run Elasticities Income	Constants Greece	Constants Spain	Constants Turkey	Price Energy	Temperature
9 INDFO	-1.01 (-3.65)	.368 (1.48)	.651 (6.93)	57	.968	253	1.61	-2.89	1.05	6.04 (1.29)	10.7 (1.89)	9.7 (2.06)	.007 (.022)	
10 INDFO	-2.25 (-7.74)	1.52 (5.97)	--	57	.937	153	--	--	--	1.16 (.180)	10.4 (1.33)	10.9 (1.66)	.841 (2.02)	
*11 INDFO	-1.01 (-3.70)	.365 (1.79)	.651 (7.55)	57	.968	309	1.61	-2.89	1.05	6.11 (2.05)	10.7 (2.54)	9.78 (2.72)	--	
12 RESFO	.385 (1.42)	.676 (2.29)	.760 (12.5)	43	.973	181	2.53	1.60	2.81	-13.7 (-1.78)	-14.5 (-1.83)	-11.8 (-1.75)	.108 (.683)	.648 (.974)
13 RESFO	1.83 (3.27)	3.26 (6.71)	--	43	.854	35	--	--	--	-62.1 (-4.15)	-66.0 (-4.26)	-53.6 (-3.99)	.791 (2.31)	1.36 (.89)
*14 RESFO	--	.653 (2.86)	.796	27 (65-73)	.981	288	3.04	--	3.20	-5.34 (-2.51)	-6.09 (-2.61)	-4.10 (-2.40)	--	
													Price of Electricity	
*15 FOPET	-.219 (-.937)	.699 (1.58)	.570 (4.94)	53	.966	215	1.23	-.509	1.62	4.45 (.324)	4.99 (.272)	3.87 (.317)	-.434 (-.621)	
16 FOPET	-.626 (-2.33)	1.62 (3.32)	--	53	.947	169	--	--	--	7.30 (.435)	6.10 (.339)	6.16 (.412)	-.745 (-.874)	
*17 LPG	--	.535 (2.98)	.702 (23.7)	33	.993	1005	1.96	--	1.80	-4.00 (-2.29)	-4.04 (-2.18)	-3.02 (-2.14)		
*18 LPG	-.636 (-4.17)	-.137 (-.637)	.733 (29.8)	33	.996	1279	2.23	-2.38	-.513	11.54 (2.90)	11.9 (2.91)	8.7 (2.88)		

* preferred specification, see notes on page 15.

TABLE 6A

ALTERNATIVE EQUATION SPECIFICATIONS FOR JAPAN

Dependent Variable	Price	Income	Lagged Dependent	Range	R^2	F	T_m	Long Run Elasticities Price	Long Run Elasticities Income	Constant
1 MG	.336 (1.30)	.852 (2.26)	.429 (1.83)	55-73	.996	1311	.82	.588	1.49	-12.4 (-1.77)
*2 MG	--	.481 (1.90)	.631 (3.53)	55-73	.996	1883	1.51	--	1.30	-3.67 (-1.74)
3 DS	.685 (1.17)	.922 (1.31)	.621 (2.29)	55-73	.993	675	1.45	1.81	2.43	-20.0 (-1.24)
*4 DS	--	.179 (.595)	.876 (5.45)	55-73	.992	990	5.24	--	1.44	-1.46 (-.490)
5 KS	.075 (.152)	.310 (.418)	.863 (3.82)	55-73	.994	772	4.70	.547	2.26	(-4.14)
*6 KS	--	.219 (.510)	.881 (4.69)	55-73	.994	1232	5.47	--	1.84	-1.95 (-.437)
7 LPG	-.120 (-.202)	-.245 (-.590)	.963 (4.82)	57-73	.987	319	18.4	-3.24	-6.62	5.53 (.500)
*8 LPG	-2.29 (-3.75)	1.09 (2.20)	--	57-73	.963	180	--	--	--	28.2 (1.75)
9 JF	-.482 (-.602)	1.28 (1.87)	-.066 (-.362)	60-73	.976	133	--	--	--	-5.30 (-.263)
10 JF	-.471 (-.614)	1.17 (1.97)	--	60-73	.975	216	--	--	--	-4.34 (-.227)

* preferred specification, see note on page 15.

TABLE 6B

ALTERNATIVE EQUATION SPECIFICATIONS FOR JAPAN

Dependent Variable	Price	Income	Lagged Dependent	Range	R^2	F	T_m	Long Run Elasticities: Price	Long Run Elasticities: Income	Constant	Other Fuel Prices: Coal	Other Fuel Prices: Electricity	Other Fuel Prices: Gas
*11 INDFO	-.619 (-.965)	1.46 (2.94)	--	55-73	.971	268	--	--	--	-2.68 (-.175)	--	--	--
12 INDFO	-1.14 (-1.76)	1.29 (1.71)	--	55-73	.992	326	--	--	--	-.501 (-.018)	-2.08 (-3.22)	.235 (.211)	2.16 (3.95)
13 RESFO	-.113 (-.264)	.789 (2.43)	.485 (2.31)	55-73	.998	1143	.96	-.219	1.53	-3.37 (.310)	-.524 (-.579)	.438 (.855)	-.118 (-.116)
*14 RESFO	-.624 (-2.57)	.584 (2.22)	.519 (4.09)	55-73	.998	2318	1.06	-1.30	1.21	4.69 (.865)	--	--	--
15 RESFO	-.868 (-2.54)	1.46 (6.81)	--	55-73	.996	1106	--	--	--	-1.30 (-.154)	--	--	Temperature .375 (.407)
16 FOPET	-1.34 (-2.57)	.345 (.473)	.013 (.111)	55-73	.995	442	--	--	--	31.4 (1.13)	--	-.877 (-1.05)	--
*17 FOPET	-1.37 (-3.05)	.350 (.501)	--	55-73	.995	654	--	--	--	31.9 (1.23)	--	-.887 (-1.13)	--

* preferred equation, see notes on page 15.

TABLE 7

ALTERNATIVE EQUATION SPECIFICATIONS FOR BRAZIL AND MEXICO

Independent Variable	Price	Income	Lagged Dependent	NOB	R^2	F	T_m	Long Run Elasticities: Price	Long Run Elasticities: Income	Constant	Dummy for Mexico
1 Gasolines	-.020 (-.199)	.864 (12.2)	--	32	.966	269	--	--	--	4.44 (7.01)	-4.77 (-6.81)
*2 Gasolines	-.118 (-1.72)	.260 (2.41)	.787 (6.21)	32	.986	482	2.89	-.554	1.22	1.48 (2.35)	-.877 (-1.13)
3 Fuel Oils	.094 (1.19)	.678 (6.12)	--	34	.881	74	--	--	--	4.99 (9.76)	-2.94 (-3.49)
*4 Fuel Oils	-.084 (-1.87)	.126 (1.53)	.777	34	.970	232	2.75	-.377	.565	1.69 (3.83)	-1.47 (-3.21)
5 Kerosine	-.096 (-1.54)	.117 (1.60)	--	34	.991	1076	--	--	--	4.91 (15.6)	1.19 (2.84)
*6 Kerosine	-.129 (-2.14)	.100 (1.44)	.349	34	.992	912	.658	-.198	.154	3.53 (5.09)	.937 (2.29)
*7 LPG	-.762 (-3.45)	1.72 (6.21)	--	28	.931	108	--	--	--	4.97 (2.87)	-5.78 (-2.41)
8 LPG	-.065 (-.430)	.130 (.497)	.766 (7.57)	28	.980	285	2.60	-.278	.556	1.23 (1.45)	-.200 (-.137)

*preferred specification, see notes on page 15.

indicated with an asterisk. Not a precise term, "preferred" indicates a combination of significance and correct sign in the elasticities and reasonable behavior in the lag structure. An attempt has been made to show the logical alternative(s) to the preferred specification. The most common reason for selecting an equation which excludes a variable which should in theory be included (such as price) is an incorrect sign for the coefficient of that variable (such as a positive elasticity for price).

In the case of motor gasolines and diesel fuel where, strictly speaking, other fuels do not compete for the same uses, alternative specifications attempted include only the basic equations. That is, only the static and dynamic version where product price and income are used as explanatory variables. For the fuel oils the appropriate prices (retail or industrial) of alternative fuels were used; generally with poor result. Alternatively the respective constructed price of energy was used in the fuel oil equations for each group (regressions not shown for every case) also with mixed results. For other fuel oil, the major use of which is space heating, an average temperature variable was included. Good results were achieved using the temperature variable in equations for Europe and North America. Fuels used to generate electricity constitute a significant portion of the category "other petroleum products" (FOPET). Therefore the price of electricity was employed and expected to have a negative coefficient. A time variable was used in some specifications for aviation gasoline in an attempt to account for the replacement over time of internal conbustion engines by jet engines in most commercial aircraft. As would be expected, jet fuel has a high income elasticity in most cases; higher than would be expected to hold after the above mentioned replacement has been more or less completed.

The results in many cases indicate a negative income elasticity for kerosene. It is reasonable that kerosene is an inferior good, being replaced by more convenient heating and cooking fuels as incomes rise. LPG, only recently a significant consumption category, generally displays a very high positive income elasticity. One would not expect these high elasticities to hold in the long run.

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