Energy demand in Pakistan and the possibility of inter fuel substitution

Ahmed, Ather Maqsood and Kemal, M. Ali

NUST, Islamabad, Pakistan Institute of Development Economics, Islamabad

January 2001

Energy Demand in Pakistan and the Possibility of Inter Fuel Substitution

by

Ather Maqsood Ahmed and M. Ali Kemal

1. Introduction

Energy in the shape of petroleum products (primary fuel) is one of the essential consumption item of household, industrial, commercial, and government sectors. Its use increases with the level of urbanization and industrialization. The use of energy by households, especially in urban areas, is mainly in the transport sector. According to an estimate, the transport sector alone consumes nearly 90 percent of the imported petroleum products in the country. Over the years there has been some growth in the demand for petroleum products by transport sector despite increases in prices of various petroleum components. This growth can, in part, be attributed to (a) increase in per capita income, and (b) consumer preference for convenient fuel.

Notwithstanding the increase in petroleum demand due to natural increase in base, there has been a tendency of inter-fuel substitution due to manifold increase in gasoline prices and the option and availability of alternative fuel in transport sector. Thus, the conversion of vehicles initially to diesel fuel and now to CNG is a common phenomenon. Within this perspective the objectives of the study are a) to identify the factors that influence gasoline demand, b) to measure the possibility of inter-fuel substitution and the resulting consequences for petrol demand and c) generate alternative demand scenarios to overcome the existing excess supply.

The study is arranged as follows. The trend and growth of determinants of demand of motor spirit, diesel and CNG including per capita income and prices of fuels are presented in section II. The descriptive analysis of data is based on correlation between important variables related to energy demand. Model specification and quantitative analysis based on time-series is conducted in Section III and section IV presents the results based on monthly data. The outcome of policy analysis is discussed in Section V and the results are summarized in the last section.

II. Descriptive Analysis

II.a. Trends and Growth Pattern

Tables 1 and 2 provide the descriptive statistics of prices of petroleum products including motor spirit and diesel and income, expressed in level and per capita form, for the periods 1972-73 to 1986-87 and 1987-88 to 1999-2000. The time series data has been divided into two parts because of two reasons: first, the Government accepted to implement the structural adjustment program in 1988 and as a consequence domestic price of petroleum products were linked with international prices, and second the CNG was introduced as an alternative fuel to motor spirit.

The data clearly indicates that the average per capita consumption of diesel has exceeded the per capita consumption of motor spirit in both the periods. For example, between 1972/73 and 1986/87 the per capita demand for diesel was 3.22 times higher than the per capita consumption of motor spirit and between 1987/88 and 1999/2000 it was 4.62 times higher. The coefficient of variation indicates greater variation in the price of diesel in first period. However, the price variability of motor spirit has remained the same during the two periods. The per capita consumption of both these fuels has

remained stable. Finally, the value of standard deviation of motor spirit during first period was 1.94, which increases sharply to 6.14 indicating a high degree of price volatility during late 1980s and 1990s as compared to the earlier period. On the other hand the standard deviation of diesel price increased from 1.36 during 1972-87 to 2.75 during 1988-200.

Table 1
Descriptive Statistics From 1972-73 To 1986-87

	Motor Spirit Price	Per Capita Consumption of Motor Spirit	Diesel Price	Per Capita Consumption of Diesel	Per Capita Income
Mean	4.13	4961.42	2.43	15975.9	3431.43
Median	3.83	4856.12	2.18	15563.73	3433
Maximum	7.15	6555.58	4.67	22954.69	4248
Minimum	1.31	3806.77	0.67	9099.62	2770
Std. Dev.	1.94	995.81	1.36	4959.15	522.85
Coefficient of variation	46.95	20.07	55.97	31.04	15.24

Table 2
Descriptive statistics from 1987-88 to 1999-2000

	Motor Spirit Price	Per Capita Consumption of Motor Spirit	Diesel Price	Per Capita Consumption of Diesel	Per Capita Consumption of CNG	Per Capita Income
Mean	13.55	8439.18	6.77	39006.07	45.02	4803.54
Median	13.13	8752.58	6.12	41446.37	6.24	4826.00
Maximum	27.33	9635.30	12.60	47849.69	365.25	5083.00
Minimum	7.15	6948.02	3.85	28101.85	2.12	4433.00
Std. Dev.	6.14	952.96	2.75	7374.33	99.87	201.87
Coefficient of variation	45.32	11.29	40.63	18.91	221.83	4.20

To see how prices and consumption of motor fuels have increased over time, compound growth rate of the variables ere calculated and reported in table 3. On the

whole, the rate of increase in price of motor spirit was more than the rate of increase in the price of diesel oil. However, per capita consumption of diesel increased by 6.34 percent per annum and motor spirit demand increased by 2.83 percent per annum. Ever since the introduction of CNG in the market, the rate of growth of per capita consumption of motor spirit as well as diesel has declined to 2.17 percent and 4.54 percent as compared to 3.29 percent and 7.35 percent respectively before 1987. In comparison the rate of increase of per capita consumption of CNG was 51.77 percent (per annum) during 1988-2000. Finally, due to onset of recession, the growth rate of per capita income also experienced a decline to 1.15 percent during 1988-2000 as compared to 3.25 percent during 1972-87.

The descriptive analysis of data indicates that the demand of motor spirit has declined over the years due to declining per capita income and availability of cheaper fuel (i.e., CNG). Thus, the inter-fuel substitution is a direct consequence of demand side factors.

The main factor behind the decline in growth rate of per capita consumption of motor spirit is the decline in the growth rate of per capita income. This implies that due to less increase in the income, purchasing power of the consumers declined as compare to previous years. But because price of both the fuel (diesel and petrol) declined so, therefore consumption increased too. Otherwise, if prices increased more than increase in previous periods then there is a possibility that growth rate of consumption would be zero or even less than that. The other reason why consumption increased irrespective of the matter that growth of per capita income declined that after 1987, small cars like Suzuki

were available in market whose petrol consumption is low and cheaper than the other cars.

Table 3
Compound Growth Rate

Years	Motor Spirit Price	Per Capita Consumption of Motor Spirit	Diesel Price	Per Capita Consumption of Diesel	Per Capita Consumption of CNG	Per Capita Income
1973-2000	11.89	2.83	11.50	6.34		2.28
1973-1987	12.71	3.29	13.51	7.35		3.25
1988-2000	11.82	2.17	10.38	4.54	51.77	1.15

Tables 4 and 5 present correlation matrix of relevant variables for the two time periods, i.e., when CNG was still not available as an alternative fuel in the transport sector and after its introduction. Whereas the relationship between motor spirit demand and its relative price is negative, which shows that a reduction in the price of motor spirit would lead to an increase the demand for motor spirit, the opposite is true for per capita consumption and per capita income which is consistent with the theoretical perception. Not only that the correlation between these two variables is high, it is positive as well.

The low correlation between the relative prices of motor spirit to diesel with per capita consumption of motor spirit during 1988-2000 shows the decrease in relative importance of price of motor spirit to diesel in the determination of the demand for motor spirit.

Here is the matter of concern that in the period from 1972-73 to 1986-87 the relationship between diesel and motor spirit is negative and now it is negative, but in this case it is positive. But if we calculate its significance then we come to know that the in this period the relationship between diesel and motor spirit is insignificant. So,

statistically speaking we ignore the sign if it is wrong when the relationship is insignificant.[1]

Table 4
Correlation Matrix for the year 1972-73 to 1986-87

	Per Capita Consumption of Motor Spirit	Per Capita Consumption of Diesel	Relative Price of Motor Spirit to Diesel	Per Capita Income
Per Capita Consumption of Motor Spirit	1			
Per Capita Consumption of Diesel	0.97	1		
Relative Price of Motor Spirit to Diesel	-0.77	-0.77	1	
Per Capita Income	0.97	0.99	-0.72	1

Table 5
Correlation Matrix for the year 1987-88 to 1999-2000

	Per Capita Consumption of Motor Spirit	Per Capita Consumption of Diesel	Per Capita Consumption of CNG	Relative Price of Motor Spirit to Diesel	Per Capita Income
Per Capita Consumption of Motor Spirit	1				
Per Capita Consumption of Diesel	0.95	1			
Per Capita Consumption of CNG	0.35	0.51	1		
Relative Price of Motor Spirit to Diesel	0.38	0.45	0.35	1	
Per Capita Income	0.85	0.92	0.52	0.56	1

III. Quantitative Analysis

In this section a simple model has been specified to estimate price and income elasticities of demand of motor spirit and other fuels.

---

[1] F-statistic is calculated by a formula: $F = \frac{R^2/k-1}{(1-R^2)/n-1}$, and in this case R is the correlation coefficient which is 0.38 and 0.45 for motor spirit and diesel respectively with the relative price of motor spirit to diesel price. F-statistic is 1.68 for motor spirit case, which is insignificant even at 10 percent level of significance and F-statistic is 2.53 for diesel case, which is also insignificant at 10 percent level of significance. However in earlier case F-statistic for both diesel and motor spirit came out to be 14.56, which is significant even at 1-percent level of significance. This shows that in earlier period from 1972-73 to 1986-87, diesel is used as substitute and after that it is no more substitute to motor spirit, there could available other substitute, which were preferable by the people.

i. Model and Procedure when Annual Time Series Data are used

The primary objective is to identify the factors that influence gasoline demand. To estimate demand elasticities, the following model is specified in log-linear form.

$$Log\left(\frac{MS}{POP}\right) = \alpha + \beta Log\left(MS \text{ Pr } ice\right) + \chi Log\left(HSD \text{ Pr } ice\right) + \delta Log\left(PCY\right) \qquad (1)$$

Where MS is annual average consumption of motor spirit in TOE, POP is Population in millions and PCY is annual real per capita income in Rupees. α is an intercept and β, χ, δ are the elasticity estimates of per capita consumption of motor spirit with respect to its price (own price elasticity), price of diesel as its substitute price and per capita income respectively.

To estimate these elasticities, annual time series data on consumption of motor spirit and diesel and prices of motor spirit and diesel has been collected from various issues of Energy Year Book. Data on per capita income has been taken from various issues of Pakistan Economic Survey and 50 years of Pakistan Statistics. In the absence of information on CNG prices for the entire duration, the data from 1987-88 to 1999-2000 has been used which reduces the total number of observations reduced to 13. However, excluding CNG price, it was possible to run the model (1) for a period of 27 years, i.e., from 1972-2000. For comparison, the model has been estimated for two different time periods, i.e., for the period 1972-73 to 1986-87, and for the period 1987-88 to 1999-2000. Model is also estimated for the entire time period to verify. It may again be pointed out that non-availability of data on CNG prices prior to 1987; price of diesel has been used as substitute price.

Since the model has been estimated for two periods, it necessitates that Chow test is used to determine if the parameters have remained stable or not. Parameters stability would imply absence of fundamental structural change, to verify stability of coefficients over-time.

ii. Model and Procedure When Monthly Data are Used

Since monthly data are also available on consumption and prices, different model specification has been specified to estimate price elasticities. The alternative models are;

$$Log(\frac{MS}{POP}) = \alpha + \beta Log(MS\,\mathrm{Pr}ice) + \chi Log(Diesel\,\mathrm{Pr}ice) + \delta Log(CNG\,\mathrm{Pr}ice) \quad (2)$$

$$Log\,(\frac{MS}{POP}) = \alpha + \beta Log\,(MS\ \mathrm{Pr}\ ice) + \delta Log\,(CNG\ \mathrm{Pr}\ ice) \quad (3)$$

Where MS and POP are defined as before. In addition CNG price has also been included in the model. α is an intercept for both equations and β, χ, δ are the elasticity estimates of per capita consumption of motor spirit with respect to its own price, price of diesel as its substitute price and price of CNG as substitute price.

Data on prices of CNG, diesel and motor spirit, consumption of CNG, diesel, and motor spirit is needed for the monthly analysis. Data on CNG consumption is not available so, equation is estimated only for motor spirit consumption. Total numbers of observation are different for each variable. Adjusted numbers of observations are 21.

Annual data does not give the clear picture of what happened during that year. We do not know about the month-to-month variation. Monthly data has been used here to check the variation within months. Price of petroleum change many times during a year. So, in order to capture that impact, we should use monthly data, and capture those rapid changes in the relevant variables during a year.

2. Empirical Findings and Interpretation of the Results

3.1 Analysis based on Annual Data

Table 6 gives the result of model (1) by taking whole period data, where per capita consumption of motor spirit is regressed against per capita income to get the estimate of income elasticity of demand, motor spirit (own price elasticity) and price of diesel (cross price elasticity).

The OLS estimation of the model resulted in per capita income elasticity of demand 1.11, own price elasticity -0.06 and cross price elasticity 0.16. this shows that increase in per capita income by one percent results in 1.11 percent increase in the demand for motor spirit, t-value for the coefficient is 4.68[2], which is significant at one-percent. This implies the impact of per capita income on per capita consumption of motor spirit is quite significant. However, the results are not much significant of price of motor spirit but the sign is correct, which shows that increase in the price of motor spirit has negative impact on the demand for motor spirit. t-value of the coefficient of price of motor spirit is -0.64[3]. Coefficient of price of diesel is quite significant and sign is also correct, shows that increase in the price of diesel increase the demand of motor spirit. Coefficient of motor spirit is 0.16, which shows that one percent increase in the price of diesel results in 0.16 percent in demand for motor spirit. Further it implies that motor spirit and diesel are substitutes of each other. MA(1) is used to remove the autocorrelation from the equation, value of MA(1) is very significant, its t-value is 51.83, which shows that it captures significant autocorrelation. R-square is quite good and F-stat

[2] If t-calculated value is greater than the t-critical value then we say that the coefficient is significant and it has significant impact on the dependent variable. In this case our t-critical is 2.06 at five-percent level of significance.

[3] Given this insignificant result, change in price would have no effect on its demand in pure statistical term.

is significant[4], which shows that explanatory variables are explaining the dependent variable quite significantly. DW value is good, shows that there is no serious problem of autocorrelation in it[5].

Table 6
Regression results.

Variable	Coefficient	t-Statistic
C	-0.58	-0.31
LOG (Per Capita Income)	1.11	4.68*
LOG (Motor Spirit Price)	-0.06	-0.64
LOG (Diesel Price)	0.16	2.31**
MA(1)	0.95	51.83*

Note: *and ** indicate significant at one-percent and five-percent level

R-squared	0.98	F-statistic	275.24
Durbin-Watson stat	1.79		

Dependent variable is LOG (Per Capita Consumption of Motor Spirit), N = 27; 1973 2000, Convergence achieved after 9 iterations.

Table 7 gives the results of model (1) for the initial sub set of time period from, i.e., 1972-73 to 1986-87 when CNG was not available as substitute fuel in transport sector. Broadly stating the results are in conformity with those obtained for the entire period. There is positive association between per capita consumption of motor spirit and per capita income. Coefficient of per capita income shows that one percent increase in per capita income leads to an increase in per capita consumption by 1.58 percent. Negative association between price of motor spirit and per capita consumption of motor

[4] In this case our F-critical value is 14.0, 5.77 and 3.83 at one-percent, five-percent and ten-percent level of significance. Our calculate F-statistic is significant at all levels of significance.
[5] Durbin Watson is test to detect autocorrelation, its value ranges from zero to four. If the value of DW is close to 2, this shows that there is no serious problem of autocorrelation.

spirit is reported. Coefficient of motor spirit is –0.58, shows that one percent increase in price of motor spirit results in the decline of 0.58 percent the demand for motor spirit.

Positive association is reported between price of diesel and per capita consumption of motor spirit, shows that if price of diesel change the demand will respond in the same direction. Coefficient of diesel price is 0.41, shows that one percent increase in the price of diesel will lead to increase in the demand for motor spirit by 0.41 percent. R-square is quite good and F-stat is significant, which shows that explanatory variables are explaining the dependent variable quite significantly. DW shows that there is no serious problem of autocorrelation.

Table 7
Regression results

Variable	Coefficient	t-Statistic
C	-3.85	-2.11**
LOG (Per Capita Income)	1.58	6.77*
LOG (Motor Spirit Price)	-0.58	-3.43*
LOG (Diesel Price)	0.41	2.92*

Note: *and ** indicate significant at one-percent and five-percent level

R-squared	0.97	F-statistic	106.58
Durbin-Watson stat	1.35		

Dependent variable is LOG (Per Capita Consumption of Motor Spirit), N = 15, 1972-73 to 1986-87

Table 8 gives the regression results of model (1) when CNG was also available as substitute fuel in the transport sector. Result shows insignificant behaviour for all the variables. This shows that there may be other factors, which determine the demand for motor spirit in this era.

If we compare the results with previous period results it is quite clear that parameters are not stable. Results of chow test are show in table 9. F-stat and log likelihood ratio test is significant at 5 percent level of significance; this shows that parameters of both periods are not stable. Determinants of the demand for motor spirit are changed.

Table 8
Regression results

Variable	Coefficient	t-Statistic
C	-1.41	-0.18
LOG (Per Capita Income)	1.21	1.28
LOG (Motor Spirit Price)	-0.06	-0.29
LOG (Diesel Price)	0.21	1.03

R-squared 0.816574 F-statistic 13.35533
Durbin-Watson stat 1.542893
Dependent variable is LOG (per capita consumption of motor spirit), N=13, 1987-88 to 1999-2000

Table 9
Chow Forecast Test: Forecast from 1987 to 2000

F-statistic	3.838880	Probability	0.015960
Log likelihood ratio	47.91996	Probability	0.000007

3.2 Analysis Based on Monthly Data

Table 10 gives the results of model (2), where consumption of motor spirit is regresses against price of motor spirit to get own price elasticity of demand, price of diesel to get cross price elasticity of demand and price of CNG (other substitute price) to get cross price elasticity of demand. Result shows that there is negative association between motor spirit price and motor spirit demand. t-statistic is quite good which shows

that price of motor spirit has significant impact on its demand and whenever we change the price it affects its demand negatively. Elasticity of motor spirit with respect to its own price is –1.28. This implies that the reduction in the price of motor spirit by one percent decreases the demand of motor spirit by 1.28 percent

Positive but insignificant association has been found between demand for motor spirit and price of CNG. This implies that change in price of CNG does not affect the demand for motor spirit.

Coefficient of the price of diesel is quite significant. Elasticity of demand for motor spirit with respect to price of diesel is 0.36, which shows that one-percent change in price of diesel leads to change in demand for motor spirit increase by 0.36 percent. Positive coefficient shows that demand responds positively with the change in price of diesel.

MA(6) is used to remove the autocorrelation from the equation. Coefficient of MA(6) is highly significant as its t-value is –24.51. Sign of coefficient is negative, shows that negative autocorrelation was causing problem which is quite reasonably captured by MA(6)

Table 10
Dependent Variable is LOG (MS)

Variable	Coefficient	t-Statistic
C	14.60	17.08
LOG (MSP)	-1.28	-3.33
LOG (CNGP)	0.07	0.62
LOG (HSDP)	0.36	1.93
MA (6)	-0.92	-24.51

R-squared	0.78	F-statistic	14.13
Durbin-Watson stat	2.14	Prob (F-statistic)	0.000041

N = 21; 1999:01 2000:09, Convergence achieved after 15 iterations

Table 11 gives the results of model (3). Results are significant for own price of motor spirit and insignificant for the price of CNG. Own price elasticity is –0.67, which shows that one-percent increase in the price of motor spirit results in the decline in the demand for motor spirit by 0.67 percent. Insignificant cross price elasticity means that there is no impact of change in price of CNG on the demand for motor spirit.

MA(6) is used to remove autocorrelation. Coefficient of MA(6) is highly significant, its t-value is –21.05. Negative sign of the coefficient shows that there was negative autocorrelation which is captured by MA(6) quite reasonably.

Table 11
Dependent Variable is LOG (MS)

Variable	Coefficient	t-Statistic
C	13.37	23.19
LOG (MSP)	-0.67	-2.78
LOG (CNGP)	0.12	1.04
MA (6)	-0.89	-21.05

R-squared = 0.73, F-statistic = 15.52, D.W.= 1.70,
N = 21; 1999:01 2000:09, Convergence achieved after 13 iterations

Simulation Results

The monthly data on CNG consumption is not available. This information has been generated on the basis of yearly series of CNG consumption. The procedure, which has been used to compute the monthly series, is as follows.

The monthly series is computed from annual series, first by compound growth rate of CNG annual demand and then adjusted by the growth rate of monthly data available on supply of Sui Northern Gas. Monthly data on the other three variables, i.e., Petrol demand, Price of Petrol and Price of CNG are readily available.

Growth of CNG demand is regressed on the percentage change in price of CNG and growth of Petrol demand is regressed on the percentage change in the price of Petrol. Mathematically it is written as,

$$\text{Growth of CNG Demand} = \alpha_0 + \beta_0 PCPG$$

$$\text{Growth of Petrol Demand} = \alpha_1 + \beta_1 PCPP$$

PCPG = Percentage change in the price of CNG

PCPP = Percentage change in the price of Petrol

After regressing the variables simulation exercise is conducted by changing (downward) the percentage change in price of petrol by 10, 20, 50 and 90 percent. Simulation exercise is done in order to check how the demand of Petrol will change when we the difference between the price of Petrol and CNG narrows.

The simulation results show that if the difference between price of CNG and price of Petrol narrows by 50 percent the petrol demand will increase by 42 percent. Translated into rupees, this result means that the petroleum demand would increase by about 42 percent if per liter price of gasoline is reduced by seven to eight rupees. This reduction in petroleum price could be charged from reduction in petroleum surcharge rather than the actual (import) price of petroleum. Incidentally, this quantitative result is also consistent with the qualitative response of users.

Simulation Results

(Millions TOE)

Original Demand	20% decline in the percentage price of petrol	50% decline in the percentage price of petrol	90% decline in the percentage price of petrol
98724	128607	140222.7	155710.4
	(30.27)	(42.04)	(57.73)

Note: Values in parentheses represent the change in demand with respect to actual demand