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WORLD DEMAND FOR GASOLINE: Some Empirical Findings†

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The experience of the past few years has shown that the consumption of energy in the world cannot continue to increase at the present rate unless new sources of energy are discovered. Therefore, it is necessary to explore some long run solutions for the present energy shortage. In order to understand the nature of possible solutions for this present shortage, it is necessary to understand the characteristics of energy sources and consumption. The purpose of this paper is to determine the characteristics of the demand function for energy used directly in the transport sector of the world. We focus on this sector for two fundamental reasons: (a) with the recent embargo on crude oil, this sector is in the forefront of the debate, primarily because the shortage affects both the consumption and production activities in almost all economies, and (b) the transportation sector accounts for about one-third of the total net consumption of energy.

MODEL

Most of the previous studies [1–4, 7, 8] have concentrated on short-run demand functions and their empirical findings have been based on time series data. However, a recent study [6] for the United States based on cross-section data deals with the long-run demand function. These studies have used data which have rather small variations in the price of gasoline. For example, in 1970, the lowest price per gallon of gasoline was 32.23 cents in Houston, Texas and the highest price was 38.12 cents in Indianapolis, Indiana. This makes these studies useful for policy purposes *only* when there are small changes in price. In the present study the price variations are much wider. For example, in 1970 the lowest price per gallon in the sample countries was 18.3 cents (U.S.) in the Phillipines and highest was 78.0 cents (U.S.) in Italy. This wide spread makes the data relevant in our study statistically more reliable. In our study also we develop a model for a long-run demand function for gasoline (petrol) based on 40 countries.

The world gasoline industry is characterized as oligopolistic. However, since the price of gasoline in almost all the countries is directly or indirectly controlled[1] by the

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[1] For example, even in the United States the government has kept the price of gasoline fairly low by (i) controlling the price of domestic crude oil, (ii) allowing depletion allowances and (iii) keeping taxes on gasoline at a low level.

respective governments, it is reasonable to assume that the quantity consumed is just demand determined. The demand function for gasoline in the i-th country is assumed to be downward sloping, and *in addition to price* depends upon (i) the number of cars in the country (ii) the number of commercial vehicles in the country (iii) and the per capita income. Symbolically, the demand function may be written as follows:

$$Q_{di} = F(P_i, C_i, V_i, Y_i), \tag{1}$$

where in the i-th country: Q_{di} is the quantity of gasoline demanded in gallons, P_i is the price per gallon in cents (U.S.), C_i is the number of registered cars, V_i is the number of registered commercial vehicles, and Y_i is per capita income in U.S. dollars.

Specifically, the demand function is assumed to be of the following form:

$$Q_d = aP^b C^c V^d Y^f e^U, \tag{2}$$

where Q_d, P, C, V, and Y are defined above, and U is a random error term. The subscript i is dropped for simplicity.

Other things being equal, the higher the price, the lower will be the quantity demanded. Therefore,

$$\partial Q_d / \partial P < 0. \tag{3}$$

As the number of cars increases, *ceteris paribus,* the quantity of gasoline demanded will increase. Therefore, we expect that

$$\partial Q_d / \partial C > 0. \tag{4}$$

Similarly, as the number of registered commercial vehicles increases, *ceteris paribus,* the quantity of gasoline demanded will increase. Accordingly,

$$\partial Q_d / \partial V > 0. \tag{5}$$

As income increases, the ability of individuals to afford driving increases, *ceteris paribus,* therefore, we expect that

$$\partial Q_d / \partial Y > 0. \tag{6}$$

DATA

Data for this study pertain to the 40 countries listed in Appendix I. These data are for the year 1970. Data for gasoline consumption and the average price of gasoline are collected from the International Petroleum Annual [10]. Data for cars and commercial vehicles is obtained from the *United Nations Statistical Year Book* [9].

THE EMPIRICAL RESULTS

In order to estimate the values of a, b, c, d, and f, the model [2] is transformed into a linear model by taking logarithms of both sides. Using the above data and applying multiple regression analysis, we obtain the statistical results summarized in Table 1. The regression results are presented in a stepwise fashion; the order of the variables is controlled by the authors. The numbers in parentheses beneath the coefficients are their t values. R^2 denotes the coefficient of determination; $\bar{R}^2$ is the coefficient adjusted for degrees of freedom. The F-ratio tests the overall fit.

Statistically the results of equation (7-d) are impressive. This relationship explains more than ninety-seven percent of the variations in gasoline consumption. All the coefficients have the expected signs and are statistically significant (at least at the 1 percent level of significance).

An examination of the results in Table 1 shows that price elasticity of gasoline is almost unitary but income elasticity is only 0.26. This suggests that gasoline is a normal good and tends to be a necessity. In order to get further insight into these questions it may be worthwhile to divide these countries into two groups—(i) countries with per capita income greater than or equal to \$700 and (ii) countries with per capita income less than \$700. These groupings of countries are also shown in Appendix I. The statistical results obtained on the basis of this grouping are summarized in Tables 2 and 3. The results in these tables are also impressive and explain more than ninety-four percent of the variations in quantity demanded of gasoline. However, in Table 2 the coefficient of the income variable is statistically insignificant and in Table 3 the statistical significance of the coefficient of the car variable is low. This is due to the problem of multicollinearity[2] between log C and log V and between log C and log Y. In order to overcome this problem, a new variable VC is defined by adding three times the variable V to the variable C.[3] Accordingly, VC is defined as the number of vehicles standardized in terms of car units. The statistical results obtained by replacing log V and log C by log VC are summarized in Table 4.

The statistical results of Table 4 are impressive and the coefficients of the independent variables in all the equations are statistically significant (*at least at the 5 percent level of siquificance*). The most interesting point of these results is that for all equations in Table 4, the coefficient of log VC is equal to the sum of the coefficients of log C and log V in Tables 3, 2, and 1 respectively. This suggests that our standardization of the vehicle variable is correct and in this way we are able to overcome the problem of multicollinearity.

[2] The simple correlation between log C and log V for high income countries is 0.91 and for low income countries is 0.84. Even though this correlation for all 40 countries is 0.9233, the problem does not appear to have shown in equation (7-d) since an increase in number of observations usually eliminates the problem of multicollinearity. The simple correlation between log C and log Y is 0.54 and 0.52 respectively for high and low income countries.

[3] The choice of the new variable $VC = 3V + C$ to replace the variables V and C is based upon the fact that commercial vehicles (V) consume almost three times as much gasoline as cars (C). From the 1975 Statistical Abstract of the U.S. data for 1970 indicates annual average consumption for cars, buses, and trucks was 722 gallons, 2491 gallons, and 1365 gallons, respectively. Thus the average annual consumption per commercial vehicle is (1/2) (2491 + 1365) = 1928, or about three times the figure for cars.

TABLE 1. SUMMARY OF STATISTICAL RESULTS FOR 40 COUNTRIES

Year	Equation No.	Constant	Coefficient of log P	log C	log V	log Y	R^2	$\bar{R}^2$	F-ratio
1970	7–a	9.9424	0.1621 (0.26)				0.0018	−0.0245	0.17
	7–b	3.8784	−1.2840 (8.72)	0.8907 (31.98)			0.9651	0.9633	512.19
	7–c	2.9190	−1.1347 (7.75)	0.7088 (9.95)	0.2304 (2.74)		0.9711	0.9687	403.89
	7–d	2.4475	−1.1760 (8.86)	0.5361 (6.26)	0.3288 (3.99)	0.2565 (3.05)	0.9772	0.9746	374.95

Note: The numbers in parentheses beneath the coefficients are their t values.

TABLE 2. SUMMARY OF STATISTICAL RESULTS FOR 20 HIGH INCOME COUNTRIES

Year	Equation No.	Constant (log a)	Coefficient of log P	log C	log V	log Y	R^2	$\bar{R}^2$	F-ratio
1970	8–a	28.4925	−4.1266 (2.42)				0.2458	0.2039	5.87
	8–b	5.8418	−1.6932 (6.37)	0.8734 (28.41)			0.9844	0.9826	537.86
	8–c	4.9156	−1.5068 (5.74)	0.7566 (11.64)	0.4466 (2.00)		0.9875	0.9852	422.88
	8–d	3.9757	−1.4381 (5.17)	0.7111 (8.23)	0.1791 (2.11)	0.1141 (0.81)	0.9881	0.9849	310.67

Note: The number in parentheses beneath the coefficients are their t values.

TABLE 3. SUMMARY OF STATISTICAL RESULTS FOR 20 LOW INCOME COUNTRIES

Year	Equation No.	Constant	Coefficient of				R^2	$\bar{R}^2$	F-ratio
			log P	log C	log V	log Y			
1970	9–a	14.6333	−1.2916 (2.35)				0.2340	0.1915	5.50
	9–b	5.1339	−1.3386 (5.90)	0.7958 (10.31)			0.8944	0.8820	72.01
	9–c	3.8315	−1.1904 (5.37)	0.5595 (4.14)	0.3189 (2.76)		0.9156	0.8998	57.84
	9–d	0.4054	−0.9389 (4.35)	0.2661 (1.60)	0.5555 (3.34)	0.5755 (2.53)	0.9408	0.9250	59.59

Note: The number in parentheses beneath the coefficients are their t values.

TABLE 4. SUMMARY OF STATISTICAL RESULTS OF THE MODEL USING STANDARDIZED VEHICLES

Country grouping	Constant (log a)	Coefficient of			R^2	$\bar{R}^2$	F-ratio
		log P	log VC	log Y			
Low income	−0.2154	−0.9875 (5.68)	0.8314 (11.85)	0.4875 (3.03)	0.9447	0.9343	91.07
High income	0.8528	−1.2310 (4.15)	0.8817 (22.23)	0.3310 (2.49)	0.9826	0.9793	300.77
Total	0.8600	−1.1160 (9.13)	0.8625 (24.16)	0.3107 (4.56)	0.9782	0.9764	539.09

Note: The numbers in parentheses beneath the coefficients are their t values.

TABLE 5. BETA COEFFICIENTS AND PARTIAL CORRELATION COEFFICIENTS

Variable	Beta coefficient			Partial correlation coefficient		
	L	H	T	L	H	T
Log *P*	−0.3429	−0.1479	−0.2451	−0.9863	−0.7197	−0.8358
Log *VC*	0.7582	0.8766	0.8904	0.8314	0.9842	0.9705
Log *Y*	0.1970	0.0945	0.1773	0.4875	0.5287	0.6001

Note: L = low income; H = high income; T = total (low + high).

Since for policy purposes we are interested in the absolute values of various coefficients, it is important that we now concentrate on the results produced in Table 4. The coefficients of log *P*, log *VC*, and log *Y* are values of partial elasticities with respect to *P*, *VC*, and *Y*. It must be remembered that these values should be interpreted as *long-run rather than short-run* elasticities since these estimates are based on cross-section data.

Thus from these results it appears that in the long run, world demand for gasoline is almost unit elastic. To some extent the recent experience in the United States as well as other countries has confirmed this. Price elasticity is slightly lower for low income countries while vehicle elasticity of demand is not appreciably different between low and high income countries. According to these results, a *ten percent* increase, *ceteris paribus*, would be accompanied by a decrease in gasoline demanded by about 9.9 percent in low income countries and 12.3 percent in high income countries. Similarly, a ten percent increase in standardized vehicles, other things being equal, would be accompanied by an increase in gasoline consumption by about 8.3 and 8.8 percent in low and high income countries respectively. A ten percent increase in income, *ceteris paribus*, would bring an increase in gasoline consumption by about 4.9 and 3.3 percent in low and high income countries respectively. This suggests that gasoline tends to be more of a "necessity good" in high income countries than in low income countries.

In order to show the relative importance of the independent variables in explaining the variations in gasoline consumption in the world, we present in Table 5 *Beta* coefficients, that is, the coefficients for normalized variables, and partial correlation coefficients. The values in this table are rather revealing. Both for low and high income countries vehicles have the greatest effect upon gasoline consumption compared to the effect of other variables, namely, price and income. But, the income has the lowest effect upon gasoline consumption compared to the other two independent variables. However, the values for the partial correlation coefficients suggest that for low income countries, the price accounts for 97 percent of the variance of gasoline consumption not accounted for by the other two independent variables.[4] But the corresponding figure for high income countries is

[4] The value of 97 percent is obtained by squaring −.9863, the partial correlation coefficient for low income countries in Table 5.

only 52 percent. On the other hand, for high income countries, 97 percent of the variance of gasoline consumption not accounted for by the other independent variables is accounted for by vehicles. The corresponding figure for low income countries is 69 percent. The income variable explains only 28 percent for high income countries and 24 percent for low income countries the variations not explained by the other two independent variables.

The above analysis suggests that price is an important variable in determining the consumption of gasoline. The high value for price elasticity is probably due to the large importance given to road transport over the last two decades. It has been observed that the World Bank experts have overemphasized the development of road transport over the other modes of transport. As a consequence, road use has been extended to include many users who are highly sensitive to fuel prices. Road transport not only uses gasoline but on a relative basis uses more energy per unit of output (4). However, further analysis is needed to investigate the various reasons for such a high price elasticity of gasoline.

In summary, the overall long-run price elasticity of gasoline for the world as a whole is higher for high income countries than for low income countries. The nearly unitary value for elasticity suggests that in the *long-run* further price increases would not bring substantial extra revenue to the oilproducing countries.

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APPENDIX 1
List of Countries Used for Statistical Analysis

1.	US	H	21.	Morocco	L
2.	Australia	H	22.	Netherlands	H
3.	Belgium	H	23.	Norway	H
4.	Bolivia	L	24.	Pakistan	L
5.	Canada	H	25.	Panama	L
6.	Chile	L	26.	Peru	L
7.	Denmark	H	27.	Philippines	L
8.	El Salvador	L	28.	South Africa	L
9.	Finland	H	29.	Spain	H
10.	France	H	30.	SRI Lanka	L
11.	Germany (Rep.)	H	31.	Switzerland	H
12.	Ghana	L	32.	Turkey	L
13.	Greece	H	33.	U.K.	H
14.	Iran	L	34.	Uruguay	H
15.	Ireland	H	35.	Dominican Republic	L
16.	Israel	H	36.	Equador	L
17.	Italy	H	37.	Paraguay	L
18.	Japan	H	38.	Portugal	L
19.	Lebanon	L	39.	Sweden	H
20.	Mexico	L	40.	Tunisia	L

Note: L, low income countries per capita income below $700.
H, high income country—per capita income equal to or greater than $700.

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