CHAPTER 2
METHODOLOGY AND DATA

The details of the methodology are provided in this chapter, as it would be useful to present a broad picture of the type of methodology that is attempted. Growth of oil consumption have been calculated in chapter 4, by regression of consumption of oil and individual petroleum products consumed by nation and major states of nation on time, and then using a measure of structural change in consumption, growth rates in consumption before and after liberalization have been analyzed.

2.1 Calculation of growth rates

For calculation of growth rates, semi - log model or what is also known as log – linear has been used. This is explained as below:

Let \( Y = ab^t = a (1+r)^t \)

Log \( Y = \log (ab^t) = \log a + \log b \cdot t \)

Or \( \log y = l + B \cdot t \) (Here \( \log a = L, \log b = B \))

Or \( \log Y^t = L + B \cdot t + \epsilon \) (E = 1, 2 - - - , n)

Here \( Y^t \) = \( t^{th} \) observation on the dependent variable

\( Y \), which in our case is the consumption of total oil or individual oil products in nation and in, States for which growth rate is required.

Log \( Y^t \) = natural logarithm of \( Y^t \) i.e. \( \ln Y^t \)

\( t \) = Time variable taking n values 1, 2, - - - n, and in this study n takes 25 values for nation from 1980-81 to 2004-05 and 25 values for States from 1980-81 to 2004-05

\( \epsilon \) = a random disturbance (or error) term satisfying the usual assumption of ordinary least square.
\( \bar{r} = \text{compound annual rate of growth (CAGR)} \)

\( B1 = \text{Constant percentage (instantaneous) rate of growth if } B1 > 0 \)  
and rate of decay if \( B1 < 0 \).

To test, for structural change in the two time period before and after liberalization, dummy variable both in the additive and multiplicative forms has been used as below:

\[
\text{Log } Y_t = L + B1_t + D_1 + D_2 + u_t
\]

Where \( D = 0 \) before liberalization till 1990 

\( = 1 \) after the liberalization

In the fourth chapter we thus study the consumption pattern of oil in India & different states of India, what has been the growth rate of consumption of oil and individual petroleum products. We also study the structural changes, which occurred in the consumption pattern of oil and oil products for the whole nation and selected states of India before and after liberalization i.e. before and after 1990. On the basis of estimated equation we have also forecasted the total consumption of petroleum products in 2020.

2.2 Estimation of price and income elasticities

In chapter 5, we have analyzed the relationships and changes over time for income, population, and oil demand. We then focus on 8 major petroleum products- liquefied petroleum gases (LPG), Motor Gasoline, Jet Fuel, Kerosene, HSDO, LDO, Furnace oil, Lubricants and LPG- and analyze some important phenomena that explain many of the changes in demand for these products. Income and price elasticities are calculated for total oil demand and for each of the eight major oil products in the nation.
The time period taken for estimating growth rates in chapter 4 is from 1980-81 to 2004-05 and the time period taken for estimating elasticities in chapter 5 of different oil products is from 1981-82 to 2005-06. This is because until the early 1950's coal was the principal source of commercial energy in India. Since then, the direct use of coal as a fuel has been declining in importance in relation to other fuels. In 1953-54, coal accounted for 47.8 per cent of the total commercial energy consumption (in terms of coal replacement) in the country. In 1974-75, the relevant ratio was about 24 per cent. On the other hand, the share of oil went up from 39.6 per cent to about 50 per cent during the same period. This shift in the pattern of energy consumption coincided with a sharp increase in domestic production of crude oil. Between 1960 and 1986, the domestic production of crude oil increased from 4,51,000 tonnes to 3,115,7000 tonnes. The growth in domestic consumption of petroleum products was, however, much faster, and as a result a significant increase took place in imports of crude oil and petroleum products. The total consumption of petroleum products between 1970 and 1987 increased substantially from 18.73 million tones to 48.16 million tones. It is interesting to note that gross imports of petroleum products increased sharply between 1970 and 1973, from 0.97 million tones to 3.74 million tones. In the subsequent period, 1973 to 1987, imports of petroleum products fluctuated from year to year, but there was no noticeable upward trend. It is also interesting to note that in 1980’s and again in 1984, there were marked increases in imports of petroleum products. In 1990-91, liberalization process and removal of licence raj and lowering of duties, there was a sharp upsurge and growth in the industry as a whole. The automotive sector also took off. To keep pace there was lot of investment in the refining capacity. Transport infrastructure has expanded considerably and its energy-intensity has grown gradually. Rapid urbanization along with the conglomeration of industrial and commercial activities has consequently increased the transport demand. Uncontrolled
expansion of cities coupled with inadequate public transport has contributed to a phenomenal growth in the number of mechanized energy-intensive private modes. In the domestic sector also rapid urbanization and diverse urban growth patterns involved many basic structural changes in the economy that have important ramifications for energy use. The growing demand for modern household fuels such as LPG and kerosene adds greatly to the already burden on scarce resources of capital and foreign exchange. Oil and gas accounted for nearly 54 percent of the total final commercial energy consumption in 1996-97. The share of the four oil products LPG, SKO, MS, and Diesel has increased from 54.9 per cent in 1970-71 to 70.4 in 1996-97. Therefore, the economy is progressively becoming oil intensive in view of the increasing share of natural gas and petroleum products in the final commercial energy use especially after liberalization process. Due to these changes in the pattern of consumption of energy over time as well as in the fuel wise elasticities and also due to the easy availability of the data the study has chosen this period.

In a partial equilibrium framework we thus have estimated the various determinants of oil product demand in general and have analyzed how this is influenced by price and GDP by estimating the price and income elasticity of oil demand by using autoregressive distributed lag model (ARDL) model. An Econometric Analysis of demand for total oil and eight major oil products has been made.

J.Bentzen and Tom Engsted in 1999 discussed that the findings in the recent energy economics literature that energy economic variables are non-stationary, have led to an implicit or explicit dismissal of the standard autoregressive distributed lag model (ARDL) in estimating energy demand relationships. The authors depict that recent research however, shows that ARDL model, an econometric model remains valid when the underlying variables are non-stationary, provided the variables are cointegrated. In 2001 they again gave a paper in which they used the ARDL approach to
estimate a demand relationship for Danish residential energy consumption, and the ARDL estimates were compared to the estimates obtained using cointegration techniques and error correction models (ECM's). Both authors have said that it is very interesting to compare the long-run elasticity estimates obtained from the ARDL model with estimates obtained using standard cointegration methods (the static OLS, DOLS, the non linear least squares (NLLS) procedure and the VAR procedure. The static OLS procedure as usual according to the authors does not provide consistent standard errors and where standard hypothesis testing is in general invalid. The latter three procedures are asymptotically equivalent but differ in the way the short-run dynamics are modeled and, hence, may give different results in finite samples. All three methods provide consistent estimates of standard errors of the long-run parameters and they allow standard statistical inference based on asymptotic normality. Thus the three asymptotically equivalent methods (DOLS, NLLS and Johansen) give almost identical estimates. The ARDL estimates are slightly larger than the estimates obtained from the four-cointegration methods. Finally the authors estimate an error correction model (ECM) where the error correction term is given as the lagged cointegrating relationship from the Johansen analysis in order to compare the results obtained from the ARDL approach. Comparing the ARDL estimates and the estimates obtained using cointegration techniques and error correction model (ECM’s), they found out that quantitatively and qualitatively, the ARDL approach and the cointegration/ECM approach give very similar results.

In the light of the above discussion and the estimated results, one may ask about the role of cointegration analysis in estimating energy demand relationships using non-stationary time series data. Here it is important to remember that the nice results for the ARDL model presume the existence of a unique long-run relationship among the variables. Cointegration analysis can be used to establish the existence of such a
relationship. The widely used Johansen analysis seems to particularly well-suited in this respect since it makes it possible to test for the number of cointegrating relationships among a set of non-stationary variables. If this number is larger than one, the ARDL described above fails because it can only estimate one long-run relationship and it might be that the estimated relationship is a linear combination of the true underlying relationships. Hence, when there are more than one cointegrating vector among the variables, one has to impose and test different identifying restrictions on each of the vectors in order to interpret them economically and this can be done within Johansen analysis.

Thus the ARDL approach should not be seen as a substitute but as a supplement to the cointegration approach, which is useful when it has been established that there is only long-run relationship among the variables under study.

Over the years, a vast amount of empirical evidence on short and long run energy demand elasticity’s has been accumulated based on the standard ARDL approach. It is conforming that this approach remains valid in presence of non-stationary variables (given that certain cointegration properties hold), so that the recent finding that many energy economic variables are non-stationary does not automatically mean that we should dismiss these previous ARDL studies.

Infact, it is suggested that it may be wise to continue using the ARDL approach in estimating energy demand relationships. In contrast to earlier studies, however such an analysis should start by investigating the stationarity and cointegration properties of the variables at hand. Thus, combining the ARDL approach with cointegration analysis and reporting parameter estimates based on both the ARDL model and on cointegration/error correction techniques, seems to be the natural way to precede in future energy demand studies.
In the ARDL model, energy consumption is explained by lags of itself and current and lagged values of a number of explanatory variables (income, energy prices, temperature, etc). The lagged values of the dependent variable are included to account for the sluggish adjustment that often characterizes energy consumption in response to changes in the explanatory variables. Thus, the ARDL model has an appealing separation of short and long-run effects. One should be careful in applying the ARDL model when variables are non-stationary, because regressions among such variables are often spurious unless the variables are cointegrated and even if the variables are cointegrated, standard statistical inference (e.g., t-test and F-test of linear restrictions) is generally not valid. The appealing thing about the ECM is that it contains only variables that have been transformed into stationarity whereby standard statistical inference based on asymptotic normality can be used to test hypothesis about example short and long-run elasticity’s.

In some cases, however, hypothesis testing using standard methodology remains valid in regressions containing non-stationary variables. In fact, in the ARDL model, both short and long-run parameters can be consistently estimated by OLS (super consistently in the case of long-run parameters) and valid inferences on both the short and long-run parameters can be made using standard normal asymptotic theory. The requirement for these results to hold is that there exists a unique long-run relationship between the variables i.e. a unique cointegrating relationship. These results are striking and point to a rehabilitation of the traditional ARDL approach to the dynamic modelling of time series variables. In particular, the results imply that even if we believe energy economic variables to be non-stationary, we should not automatically reject the vast amount of evidence concerning energy demand accumulated over the years based on ARDL model.
According to Yunchang Jeffrey Bor, Shi-Miin Liu, Hung-Kang jan and FengiYing Chou in general there are three basic methods of forecasting energy demand: (i) statistical, (ii) econometric, and (iii) engineering. Each method has its own pros and cons. The statistical method, mainly the time series method, offers better accuracy in forecasting but seldom provides a satisfactory explanation in accord with economic theory. Also, the statistical method generally depends on fairly long-term series data to achieve accurate forecasting. The econometric method, mainly the regression method, follows the fundamental demand and supply theories of economics. In this way, it provides a good explanation of energy demand growth. Easy of use is another point in its favor. However, there is a vacuum in terms of technological improvements on energy demand. The engineering method, mainly the end use method, is the most transparent method for examining technological improvement changes on the energy demand. It tracks and records all major technological improvements and the fuel efficiency of equipment. The weakness of this method is the tremendous cost of collecting and updating the database. Another type of engineering method is the mathematical programming method, which uses linear, nonlinear, or dynamic programming models to solve a single objective or multi-objective energy-planning problem.

In this section we describe our methodology based on ARDL model due to the above-mentioned benefits of econometric methods. For each of products, using annual data for 1981-82 to 2005-06 and each of the countries using data from 1980-81 to 1999-2000, we examined several alternative equation specifications of per-capita oil product demand as a function of per-capita real income and the real price of crude oil. Income and price elasticities are calculated for the entire nation and 19 major states.

Given the heterogeneity of oil demand response to change in income and prices, both across countries and oil products, it is necessary to
examine several specifications of the demand equation. There are two general types of specifications for which results are given. In each case, the demand and income variables are measured in per-capital terms, and logarithms of all variables are used.

\[
\begin{align*}
D_t & \quad \text{logarithm of per-capita oil demand} \\
GDP_t & \quad \text{logarithm of per-capita real income} \\
P_t & \quad \text{logarithm of the real international price of crude oil.}
\end{align*}
\]

The two specifications are the following:

1) Demand as a function of income only, with no price variable; demand responds symmetrically to income increases and decreases. We assume that demand is a Koyck-lag function of income, that is, there is geometrically declining weights on past levels of income.

\[
D_t = a + \gamma (GDP_t + \lambda GDP_{t-1} + \lambda^2 GDP_{t-2} + \lambda^3 GDP_{t-3} + \ldots + \lambda^1 GDP_{t-1} + \ldots)
\]

We expect \(0 < \lambda < 1\)

The function actually estimated is the standard Koyck-lag specification:

\[
D_t = c + \gamma GDP_t + \lambda D_{t-1}
\]

2) Demand as a function of income (symmetric for income increases and decreases) and price (symmetric for price increases and decreases). Following Dargay-Gately (1995a) and Johnston (1984), we assume geometrically - declining lagged weights, that are separately estimated for income \((0 < \phi \gamma < 1)\) and for price \((0 < \phi P < 1)\):

\[
D_t = a + \beta \Sigma I=0, \phi P1 P_{t-1} + \gamma \Sigma I=0 \phi \gamma GDP_t
\]

\[
GDP_{t-1}
\]

The actual demand equation estimated is:
\[
Dt = a (1-\phi p) (1-\phi y) + (\phi p + \phi y) D_{t-1} - (\phi p \phi y) D_{t-2} + \beta P_{t-1} - \phi y \beta P_{t-1} + \gamma GDP_{t-1} - \phi p \gamma GDP_{t-1}
\]

There are two special cases of this specification

2a) Koyck-lag specification, in which the income and price lag coefficients are assumed to be equal:

\[\phi y = \phi p\]

The specification can be simplified to its standard form:

\[Dt = a + \beta P_{t-1} + \gamma GDP_{t-1} + \lambda D_{t-1}\]

2b) Specification with no income lag: \(\phi y = 0\) (i.e., instantaneous adjustments of demand to income changes):

\[Dt = a + \beta \Sigma I = 0 = \phi p P_{t-1} + \gamma GDP_{t-1}\]

3) Demand as a function of price and income without Koyck specification.

After estimating the price and income elasticites of total oil and oil product demand we have felt that within this framework, econometric modeling is useful for analyzing the factors that influence domestic demand for petroleum products. To the best of our knowledge, no one has so far analyzed the determinants of domestic demand for different petroleum products in India. Earlier econometric research was done on India's Petroleum imports mainly concerned with Income & price elasticities of import demand for crude at the petroleum products (Patel 1979), Marwan (1985), & Krishnamurty, Pandit & Sharma (1989)]. Only Ghosh, Lahiri and Wadhwa (1986) adopted a different approach.

They first attempted a function determining total domestic demand for petroleum and related products and then import demand related products and then import demand was derived as the difference between domestic
demand and domestic production. Though methodologically superior to the models used in other earlier studies, such as Marwah (1985), the econometric model of Ghosh, Laheri and Wadhwa (1986) did not take into account inter fuel substitution possibilities and it employed a very functional form for domestic demand, not recognizing explicitly the possibility of the determinants of demand being different for different petroleum products.

The way we model domestic demand in our chapter we allow for interfuel substitution. Also, the model enables us to examine the impact of trucks, buses & cars, industrial production, pre capital Income, Power generation, etc. on domestic demand for different petroleum products. However, a serious estimation problem arises because data is available not on domestic demand but on domestic consumption. Taking domestic consumption as a proxy for domestic demand does not solve the problem, since it reduces the above functional relationship to an identity devoid of any economic interest.

Thus, to estimate the above functional relationship, one requires some estimates of domestic demand for petroleum products. This can be obtained by estimating a demand function for petroleum products at the aggregate level as Ghosh, Lahiri and Wadhwa (1986) do. Alternatively, demand functions may be estimated for different petroleum products, and the estimated demand for the products, computed on the basis of the estimated demand functions and values of explanatory variables may be aggregated to yield an estimate of D. This is what we attempt in this chapter.

Before discussing the functional forms chosen for the demand functions, it would be useful to go over another interesting point. Let the demand function of the ith the petroleum product be

\[ D_i = f_i(P_i, P_j, K) + e \]

Where \( D_i \) is the demand for the ith product, \( P_i \) is the price of that product, \( P_j \) is the price(s) of other product(s) with which substitution

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possibilities exist, k is the vector of other erogenous variables (say, per capita income or industrial production), and e is the error term.

Because domestic demand is not observed, it has to be replaced by domestic consumption to estimate the demand function. Let $C_i$ denote the consumption of ith petroleum product then the regression equation we estimate is

$$C_i = f_i (P_i, P_j, k) + e + u$$
$$= f_i (P_i, P_j, k) + w$$

Where $w = C_i - D_i$ & $w = u+e$. It would realize that year to year variations in the gap between consumption and demand of the ith product should be influenced by the quantity of petroleum imports.

Thus, the exclusion of variable M (net imports of crude oil and petroleum products) from the regression equation causes specification bias in the estimation of parameters of the demand function. However the inclusion of M in the demand gives rise to other serious problem. It makes the estimate of D dependent on M, so that the estimation of function faces a problem of simultaneity.

We find no simple way of tacking both the problems. It was felt by us that the problem of simultaneity would be far more serious than the specification problem caused by the exclusion of variable M. Accordingly; we have not taken imports as an explanatory variable in the domestic demand function for petroleum products.

We have estimated demand functions for seven important petroleum products, namely LPG, Kerosene, Naphtha, FO (Furnace oil), HSFO, LDO, and MS (Motor spirit.) For FO (Furnace oil), HSFO, LDO and Kerosene, we have used data for the period 1970-71, 1975-76, 1980-81 to 1995-96. For LPG data from 1990-91 to 1998-99 have been taken, for Naphtha from 1981-82 to 1995-96 & for MS 1980-81, 1985-86, 1990-91 to 1995-96. The demand equations for the seven major petroleum products have been estimated in a log-linear specification applying the OLS technique.
2.3 Why functional form matters.

The sixth chapter applies a methodology recently developed by Hamilton (2000), which provides a valid test of the null hypothesis of linearity. The chapter uses a linear instrumental variables regression, in which oil prices are presumed to have a linear effect on the economy and identifiable exogenous disruptions in world petroleum supplies are used as instruments. The approach by Hamilton suggests that the time series for the magnitude of war-induced petroleum supply disruptions can be used to estimate linear reduced-form regressions as an alternative to using nonlinear transformation of the oil price series itself. The next section discusses why an investigation of the linearity of the relationship is important both for econometric inference and economic interpretation.

Many economic analyses of the effects of oil shocks begin with a production function relating output to inputs of capital, labor, and energy. An exogenous decrease in the supply of energy reduces output directly by lowering productivity and indirectly to the extent that lower wages induce movement along a labor supply schedule (Rasche and tatom, 1977, 1981; Kim and Loungani, 1992), changes in business markups (Rotemberg and woodford, 1996), or capacity utilization rates (Fin, 1997). These models imply that the log of real GDP should be linearly related to the log of the real price of oil. One implication of this linearity is that if the oil price of oil goes down, then output should go up; if an oil price increase brings about a recession, then an oil price decline should induce an economic boom by the same mechanism operating in the reverse direction.

These models view recessions as supply driven rather than demand driven. According to these models, an oil price increase produces a recession because it makes cars more costly to manufacture. This seems contrary to reports in the trade and business press, in which the problem is invariably perceived as a reduction in the number of cars consumers are willing to buy.
A number of early analyses focused instead on demand side effects of an oil price increase. In these models, an increase in oil prices would increase the overall price level, which given the Keynesian assumption of rigid wages, reduces employment. Example of such models includes Pierce and Enzler (1974), Solow (1980), and Pindyck (1980). Mork and Hall (1980) demonstrated the potential for interactive effects between wage rigidities and supply side effects. These models again all maintain the existence of a linear relation between the log of the price of oil and the log of GDP, so that again an oil price decline is expected to produce an economic boom.

These models also have the characteristic that there is nothing all that special about oil. The basic economic inefficiency is the familiar Keynesian mismatch between the aggregate wage and the aggregate price level, and oil price disruptions are just one of many developments that might contribute to such a mismatch.

Surely the price and availability of gasoline matter for car sales not simple because they affect the overall price level but further because they are key inputs in how cars get used. Is your next car going to be a small foreign car or a large SUV? Your decision depends in part on what you think about gasoline availability. If you are very unsure about where gas prices are headed, you might be inclined to postpone a new purchase until you have a better idea of where the market stands.

Energy prices and availability may be quite relevant for a host of other durable goods purchases, including housing. How long a commute to work are you willing to put up with? How energy-efficient should your appliances, windows, and insulation be? What equipment and industrial techniques should a firm build a new factory around? When energy prices and availability are as uncertain as they were in early 1974, it is rational to postpone such commitments until better information is available.

Oil shocks may matter for short-run economic performance precisely because of their ability temporarily to disrupt purchases of large-ticket
consumption and investment goods. A major disruption in oil supplies makes people uncertain about the future, with the result that on cars, housing, appliances, and investment goods temporarily falls. A variety of microeconomic evidence suggests that oil shocks have substantial potential to exert such effects. Bresnahan and Ramey (1993) documented that the oil shocks of 1974 and 1980 caused a significant shift in the mix of demand for different size classes of automobiles with an attendant reduction in capacity utilization at U.S. automobile plants. Sakellaris (1997) found that changes in the stock market valuation of different companies in response to the 1974 oil shock were significantly related to the vintage of their existing capital. Davis and Haltiwanger (1997) discovered a dramatic effect of oil price shocks on the rate of job loss in individual economic sectors, with the job destruction rising with capital intensity, energy intensity, product durability, and plant age and size. See also Bernanke (1983), Loungani (1986), Davis (1987a,b), Hamilton (1988a,b), Santini (1992), and Davis, Loungani, and Mahidhara (1996) for related evidence and discussion.

These studies have further noted that, if allocative disturbances are indeed the mechanism whereby oil shocks affect economic activity, and then there is no reason to expect a linear relation between oil prices and GDP. An oil price increase will decrease demand for some goods but possibly increase demand for others. If it is costly to reallocate labor or capital between sectors, the oil shock will be contractionary in the short run. Note moreover an oil price decrease could also be contractionary in the short run. A price decrease also depressed demand for some sectors, and unemployed labor is not immediately shifted elsewhere. Furthermore, if it is primarily the postponement of purchases of energy sensitive big-ticket items that produces the downturn, then an oil price decrease could in principle be just as contractionary as an oil price increase.

Of course, an oil price decrease is not all bad news, by virtue of the production function and inflation effects noted earlier. But surely it is
unreasonable to assume that an oil price decrease would produce an economic boom that mirrors the recession induced by an oil price increase.

Suppose that every one percent increase in oil prices produces a $\beta$ percent decrease in real GDP, but that a decrease in oil prices has no effect on GDP. Then the function $f(ot)$ takes the form

$$f(ot) = \begin{cases} 
\alpha & \text{if } ot \leq 0 \\
\alpha - \beta ot & \text{if } ot > 0
\end{cases}$$

The chapter provides an assessment of the implications of a rise in domestic petroleum product prices on the macro economic scenario of India by examining the impact of oil shocks on five important macro variables viz. GDP, inflation as measured through WPI, employment, wages and BOP and also on different sectors of the economy using distributed lag regression model, which produces excellent inference about the values of $\alpha$ and $\beta$.

The total imports and exports discussed in chapter sixth does not reveal the compound annual growth rate of BOP deficit, which is an important parameter to see the effect of increasing consumption, imports of oil and oil prices on our country's BOP and foreign exchange position. Therefore in order to check the intensity of problem, the growth rates of imports of crude and petroleum products for the period 1970-71 to 2005-06 have been estimated. The method adopted for estimating is statistical method. The method is a semi-log model or what is also known as log-linear model. This is explained as below:

Let $y = ab^t = a \left(1 + r\right)^t$

Log $y = \log(ab)t = \log a + \log b.t$

Log $y = \alpha + \beta_1 t$ (here $\log a = \alpha$, $\log b = \beta_1$)

Log $yt = \alpha + \beta_1 t + \mu t \ (t = 1, 2 \ldots \ldots \ldots n)$
Here $y_t$ = $t^{th}$ observation on the dependent variable.

$Y$ in our 1st case is the imports of crude for which growth rate is required.

$Y$ in our 2nd case is the imports of petroleum products for which growth rate has been estimated.

The growth of import demand, which we would estimate, will get translated into our BOP deficit.

Log of $Y_t = \text{natural logarithm of } Y_t \text{ i.e. In } y_t$

$T = \text{time variable taking $n$ values I, 2 \ldots \ldots \ldots \ldots \ldots \ n.}$

In this study $n$ takes thirty-six values from 1970-71 to 2002-03.

$\mu = \text{A random disturbance (or error) term satisfying the usual assumption of ordinary least square.}$

$R = \text{compound annual growth rate (CAGR)}$

$\beta_1 = \text{constant } \% \text{ (instantaneous) rate of growth if } \beta_1 > 0 \text{ and rate of decay if } \beta_1 < 0.$

Based on the growth rates; we have estimated the value of import demand of crude and petroleum products for the year 2020. For achieving a sustainable economic growth and development in any society, it is necessary to design a master plan for oil production and utilization. To design such an appropriate plan, requires adequate data. Therefore we have estimated the future domestic oil production for the year 2020. For this the data about the past production pattern have been collected. In order to estimate the domestic oil production in the year 2020, we have calculated the growth rates of domestic production of crude and petroleum products by the same log-linear approach for the period 1970-71 to 2005-06.
Log \( y = \log a + t \log b \)
Log \( y = \alpha + \beta_1 t \)
Log \( y_t = \alpha + \beta_1 t + \mu t \)

Here \( \log y \) in 3rd case is the domestic production of crude oil for which growth rate has been estimated.

In the 4th case \( \log y \) is domestic production used for the growth rate of petroleum products.

2.4 Data Limitations

An attempt to make empirical study of the oil sector of India encountered a number of statistical problems proved to be more complex than was originally envisaged when this study was undertaken.

I visited all the important offices in India dealing with energy affairs during the course of my study to collect the required data. But the problem with national sources is that there is often a difference in coverage of census and current statistics, which makes it difficult to link data from the two sources.

Although the data requirements are different for different issues examined in the study and different sources of data are employed, our main sources have been the various publications of national agencies and international institutions, viz, CII, Ministry of Statistics and Programme Implementation, Government of India, Ministry of Petroleum & Natural Gas (MOPNG), Planning Commission, British Petroleum Statistics, Government of India (GOI); Five Year Plans Document on Energy, World Bank International Monetary Fund, IRDP, United Nations.