# India's Petroleum Demand:
# Empirical Estimations and Projections for the Future

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## ABSTRACT

With rapid economic growth, energy demand in India has been rising rapidly, and India is now the fourth largest consumer of crude oil in the world. Unfortunately, India has to import most of its oil requirement, which leads to severe pressure on the economy when the oil prices rise. Thus, estimations of crude oil demand and projections for the future should be useful to policy makers in making appropriate supply arrangements for the future.

This paper empirically estimates demand relations for crude oil, diesel, and petrol for India for the period between 1970–71 and 2010–11 using the ARDL co-integration procedure and uses these estimations to project demand for these products up to 2025 under various scenarios of gross domestic product (GDP) growth (with a mean of 7 per cent) and oil prices. Our projections show that over 2011–2025, demand for crude oil is likely to increase by about 90 per cent, for diesel by about 110 per cent, and for petrol by about 165 per cent under likely future growth scenarios. The corresponding annual growth rates come to about are 4.7 per cent for crude oil, 5.4 per cent for diesel, and 7.2 per cent for petrol.

Therefore, India should take various measures to improve efficiency in the use of petroleum products and try to enhance supplies such as through production sharing agreements by Indian oil companies with other countries. We also need to increase use of nuclear, hydro, solar, and other alternative energy sources, as Western European countries have been doing. Careful planning to ensure that future petroleum requirements can be met will be useful in sustaining rapid economic growth in the future.



Key words: Demand estimations, projections, India, crude oil, petroleum, diesel, petrol, gasoline

JEL codes: Q41, Q47, Q48

## 1. INTRODUCTION

Energy security is crucial for both sustaining high economic growth and controlling inflation. With rapid economic growth, energy demand in India has been rising rapidly, and India is now the fourth largest consumer of crude oil in the world. Unfortunately, India has to import most of its oil requirement, leading to severe pressure on the economy when the oil prices rise. Thus, estimations of crude oil demand and projections for the future should be useful to policy makers in making appropriate supply arrangements for the future.

There are many different sources of energy consumption, such as coal, crude oil, natural gas, hydroelectric, solar, wind, and nuclear energy. Out of India's total energy consumption, crude oil accounts for 24 per cent, natural gas 6 per cent, coal 40 per cent, combustible renewable and waste 27 per cent, hydroelectric power 2 per cent, and nuclear energy and wind energy about 1 per cent each; solar energy has an insignificant share (IEA 2008). Thus, crude oil and coal account for about two-thirds of India's energy consumption. While India is reasonably self-sufficient in coal, it imports most of its crude oil requirement. Further, there are hardly any suitable alternatives to crude oil derivatives such as petrol and diesel for transportation purposes and most industrial machinery. Bio-fuels cannot be used on a large scale in a land-scarce country such as India, already struggling to produce sufficient food for its population. Thus, controlling crude oil consumption is difficult. India consumed nearly 3.25 million barrels of crude oil per day in 2010 and was the fourth largest consumer of oil in the world next to the US, China, and Japan. Of this, 70 per cent (nearly 2.2 million barrels per day) was imported in 2010, largely from Middle Eastern countries; this level of imports made it the fifth-largest importer of oil in the world. The International Energy Agency (IEA) expects that India would become the fourth largest net importer of oil in the world by 2025 after the US, China, and Japan (and ahead of Germany).

Due to the global recession, crude oil prices have remained relatively stable over the last couple of years (Brent crude oil spot price rose marginally from US$107.97 per barrel in December 2011 to US$109.64 in December 2012 (Global Economic Monitor, 2013)). However, if the recession in USA and Western Europe ends in two or three years, their demand (which has been roughly constant for the past few years) could start increasing. This, together with rapidly increasing demand from emerging economies such as China and India, could lead to a rising long-term trend in crude oil prices, unless there are major new oil finds or technological breakthroughs in alternative energy sources. Thus, if this assessment holds, the Indian economy's growth path could be affected adversely unless well-planned policy responses are adopted. For example, sharp crude oil price increases in 2007–08 and

again in 2009–2010 did lead to episodes of high inflation in India that slowed growth because of the tight monetary policy that had to be adopted to fight inflation.

In view of this importance of crude oil and other petroleum products in India's energy security and in the sustainability of its high growth rate, this study focuses on an empirical analysis of petroleum demand. We estimate demand functions for crude oil, diesel, and petrol, and project demand for these products up to the year 2025 for several different reasonable scenarios of GDP growth and crude oil prices. This analysis should help policy makers make appropriate supply arrangements and improve India's energy security.

Several previous studies estimate the demand for crude oil and other components. For India, Goldar and Mukhopadhyay (1990) and Ghosh (2009) estimate demand for imported crude oil. Several studies estimate demand for crude oil derivatives, e.g., Ramanathan (1999) and Chemin (2012) estimate demand for gasoline and Ghosh (2010) estimates demand for diesel. Similarly, a few studies estimate and forecast demand for various derivatives of crude oil (Rao & Parikh 1996; Ghosh 2006; Parikh et al. 2007; Kumar & Jain 2010). Comparable estimations for petroleum demand have also been done for other countries, e.g., Adams and Shachmurove (2008) for China; Altinay (2007) for Turkey and Saad (2009) for Indonesia. An interesting review of previous studies on petroleum demand estimations for various countries is available in Suganthi and Samuel (2012).

Several studies on India use the ordinary least square (OLS) method (Goldar and Mukhopadhyay 1990; Rao & Parikh 1996; Parikh et al., 2007), but results can be unreliable as most variables involved are actually non-stationary. Other studies that used co-integration techniques focused on petroleum derivatives (Ramanathan 1999; Ghosh 2010; Chemin 2012) or on demand for imported oil only (Ghosh 2009). Thus, none of these studies estimates and forecasts the total crude oil demand for India.[1] Even the studies that estimate imported crude oil demand (Ghosh 2009) are a bit dated, with data until 2005–06. However, since economic growth (and probably also the crude oil demand) has been significantly more rapid since 2003 than the earlier trend, it is important to estimate demand using more recent data and provide reliable forecasts for the future. Thus, in this study, we estimate the demand for crude oil, diesel, and petrol using the ARDL co-integration technique and project their future demand up to 2025.

The rest of the paper is organised as follows. Section 2 discusses the empirical model, econometric methodology, and data sources. Section 3 presents the empirical results from

[1] Except Ghosh (2006); however, he used data until 2001 only and projected demand until 2011–12. Thus, more up-to-date work is needed now, given the critical importance of crude oil in the Indian economy.

our estimation. Section 4 provides projections of India's future demand of crude oil, diesel, and petrol up to 2025. Section 5 summarises the main conclusions of the paper.

## 2. EMPIRICAL METHODOLOGY AND DATA SOURCES

Under currently available technologies, most industries using crude oil and its derivatives in various forms have hardly any suitable alternatives to crude as the source of energy for a large range of crude oil prices. Further, in India, the government—rather than the market—determines the price of plausible substitutes such as coal (for some industries, like power generation) and, often, the price does not change for long periods. Thus, we follow the traditional demand function for crude oil (see, for example, Parikh et al. 2007; Saad 2009; and Chemin 2012), where crude oil demand is simply a function of the real prices of crude oil and the real national income, which can be well proxied by real GDP at factor cost. We tried the linear and log-linear versions and found that the log-linear model worked best and satisfied all the diagnostic tests, such as the acceptability of functional form, normality of error term, heteroskedasticity, etc. Thus, we used the following log-linear model to estimate the demand for crude oil:

$$LnDcrude_t = \alpha + \beta\, Ln\, Pcrude_t + \gamma\, LnY_t + u_t \qquad \ldots (1)$$

where
$\alpha$, $\beta$, $\gamma$ are the parameters to be estimated;
$u_t$ is the error term;
$LnDcrude_t$ is the log of demand for crude oil in year $t$;
$LnPcrude_t$ is the log of real price of crude oil obtained by converting the yearly average of the international crude oil price from US dollar to Indian rupee using the official exchange rate and then dividing by India's wholesale price index (WPI, base year 2004–05 = 100); and $LnY_t$ is the real national income proxied here by the real GDP at factor cost (base year 2004–05 = 100).

It is expected that an increase in price would reduce crude oil demand ($\beta<0$) whereas an increase in real GDP would imply greater industrial production and increased transportation of goods and people, leading to increasing crude oil demand ($\gamma>0$). The magnitude of the income and price elasticities determines the changes in crude oil demand in response to changes in its price and the real GDP and, thus, has major implications for projecting the future demand of crude oil in India, which can be important for policy makers. Thus, a careful empirical estimation of these elasticities will be an important focus of this study.

In this study, we also separately estimate the demand for petrol and diesel. We consider the possibility that other variables (such as the number of vehicles of various kinds used in India) may influence petrol and diesel demand. However, different types of vehicles consume different amounts of fuel, and consistent time series data on the number vehicles of various types is not available, except for a few years. Moreover, the number of various vehicles etc. in use is itself determined by the level of economic activity. For this reason, we felt that real GDP, which is perhaps the single best measure of the level of economic activity in the country, is a good explanatory variable to use instead of the number of vehicles, etc.

Thus, the demand function for diesel is also estimated with the real price of diesel and real GDP as explanatory variables. We also considered the possibility of including the price of substitutes, especially petrol. However, we found it to be insignificant, probably because a vehicle designed to run on diesel cannot really use petrol—no matter what its price. We used the traditional log-linear demand function for diesel as given below as it satisfied all the diagnostic tests such as the acceptability of functional form, normality of error term, heteroskedasticity, etc:

$$LnDdiesel_t = \alpha + \varphi LnPdiesel_t + \gamma Y_t + v_t \quad \ldots (2)$$

where $\alpha$, $\varphi$, $\gamma$ are the parameters to be estimated;
$\varepsilon_t$ is the error term;
$LnDdiesel_t$ is the demand for diesel in period *t;* and
$LnPdiesel_t$ is the log of real price of diesel, obtained by dividing the retail price of diesel by the WPI, base year 2004–05=100).

We have used the diesel price in Delhi as a proxy for diesel prices in India because while prices may vary somewhat between states due to differences in local taxes and transportation costs, they are highly correlated with each other. Also, data was not available for all states for the whole sample period. $LnY_t$ is the real income in terms of real GDP at factor cost (base year 2004–05). An increase in the real price of diesel would decrease demand for diesel so that $\varphi$ is expected to be negative, whereas an increase in the real income would increase demand for diesel and so its coefficient, $\gamma$, is expected to have a positive sign.

Finally, the demand function for petrol is estimated with the real price of petrol and real GDP as explanatory variables. We did consider the possibility of including the price of substitutes, especially diesel. However, we found it to be insignificant, probably because a

vehicle designed for running on petrol cannot really be run on diesel, no matter what its price. We estimated the demand for petrol using a similar log-linear demand function:

$$LnDpetrol_t = \alpha + \lambda LnPpetrol_t + \gamma Y_t + v_t \quad \ldots (3)$$

where $\alpha$, $\lambda$, $\gamma$ are the parameters to be estimated;
$v_t$ is the error term;
$LnDpetrol_t$ is the demand for petrol in year *t*; and
$LnPpetrol_t$ is the log of real price of petrol, obtained by using the retail price of petrol and by dividing with the WPI (base year 2004–05).

As with diesel, we have used the petrol price in Delhi as a proxy for petrol prices in India for our analysis. As before, LnYt is the log of real income as measured by real GDP at factor cost (base year 2004–05). An increase in the real price of petrol is expected to decrease petrol demand ($\lambda<0$), whereas an increase in the real national income should encourage more people to buy vehicles and lead to greater transportation of goods and services, thus increasing the demand for petrol ($\gamma>0$).

### 2.1 Econometric Methodology

As usual, we began by testing for the stationarity of the variables. Most variables were found to be integrated of order one (denoted I(1)). Thus, a co-integration estimation procedure is needed. In this study, we estimate the demand for crude oil, petrol, and diesel in India using the auto-regressive distributed lag (ARDL) co-integration procedure proposed by Pesaran et al. (2001). The ARDL model is valid for non-stationary variables as well as for a mixture of I(0) and I(1) variables. Further, we have a small sample size of about 40 annual observations, which is not sufficient for a vector error correction procedure of the Johansson and Juselius (1990) type. Thus, the ARDL estimation procedure is appropriate in our case for determining the long run demand relation for crude oil, petrol, and diesel.

The augmented ARDL model can be written as follows:

$$\alpha(L)y_t = \mu_0 + \sum_{i=1}^{k} \beta_i(L)x_{it} + u_t \quad \ldots (4)$$

where $\alpha(L) = \alpha_0 + \alpha_1 L + \alpha_2 L^2 + \ldots + \alpha_t L^t$; $\beta(L) = \beta_0 + \beta_1 L + \beta_2 L^2 + \ldots + \beta_t L^t$;
$\mu_0$ is a constant;
$y_t$ is the dependent variable;
$L$ is the lag operator such that $L^i x_t = x_{i-t}$ .
In the long run equilibrium $y_t = y_{t-1} = y_{t-2} = \ldots y_0$ and $x_{it} = x_{it-1} = x_{it-2} = \ldots x_{i0}$ .

Solving for y, we get the following long run relation:

$$y = \alpha + \sum b_i x_i + \gamma_t \quad \ldots (5)$$

where $a = \frac{\mu_0}{\alpha_0 + \alpha_1 + \ldots \alpha_t}$; $b_i = \frac{\beta_{i0} + \beta_{i1} + \beta_{i2} + \ldots \beta_{it}}{\alpha_0 + \alpha_1 + \alpha_2 + \ldots \alpha_t}$ and $\gamma_t = \frac{u_t}{\alpha_0 + \alpha_1 + \alpha_2 + \ldots \alpha_n}$

In this procedure, the existence of the long run relationship is confirmed with the help of an F-test, which determines if the coefficients of all explanatory variables are jointly different from zero. Pesaran and Shin (1999) have provided upper and lower critical bound values for an F-test when all or some of the variables are I(1).

The error correction (EC) representation of the ARDL method can be written as follows:

$$\Delta y_t = \Delta\hat{\alpha}_0 - \sum_{j=2}^{p} \hat{\alpha}_j \Delta y_{t-j} + \sum_{i=1}^{k} \hat{\beta}_{i0} \Delta x_{it} - \sum_{i=1}^{k} \sum_{j=2}^{q} \beta_{i,t-j} \Delta x_{i,t-j} - \alpha(1, p) ECM_{t-1} + \mu_t \quad \ldots (6)$$

where $ECM_t = y_t - \hat{\alpha} - \sum_{i=1}^{k} \hat{\beta}_{i0} \Delta x_{it}$ ;

$\Delta$ is the first difference operator;

$\alpha_{j,\ t-j}$ and $\beta_{ij,\ t-j}$ are the coefficients estimated from Eq. 3; and

$\alpha(1,p)$ measures the speed of adjustment.

### 2.2 Data Sources

The present study is based on yearly data for the 1970–2011 period. The data for India's crude oil, petrol, and diesel consumption (in million tonnes) was collected from the Ministry of Petroleum and Natural Gas, Government of India (MoPNG). We collected the annual average international crude oil prices in US$ per barrel from www.indexmundi.com, and then converted into constant rupee (or 'real') price of crude oil by converting the prices into current Indian rupees using the official exchange rate and then dividing by India's WPI (base year 2004–05). In the case of petrol and diesel, we used the data on their retail prices in Delhi[2] collected from the MoPNG. We then converted the nominal price into real price by dividing it with the WPI (base year 2004–05). The real GDP at factor cost (in 2004–05 prices) is used as a proxy for real national income. The data are collected from the Handbook of Statistics on Indian Economy (Reserve Bank of India 2011).

[2] We can mention the price of diesel and petrol in metric tonnes by multiplying by a constant factor (number of litres per metric tonne), but it will make absolutely no difference to the estimates of the equation, which work in percentage terms because the log-linear form is used. We used the price of diesel and petrol per litre because it is better known and understood by most people.

## 3. RESULTS OF EMPIRICAL ESTIMATION

### 3.1 Results for Demand for Crude Oil

We estimated the demand for crude oil in India using equation (1) by employing the ARDL co-integration methodology. The results for the long run demand function are given below:

$$Ln\ Dcrude_t = \underset{(4.86)^{**}}{-9.09\ C} - \underset{(2.37)^{*}}{0.41\ Ln\ Pcrude_t} + \underset{(9.73)^{**}}{1.00\ Ln\ Y_t} \quad \ldots \quad (7)$$

*F*-Test Statistics (for testing co-integration) = 3.92**

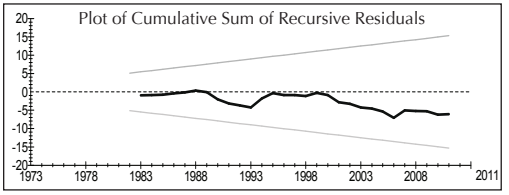
$R^2$=.99; *DW* = 2.14; Serial correlation $[\chi^2(1)]$ = 1.51; Functional form $[\chi^2(1)]$ = 2.02
Normality test $[\chi^2(2)]$ = 1.00; Heteroskedasticity $[\chi^2(1)]$ = 0.003

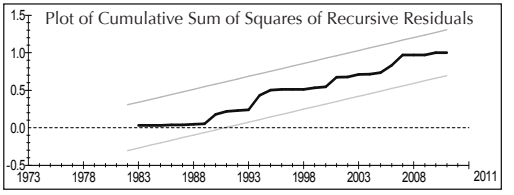
Note: Numbers in parentheses below equation (7) denote the t-statistics of the respective coefficients. Asterisks * and ** denote significance at the 5 per cent and 1 per cent significance levels.)

The F-statistics confirm the co-integration relationship as its values are above the upper bound at the 1 per cent significance level. Further, diagnostic tests show that serial correlation in the error term is not significant, functional form is not rejected, normality of error term is not rejected, and there is no heteroskedasticity in the model. These tests corroborate the validity of the estimated demand function for crude oil. The coefficient of crude oil price is negative and significant at the 5 per cent level, indicating that crude oil price in India does have a significant influence on crude oil demand. Further, the coefficient of income is positive as expected and statistically significant at the 1 per cent level. The income elasticity is found to be highly elastic, with a value of one. This implies that a 1 per cent increase in real GDP would lead to an increase in the crude oil demand by about 1 per cent in the long run. This suggests that the crude oil demand would keep increasing rapidly due to rapid economic growth.

The stability of coefficients is essential in estimation for making policy recommendations. Since we will use the coefficients of real price and real GDP in the above estimation (i.e., the price and income elasticities) for projecting future demand for crude oil, it is particularly important to test the stability of these coefficients in the above estimation. Generally, unstable parameters tend to result from model mis-specification and thus lead to biased results. Hence, stability tests like the cumulative sum of recursive residuals (CUSUM) and the CUSUM of square of recursive residuals (CUSUMSQ) tests proposed by Brown et al. (1975) are considered important to analyse coefficients' stability. The result of these two tests is given by Figure 1 below. It is seen that neither the CUSUM nor the CUSUM square test statistics exceed the bounds of 5 per cent levels of significance. Thus, the estimated demand model (equation 7) for crude oil appears stable and correctly specified.

**Figure 1: Plots of CUSUM and CUSUMSQ Statistics for Crude Oil Demand Estimation**




### 3.2 Results Regarding Demand for Diesel

We also estimated the diesel demand function to know the long run elasticities and the results are given below:

$$Ln\ Ddiesel = \underset{(6.87)^{**}}{-11.89\ C} - \underset{(3.61)^{**}}{0.56\ Ln\ Pdiesel} + \underset{(8.62)^{*}}{1.02\ Ln\ Y} \qquad \ldots (8)$$

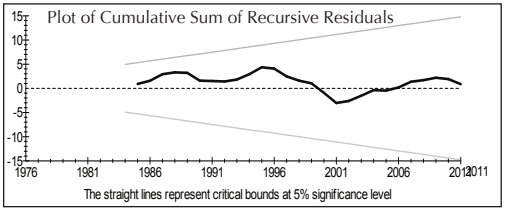
*F*-Test for Co-integration = 11.73**

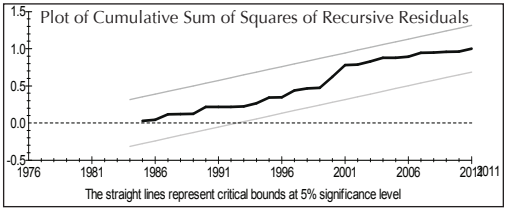
$R^2$=.99, DW = 1.50, Serial Correlation [$\chi^2(1)$] = 2.16; Functional Form [$\chi^2(1)$] = 0.02 Normality test [$\chi^2(2)$] = 1.77; Heteroskedasticity [$\chi^2(1)$] = 0.313

Note: Numbers in parentheses below equation (8) denote the t-statistics of the respective coefficients. Asterisks * and ** denote significance at the 5 per cent and 1 per cent significance levels.

The F-test confirms the long run relationship between diesel price and real income on diesel consumption in India. Further, diagnostic tests show that serial correlation in the error term is not significant, functional form and normality of error term are not rejected, and that there is no heteroskedasticity in the model. These tests corroborate the validity of the estimated demand function for diesel. Finally, as discussed in the case of crude oil, we also carried out the CUSUM and CUSUM square test for the stability of estimated coefficients (Figure 2). It is seen that neither the CUSUM nor the CUSUM square test statistics exceed the bounds of 5 per cent level of significance. Thus, the estimated demand model (equation 8) for diesel appears stable and correctly specified.

**Figure 2: Plots of CUSUM and CUSUM Square Statistics for Diesel Demand Estimation**



The estimation results for demand for diesel in equation (8) show that, as expected, the price elasticity is negative and significant at 1 per cent level while the income elasticity is positive and significant at 1 per cent level. The price elasticity for diesel is -0.57, meaning a 1 per cent increase in diesel price leads to a decrease in diesel demand by 0.57 per cent. Similarly, the income elasticity is +1.02, meaning a 1 per cent increase in real income (i.e., real GDP) leads to an increase in the diesel demand by 1.02 per cent. Thus, the demand for diesel is quite sensitive to its price in the long run. Further, the demand for diesel is quite responsive to changes in real GDP as the coefficient is greater than one. This could be capturing effects such as an increasing number of motor vehicles for personal travel and increased transportation of goods and services as the real GDP increases.

### 3.3 Results Regarding Demand for Petrol

Similarly, we estimated the demand function for petrol with petrol price (P*) and real income (Y) as explanatory variables (see equation 3) and the results were as follows:

$$LnDpetrol = \underset{(21.88)^{**}}{-18.67\ C} - \underset{2.29)^{*}}{0.85\ LnPpetrolt} + \underset{(14.47)^{*}}{1.39\ LnY_t} - \underset{(1.92)^{*}}{0.80\ D74} \qquad \ldots (9)$$

*F*-Test Statistics for testing for co-integration = 2.81**

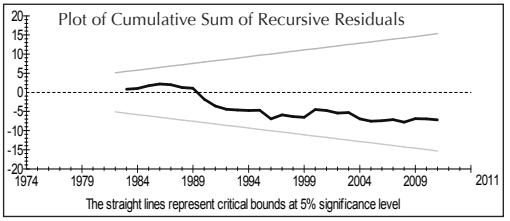
$R^2$=.99, DW = 1.87; Serial Correlation [$\chi^2(1)$] = 0.25; Functional Form [$\chi^2(1)$] = 1.87 Normality test [$\chi^2(2)$] = 0.16; Heteroskedasticity [$\chi^2(1)$] = 0.16

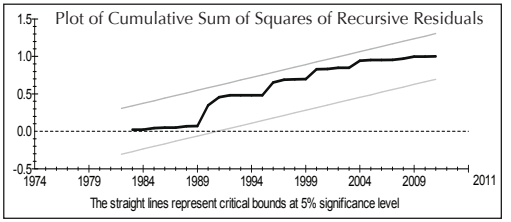
Note: Numbers in parenthesis below equation (9) denote the t-statistics of the respective coefficients. Asterisks * and ** denote significance at the 5 per cent and 1 per cent significance levels.

The F-test for co-integration is significant at the 1 per cent confidence level, which confirms the existence of a long-term relation between the demand of petrol with its price and with real GDP. Further, diagnostic tests show that serial correlation in the error term is not significant, functional form is not rejected, normality of error term is not rejected, and the heteroskedasticity test is at an acceptable level. These tests corroborate the validity of the estimated demand function for petrol. We included dummy variables for a few years (such as 1973, 1980, 1985, 2000, etc.) when there were large exogenous shocks to crude oil market and only D74, the dummy for 1974, was found to be significant (D74 takes the value 1 for 1974 and 0 for all other years). Finally, as discussed in the case of crude oil, we also carried out the CUSUM and CUSUM square tests for the stability of estimated coefficients (Figure 3). Neither the CUSUM nor the CUSUM square test statistics exceeds

the bounds of 5 per cent levels of significance. Thus, the estimated demand model (equation 9) for petrol appears stable and correctly specified.

**Figure 3: Plots of CUSUM and CUSUM Square Statistics for Petrol Demand Estimation**




The results of estimation in equation (9) show that the long run elasticity of demand for petrol in India with respect to petrol price is negative and is about 0.85, suggesting that petrol consumption will decline by about 0.85 per cent when the price of petrol goes up by 1 per cent. The elasticity of petrol demand with respect to real GDP has the expected positive sign and is about 1.39, suggesting that petrol consumption will rise by about 1.39 per cent if real GDP goes up by 1 per cent. Thus, the demand for petrol is reasonably sensitive to its price, at least in the long run. Further, the demand for petrol in India seems to be quite responsive to changes in real GDP as the coefficient is greater than 1. This could be capturing effects such as an increasing number of motor vehicles like motor bikes, cars, etc. for personal travel as well as the increased demand for transportation of goods and services as the real GDP increases.

The above empirical estimations of demand functions for crude oil, diesel, and petrol can be used to project their future demand for various likely scenarios regarding real GDP growth and crude oil prices. Such projections should help policy makers know the likely future demand and help them design supply side policies to meet the expected demand. The next section attempts such projections up to 2025.

## 4. PROJECTIONS OF FUTURE DEMAND FOR CRUDE OIL, DIESEL, AND PETROL IN INDIA

This section deals with projecting the likely future demand for crude oil, diesel, and petrol in India. Here, we do so until 2025 using the estimated demand elasticities in relations (7), (8) and (9) in Section 3. The growth rate for demand for crude oil, diesel, and petrol can be obtained using our demand relation given in equations (1), (2) and (3):

$$LogD_{it} = \alpha_i + \beta_i LogP_{it} + \gamma_i LogY_t + u_i \quad \ldots (10)$$

where D is the demand with subscripts i can take three values: c for crude oil, d for diesel and p for petrol and subscript t denotes the time period. Differentiation of the demand equation with respect to time yields the relation (where a caret (^) over a variable denotes its growth rate.

$$\hat{D} = \beta_i \hat{P}_i + \gamma_i \hat{Y} \quad \text{.... (11)}$$

which can then be used to project future demand starting from a base year, t, using:

$$\hat{D}_{t+1} = D_t + \beta_i \hat{P}_i + \gamma_i \hat{Y} \quad \text{... (12)}$$

Using (12), the future demand for crude oil, diesel, and petrol can be projected using the likely scenarios for growth rates of real GDP and the real price of crude oil, petrol, and diesel respectively. Thus, for projecting future demand we need to know the likely future growth rates of real GDP in India and the likely growth rates of real prices of crude oil, diesel, and petrol.

### 4.1 Likely Growth Rates of GDP and Petroleum Prices

Regarding the likely future growth rates of real GDP, it is worth noting that the annualised average growth rate of real GDP for the past 40 years between 1971 and 2011 has been about 5.57 per cent. Following the 1991 economic reforms, between 1991 and 2011, the annual growth rate of real GDP has averaged about 6.92 per cent or almost 7 per cent. Finally, the average annual growth rate of real GDP for the past 10 years (2001–11) was about 7.82 per cent or close to 8 per cent. From these considerations, it appears quite likely that (despite current pessimism) the average GDP growth rate over the next decade should most likely be between 6 per cent and 8 per cent. Thus, we consider three likely scenarios for average annual GDP growth rate until 2025:

(1) A normal scenario with average annual GDP growth rate of 7 per cent;

(2) An optimistic scenario with average annual GDP growth rate of 8 per cent; and

(3) A pessimistic scenario in which real GDP grows at an annual average rate of 6 per cent.

A likely scenario for the probable growth rates of crude oil prices is harder to determine given the high volatility of oil prices. However, between 1970 and 2011, crude oil prices grew at an average rate of 5.62 per cent in real rupee terms (and 4.68 per cent in real dollar terms). Besides, the annualised growth rate of crude oil prices has increased to 6.72 per cent between 1991 and 2011 (4.66 per cent in real dollar terms between 1991 and 2011). Considering these data, we consider three scenarios with oil prices in real rupees, assuming

them to be growing at an average rate of about 4 per cent, 5.5 per cent, and 7 per cent respectively. Given the current price of crude oil of about $108 per barrel, these growth rates yielded 2025 crude oil prices of around $187, $229, and $278 respectively.

Similarly, we observed that the average annual growth rate of diesel and petrol prices between 1973 and 2011 in real rupee terms was about 2.98 per cent and 2.87 per cent respectively (or almost 3 per cent). These rates are significantly lower than those of crude oil, probably because petrol and diesel prices also include refining, transportation, and taxation components that have not risen nearly as rapidly as crude oil prices have. Also, petrol and diesel prices in India were regulated by the government and subsidies were used at times to keep diesel and petrol prices from increasing in response to increasing crude oil prices. Given these historical growth rates, we consider three different scenarios of growth rate of diesel and petrol prices—2 per cent, 3 per cent, and 4 per cent—for projecting diesel and petrol demand. Under these scenarios, we expect real diesel price (in 2011 price base) to grow from about Rs 40.91 in 2011 to around Rs 55, Rs 65 or Rs 75 per litre by 2025 while real petrol price can be expected to grow from about Rs 65.65 to around Rs 90, Rs 105 or Rs 120 per litre by 2025.

### 4.2 Projections for the Future Demand for Crude Oil in India

We can project future demand for crude oil in India using equation (12) and the estimate of the price and income elasticities of demand for crude oil that was obtained in relation (7) above. As discussed in Section 4.1, we consider three likely scenarios for average annual GDP growth rate at 6 per cent, 7 per cent, and 8 per cent. Regarding real crude oil prices, we also consider three scenarios, with average annual growth rates of 4 per cent, 5.5 per cent, and 7 per cent. These average annual growth rates of crude oil prices and real GDP try to capture the likely long-term scenarios up to 2025 and not the short-term fluctuations (which are extremely difficult to predict). Table 1 gives the projections of crude oil consumption in India using the estimated equation (7) and the above-mentioned scenarios for the likely prices of crude oil and GDP growth rates for the year 2025.

Table 1 shows that the annual growth rate of projected crude oil demand would likely be 3.1—6.34 per cent per annum with a mean of about 4.72 per cent per annum or about 0.7 times the assumed mean of real GDP growth rate of 7 per cent. This will translate into total compounded increase in crude oil demand between 53 per cent and 136 per cent by the year 2025. The average of the nine different scenarios in Table 1 is 91 per cent for 2011–25. For our normal and most likely case—real GDP grows at 7 per cent and crude oil price grows at 5.5 per cent—the demand for crude oil would likely increase from

147 million tonnes in 2011 to 281 million tonnes in 2025, i.e., at about 90 per cent from 2011 to 2025, which can thus be considered most likely according to our projections. The trajectory of projected demand for 2012 to 2025 for this case is plotted in Figure 4 below.

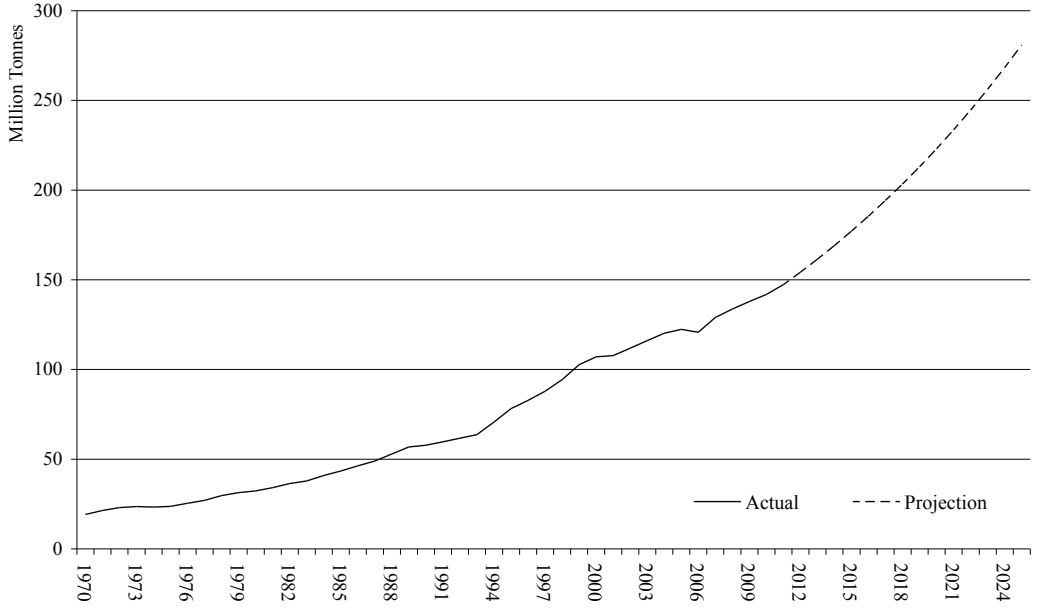
**Table 1: Projections of India's Crude Oil Demand for 2012-2025** (million tonnes)

| Year | Crude oil demand projection at **6% real GDP growth** and at following growth rate of crude oil prices | | | Crude oil demand projection at **7% real GDP growth** and at following growth rate of crude oil prices | | | Crude oil demand projection at **8% real GDP growth** and at following different growth rate of crude oil prices | | |
|---|---|---|---|---|---|---|---|---|---|
| | *4%* | *5.5%* | *7%* | *4%* | *5.5%* | *7%* | *4%* | *5.5%* | *7%* |
| 2011 | *The actual demand for crude oil in 2011 is about 147.24 million tonnes* | | | | | | | | |
| 2012 | 153.63 | 152.72 | 151.81 | 155.10 | 154.19 | 153.28 | 156.58 | 155.66 | 154.75 |
| 2013 | 160.30 | 158.41 | 156.52 | 163.39 | 161.47 | 159.57 | 166.50 | 164.57 | 162.64 |
| 2014 | 167.26 | 164.30 | 161.38 | 172.11 | 169.10 | 166.11 | 177.06 | 173.98 | 170.94 |
| 2015 | 174.53 | 170.42 | 166.38 | 181.31 | 177.08 | 172.93 | 188.28 | 183.93 | 179.66 |
| 2016 | 182.10 | 176.76 | 171.55 | 190.99 | 185.44 | 180.02 | 200.22 | 194.46 | 188.83 |
| 2017 | 190.01 | 183.34 | 176.87 | 201.19 | 194.20 | 187.40 | 212.91 | 205.58 | 198.46 |
| 2018 | 198.26 | 190.17 | 182.36 | 211.94 | 203.37 | 195.09 | 226.41 | 217.34 | 208.58 |
| 2019 | 206.87 | 197.25 | 188.02 | 223.26 | 212.97 | 203.09 | 240.77 | 229.77 | 219.22 |
| 2020 | 215.85 | 204.59 | 193.85 | 235.18 | 223.02 | 211.43 | 256.03 | 242.92 | 230.40 |
| 2021 | 225.23 | 212.20 | 199.87 | 247.74 | 233.55 | 220.10 | 272.27 | 256.81 | 242.16 |
| 2022 | 235.00 | 220.10 | 206.07 | 260.97 | 244.58 | 229.13 | 289.53 | 271.50 | 254.51 |
| 2023 | 245.21 | 228.30 | 212.46 | 274.91 | 256.13 | 238.53 | 307.88 | 287.04 | 267.49 |
| 2024 | 255.86 | 236.80 | 219.05 | 289.60 | 268.22 | 248.31 | 327.40 | 303.46 | 281.13 |
| 2025 | 266.96 | 245.61 | 225.85 | 305.06 | 280.88 | 258.50 | 348.16 | 320.82 | 295.48 |
| *Total Increase in Projected Crude Oil Demand from 2011 to 2025* | | | | | | | | | |
| | *81.31* | *66.81* | *53.39* | *107.19* | *90.77* | *75.56* | *136.46* | *117.89* | *100.68* |
| *Annualised Growth Rate of Projected Crude Oil Demand for 2011 to 2025* | | | | | | | | | |
| | 4.34 | 3.72 | 3.10 | 5.34 | 4.72 | 4.10 | 6.34 | 5.72 | 5.10 |

Source: Author's calculations.

It is clear from these calculations that a substantial increase in India's crude demand is very likely by 2025, and that policy makers in the petroleum ministry must plan to ensure supply to meet the near doubling of demand in the next 15 years. Demand for crude oil is increasing rapidly because rapid economic growth in India is leading to greater output of goods and services, which require more petroleum products for both production and transportation. Also, rising income levels are increasing the number of people purchasing automobiles, motorcycles, etc. for personal transportation, which in turn increases the demand for petrol and diesel and thence, crude oil.

**Figure 4: Crude Oil Consumption (1970-2011) and Projections for the Future (2012-2025)**




Note: The projections for crude oil demand for 2012-2025 are for the case where real GDP grows at 7% per annum and real crude oil prices grow at 5.5% per annum (see Table 1 for other cases).
Source: Author's calculations

### 4.3 Projections for Future Demand for Diesel in India

Similarly, the future demand for diesel in India up to the year 2025 can be projected using equation (12) and using income and price elasticities from the estimated equation (8). As discussed in Section 4.1, we consider three different scenarios of growth rate of real GDP at 6 per cent, 7 per cent, and 8 per cent. For diesel prices, we consider three scenarios with average annual growth rates of real diesel prices in rupees at 2 per cent, 3 per cent, and 4

per cent, respectively. Under these scenarios, we expect real diesel price (in 2011 rupees) to grow from about Rs 40.91 in 2011 to around Rs 55, Rs 65 or Rs 75 per litre by 2025 The results of the projections are shown in Table 2 below.

**Table 2: Projections for India's Diesel Demand for 2012-2025** (million tonnes)

| Year | Diesel demand projection at 6% real GDP growth rate and at following growth rate of diesel prices | | | Diesel demand projection at 7% real GDP growth rate and at following growth rate of diesel prices | | | Diesel demand projection at 8% real GDP growth rate and at following growth rate of diesel prices | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2% | 3% | 4% | 2% | 3% | 4% | 2% | 3% | 4% |
| 2011 | The actual demand for diesel in 2011 is about 63.70 million tonnes | | | | | | | | |
| 2012 | 66.88 | 66.51 | 66.15 | 67.53 | 67.16 | 66.80 | 68.18 | 67.81 | 67.45 |
| 2013 | 70.21 | 69.45 | 68.69 | 71.58 | 70.81 | 70.05 | 72.96 | 72.19 | 71.42 |
| 2014 | 73.70 | 72.51 | 71.33 | 75.87 | 74.66 | 73.45 | 78.08 | 76.84 | 75.62 |
| 2015 | 77.37 | 75.71 | 74.07 | 80.42 | 78.71 | 77.02 | 83.57 | 81.80 | 80.06 |
| 2016 | 81.23 | 79.05 | 76.91 | 85.25 | 82.98 | 80.76 | 89.43 | 87.08 | 84.77 |
| 2017 | 85.27 | 82.53 | 79.86 | 90.37 | 87.49 | 84.69 | 95.71 | 92.69 | 89.75 |
| 2018 | 89.52 | 86.17 | 82.93 | 95.79 | 92.24 | 88.80 | 102.43 | 98.67 | 95.03 |
| 2019 | 93.98 | 89.97 | 86.12 | 101.53 | 97.25 | 93.12 | 109.62 | 105.03 | 100.62 |
| 2020 | 98.66 | 93.94 | 89.42 | 107.63 | 102.53 | 97.65 | 117.31 | 111.81 | 106.53 |
| 2021 | 103.57 | 98.08 | 92.86 | 114.08 | 108.10 | 102.39 | 125.55 | 119.02 | 112.80 |
| 2022 | 108.73 | 102.41 | 96.42 | 120.93 | 113.97 | 107.37 | 134.36 | 126.70 | 119.43 |
| 2023 | 114.14 | 106.92 | 100.13 | 128.18 | 120.15 | 112.59 | 143.80 | 134.87 | 126.45 |
| 2024 | 119.83 | 111.64 | 103.97 | 135.88 | 126.68 | 118.06 | 153.89 | 143.57 | 133.89 |
| 2025 | 125.79 | 116.56 | 107.96 | 144.03 | 133.56 | 123.80 | 164.69 | 152.83 | 141.76 |
| Total Increase in Projected Diesel Demand from 2011 to 2025 | | | | | | | | | |
| | 97.47 | 82.97 | 69.47 | 126.09 | 109.65 | 94.33 | 158.53 | 139.91 | 122.53 |
| Annualised Growth Rate of Projected Diesel Demand Over 2011–2025 | | | | | | | | | |
| | 4.98 | 4.41 | 3.84 | 6.0 | 5.43 | 4.86 | 7.02 | 6.45 | 5.88 |

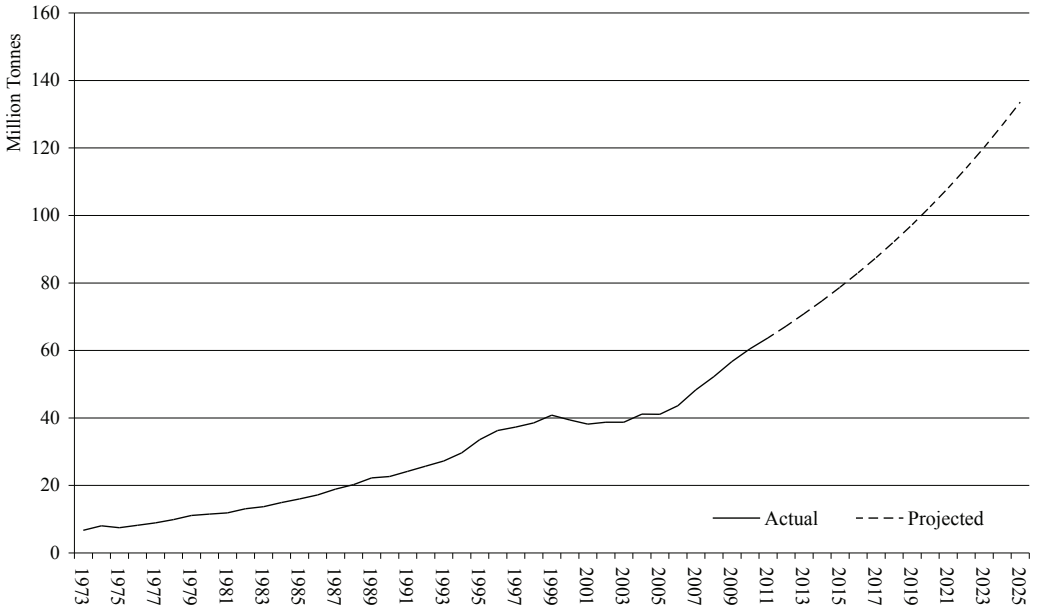
Source: Author's calculations.

Table 2 shows that the annual growth rate of projected diesel demand is expected to be 3.84—7.02 per cent per annum, with a mean of 5.43 per cent per annum or about 0.8 times the assumed mean of real GDP growth rate of 7 per cent. This will translate into a total compounded increase in diesel oil demand between 70 per cent and 158 per cent by the

year 2025. The average of the nine different scenarios in Table 2 is 111 per cent over 2011–25. On the other hand, if we consider that the most likely scenario is that real GDP will grow at 7 per cent and that diesel will grow at 3 per cent, then the demand for diesel would increase from 67 million tonnes in 2011 to 133.56 million tonnes in 2025—an increase of about 110 per cent. The exact trajectory of projected demand for diesel for 2012 to 2025 for this case with GDP growth of 7 per cent and diesel price growth rate of 3 per cent is plotted in Figure 5 below.

Thus, although there is a large band of projections depending upon actual GDP growth and diesel price increases, it appears quite likely that diesel demand would increase substantially, probably around 110 per cent or so between 2011 and 2025.

**Figure 5: Diesel Consumption (1970–2011) and Projections for the Future (2012–2025)**




Note: The projections for diesel demand for 2012-2025 are for the case where real GDP grows at 7% per annum and real diesel prices grow at 3% per annum (see Table 2 for other cases).
Source: Author's calculations.

### 4.4 Projection of Future Petrol Demand in India

Finally, this section attempts to project the future demand for petrol in India up to the year 2025 using equation (12) and using income and price elasticities from the estimated equation (9). As discussed in Section 4.1, we consider three different scenarios of growth rate of real GDP at 6 per cent, 7 per cent, and 8 per cent. For petrol prices, we consider

three scenarios with average annual growth rates of real petrol prices at 2 per cent, 3 per cent, and 4 per cent, respectively. Under these scenarios, real petrol price can be expected to grow from about Rs 65.65 to around Rs 90, Rs 105, or Rs 120 per litre by 2025. The results of the projections are shown in Table 3 below.

**Table 3: Projections of India's Petrol Demand for 2012-2025**

| Year | Petrol demand projection at 6% real GDP growth rate and at following growth rate of petrol prices | | | Petrol demand projection at 7% real GDP growth rate and at following growth rate of petrol prices | | | Petrol demand projection at 8% real GDP growth rate and at following growth rate of petrol prices | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2% | 3% | 4% | 2% | 3% | 4% | 2% | 3% | 4% |
| 2011 | The actual demand for petrol in 2011 is about 15.01 million tonnes | | | | | | | | |
| 2012 | 16.00 | 15.87 | 15.75 | 16.21 | 16.08 | 15.96 | 16.42 | 16.29 | 16.16 |
| 2013 | 17.06 | 16.79 | 16.53 | 17.51 | 17.24 | 16.97 | 17.97 | 17.69 | 17.41 |
| 2014 | 18.20 | 17.77 | 17.34 | 18.92 | 18.48 | 18.04 | 19.66 | 19.20 | 18.76 |
| 2015 | 19.41 | 18.80 | 18.20 | 20.44 | 19.80 | 19.18 | 21.51 | 20.85 | 20.20 |
| 2016 | 20.70 | 19.88 | 19.10 | 22.08 | 21.22 | 20.40 | 23.54 | 22.64 | 21.76 |
| 2017 | 22.07 | 21.03 | 20.04 | 23.85 | 22.75 | 21.69 | 25.75 | 24.58 | 23.44 |
| 2018 | 23.53 | 22.25 | 21.03 | 25.77 | 24.38 | 23.06 | 28.18 | 26.68 | 25.25 |
| 2019 | 25.10 | 23.54 | 22.07 | 27.84 | 26.13 | 24.52 | 30.83 | 28.97 | 27.20 |
| 2020 | 26.76 | 24.90 | 23.16 | 30.07 | 28.01 | 26.07 | 33.74 | 31.45 | 29.30 |
| 2021 | 28.54 | 26.35 | 24.30 | 32.49 | 30.02 | 27.72 | 36.92 | 34.15 | 31.57 |
| 2022 | 30.44 | 27.87 | 25.50 | 35.10 | 32.17 | 29.48 | 40.40 | 37.07 | 34.00 |
| 2023 | 32.46 | 29.48 | 26.76 | 37.91 | 34.48 | 31.34 | 44.20 | 40.25 | 36.63 |
| 2024 | 34.61 | 31.19 | 28.09 | 40.96 | 36.96 | 33.33 | 48.36 | 43.70 | 39.46 |
| 2025 | 36.91 | 33.00 | 29.47 | 44.25 | 39.61 | 35.44 | 52.92 | 47.45 | 42.50 |
| Total Increase in projected petrol demand from 2011 to 2025 | | | | | | | | | |
| | 145.97 | 119.90 | 96.42 | 194.86 | 163.99 | 136.15 | 252.66 | 216.18 | 183.24 |
| Annualised Growth Rate of Projected Petrol Demand over 2011-2025 | | | | | | | | | |
| | 6.64 | 5.79 | 4.94 | 8.03 | 7.18 | 6.33 | 9.42 | 8.57 | 7.72 |

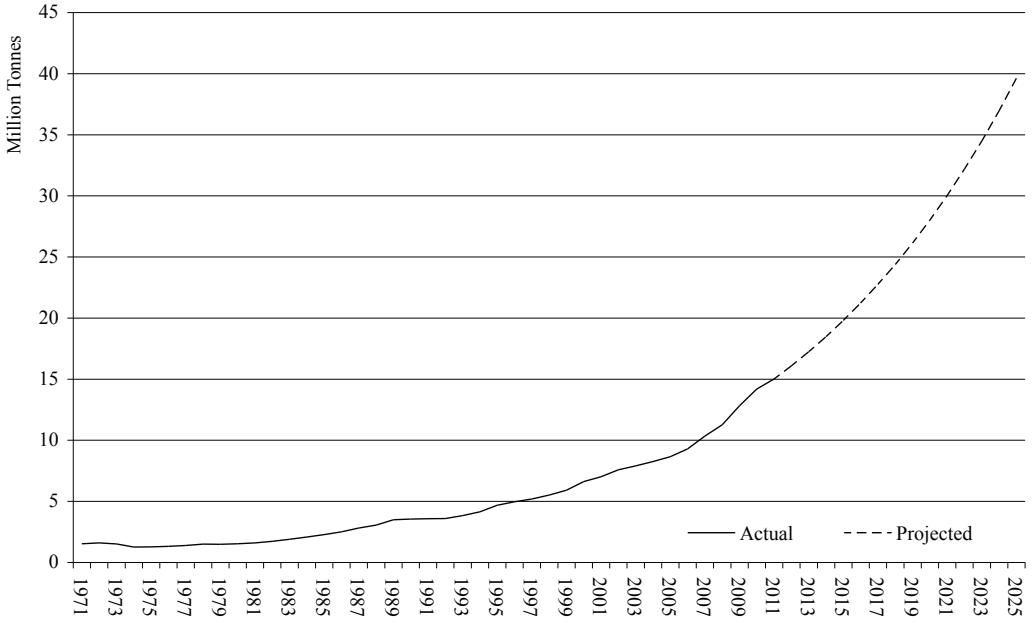
Source: Author's cmputations.

Table 3 shows that the annual growth rate of petrol demand would likely be 4.94—9.42 per cent per annum with a mean of 7.18 per cent per annum, or roughly the same as the assumed mean of real GDP growth rate of 7 per cent. This will translate into a total compounded increase in petrol demand between 96 per cent and 252 per cent by the year 2021. The average of the nine different scenarios in Table 3 is 167 per cent in 2011–25. On the other hand, if we consider that the most likely scenario is that real GDP will grow at 7 per cent and the price of petrol will increase at 3 per cent, then the demand for petrol would increase from 16.1 million tonnes in 2011 to 39.6 million tonnes in 2025—an increase of about 164 per cent. The exact trajectory of projected demand for 2012 to 2025 for this case is plotted in Figure 6 below. Thus, although there is a large band of projections depending upon actual GDP growth and diesel price increases, it appears quite likely that petrol demand would increase substantially, probably around 165 per cent or so between 2011 and 2025.

It is clear from the above analyses that demand for crude oil, petrol, and diesel will increase substantially (probably around 100 per cent, 110 per cent, and 165 per cent, respectively), between 2011 and 2025. Therefore, India should take various energy efficiency and demand management measures to meet the growing demand of crude oil, petrol, and diesel in the long run. This should include market linked prices for petrol and diesel. Petroleum subsidies on fertilisers, kerosene, and LPG need to be well targeted and minimised to the extent possible.

Due to the global recession, crude oil prices have remained relatively stable over the last couple of years. However, if the recession in USA and Western Europe ends in two or three years then their demand (currently roughly constant for last few years) could start increasing. This, together with rapidly increasing demand from emerging economies such as China and India, could lead to a rising long-term trend in crude oil prices, unless there are major new oil find or major technological breakthroughs in alternative energy sources. If this assessment holds, the Indian economy's growth path would be affected adversely. It needs to be remembered that following sharp increase in crude oil prices in 2007–08 and then again in 2009–10, transportation costs rose considerably and contributed significantly to episodes of high inflation and consequently slowing growth (due to tight monetary policy that had to be adopted to fight inflation). Thus, the government must plan and adopt a strategy to meet the country's future energy and fuel requirements to ensure that high growth rates can be sustained. Unfortunately, so far, the urgency of the issue does not seem to be properly recognised. If this is not corrected soon, growth could slow down and inflationary pressures increase.

**Figure 6: Petrol Consumption (1970-2011) and Projections for the Future (2012-2025)**

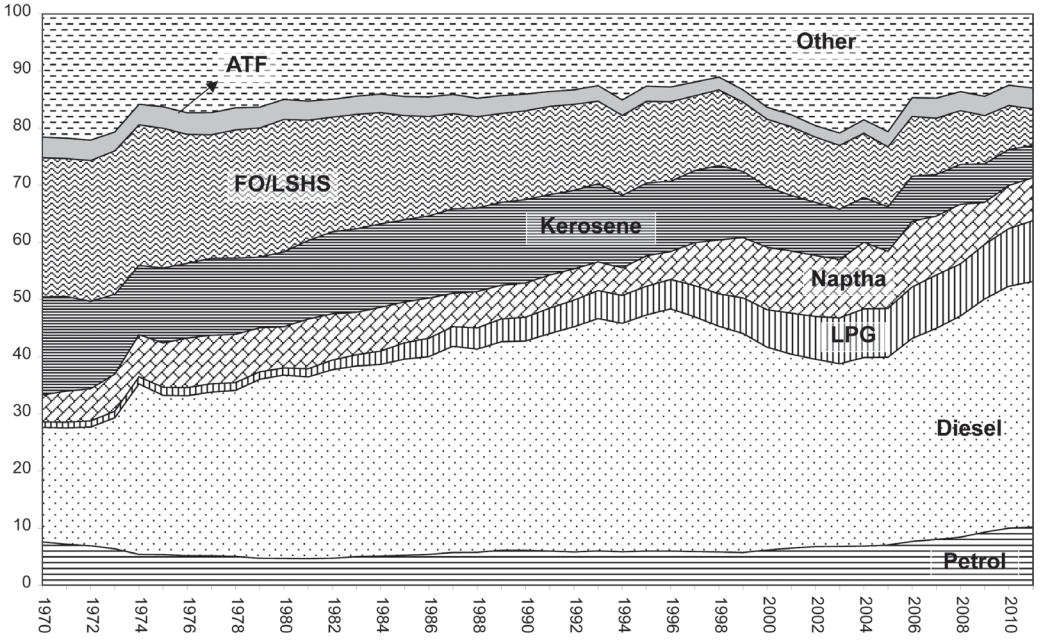



Note: The Note: The projections for petrol demand for 2012-2025 are for the case where real GDP grows at 7% per annum and real petrol prices grow at 3% per annum (see Table 3 for other cases).
Source: Author's calculations

### 4.5 Varying Demand Growth Rates of Different Petroleum Products

The projections in sections 4.2, 4.3, and 4.4 showed that the projected demand growth for diesel and, especially, petrol is significantly greater than that of crude oil. These results can lead one to wonder how demand for crude oil can grow significantly below that of its major derivatives such as petrol and diesel. This can be true only if there are other crude oil derivatives for which demand is growing significantly less rapidly than that of crude oil. To examine this issue, we have plotted in Figure 7 the share of various petroleum products in India's total consumption of petroleum products. It is seen from the figure that the share of diesel and petrol is rising more rapidly than that of many other petroleum products (such as kerosene, naphtha, furnace oil, and low sulphur heavy stock (FO/LSHS))—their shares show clear signs of decline. This corroborates our finding that among the petroleum products that lead to the increase in crude oil demand in India, diesel and petrol are important and increasing components. This could be because—besides a general increase in demand for petroleum products for production and transportation of goods and services with rapid growth—rising income levels are also allowing increasing numbers of people to use automobiles and motorcycles, etc. for personal transportation which also increases demand for petrol and diesel.

**Figure 7: Percent Share of Different Petroleum Products in Total Petroleum Consumption in India, 1970–2011**




Note: ATF= aviation turbine fuel; FO/LSHS = furnace oil and low sulphur heavy stock; 'Others' includes lubricants, refinery fuel, petroleum coke, light distillates, middle distillates and heavy ends and Imports through private parties.
Source: Ministry of Petroleum and Natural Gas, Government of India

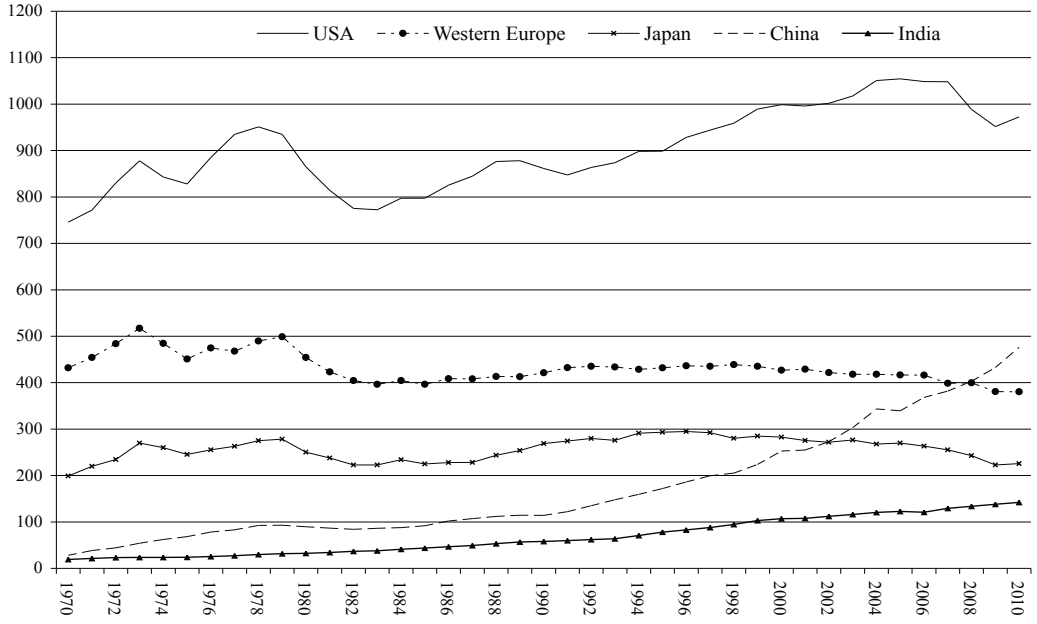
### 4.6 Likely Trends in Future World Demand for Crude Oil

We have seen above that the demand for crude oil in India is projected to increase about 90 per cent by 2025. Given the concerns about possible increases in world crude oil prices due to rising demand, we thought it might be worthwhile to briefly consider the likely demand scenario for crude oil from other major regions of the world. Figure 8 plots the oil consumption in the major developed regions of the world (USA, Western Europe, and Japan) and two emerging economies (China and India). The figure shows a mild declining trend since the mid-1990s in the developed countries of Western Europe and Japan but a mild rising trend in the US, so that the overall trend for all developed countries together is that of roughly constant demand.

However, in many emerging economies that have rapid economic growth and a relatively low per capita consumption of crude oil, demand has been increasing with rising income levels. For example, demand in China has risen dramatically by about 88 per cent from 252 million tonnes a year in 2000 to 476 million tonnes a year in 2010 (and now

exceeds the total crude oil consumption of Western Europe). Over the same period, India's crude oil consumption too increased about 32.5 per cent from 107 million tonnes to 141.8 million tonnes. Oil consumption has also increased in some other emerging and developing markets (over the 2000–2010 period, crude oil demand grew by 18.17 per cent in Brazil and 17.82 per cent in Russia). Given the large population of the emerging economies and the fact that their current per capita energy consumption is much lower than levels prevailing in developed countries, the world oil demand will in all probability rise significantly in the future given the continued rapid economic growth expected in China, India, and other emerging economies over the next decade. Thus, the tendency for oil prices to rise may become much more pronounced once the current economic slowdown in the US (due to the sub-prime debt crisis) and in Western Europe (due to the sovereign debt crisis) is resolved in, say, the next two to four years. This expected increase in oil prices would be mitigated if there are major new discoveries of oil; if production increases sufficiently in USA and the Arab countries, in some of which oil production has declined due to the current political turmoil (Libya, Iraq, Syria, etc); or if technological innovations make some new sources of energy commercially viable (e.g., solar energy, wind energy, energy from splitting water, ethanol from biomass waste, etc). However, without some such breakthrough on the energy front, crude oil prices could have a tendency to increase in the future, especially once the economic problems in Europe and the US are resolved and growth is restored to normal levels.

**Figure 8: Crude Oil Consumption of Selected Countries, 1970-2011**




Source: BP Statistical Review of World Energy, 2011

## 5. CONCLUSIONS

Energy security is crucial for sustaining high economic growth and ensuring the stability of domestic petroleum prices that seems so crucial to controlling inflation. With high economic growth rates and a population of over a billion, India can expect its energy demand to rise rapidly. Thus, a careful analysis of India's future petroleum requirements should be useful for proper policy formulation. It is particularly important for a country like India, which is largely dependent on imports (nearly 70 per cent of total consumption in 2010) to meet much of its petroleum requirements.

In this paper, we have empirically estimated demand relations for crude oil, diesel, and petrol for India using the ARDL co-integration procedure and data from 1970 to 2011. Our estimations found the income elasticity of about 1 for crude oil and diesel and 1.39 for petrol. Thus, petroleum demand seems to be growing about proportionately to real GDP. This is so because GDP growth is leading to greater output of goods and services, which require more petroleum products for both production and transportation. Further, rising income levels are increasing the numbers of people purchasing automobiles, motorcycles, etc. for personal transportation, which in turn increases the demand for diesel and petrol and, thence, crude oil. Further, the price elasticity of the petroleum products was found to be negative and statistically significant in all the models. The values of price elasticities were found to be -0.41, -0.56 and -0.85 for crude oil, diesel, and petrol respectively, which show that demand is not very elastic but does decline to some extent with rising petroleum prices.

From the estimated demand function, we projected the future demand for crude oil, diesel, and petrol until 2025 for three possible scenarios of GDP growth rates and oil price growth rates, based partly on past trend etc. For GDP growth rate, we considered three scenarios with average annual GDP growth rate of 6 per cent, 7 per cent, and 8 per cent. Similarly, for crude oil prices in real rupees, based on past trends, we considered average growth rates of 4 per cent, 5.5 per cent, and 7 per cent. Finally, for the price of both diesel and petrol and again based on past trends, we considered the expected growth rate of 2 per cent, 3 per cent, and 4 per cent respectively. (Diesel and petrol prices have grown less rapidly in the past because their refining, transportation, and tax components have been growing less rapidly than oil prices; this trend is expected to continue).

Our projections show that for the normal scenario—real GDP grows at 7 per cent and the real price of crude oil at 5.5 per cent—the demand for crude oil in India would increase at about 4.72 per cent per annum, which means a total increase of about 90 per cent between 2011 and 2025. Similarly, for the normal scenario of 7 per cent real GDP growth

rate and 3 per cent growth rate in real diesel and petrol price, the demand for diesel would increase at about 5.43 per cent per annum and for petrol at about 7.18 per cent per annum, or by a total of 110 per cent and 165 per cent respectively between 2011 and 2025. If we assume that crude oil price too could increase by 50 per cent to 100 per cent by 2025, India's crude oil import bill could increase threefold or fourfold (i.e., about $450 to $600 billion) by the year 2025. Considering that India's total exports were only $305 billion in 2011–12, this scenario is worrisome and requires urgent action.

Thus, to meet the growing demand for crude oil, diesel and petrol etc in the long run, India should take various measures for efficiency improvement in energy use such as market linked relative prices, minimising subsidies, and targeting them well. It also needs to enhance petroleum supplies through increased domestic explorations as well as other measures, such as participation in exploration and production in foreign oil fields by Indian oil companies (which the Chinese are using extensively) to avoid excessive dependence on imported crude oil. India also needs to more vigorously pursue the use of renewable energy sources like hydro, wind, solar, bio-fuels, nuclear, etc., as the Western European countries have done. India should take measures to increase exports to be able to meet its growing future oil import requirements. Careful planning to ensure that future petroleum requirements can be met will be crucial in sustaining rapid economic growth in the future.

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