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Muhammad Omer

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Research Department,
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Estimating Elasticity of Transport Fuel Demand in Pakistan

Muhammad Omer*

Abstract

This study investigates the fuel demand elasticities separately for petrol, diesel, and CNG using data from July 2004 to June 2015 for Pakistan. The results show that fuel demands are generally (own and cross price) inelastic in the short run, but are relatively elastic in the long run. Though these short run estimates are in line with the literature, the long run estimates differ considerably. Administrative intervention in fuel pricing, load management in CNG sector and its close to perfect substitutability with petrol is driving this long run price elasticity result. Moreover, income elasticity estimates suggest that petrol is a normal good while diesel and CNG are inferior goods. The estimates remain robust when lag demands of substitutes, the exchange rate, and real fuel prices are separately included in the model.

JEL Classification: Q40, L90

Key Words: Fuel Price, Elasticity, Transport Sector

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* Joint Director, Economic Policy Review Department, State Bank of Pakistan, Karachi (muhammad.omer@sbp.org.pk)

Non-technical Summary

This study investigates the short and long run responsiveness of fuel [petrol, diesel, and CNG] demands in transport sector of Pakistan to changes in prices, prices of its substitutes, and the economic activity, using monthly data from July 2004 to June 2015. The recent decline in the oil prices has increased the demand for POL products, specifically from transport sector. To be able to anticipate such increases in demand and formulate a policy response proactively, the information about price and income elasticities of various POL products is important for policy makers.

This research is, therefore, specifically significant for people in the central bank and in the government, as the findings allow them to assess the impact of fuel price shock on both the balance of payments and the public finance; and formulate an appropriate policy response (e.g., level of subsides and taxes on fuel consumption). Moreover, the usefulness of the study in identifying the appropriate fuel mix for the transport sector and helping the environment regulators on CO_2 emissions cannot be underestimated. Universally, these are important aspects but remained of secondary relevance in Pakistan.

The findings of this research suggests that the fuel demands are mostly (own and cross) prices inelastic in short run; which is consistent with the findings in literature. Elaborately, one percent increase in the prices of petrol, diesel, or CNG leads to 0.28 percent, 0.21 percent and 0.66 percent decrease in their respective demand. Moreover, the demands of these fuels are positively related with the prices of their substitutes, as suggested by economic theory. Furthermore, estimated income elasticity suggests that only petrol behaves as a normal good as its demand increases with an increase in income, while diesel and CNG behave as inferior goods.

From policy perspective, the short run inelastic fuel demands suggests that environment policies, such as carbon tax, to reduce fuel consumption and to control CO_2 emissions may not produce the desired result. Therefore, policy makers need to formulate non-oil dependent strategy for environmental protection after the inception of CPEC. Probably, emphasis on the environment friendly public transport system may help in achieving the sustainable environment goals. From the standpoint of the government finances, the short run inelastic estimates suggest that higher taxes on fuel consumption will positively impact the government's revenue, but will reduce the demand only marginally.

Interestingly, the long run estimates suggest that fuel demands are more responsive to the changes in prices and income, which is relatively different from the findings in literature. Deviation in our long run estimates is due to the load management policy adopted by the government in the CNG sector. These long run elasticity estimates show that decline in oil prices, amid increasing economic activity, may lead to strong growth in petrol demand thereby invigorating the balance of payment stress. Specifically, expected increase in economic activity going forward may contribute more than proportionally to increase in petrol demand (one percent increase in economic activity contributing to 1.9 percent increase in petrol demand). On top of that, one percent exchange rate depreciation may add to petrol demand by almost three percent. Simultaneous changes in these factors may invigorate serious balance of payment stress.

The downward movement in a substitute's price (say CNG price), in this situation, may alleviate some pressure on petrol, as its demand is positively related to CNG prices. However, the government's decision to allow the CNG business owners to fix retail price may have limited this downward flexibility in the CNG prices. The CNG prices have become less flexible in downward since deregulation, even when the impact of falling oil prices is passed-on to the natural gas prices.

Additionally, the result of our auxiliary estimate, on the relationship between the fuel prices, supports the presence of long run relationship between real fuel prices, instead of nominal prices, which essentially holds the substitutability between these fuels. This result confirms that the frequent government intervention in POL market have distorted its price setting mechanism. Moreover, the result suggests that only real CNG prices adjust to the long run equilibrium in response to shock to petrol and/or diesel real prices. Neither petrol nor diesel (real) prices show any significant adjustment towards equilibrium, if real prices of their substitutes receive any shock.

1. Introduction

The recent decline in POL (Petroleum, Oil and Lubricants) products' prices reinvigorated the transport sector, which otherwise became painstakingly less profitable due to high input cost, specifically in oil importing developing economies. While low energy prices have increased the profitability of air, water, rail, and road transports, it may also have contributed to the increased demand for POL products. To be able to anticipate such increases in demand, the knowledge of the price and income elasticities of various POL products is important for policy makers. For example in late 2014, the decline in domestic oil prices in Pakistan following the international trend fueled a full-blown oil crisis.[1] People started panic buying and queued before petrol pumps for a number of days. Though emergency response by economic managers controlled the situation from escalating further, Pakistan remains vulnerable to these kinds of surprises as analytical research in this field is almost non-existent.

For policy purposes, this research is specifically significant for people in the central bank and in the government, as the findings allow them to assess the impact of fuel price shock on both the balance of payments and the public finance; and formulate an appropriate policy response (e.g., level of subsides and taxes on fuel consumption). Moreover, the usefulness of the study in identifying the appropriate fuel mix for the transport sector and helping the environment regulators on CO_2 emissions cannot be underestimated. Universally, these are important aspects but remained of secondary relevance in Pakistan.

Specifically from environment's perspective, the industrial carbon footprint in Pakistan is likely to increase going forward; not only the low fuel prices would be driving its consumption up, but also due to expected increase in fuel demand from the transport and energy projects committed under China-Pakistan Economic Corridor (CPEC). Interestingly after energy, transport contributes the most in green house gases (GHG); nearly 26 percent of global CO_2 emissions (Ajanovic *et al.*, 2012).[2] Pakistan is in process of developing its comprehensive transport and environment protection policy based on the United Nations regulations and standards (ADP, 2016). Therefore, this study may provide essential input in this perspective.

To the best of our knowledge, the fuel demand elasticities for Pakistan have never been studied in past, in detail. This study, estimating the elasticities of demand of different types of transport fuels [petrol (motor spirit), diesel (high speed diesel or HSD) and natural gas (Compressed Natural Gas or CNG)] is first in this direction. We study the petrol and the Natural gas (CNG) separately, as nature of the government interventions and the price administration for these two fuels is different. This paper attempts to answer the key research question: how demand for a certain fuel responds to changes in prices, prices of substitutes, and in economic activity?

Conceptually, inclusion of substitutes' prices in demand function becomes questionable in administrative fuel price setting environment. Due to the government intervention, the long run positive relationship between fuels prices may disappear thereby weakening the case for substitutability between these fuels. Using Vector Error Correction Mechanism (VECM) on July 2004 to June 2015 data, we failed to find any long run relationship between the prices of these fuels. In absence of clear price signal, a rational agent is expected to optimize utility/cost using real prices. Estimates using real prices (deflated with CPI with base

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[1] Other factors, beside oil price decline, also contributed to petrol crisis of late 2014.
[2] In Pakistan, this share is around 20 percent (UNFCCC, 2011).

year 2007-08) confirm the presence of long run relationship, suggesting that the real CNG prices adjust to the long run equilibrium in response to shock to the real petrol and/or diesel prices. The result not only provides justification for substitutes' prices inclusion in the model, but also suggests that the government intervention distorts the price signal even between the substitutes.

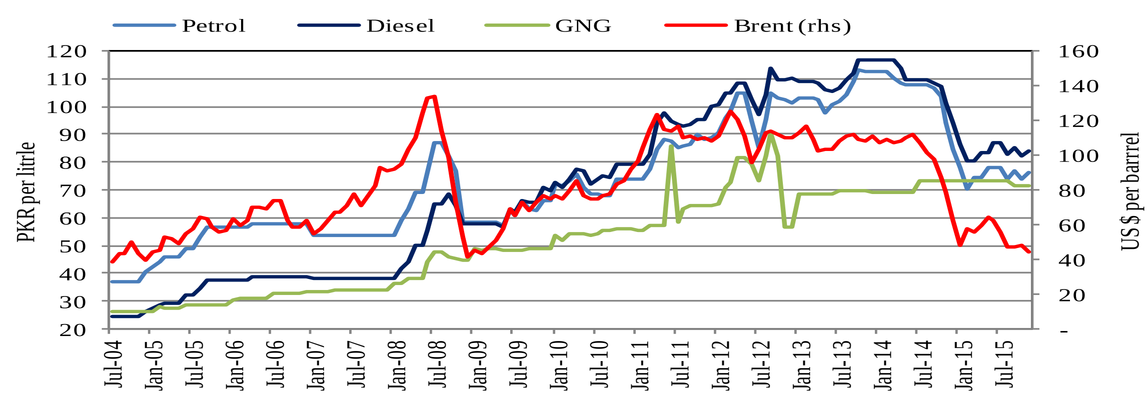
To answer the key research question, we use Seemingly Unrelated Regression Equations (SURE) methodology on system of lagged endogenous model as used by Ajanovic *et al.* (2012). Our results suggest that fuel demands are generally own price and cross price inelastic in the short run; a finding in line with the literature. One percent increase in the price of petrol, diesel, or CNG leads to 0.28, 0.21 and 0.66 percent decrease in their demands respectively. However, our long run estimates suggests that fuel demands are more elastic then suggested by the literature on gasoline demand. Close to perfect substitutability of CNG with petrol is driving this long run elasticity result. The estimates of the income elasticity of demand suggest that only petrol behaves as a normal good, as its demand increases with an increase in income, while diesel and CNG behave as inferior goods. Additionally, demand for petrol and diesel increases with the increase in the number of vehicles running on CNG/petrol and diesel. Our results are robust to alternate specifications, as estimates remain more or less the same when the lag demand of substitutes, real fuel prices, and exchange rate are introduced separately in the model.

Rest of the paper is structured as follows. Section 2 explores the dynamics of fuel prices in Pakistan. Section 3 reviews literature. Section 4 discusses the methodology adopted for the empirical analysis. Section 5 explains data. Section 6 delves into the results, and finally Section 7 concludes the discussion.

2. Dynamics of Price setting and Fuel Demand in Pakistan

Though fuel prices in Pakistan are largely driven by international oil prices, the relationship between the prices of the three fuels is not very obvious (see Figure 1). The administrative intervention often distorts the pass-through of international prices to domestic POL prices, despite the fact that oil prices have been officially deregulated since June 2011.

Figure 1: Trend in Brent Crude Oil and Fuel Prices in Pakistan



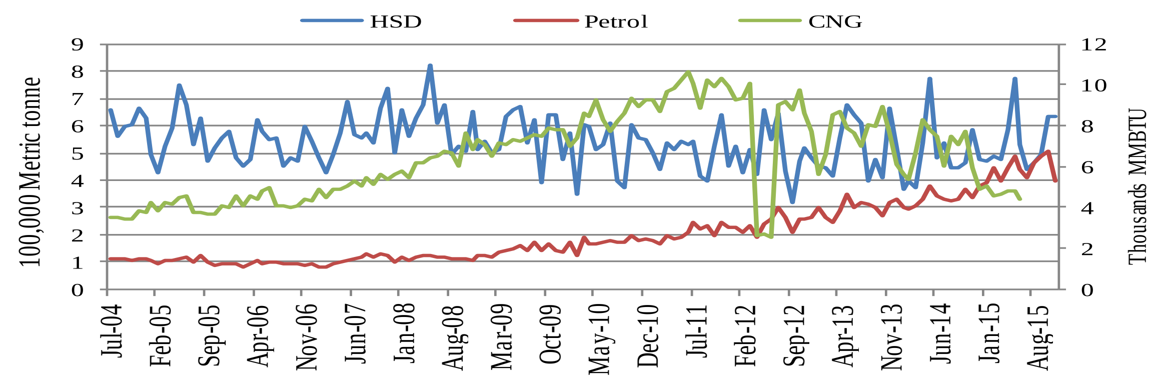
Source: World Bank, Pakistan State Oil, and Energy Year Books

The government administers the tax and levy rates to cover the fiscal deficit or to enforce certain political considerations. For example, the government may increase tax rates instead of passing on the benefits fully or partially to the consumers when global oil price declines. Similarly, when global oil prices increases, it may decide against increasing the domestic fuel prices to avoid popular resentment. Following sub-sections briefly discusses the fuel price setting in administrative setup, and the fuel demand in Pakistan.

2.1 Administration of POL Prices

The government of Pakistan deregulated the prices of petroleum products initially by mandating the Oil and Gas Regulatory Authority (OGRA) to fix the prices in April 01 2006. Later on, in June 2011, the private sector (refineries and Oil Marketing Companies) was allowed to fix the prices of Motor Spirit, HOBC, Light Diesel Oil, and Jet fuels (JP1, JP4 and JP8). OGRA now computes and notifies the price for kerosene oil only. Based on the government's approval, oil-marketing companies announces the domestic prices of petroleum products on bi-monthly basis using governments approved mechanism.

Figure 2: Trend in Fuel Demand in Pakistan



Source: Oil Companies Advisory Council, Oil and Gas Regulatory Authority

As per the government's announced mechanism, ex-refinery price of POL products cannot be more than Pakistan State Oil's average import price for the last fortnight. In case of non-availability of PSO import price, the refineries are allowed to fix ex-refinery price as per OGRA's Import Parity Pricing Formula (IPPF). Ex-refinery (or ex-depot) prices include, ex-refinery import parity prices (or PSO weighted average cost of purchases), Inland Freight Equalization Margin (IFEM), distribution margin, dealers' commission, and the petroleum levy notified by the government.

Retail prices also include the General Sales Tax (GST) on depot price, which is the major source of the government's revenue. Previously, the government used Petroleum Levy proactively to finance the budget deficit; nowadays it uses sales tax for this purpose. OGRA monitors the prices of petroleum products and may intervene in the market if required. Moreover, OGRA computes and notifies the IFEM for all products.

2.2 Administration of Natural Gas Prices

Natural gas prices are revised bi-annually by the government; following the changes in international crude oil and High Sulphur Fuel Oil (HSFO) prices. The impact of changes in the international crude oil prices first appears in domestic wellhead gas prices, and then passed-on to the end consumers.

OGRA first computes the revenue requirements of the gas utilities after ascertaining the weighted average cost of gas, which is the average of the cost incurred by the gas utilities on purchase and distribution of gas. The revenue requirement also includes transmission and distribution cost (including depreciation), prescribed return for gas utilities, and certain part of distribution losses.[3] Based on revenue requirement, OGRA recommends prescribed price for gas utilities to the government. The government then notifies the consumer's prices for natural gas for various sectors (domestic, commercial, general industries, power, and CNG) after including different taxes and levies. However, the business owners are allowed to fix retail CNG prices, as this sector has been deregulated from December 2016.

Currently, the government collects sales tax (at the rate of 17 percent), Gas Infrastructure Development Cess (GIDC), and Natural Gas Development Surcharge (NGDS) from CNG consumers.[4] Besides administrating the gas prices, the government often delays announcement, thereby further distorts the pass-through mechanism of the prices; which otherwise requires 7-13 months for transmitting to the consumer prices.

2.3 Fuel Demand

In the absence of clear price signal, the consumer's ability to choose between the best available alternatives may weaken, which will also have implications for the fuel demand function. This situation is not different in Pakistan. Figure 2 shows that apparently no common long term trend exists between the monthly demands for petrol, diesel and CNG, though these fuels share similar fundamental characteristics. For example, CNG demand increased rapidly and peaked in 2011 before declining thereafter. Petrol demand witnessed a secular increase despite rapid increase in global oil prices in later part of last decade (see Figure 1), whereas diesel demand shows mean reverting behavior over the period under consideration (Khan and Yasmin, 2014).

Misdirected government price interventions led to this deviation in demand trends. To date, CNG remains cheaper against its nearest substitutes, petrol and diesel. Moreover in the last decade, the government actively promoted use of CNG in the transport sector as a policy, without assessing its long term implications. Consequently, a mushroom growth in CNG demand latter led the government to announce CNG holidays for three to four days per week.[5]

A number of factors such as, increased gas demand by industries to overcome the power supply shortage and rapid increase in household demand as a result of infrastructure expansions undertaken by the gas utilities contributed to the recent increase in demand for gas. The depleting natural gas reserves further complicated the situation. The Transport sector relegated to the bottom in the list of sectors prioritized in the gas load management policy. Moreover, the government banned the import of CNG kits used to convert vehicles designed for petrol consumption though the decision was reversed later. With the CNG kits installed in petrol vehicles, CNG becomes perfect substitute to the petrol.

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[3] Currently, prescribed return on value of average net operating fixed assets for Sui Northern Gas Pipelines Limited and for Sui Southern Gas Company Limited are 17.5 percent and 17 percent respectively. Distribution losses, referred to as 'Unaccounted of Gas (UFG), remain a bone of contention between the gas utilities and the regulator. The UFG in Pakistan is quite high by global standards, which undesirably affects end consumer price. For detail discussion on UFG, see Chapter 3 SBP (2014).

[4] NGDS was imposed in 1963 for the development of gas pipeline infrastructure across the country, and for ensuring equalization of gas prices. However, in 1991, GDS was handed over to the provinces.

[5] An interesting research question would be, how the fuel demand responds to CNG rationing in Pakistan? Answering this question is beyond the scope of current research as it requires separate set of information, and special survey design etc.

Interestingly, the demand for petrol kept increasing over time despite POL product prices remaining historically high over this period (see Figure 2). Flexible policy for reconditioned (petrol using) car imports, increased production of locally assembled vehicles, increased used of two wheelers, and deterioration of public transport facilities contributed to this rise in petrol consumption. Increase in level of per capita income and environmental awareness may have contributed to the declining trend witnessed in the diesel demand.

3. Literature Review

Given the usefulness of fuel demand elasticities, literature discussing this subject has grown significantly over the years conferring both individual and group of countries. Notable among the recently appeared are: Winebrake *et al.* (2015), Lin and Zeng (2013), Sene (2012), Havranek *et al.* (2012), Dahl (2012), Ajanovic *et al.* (2012), Baranzini and Weber (2013), Akinboade *et al.* (2008), Rao and Gyaneshar (2009), De Vita *et al.* (2006), Polemis (2006), Cheung and Thomson (2004), Eltony (2004), and Ramanathan and Subramanian (2003). Detailed surveys covering this subject with non-parametric, semi-parametric, and parametric analysis can be found in Ajanovic *et al.* (2012), Dahl (2012), Brons *et al.* (2008), Sterner (2012), Goodwin *et al.* (2004), and Graham and Glaister (2004). We refrain from reproducing here the findings of these studies.

Generally, literature is in agreement that the fuel demand is price inelastic both in short run and in long run, but their income elasticities vary widely. For instance, survey analysis of Ajanovic *et al.* (2012) suggests that the short run price elasticities ranges between -0.20 and -0.30 while the long run price elasticities ranges between -0.60 and -0.85. On the other hand, income elasticity reportedly ranges between 0.30 and 0.50 for short-run and between 0.9 and 1.4 for long run. Other studies also report similar findings.

Literature on the estimation of fuel demand elasticity has evolved over time incorporating various dimensions like Rebound Effect of consumption demand [Chitnis and Sorrell (2015), Chan and Gillingham (2015), Gillingham *et al.* (2015 and 2016), Winebrake *et al.* (2015), Winebrake *et al.* (2012), Greene (2012), De Borger and Mulalic (2012), Matos and Silva (2011), Sorrell and Dimitropoulos (2007), and Small and Van Dender (2005)], Structural shift in elasticity estimates [Sita *et al.* (2012); Baumeister and Peersman (2012), and Hughes (2006)], volatility in fuel prices [Chan and Grant (2016), Lin and Prince (2013), Baumeister and Peersman (2012)], and asymmetry in consumers' responsiveness [Sentenac-Chemin (2012), Ajanovic and Haas (2012)].

The most widely investigated is the Rebound Effect − a phenomenon when low fuel cost induces the fuel demand thereby reverting some of the gains from fuel efficiency introduced in the vehicle design in terms of energy savings. The literature reports mixed result on presence of Rebound Effect however, this topic is premature as Pakistan is yet to update and implement its obsolete vehicle efficiency standards. We leave the study of Rebound Effect and other dimensions for future research.

Unfortunately, the literature discussing the energy issues in Pakistan are scarce. Most of them [including, Khan and Ahmed (2009), Razzaqi et. al., (2011), and Alam (2006)] focused on the relationship between the energy consumption demand and the economic growth, as energy (specifically power) stifled Pakistan's economic growth in recent past (Kessides, 2013). Jamil and Ahmad (2010), Abbas and Choudhury (2013) and Kessides (2013) were more specific in their approach and discussed the role of electricity consumption in economic growth for Pakistan. These studies conclude that growth in economic activity led to increase in the electricity consumption in Pakistan.

Only Burney and Akhtar (1990) and Chaudhary *et al.*, (1999) estimated the fuel demand and income elasticities in Pakistan, albeit using household Income and Expenditure Surveys. Both paper studied the urban and rural households' expenditure pattern on fuel consumption. Burney and Akhtar (1990) reported that fuels, Coal, Oil, Natural Gas and Electricity are necessities for a Pakistani household and their consumption is highly price inelastic.

Chaudhary *et al.*, (1999) estimated the price and income elasticities of a large number of agricultural, industrial and energy products. Their estimates suggest that the demand for all type of petroleum products, including high-speed diesel oil, is price elastic. Moreover, the demands for natural gas and electricity are also highly price elastic. Both studies has used cross-sectional data and failed to account for changing taste and the consumption behavior over time. Moreover, elasticity estimates of these studies are constrained by the welfare maximization of the households'. The scope of our study is entirely different focusing on the fuel demand estimation for the transport sector of Pakistan. We do not know any study dealing this subject for Pakistan.

4. Methodology

For estimation of price and income elasticities of demand, we use Seemingly Unrelated Regression Equations (SURE) on Lagged Endogenous model, as employed by Ajanovic *et al.* (2012). Equation (1) shows the system design, which consists of three equations representing separately the demand for each fuel.

$$\ln E_{it} = \beta_0 + \beta_i \ln P_{it} + \sum_{j=1}^{m} \beta_{ij} \ln P_{tj} + \sum_{k=1}^{n} \beta_{ik} x_{ik} + \beta_{E_{t-1}} \ln E_{(t-1)i} + \varepsilon_{it} \qquad (1)$$

The β coefficients show the short run elasticity of the fuel demand relative to the regressors. E_{ti} indicates demand for i^{th} fuel and P_{ti} is its price, P_{tj} is the price of its j^{th} substitute, x_{tk} includes information on other macroeconomic factors at any given time *t*, like economic activities (per capita income), number of vehicles, international crude oil price, and exchange rate of Pak rupees against US dollar.

The long run elasticity is calculated using the above short run elasticity estimates, given by equation (2),

$$\hat{\beta}_{LR} = \frac{\beta_{SR}^{\pi}}{1 - \beta_{E_{t-1}}} \qquad (2)$$

where β_{LR} is the long run elasticity estimate of any specific variable π, and β_{SR}^{π} is the short run elasticity estimate obtained from equation (1) for the variable π, which could be own price, cross price, or the income coefficients.

We use Seemingly Unrelated Regression Equations (SURE) technique primarily because our regressors are weakly exogenous. As fuel prices are set administratively, adequate supply is ensured by the government (running the monopoly in the POL sector) to match the demand and to defend administrative prices. The literature estimating the fuel demand elasticities, therefore, mostly estimates the demand elasticities without bothering about supply features, and the identification issues. Weak exogeneity also holds for the true Income elasticity, as the economic theory guides that income positively affects the fuel demand. The higher the income, the more is the fuel consumption demand, but the *vice versa* may not be true. Moreover, both theory and empirical literature suggest that own price elasticity should be negative while cross price elasticity should be positive for substitutes. Intuitively, fuel demand should be positively related with the number of vehicles running on that fuel.

In these circumstances, SURE methodology provides efficient estimates as no additional restriction is required to be imposed on the parameters. Often the restriction imposed *a priori*, while using other demand estimation technique, limits the efficiency gain in the estimation process.[6] A SURE system contains several individual relationships which are linked by the fact that their errors are correlated; due to correlated shocks to prices, say from global oil price, or economic activity. The basic philosophy of the SURE model is that the relationship between dependent variables of the equations can be explained by the structure of the SURE model and the covariance matrix of the associated disturbances. Such a common relationship introduces additional information beyond what is available, when the individual equations are considered separately.

To be sure that the errors of each equation are following stationary process, we subject them to generic unit root tests such as Augmented Dickey-Fuller (ADF) test or Phillips and Perron (PP) test. Stationary errors indicate that the estimates are reliable and can be used for making inferences. A fuel demand, following an autoregressive process, theoretically should also depend on the lag demand of its substitutes. Therefore, our robustness check analysis extends to the models incorporating the lagged fuel demand of the core fuel and it substitutes. Section 6 further deliberates on this issue.

5. Data

This study uses monthly data from July 2004 to June 2015 as, information on the CNG sales volume before July 2004 is not available. Gas demand in transport sector is the sum of CNG sold by SSGCL and SNGPL. Prices of petrol product are obtained from the Pakistan state oil (PSO) and from various energy year books, e.g. HDIP (2014). Demand for petroleum products is proxied by the sale volumes reported by the Oil Companies Advisory Council (OCAC). Data on vehicle sales is obtained from Pakistan Automotive Manufacturers Associations (PAMA). As, PAMA does not classify the vehicle sales by their fuel use so, based on the anecdotes, we assume that buses, tractors, and trucks run on diesel oil. Further, we assume that rest of the vehicle use either CNG or petrol. Vehicle owners normally switch between petrol and CNG frequently, and it is not easy to separate them by their fuel use. Since, motorcycles solely run on petrol. Therefore, we club all vehicles together (including two wheeler motorcycles) using non-diesel fuels.

We calculated real prices for fuel demand, where required, by transforming actual fuel prices into indices (using 2007-08 as the base year) and then dividing these indices by the consumer price index (CPI) of the same base year. We use large scale manufacturing (LSM) index as a proxy for income due to

[6] The SURE technique was propounded by Zellner (1962) and later developed by Zellner and Huang (1962); and Zellner (1963).

unavailability of GDP monthly series for Pakistan. Through this we get the income elasticity of fuel demand with respect to economic activity.

We used Hodrick and Prescott (1997) filter to extract the long term trend from the volatile LSM data. LSM data is obtained from Pakistan Bureau of Statistics. Both CPI and exchange rate for Pak rupee against US dollar are obtained from the state bank of Pakistan (SBP). Since data series are taken in logarithm, thus estimates simply represent the elasticities.

6. Results

At the outset, the variables are subjected to the unit root test. The result, reported in Table A1 in the Appendix, indicates that the data generating process of most of the variables involved in the models are differenced stationary. The non-stationary behavior of variables is not surprising given the government intervention in the POL sector. Westelius (2005) argues that frequent policy surprises may infuse persistence in an economic variable.

Though Figure 1 shows fuel prices move apparently in tandem, statistical support justifying their inclusion in the demand function as substitutes is missing. We estimate the long run relationship between the prices of fuels in support of their substitutability. As these price variables are differenced stationary, we estimate the long run relationship using Johansen's Likelihood technique based rank test and Vector Error Correction Mechanism (VECM).[7] Based on Akaike information Criteria (AIC), three lags have been selected as optimal lag length.[8] Surprisingly, the test statistics fails to reject the null hypothesis of no cointegrating relationship (at zero rank). Discretionary interventions based on popular choices often distort the fuel price setting mechanism, as these interventions overrule the dictum of economic efficiency and the market fundamentals. In this situation, the stochastic trend between nominal variable may not follow a common trend.

Therefore, we use real prices for this purpose, as discussed in Section 5. Figure A1, in the Appendix suggests that the trend in relative fuel prices remained more or less similar to their actual trends, but with less volatility. The data generating process of real fuel prices remains non stationary, as shown in Table A1 (in Appendix). The Trace statistics acquired suggest that the null hypothesis of one cointegrating relationship cannot be rejected.[9]

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[7] In a generalized form, Vector Error Correction Mechanism (VECM) is described by the equation below:

$$\Delta z_t = \alpha(\beta z_{t-1} + \mu + \rho t) + \sum_{k=1}^{n-1} \gamma_k \Delta z_{t-i} + \varphi t + \tau t + \varsigma_t ,$$

where z_t includes regressors, α measures the speed of adjustment, β is the cointegrating vector, φ, τ, μ, and ρ are trend coefficients, γ_k shows short run adjustment coefficients of the regressors, and *k* is the number of lag selected for the regressors using some information criteria. For the existence of a long run relationship α must be negative and significantly different from zero.

[8] Johansen (1995) Rank test uses rank of the cointegrating matrix, derived from common stochastic trend between the variables. These Likelihood estimators are known as Trace statistic and Maximum-Eigen value statistic; either or both can be used for making inference. The Trace statistics test the null hypothesis of no cointegration against the alternative hypothesis that there exists long run cointegrating relationship between the variables. Similarly, the Maximum eigen value statistics tests the null hypothesis that the number of cointegrating vectors is equal to rank of the cointegrating matrix against the alternative hypothesis of rank+1 cointegrating vectors.

[9] Estimates could be provided on request.

Table A2, in the Appendix, shows the VECM estimates for the long run and short run parameters of real fuel prices. The negative and significant coefficient of cointegrating equation (error correction term) at five percent level in the CNG price equation confirms the presence of the long run relationship; running from petrol and/or diesel to the CNG prices.[10] In contrast, insignificant error correction coefficients of petrol and diesel equations show that these prices do not adjusts if there is a shock to substitute's prices. This result is expected as international crude price is used for benchmarking POL prices directly while CNG prices are benchmarked indirectly via wellhead gas prices, as discussed in Section 2.[11] The bottom of the Table A2 shows the estimate of the coefficients for the long run relationship. The result suggests that any shock to real diesel prices lead to a decline in the real CNG prices in the long run. On contrary, shock to the real prices of petrol has no effect on the real CNG prices in the long run.[12]

6.1 Elasticities of Fuel Demand

To be sure of appropriateness of the SURE methodology employed, we test dependence between the fuel demand equations using Breusch and Pagan Lagrange Multiplier statistics. The results are reported in the middle of Table 1.[13] The null hypothesis that the equations are independent is rejected at five percent level of significance indicating that demand of these fuels is strongly dependent on each other. Therefore, our estimates using system SURE are more efficient and informative than single equation OLS estimates. If a variable appears insignificant, we drop it from the equation. We use Brent crude price as a proxy for domestic petrol price when the coefficient of the latter goes against the economic intuition. In this case, both domestic petrol and Brent price coefficients are reported. The estimated elasticity coefficients' sign are generally in line with the economic theory which will be discussed subsequently.

Table 1 further shows the short run elasticity estimates for petrol, diesel and CNG demand in separate columns, with respect to the relevant explanatory variables. These elasticity estimates are generally less than one, indicating that fuel demands are inelastic in short run similar to the findings in the literature. All three equations indicate persistence in demand for these fuels, as their lag explanatory variables are significant at five percent level. This persistence in demand is expected in administrative price setting, as distorted price signals lack essential information which helps the agents in choosing the best available alternatives. Therefore, agent's economic decision making process becomes either arbitrary or backward looking. Moreover, demand for CNG is more persistent as compared to that for petrol and diesel, as current demand is significantly explained by its two lags.

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[10] We also employ Pesaran *et al.* (2001) Bound test. The result of Bound test confirms that a unidirectional relationship from diesel and petrol prices to CNG prices exists only. In other words, relative prices of diesel and petrol are forcing long run relationship on the relative prices of CNG (results can be provided on request).

[11] Hartley *et al.* (2008) while investigating the relationship between the crude oil and international natural gas prices also reported that relationship between the two is indirect.

[12] We apply LM test for checking autocorrelation, and Jarque-Bera test for normality of residuals. The results suggest that errors are not correlated but the Jarque-Bera test fails to reject the null hypothesis that errors are not normally distributed. However, the graphical presentation suggests that the cointegrating vector is following stationary process. Therefore, we tolerate this marginal deviation of residuals from normality.

[13] The Breusch and Pagan (1980) LM statistics for M equations and T observations is given by:

$$\lambda = T\sum_{m=1}^{M}\sum_{n=1}^{m-1} r_{mn}^2$$

Where, r_{mn}^2 is estimated correlation between residuals distributed as χ^2 with M*(M-1)/2 degrees of freedom.

6.2 Demand for Petrol

Result of Table 1 (petrol column) suggests that almost all short run coefficients of the explanatory variables are significant at five percent level, except diesel price. The coefficient of the diesel price is significant at ten percent level. Elaborately, price elasticity of petrol demand is -0.28, indicating that in the short run petrol demand decreases by 0.28 percent with one percent increase in its prices. Moreover, the demand for petrol should be positively related to its substitutes; diesel and CNG. The result shows that one percent increase in the diesel and CNG prices respectively lead to 0.29 and 0.34 percent increase in the demand for petrol.

Table 1: Short Run Elasticity of Fuel Demand in Transport Sector

	Petrol (Motor Spirit)	**Diesel (High Speed)**	**Natural Gas (CNG)**
Petrol (-1)	0.7305*		
	(0.000)		
Diesel (-1)		0.2713*	
		(0.000)	
Natural Gas (-1)			0.5756*
			(0.000)
Natural Gas (-3)			-0.3310*
			(0.000)
Price_Petrol	-0.2844*		-1.3282*
	(0.037)		(0.000)
Price_Diesel	0.2903**	-0.2066	1.2802*
	(0.075)	(0.156)	(0.000)
Price_Natural Gas	0.3413*	0.0905	-0.6571*
	(0.005)	(0.593)	(0.000)
Economic Activity	0.5152*	-0.0584	-0.6130*
	(0.002)	(0.748)	(0.023)
Brent Oil		0.1109**	0.3875*
		(0.074)	(0.001)
No. of Diesel Vehicles		0.0949*	
		(0.000)	
No. of Petrol/CNG Vehicles	0.1394*		-0.1804*
	(0.017)		(0.094)
Constant	-2.1327**	9.1153*	12.8016*
	(0.046)	(0.000)	(0.000)
Breusch-Pagan test of independence: Chi-Sq(3) =			57.3480*
			(0.000)
Diagnostic (Unit Root) Tests on Errors			
ADF (Constant)	1.2810	-0.8540	-1.5720
	(0.996)	(0.803)	(0.497)
ADF (Constant &Trend)	-3.311**	-2.0880	0.3940
	(0.065)	(0.553)	(0.996)
PP (Constant)	0.6060	-5.149*	-2.5080
	(0.988)	(0.000)	(0.114)
PP (Constant &Trend)	-3.833*	-7.3290*	-2.4300
	(0.015)	(0.000)	(0.363)

Notes: Petrol, diesel and natural gas columns represent separate equations for these variables' demand functions estimated via SURE model. Variables are in logarithm and therefore coefficients represent elasticities. Values in parenthesis are probabilities. *, and ** respectively stand for 5 percent and 10 percent level of significance. ADF and PP indicate Augmented Dickey-Fuller and Phillips and Perron unit root tests, respectively.

Besides, one percent increase in income, leads to 0.52 percent increase in demand for petrol. Our short run elasticity estimates for prices and income are mostly in line with those reported in literature (Dahl, 2012; Ajanovic *et al.*, 2012). Moreover, one percent increase in the number of vehicles running on petrol leads to 0.14 percent increase in demand for the fuel. As discussed earlier, the vehicles on petrol are mostly hybrid in nature, since they use petrol and CNG simultaneously. Therefore, the elasticity of petrol demand with number of vehicles on petrol needs to be viewed with caution. This issue will be deliberated further latter in this section.

The Table 2 extends this analysis to long run elasticities. The long run estimates of petrol demand elasticities (Table 2: petrol column) are closer to unity suggesting that petrol demand is more elastic in Pakistan in long run, than in short run. One percent increase in price of petrol leads to almost proportional decrease in petrol demand in the long run. Similarly, one percent increase in the price of diesel or CNG respectively leads to 1.07 and 1.27 percent increase in demand for petrol.

Table 2:Long run Elasticity of Fuel Demand in Transport Sector

	Petrol (Motor Spirit)	**Diesel (High Speed)**	**Natural Gas (CNG)**
Price_Petrol	-1.0550*		-1.7583*
	(0.025)		(0.000)
Price_Diesel	1.0770**	-0.2835	1.6946*
	(0.054)	(0.15)	(0.000)
Price_Natural Gas	1.2660*	0.1242	-0.8698*
	(0.003)	(0.592)	(0.000)
Economic Activity	1.9111*	-0.0801	-0.8115*
	(0.000)	(0.748)	(0.016)
Brent Oil		0.1522**	0.5128*
		(0.072)	(0.000)
No. of Diesel Vehicles		0.1303*	
		(0.001)	
No. of Petrol Vehicles	0.5170*		-0.2388**
	(0.009)		(0.091)

Notes: Petrol, diesel and natural gas columns represent separate equations for these variables' demand functions estimated via SURE model. Variables are in logarithm and therefore coefficients represent elasticities. Values in parenthesis are probabilities. *, and ** respectively stand for 5 percent and 10 percent level of significance.

Our long run elasticity estimates are higher than that reported by Ajanovic *et al.* (2012) or Dahl (2012). Their findings suggest that the demand is (own) price inelastic in the long run with marginally higher coefficients compared to the short run. Deviation in our long run elasticity estimates could be due to high substitutability between petrol and CNG, and the load management policy of the government in CNG sector, which will be discussed subsequently.

Gasoline, as reported in literature, is generally comprised of petrol, natural gas, and even some bio-fuel. However, we estimate fuel demand separately for CNG, petrol and diesel, as the dynamics of petrol and natural gas demand are very different in Pakistan. As discussed in Section 2, CNG is cheaper in Pakistan compared to the petrol or diesel, and therefore the government manages the natural gas demand by enforcing CNG holidays thereby restricting the operation of filling stations to only for a few days in a week. Consumers, generally, queue before the CNG stations to fill their tanks. To circumvent the additional cost imposed by the limited supply, a marginal group of consumer switches to the petrol consumption. Consequently, if petrol prices decrease CNG consumer jumps to the petrol, which makes the long run petrol demand more elastic compared to what is reported in literature. This also holds if the shock comes from income increase. Our long run estimates (Table 2: petrol column) suggest that one percent increase in income leads to almost 1.9 percent increase in the petrol demand. In other words, petrol is a normal good in Pakistan, as its demand is more income elastic.

6.3 Demand for Diesel

The elasticity estimates of diesel demand suggest that these do not change much between the short run and long run horizons. Diesel columns of Table 1 and Table 2 suggest that price of diesel and its substitute fails to explain significantly the short run, as well as the long run demand for the diesel fuel; though the signs of the estimated coefficients correctly explain the relationship between these variables. For example, own price elasticity of diesel demand is negative while cross price elasticity of its substitute CNG is positive.

As petrol price's coefficient was insignificant in the initial model for Diesel, it was replaced with the international Brent crude price. The result shows that the diesel demand is positively and significantly related with the Brent price in the short run as well as in the long run. Precisely, one percent increase in Brent prices leads to 0.11 percent and 0.15 percent increase in diesel demand in short and in long run, respectively. In other words, consumers will move towards the use of diesel if Brent price increases, perhaps expecting an increase in the domestic petrol prices going forward.

The sign of the income coefficient is negative, albeit insignificant at five percent level, suggesting that income has no impact on diesel demand. The negative sign however indicates that the diesel is an inferior good in the transport consumers' basket. It suggests that consumers will switch to petrol from diesel if their income rises. The demand for diesel is positively related to the number of diesel vehicles sold. One percent increase in the sale of the diesel vehicle leads to 0.10 percent and 0.13 percent increase in its short run and long run demand respectively.

6.4 Demand for CNG

Almost all variables explaining the CNG demand in short run (Table 1: CNG column) are significant at five percent, except for the petrol prices and the number of vehicles running on CNG. For example, short run own price elasticity of CNG is -0.66 (Table 1: CNG column) indicating that CNG demand decreases by 0.66 percent with one percent increase in its price. The cross price elasticity of short run CNG demand with diesel price is 1.28 which suggests that one percent increase in the diesel prices increases CNG demand by 1.28 percent. Perhaps heavy transport, which mostly runs on diesel, switches to CNG consumption when diesel price increases.

Interestingly, its cross price elasticity with petrol shows a negative sign, which is counter intuitive, indicating that increase in the petrol prices leads to decrease in the CNG demand. There could be a number of possible explanations. For example, frequent policy interventions in an administrative price setting environment may have distorted this relationship. Alternatively, perhaps, governments restricted the supply CNG further when petrol price increases, expecting an increase in CNG demand. We introduced the Brent oil price, besides the domestic petrol price, in the CNG equation to capture the consumer's sentiment about the variation in the petrol prices. Brent oil significantly explains the CNG demand with correct sign, indicating that one percent increase in the international oil price leads to 0.39 percent increase in the CNG demand (Table 1: CNG column) in short run.

The coefficient of number of vehicles running on CNG is negative and significant at 10 percent level suggesting that CNG demand decreases with an increase in number of vehicles (CNG/petrol) sold. However, this negative sign with number of vehicles is dubious and we attempt to decipher this negative sign for a meaningful analysis. It should be noted that number of non-diesel vehicle reported here includes vehicles that runs only on petrol or on CNG, and on both petrol and CNG. Though identifying non-diesel vehicles by fuel use is very difficult, we have separated two wheelers from the rest of the group of non-diesel vehicles for this analysis, as the two wheelers mostly run on petrol. Figure A2 (in Appendix) shows that the number of two wheelers sold outstrips the rest of group (three and/or four wheelers). Moreover, growth in the sale of two wheelers is much higher compared to the growth in the non-two wheeler category, running on CNG and/or petrol. Therefore, strong variation in two wheeler sales is not only masking the overall variation in number of CNG/petrol vehicles, but also contradicting the trend of the CNG sales.

The negative income elasticity of CNG, contrary to the petrol equation, suggests that CNG appears as an inferior good in the transport consumer's basket. With rise in income, consumers not only prefer switching to the petrol and/or to hybrid (electric) cars, but they may also be attaching a social cost for queuing in front of the filling stations.

The long run elasticity estimates (Table 2: Natural gas column) are similar in sign, but stronger in magnitude than their short run estimates (Table 1: Natural gas column). For example, own price elasticity increased to -0.87 from -0.66 for short run (Table 1), while its cross price elasticity with diesel increases to 1.70 from 1.28, as reported in Table 1. These results show that CNG demand is more elastic compared to the petrol and diesel. This additional flexibility in the CNG demand stemmed from government's load management policy in the CNG sector.

To check the robustness of the results, we extend this analysis to feedback effects of substitute's demand. Following Ajanovic *et al.* (2012), we include lag of the substitutes demand in all three equations. The results are shown in Table A3 in the Appendix. Upper and middle panel of the table shows the short run and the long run elasticity coefficients. The short run coefficients of the lag demand of substitutes (lag of diesel and CNG demand) are significant at five percent level in equation for petrol. Nonetheless, the same is not true for diesel equation, where these coefficients become insignificant. Also in CNG equation, lag demand of petrol is insignificant. Apart from these indicated, most of the coefficients in all three equations shows similar sign and magnitude but turn out to be insignificance due to increase in variances. Therefore, inclusion of lag demand of substitutes is less meaningful for policy analysis and which limits the significance of this model.

We also used real prices in the model in place of actual fuel prices. Table A4 (in Appendix) show that the short run estimates of all three equations (upper panel) are close to the original estimates of Table 1, except for the real prices. However, the long run fuel demands become more elastic (middle panel), showing more than proportional change in demand for fuels in response to the changes in real fuel prices. Interestingly, some of the key coefficients become insignificant in these models as well, and therefore, we limit the use of this model to robustness check only.

Furthermore, we also introduce exchange rate in the original model to check if fuel demands are explained by fluctuations of Pak rupees against US dollar. The estimates are provided in Table A5 in the Appendix. Elaborately, the impact of exchange rate on both petrol and diesel demand is positive which shows that the depreciation of Pak rupee leads to increase sales of both petrol and diesel in the short run, as well as in the long run. Pakistan imports POL products, including petrol and diesel. As fuel demands are mostly price inelastic in short run, a depreciation of Pak rupee results in increased fuel sales only. Moreover, the results suggest that exchange rate has no impact on CNG demand, as the most of the natural gas demand is met through domestic gas production. Going forward, we expect a change in the price dynamics of natural gas in Pakistan, as LNG is being imported from Middle East to cater the growing demand for natural gas.

Although exchange rate shows a significant impact on the demand of petrol and diesel, its introduction in the model distorts behavior of some price coefficients. For example in the petrol equation, the own price elasticity of petrol becomes positive and insignificant (Table A5 in Appendix). Moreover in diesel equation, the cross price elasticity of CNG becomes negative, while the coefficient remains insignificant. Apart from the noted deviations, the coefficients remain close to our original estimates, which suggest that our results are robust.

As a diagnostic check, we tested the errors of each equation for stationarity. The bottom part of Table 1 shows the results of the unit root test on the errors of each equation. The null hypothesis of unit root is rejected at five percent level of significance, both for petrol and for diesel equations. The null hypothesis of unit root on errors of the CNG equation is rejected only at 11.4 percent. This deviation is minor and can be ignored without any significant impact on the inferences. As errors of all three fuel equations are following stationary process, our estimates are reliable for making inferences. The errors of all other models presented for robustness check also found stationary in unit root tests.

7. Conclusion

This study investigated elasticity of fuel demand in the transport sector of Pakistan using monthly data from July 2004 to June 2015, as quantum of natural gas sales could be retrieved only for this period. Our results suggest that the fuel demands are mostly (own and cross) price inelastic in short run, which is also supported by the findings in the literature. However in the long run, the demand elasticities are comparatively higher, which is relatively different from the findings in recent studies, covering as late as nineties. Deviation in our long run elasticity estimates is due to the load management policy adopted by the government in CNG sector.

Moreover, estimated income elasticity of demand suggests that only petrol behaves as a normal good as its demand increases with the increase in income, while diesel and CNG behave as inferior goods. Additionally, demand for petrol and diesel increases with an increase in the vehicles running these fuels. The demand for CNG apparently decreases with the increase in the number of CNG vehicles. The inclusion of two wheelers in non-diesel vehicles, which specifically run on petrol, may have distorted this estimate. Our results are robust as the estimates remained more or less similar when lag demands of substitutes, exchange rate, and real fuel prices are, separately, included in the model.

The result of auxiliary estimate, on the relationship between the fuel prices, supported the presence of long run relationship between real fuel prices, instead of their nominal prices, which essentially justify the inclusion of these fuels as a substitute in the fuel demand functions. The result suggests that only CNG prices adjust to the long run equilibrium in response to shock to petrol and/or diesel prices. Neither petrol nor diesel prices show any significant adjustment towards equilibrium, if prices of their substitutes receive any shock. The substitutability between the fuels is also supported by the dependence test, which suggests that the demand of these fuels is strongly dependent on each other's demand.

From policy perspective, the short run inelastic fuel demands suggests that environment policies to reduce the consumption and to control CO_2 emissions, such as carbon tax, may not produce desired result. Probably, introduction of environment friendly public transport system in cities may increase the responsiveness of fuel demand in the short run that may help in achieving the sustainable environment goals. From the perspective of government finances, short run inelastic estimates suggests that higher taxes on fuel consumption will positively impact the government's revenue, but will reduce the demand only marginally.

On the other hand, the long run elasticity estimates show that decline in oil prices amid rising income activity may lead to strong increase in the petrol demand, further stressing the balance of payment. Though decrease in petrol prices leads to proportional increase in its demand, increase in income contributes, more than proportional increase, in its demand (one percent increase in economic activity contributing to 1.9 percent increase in petrol demand). On the top of that, exchange rate depreciation adds to petrol demand by almost three percent. This situation augurs well for government finances; however, it may create substantial pressure on the current account deficit and the balance of payments in the long run.

The downward movement in the substitute's price (say CNG price), in this situation, may alleviate some pressure on petrol, as its demand is positively related to the CNG prices. However, the government's decision to allow the CNG business owners to fix retail prices may have limited this downward flexibility in CNG prices; even if the impact of falling oil prices is passed-on to the natural gas price.

A few caveats are in order. We didn't check the Rebound Effect as the efficiency standard for vehicles plying in Pakistan are obsolete and needed to be updated. Moreover, we didn't investigate the asymmetry in the fuel demand response. As we confine the scope of this study to the robust estimation of fuel demand elasticities only, we leave these topics for future research. Furthermore, we assumed that diesel demand is explained by the vehicles running on diesel only. However, most of locomotive engines, fishing boats, and agricultural pumps also consume diesel. Despite including their consumption through diesel sales, we didn't include the relevant paraphernalia in number of vehicles consuming diesel due to lack of data. We believe this will not affect our inferences given the number of rail engines and fishing boats are very small compared to the number of vehicles running on diesel.

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Appendix

Table A1: Results of Augmented Dickey-Fuller Unit Root Test

	Drift only	Drift with trend
Diesel	-1.653	-1.355
Petrol	1.318	-3.662*
Natural Gas	-1.638	-0.162
Price Petrol	-1.815	-1.065
Price_Diesel	-1.842	0.582
Price_Natural Gas	-1.709	-0.620
Real Price Diesel	-1.659	-0.240
Real Price Petrol	-0.961	-2.295
Real Price Natural Gas	-1.833	-1.655
No. of Diesel Vehicles	-1.716	-2.314
No. of Petrol Vehicles	-1.636	-3.419*
Exchange rate	-1.053	-2.260
Brent Oil	-1.256	-0.043
Income	-4.476*	-4.403*
5% Critical Values	***-2.889***	***-3.449***

Variables are in logarithm. * indicates significant at 5 percent level.

Table A2: Relationship Between Relative Fuel Prices

	Real Price CNG	Real Price Petrol	Real Price Diesel
	-0.3623*	0.0042	0.0603
Cointegrating Coefficient (-1)	(0.000)	(0.953)	(0.285)
D(Real Price CNG(-1))	-0.1221	-0.0105	-0.0549
	(0.206)	(0.892)	(0.373)
D(Real Price CNG(-2))	-0.0759	-0.0398	-0.0567
	(0.384)	(0.569)	(0.309)
D(Real Price Petrol(-1))	-0.0081	0.2295	0.2975*
	(0.968)	(0.157)	(0.022)
D(Real Price Petrol(-2))	-0.5768*	0.2693	0.0317
	(0.005)	(0.102)	(0.809)
D(Real Price Diesel(-1))	0.2815	-0.0468	-0.1643
	(0.265)	(0.817)	(0.309)
D(Real Price Diesel(-2))	0.5954*	-0.2922	0.0383
	(0.018)	(0.147)	(0.812)
Constant	0.0003	-0.0007	0.0016
	(0.961)	(0.863)	(0.639)
	1.000	0.0354	-0.2586*
Long run Relationship		(0.675)	(0.001)

* Significant at 5 percent. Figure in the parenthesis are p-values. 'D' with the variable name shows first difference of the variables, while RP suggest real or relative prices.

Table A3: Elasticity of Fuel Demand in Transport Sector

(with Lags demands of substitutes)

	Petrol (Motor Spirit)	Diesel (High Speed)	Natural Gas (CNG)
Short run Elasticity Estimates			
Petrol (-1)	0.8246*	0.1281	.03773
	(0.000)	(0.116)	(0.667)
Diesel (-1)	-0.1739*	0.1022	-0.2006*
	(0.003)	(0.251)	(0.021)
Natural Gas (-1)	-0.07231	-0.0633	0.5483*
	(0.107)	(0.354)	(0.000)
Natural Gas (-3)			-0.3367*
			(0.000)
Price_Petrol	-0.2272**		-1.3574*
	(0.090)		(0.000)
Price_Diesel	0.1995	-0.2692**	1.2332*
	(0.235)	(0.082)	(0.000)
Price_Natural Gas	0.17691	-0.1258	-0.6989*
	(0.182)	(0.537)	(0.000)
Income	0.1537	-0.4055	-0.7688*
	(0.442)	(0.106)	(0.020)
Brent Oil		0.1233	0.4198*
		(0.049)	(0.000)
No. of Diesel Vehicles		0.0988*	
		(0.000)	
No. of Petrol Vehicles	0.1113**		-0.2184**
	(0.053)		(0.064)
Constant	2.5064	13.0646*	16.8039*
	(0.153)	(0.000)	(0.000)
Breusch-Pagan test of independence: chi2(3) =			57.431*
			(0.000)
Long run Elasticity Estimates			
Price_Petrol	-1.2953**		-1.7217*
	(0.073)		(0.000)
Price_Diesel	1.1371	-0.2999**	1.5642*
	(0.187)	(0.072)	(0.000)
Price_Natural Gas	1.0085	-0.1402	-0.8865*
	(0.129)	(0.534)	(0.000)
Income	0.8763	-0.4517**	-0.9751*
	(0.368)	(0.095)	(0.014)
Brent Oil		0.1374*	0.5326*
		(0.046)	(0.000)
No. of Diesel Vehicles		0.1101*	
		(0.000)	
No. of Petrol Vehicles	0.6345*		-0.2770**
	(0.05)		(0.062)
Petrol (-1)		0.1426**	0.0479
		(0.098)	(0.667)
Diesel (-1)	-0.9911**		0.6955*
	(0.079)		(0.000)
Natural Gas (-1)	-0.4122	-0.0705	
	(0.16)	(0.356)	
Diagnostic (Unit Root) Tests on Errors			
ADF (Constant)	1.3690	-1.4980	-1.5805
	(0.997)	(0.534)	(0.491)
ADF (Constant &Trend)	-3.193**	-2.6560	0.4510
	(0.086))	(0.254)	(0.997)
PP (Constant)	0.5880	-4.0505*	-2.4790
	(0.987)	(0.001)	(0.120)
PP (Constant &Trend)	-3.4630*	-5.7080*	-2.4150
	(0.044)	(0.000)	(0.371)

Notes: Petrol, Diesel and Natural gas columns represent separate equations for these variables demand in SURE model. Variables are in logarithm and therefore coefficients represent elasticities. The short run elasticity estimates were obtained using Equation (1). The long run elasticity estimates uses Equation (2). Figures in parenthesis are probability values. *, and ** indicates 5 percent and 10 percent level of significance, respectively. ADF and PP indicate Augmented Dickey-Fuller and Phillips and Perron unit root tests, respectively.

Table A4: Elasticity of Fuel Demand in Transport Sector (Real Prices)

	Petrol (Motor Spirit)	Diesel (High Speed)	Natural Gas (CNG)
Short run Elasticity Estimates			
Petrol (-1)	0.8917*		
	(0.000)		
Diesel (-1)		0.3075*	
		(0.000)	
Natural Gas (-1)			0.6696*
			(0.000)
Natural Gas (-3)			-0.2777*
			(0.000)
Real Price_Petrol	-0.3278*		-0.0081
	(0.026)		(0.971)
Real Price_Diesel	0.2499	-0.3982*	0.1046
	(0.158)	(0.019)	(0.629)
Real Price_Natural Gas	-0.0504	-0.2125	-0.4356*
	(0.725)	(0.279)	(0.044)
Income	0.1546	-0.0623	-0.9241*
	(0.340)	(0.627)	(0.002)
Brent Oil		0.1233**	0.0685
		(0.062)	(0.533)
No. of Diesel Vehicles		0.1079*	
		(0.000)	
No. of Petrol Vehicles	0.1243**		-0.1471
	(0.052)		(0.236)
Constant	-0.2925	10.8895*	12.7272*
	(0.841)	(0.000)	(0.000)
Breusch-Pagan test of independence: chi2(3) =			39.5340*
			(0.0000)
Long run Elasticity Estimates			
Real Price_Petrol	-3.0268*		-0.0132
	(0.001)		(0.971)
Real Price_Diesel	2.3072**	-0.5749*	0.1720
	(0.076)	(0.016)	(0.627)
Real Price_Natural Gas	-0.4661	-0.3068	-0.7164*
	(0.718)	(0.282)	(0.037)
Income	1.4278	-0.0899	-1.5194*
	(0.296)	(0.627)	(0.000)
Brent Oil		0.1780**	0.1126
		(0.060)	(0.534)
No. of Diesel Vehicles		0.1558*	
		(0.000)	
No. of Petrol Vehicles	1.1474*		-0.2418
	(0.036)		(0.233)
Diagnostic (Unit Root) Tests on Errors			
ADF (Constant)	1.2090	-1.9350	-1.9730
	(0.996)	(0.316)	(0.298)
ADF (Constant &Trend)	-3.381**	-2.1050	0.2800
	(0.054)	(0.543)	(0.996)
PP (Constant)	0.4520	-5.761*	-2.845**
	(0.983)	(0.000)	(0.052)
PP (Constant &Trend)	-4.245*	-6.514*	-3.0340
	(0.004)	(0.000)	(0.123)

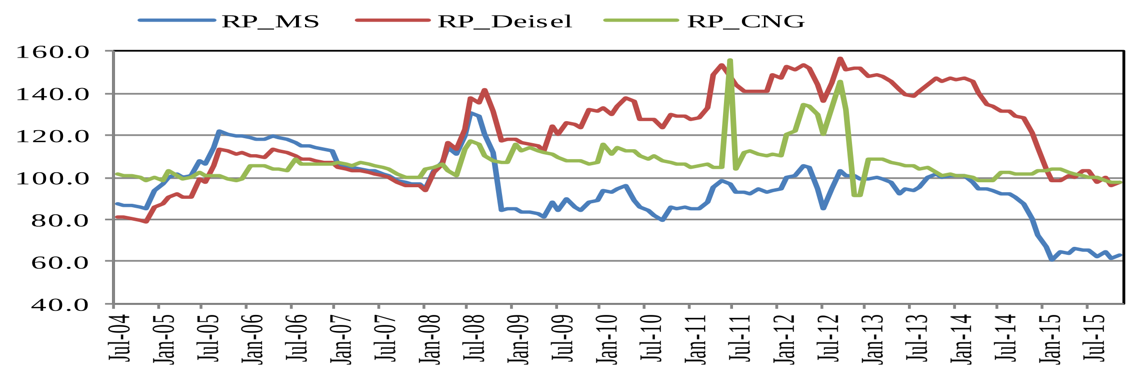
Notes: Petrol, Diesel and Natural gas columns represent separate equations for these variables demand in SURE model. Variables are in logarithm and therefore coefficients represent elasticities. The short run elasticity estimates were obtained using Equation (1). The long run elasticity estimates uses Equation (2). Figures in parenthesis are probability values. *, and ** indicates 5 percent and 10 percent level of significance, respectively. ADF and PP indicate Augmented Dickey-Fuller and Phillips and Perron unit root tests, respectively.

Table A5: Elasticity of Fuel Demand in Transport Sector (with Exchange Rate)

	Petrol (Motor Spirit)	Diesel (High Speed)	Natural Gas (CNG)
	Short run Elasticity Estimates		
Petrol (-1)	0.6095*		
	(0.000)		
Diesel (-1)		0.2198*	
		(0.002)	
Natural Gas (-1)			0.5692*
			(0.000)
Natural Gas (-3)			-0.3257*
			(0.000)
Price_Petrol	0.0257		-1.2231*
	(0.866)		(0.000)
Price_Diesel	-0.2366	-0.4900*	1.1648*
	(0.245)	(0.016)	(0.001)
Price_Natural Gas	0.2492*	-.06050	-0.6995*
	(0.035)	(0.730)	(0.000)
Income	0.4263*	-0.1168	-0.6953*
	(0.010)	(0.515)	(0.013)
Brent Oil		0.2045*	0.3646*
		(0.014)	(0.002)
No. of Diesel Vehicles		0.1085*	
		(0.000)	
No. of Petrol Vehicles	0.2724*		-0.1591
	(0.000)		(0.141)
Exchange Rate	1.0511*	0.7655*	0.1459
	(0.000)	(0.032)	(0.688)
Constant	-5.0923*	7.9773*	12.6336*
	(0.000)	(0.000)	(0.000)
Breusch-Pagan test of independence: chi2(3) =			50.518*
			(0.0000)
	Long run Elasticity Estimates		
Price_Petrol	0.0658		-1.6167*
	(0.866)		(0.000)
Price_Diesel	-0.6058	-0.6281*	1.5396*
	(0.242)	(0.014)	(0.001)
Price_Natural Gas	0.6381	-0.0776	-0.9246*
	(0.030)	(0.730)	(0.000)
Income	1.0912*	-0.1498	-0.9191*
	(0.004)	(0.512)	(0.009)
Brent Oil		0.2622*	0.4819*
		(0.013)	(0.002)
No. of Diesel Vehicles		0.1391*	
		(0.000)	
No. of Petrol Vehicles	0.6975*		-0.2103
	(0.000)		(0.138)
Exchange Rate	2.6911*	0.9812*	0.1929
	(0.000)	(0.029)	(0.688)
	Diagnostic (Unit Root) Tests on Errors		
ADF (Constant)	1.2490	-1.7060	-1.6050
	(0.996)	(0.428)	(0.480)
ADF (Constant &Trend)	-3.496*	-2.4690	0.3390
	(0.039))	(0.343)	(0.996)
PP (Constant)	0.9680	-4.796*	-2.5000
	(0.993)	(0.000)	(0.116)
PP (Constant &Trend)	-3.1230	-6.319*	-2.4290
	(0.101)	(0.000)	(0.364)

Notes: Petrol, Diesel and Natural gas columns represent separate equations for these variables demand in SURE model. Variables are in logarithm and therefore coefficients represent elasticities. The short run elasticity estimates were obtained using Equation (1). The long run elasticity estimates uses Equation (2). Figures in parenthesis are probability values. *, and ** indicates 5 percent and 10 percent level of significance, respectively. ADF and PP indicate Augmented Dickey-Fuller and Phillips and Perron unit root tests, respectively.

Figure A1: Trend in RelativeFuel Prices in Pakistan



Source: Author's calculation

Figure A2: Disaggregation of Vehicles Running on Petrol