ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

FACULTY OF BUSINESS AND ECONOMICS

DETERMINANTS OF GASOLINE AND DIESEL DEMAND IN ETHIOPIA

BY

ANILEY MOSSE

A Thesis submitted to the School of Graduate Studies of the Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Economic Policy Analysis.

JUNE 2002

ACKNOWLEDGEMENTS

I give thanks to my Lord God for giving me this opportunity to develop my career and faithfully helped me throughout the course of the study. My special thanks goes to my advisor Dr. Teki Alemu for his guidance, constructive comments and critical remarks.

I would also thank S.L. E.D. for her tireless assistances in matters pertaining to computer works. I would also express my thanks to staff of Ethiopian Petroleum Enterprises (EPE), Ministry of Mines and Energy of Ethiopia, Ethiopian Road and Transport Authority (ERTA) and staff of National Bank of Ethiopia (NBE) for kindly providing me with the necessary materials. I would also like to extend my thanks to Ato Daniel Zerfu for his valuable comment on Econometrics works.

I would wish also to express my thanks to Ato Asrat Getaneh and all my friends who directly or indirectly provided me with moral support during the study.

Finally, I would like to thank the African Economic Research Consortium (AERC) for its sponsoring my stay in Nairobi at the Joint Facility for Electives (JFE) and providing me with financial support to carry out the project.

TABLE OF CONTENTS

PAGE

ACRONYMS

ADF	Augmented Dickey-Fuller
CSA	Central Statistical Authority
CH_4	Methane
CO_2	Carbon Dioxide
DF	Dickey – Fuller
ECM	Error Correction Model
EEA	Ethiopian Economic Association
EELPA	Ethiopian Electric Light and Power Authority
EPC	Ethiopian Petroleum Corporation
EPE	Ethiopian Petroleum Enterprise
EPRDF	Ethiopian People Revolutionary Democratic Front
ERTA	Ethiopian Road and Transport Authority
ESMAP	Energy Sector Management Assistance Program
GHGs	Greenhouse Gases
G_g	Gigagram
GDP	Gross Domestic Product
GNI	Gross National Income
GNP	Gross National Product
IRG	International Resources Group
LDCs	Less Developed Countries
LPG	Liquefied Petroleum Gas
LR	Likelihood Ratio
MC	Metric Cubic
MIT	Ministry of Industry and Trade
MOFED	Ministry of Finance and Economic Development
MT	Metric Tons
NBE	National Bank of Ethiopia
N_2O	Nitrous Oxide
OECD	Organization for Economic Cooperation and Development
OLS	Ordinary Least Square
OPEC	Organization of Petroleum Exporting Countires
PECM	Parsimonious Error Correction Model

PPP	Purchasing Power Parity
UNDP	United Nations Development Program
VAR	Vector Authoregression
VECM	Vector Error Correction Model

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Page

ABSTRACT

In this paper attempts are made to identify determinants of gasoline and diesel demand in Ethiopia. The study estimates gasoline and diesel demand using time series data starting from 1964/65 to 1999/2000. To determine whether there exists long-run relation between gasoline and diesel demand and its fundamentals, the Johansen procedure of co-integration analysis is used. Accordingly, there exists one unique co-integration relation between gasoline and diesel demand, and its fundamentals. The long-run gasoline demand result shows that price of gasoline, population growth and urbanization are found to be statistically significant while price of diesel (relative price), real income per capita, gasoline using vehicles and real foreign exchange earnings are insignificant. Similarly in the case of diesel demand; price of diesel (own price), price of gasoline (relative price), real income per capita, urbanization and diesel using vehicles are found to be statistically significant while population growth and real foreign exchange are insignificant. In the short-run, price of gasoline and diesel, gasoline and diesel using vehicles are statistically significant. In terms of elasticities, gasoline and diesel prices are inelastic while income is marginally elastic for both demand model. Therefore, diesel is a substitute to gasoline in the long-run and has no effect on both demand in the short-run.

Finally, since gasoline and diesel price is inelastic in the short-run, the quantity of gasoline and diesel demand is far less responsive to price changes, while the marginal income elasticity suggesting that gasoline and diesel demand continue growing as income of the society increases. However, the prices are tightly controlled and fixed by the government, and it uses cross subsidization as a deliberate means to influence the pattern of energy demand.

CHAPTER ONE

INTRODUCTION

1.1 Background

Energy is important for economic development. Its demand is linked with factors such as energy prices, income, population, degree of urbanization, level of technological development and the overall structure of the economy. The energy sector is one indispensable sector for a country's socio-economic development, production, and better standard of living. Energy is an essential element and has a decisive role in our daily life, agriculture, industry and social services. Plants, coal, petroleum, electricity, sun, geothermal steam, and animals are the main energy sources. The effective demand for commercial energy is, therefore, related to economic conditions which influence the availability and access to energy sources. Ethiopia's energy demand and end-consumption patterns are similar to those observed in other developing countries.

The structure of energy supply and consumption in Ethiopia revealed that the traditional biomass energy sources (fuel-wood, charcoal, dung and agricultural residues) constitutes 94 %, and imported fuel oil and hydropower 5 % and 1 %, respectively (Appendix 1). The major consumer of energy in Ethiopia is the household and constitute 89 % of the overall energy requirements of the country. Industry and transport sectors are a distant second and third in importance accounting for 4 % and 2 %, respectively. Other sectors (services and agriculture) constitute 5 % (Ministry of Mines and Energy of Ethiopia, 1997).

Obviously the type of energy consumption differs between sectors. While households primarily use traditional energy sources, non cottage industry and transport sectors use modern energy resources almost exclusively.

The consumption of petroleum is mainly driven by demand within the transport sector which accounts above 50 % of the total fuel consumption (Ministry of Water Resources, 2001). Electricity demand is mainly driven by three sectors, namely, the industrial, commercial and household sectors. Ethiopia's hydropower development potential is in the range of 15,000 to 30,000 MW. This enormous potential classifies Ethiopia as one of the world's leading countries in hydro potential. However, only less than 1% of the total potential is known to have been utilized so far (The new MOFED, 1999). Most of the energy consumed in Ethiopia is non-commercial.

Ethiopia is endowed with a number of energy sources, including biomass, hydropower, natural gas and coal, geothermal, solar and wind. Although currently dwarfed by traditional biomass consumption, hydropower and fossil fuels are the main potentials of the country's development opportunities. The resource availability and primary use data are summarized in Table 1.1.

The country's energy consumption pattern is detrimental to the environment and will not guarantee sustainable development in Ethiopia. For this reason, various measures such as the use of technologies that are energy efficient or the use of alternative sources should be encouraged.

Table 1.1 - Ethiopia's Energy Resources

Source	Total Resources		Current Use	
	TOE* x 10^6	%	TOE x 10^3	%
Hydropower (annual gross)	55.5	23.2	110.0	0.7
Natural Gas	71.8	30.0	0.0	0.0
Petroleum	0.0	0.0	918.0	5.9
Coal	10.2	4.2	0.0	0.0
Geothermal	0.5	0.2	0.0	0.0
Fuel Wood	93.5	39.1	11,976	77.2
Bagasse	0.1	0.0	111.0	0.7
Other organic Residues	7.7	3.2	2,397.0	15.4
Total	**239.10**	**100.0**	**15,509.0**	**100.0**

* (One-ton oil equivalent (toe) is equal to one ton of diesel fuel, which in turn is equivalent to 40.5 million standard cubic feet (SCF) of natural gas or 11.86 mwh of electricity).

Source - CESEN, Technical Report 2,1986 and National Energy Balance, EEA, 1992.

All the energy consumed in developed countries is commercial. Of such energy, oil is the single most important fuel, supporting almost half of the total energy consumption (Dunkerly and Hock, 1987:35). By contrast, more than 75 % of the total energy used in developing countries such as Ethiopia is in the form of traditional fuel. However, commercial energy (such as gasoline and diesel)[1] is still an important input for economic development (particularly in the transport sector).

Despite a low consumption of commercial energy and substantial dependence on non-commercial fuels, the demand for the later has been rising very fast since early 1960's due to

[1] Gasoline may be defined as a mixture of the lightest or most volatile liquid hydrocarbon found in crude petroleum oil. It is not a single compound, but a mixture of many hydrocarbons. A hydrocarbon is a chemical compound of the elements hydrogen and carbon. Diesel fuel is made from crude oil by the same refining process that produces gasoline. It is a light oil with the proper Viscosity, Volatility, and Cetane number for use as a fuel (Croose H.W and Aglin L.D, 1985).

increasing commercial energy consumption (Dunkerly and Hock, 1987:66). In the absence of equivalent increase in export earnings for a significant part of the total imports (in which fuel constitutes the lion's share), Ethiopia's trade balance deteriorated with the resulting deficit being financed by borrowing or running down foreign exchange reserves.

Evaluation of future commercial energy consumption in Ethiopia revolves around development objectives. The structural changes in the economy, i.e. commercialization of the economy, and shifts in the relative importance of the industrial and service sectors will be dependent on the pace of transition from traditional to commercial energy consumption. Most of these changes are associated with changes in economic sectors such as transport sector which uses only commercial energy such as gasoline and diesel as opposed to non-commercial forms of energy.

Therefore, the share of commercial energy in the development process will increase because of rapid growth of inherently modern fuel using sectors of the economy (Dunkerly and Hock, 1987). In developing countries (hence Ethiopia) development is not only constrained by economic factors but also environmental consideration.

Thus, in Ethiopia, like other developing countries, energy (like gasoline and diesel) is an important factor for economic development, specially in the transport sector. This study has, therefore, a definite area to explore and give policy suggestions regarding energy consumption.

1.2 Statement of the problem

Commercial energy planning is an important aspect in economic development. The developing countries, nevertheless, have not mitigated much of the problem of energy. These countries (hence Ethiopia) encounter financial, policy, structural, institutional as well as technical and qualified manpower to study and develop the alternative energy resources available. In addition, these countries use the energy inefficiently.

Despite the enormous interests shown in energy planning in Ethiopia, the general awareness among energy planners of available methodological tools is still in need of improvement. This is especially true where integrated approaches to the energy sector and the rest of the economy are concerned. Moreover, the demand for petroleum products is relevant for the assessment of the effects of new policy initiatives that have direct or indirect effects on the consumption of petroleum products. It is also that knowledge of the form of the demand structure for gasoline and diesel become a prerequisite for rational policy decision.

Ethiopia is a typical third world country in which energy is one of the most important factor for economic and social development. Though commercial energy consumption in Ethiopia is important for its development, there is a considerable uncertainty about the effects of demand-oriented policies in the utilization of gasoline and diesel. Such uncertainty can undermine formulation of effective energy policies due to inability to predict the likely impacts of the changes in important variables such as price, income and population. Also there is still an information gap that must filled to guide the policy makers on which area or demand variables to put their efforts in order to achieve a sustainable energy use.

In Ethiopia the under-development and lack of modern energy sources became one of the limiting factors in the overall economic development of the country. Petroleum imports consume about large foreign exchange earnings every year. That is, the country has to use valuable income from the export to pay for imported commercial energy. For instance, the share of imported petroleum was about 23.7% and 17.6% of total import in 1979/80 and 1999/2000, respectively (Appendix 7). This implies that, petroleum import is negatively affect the trade balance.

Furthermore, the use of commercial energy in Ethiopia does not seem to be sustainable since the government spends large amount of scarce resources to finance mainly the development of hydroelectric power to increase the electricity supply, geothermal energy, natural hydrocarbon, wind, solar energy etc, (The new MOFED, 1999). This calls for an exploration of mechanisms for sustainable use of commercial energy, so that more investigation and clarification is crucial.

1.3 Objective of the study

The primary objective of this study is to investigate the demand for gasoline and diesel in Ethiopia. In addition it estimates demand elasticities for gasoline and diesel in Ethiopia using time series econometric techniques. In this regard, both short and long-run estimation are made, and finally conclusions based on the estimation result are made.

Specifically, the study relay on petroleum consumption (specially gasoline and diesel) trends to the various sectors and its importance for economic development. In addition, based on the findings derive appropriate policy recommendations for improved demand management for commercial energy consumption.

1.4 Justification and Significance of the Study

Besides being an essential input in the production processes, energy is also a direct requirement of people's daily lives. This explains why energy policy is a vital aspect of the overall development policy of the country and how energy policies are designed and implemented influences structure of the country economy.

The objectives to be pursued in this study postulate the demand for gasoline and diesel consumption. The identification of factors affecting energy consumption, specially the demand for gasoline and diesel, will indicate possible areas where action in energy development can exert significant influence on economic development. By providing such insight, this paper will also be useful in the formulation of commercial energy specific policies in Ethiopia.

In recent year, decision makers in various countries have realized that energy sector investment planning should be carried out on an integrated basis (Richard, 1985). In the past, supply and demand analyses were traditionally carried out for each energy source at disaggregate level in Ethiopia. Most existing studies on commercial energy particularly demand for gasoline and diesel have concentrated on developed countries. Hence, our study will give some insight in this area.

Unfortunately, most of Ethiopian's petroleum products consumed are imported. So achieving energy-economic long-term interests on the imported petroleum depends on the internal energy action taken by the government and sound planning must begin with a good grasp of the facts of energy and economic relations. I think, the development of econometric tools which enhance understanding of the factors influencing the demand for gasoline and diesel will give more information about future energy flow. Moreover, the future commercial energy consumption and economic development are essentially interact and therefore energy planning should be suggested. However, these suggestions must be flexible enough to accommodate developments as they occur.

One may ask why this study focuses on gasoline and diesel as a commercial energy in Ethiopia. The main reason is that, the impact of gasoline and diesel largely influence the country's economy, especially in the transport sector. Goods and services are carried from one place to another through the means of transport. Thus, the findings of this study will form a useful input into the literature and policy implications particularly gasoline and diesel (transport fuel) and even provoke further studies in the sector.

1.5 Scope of the Study

The study employs yearly data from 1964/65 to 1999/2000 to estimate both gasoline and diesel demand function during the period. Specifically, the study will focus on gasoline and diesel demand in the transport sector. The period is chosen on the basis of the availability of reliable data.

1.6 Organization of the Study

The paper is structured as follows: The next chapter reviews the theoretical and empirical evidence of previous studies on determinants of gasoline and diesel demand. Chapter three discusses commercial energy and the Ethiopian economy. Chapter four presents the data and methodology while chapter five discuses empirical results. Finally, concluding remarks and policy implications presented in chapter six.

CHAPTER TWO

SURVEY OF LITERATURE

There is a wide literature on the determinants of gasoline and diesel demand (particularly on gasoline demand) in developed countries. This ranges from theoretical literature to empirical analysis. The main focus of this chapter is to review the theoretical and empirical literature related to the on going study.

2.1 Theoretical Literature

In recent years, the energy sector of developing countries (including Ethiopia) has exhibited a dynamic character. In addition to the important changes in the shares of consuming sectors and fuels in aggregate demand patterns, the energy consumption trends of these countries have moved steadily upwards. This, together with the slowdown in the growth of total energy consumption in the industrialized countries, has underlained the rapidly growing role of developing countries in the world energy market.

For instance, according to OPEC review (1994), the share of developing countries in world energy consumption rose from 10 % in 1970 to about 20 % in 1992, while the share of OECD countries fell from 65 % to 51 % in the same period. The annual average energy consumption growth rate of developing countries was about 5.5 % in the period 1970-92, compared with 1 % per annum for the OECD countries in the same period. There are several economic, social and demographic factors behind these trends of the past two decades.

Theoretically, the demand for a good or services is determined by its own price, prices of other goods, income, geographical, demographic as well as environmental factors. The relative energy costs and their supply stability is therefore expected to have an influence on gasoline and diesel consumption. If other factors remain constant, while the price of one energy form rises, it will be costly to continue consuming this particular source of energy. Therefore, to maximize utility, given the limited level of money income, a consumer will reduce consumption and increase the consumption of another form (substitute) whose price has decreased or remained constant (Pindyck, 1980).

From the consumers' point of view, the demand for gasoline and diesel is a derived demand from the services it provides within the transport sector. For example, individuals require gasoline and diesel for their private cars to provide private and public transport of goods and passengers. In this respect, the demand for gasoline is seen as the demand for other goods and services[2]. Assuming the above conditions for gasoline and diesel as a good and bearing in mind that Hicksian demand analysis does not provide us with observable parameters, since they are based on utility concept, we can postulate how the gasoline demand function responds in a Marshallian context.

The simple static model for gasoline and diesel demand assumes that utility from gasoline (G), diesel (D) and other goods (O) depends on the price of gasoline (P_g), the price of diesel (P_d) and the price of other goods (P_o), respectively. Assuming that the consumer knows the price of gasoline (P_g), the price of diesel (P_d) and that of other goods

(P_o), he/she then chooses G, D and O to maximize utility : U (G,D,O); subject to budget constraint : $P_gG + P_dD + P_oO \leq Y$.

[2] It should be noted that, the question to be developed here will try to explain demand functions based on the gasoline demand studies by Dahl and Sterner (1991)

Assuming a dynamic response of gasoline consumption to price and income changes, several authors (as some covered in the empirical literature) have used some of the following variables.

$G = G(P_g, M, G_{t-1}, X, PoP, V,U)$ - (2.1.1)

Where: G = quantity of gasoline

P_g = Price of gasoline

M = Income

G_{t-1}= Lagged gasoline consumption

U = Level of urbanization

X = Export earnings

PoP = Population, and

V = Vehicle stock

Most studies on gasoline and diesel demand have focused on the developed countries with few studies being undertaken for developing countries especially the African countries including Ethiopia.

There are different factors that influence the demand for gasoline and diesel. We assume that the original demand is for transportation with related characteristics such as comfort and status. Therefore, gasoline and diesel demand is determined in a number of separate steps which are sequential. The first is the decision to own a car, then comes the decision on its utilization. From the stand point of a utility function, it is easier to conceive a function for individual consumer. As Archibald and Gillingham (1978) showed, the influence of social status such as age and education on individual gasoline consumption conditions at the region levels are not necessarily sufficient at the individual level.

Dahl and Sterner are mostly known by their studies on gasoline demand. Following Dahl and Sterner (1990), the most important explanatory variables in this case are the level of economic activity and the relative price of gasoline. Like most other commodities, we assume that the demand for gasoline and diesel increases with income, ceteris paribus. Furthermore, assuming that gasoline and diesel are normal goods, their demand is inversely related with prices.

Dahl and Sterner (1991) further argued that in a static model gasoline demand is a function of real price of gasoline and real income. He also argued that in the dynamic model gasoline demand is not only affected by current period but also past time. This is because if variables determining the demand for gasoline change in a given year, some consumers react with a lag due to the force of habit. As a result current consumption of gasoline is not only a function of current income and price structures but of previous incomes and prices as well.

Similarly Dahl and Sterner (1992) modeled demand for transport fuel. Accordingly, they hypothesized that people adjust consumption only partially to changes in price and income because of the inflexibility in the stock of consumer durables.

Moreover, Franzen and Sterner (1995) and Rogat and Sterner (1997) gave more insight regarding the determinants of gasoline demand in OECD and some Latin American countries. They argued that demand for transport fuels is deriven from the demand for transportation itself and therefore has at least two component adjustments, namely vehicle utilization and the composition of the vehicle stock. Given that cars are long lived assets, demand adjustment necessarily occur over a number of years. They used static and dynamic models for the adjustment process.

Ishiguro and Akiyama (1995) observed that income and price elasticities provide a quantitative measure of the impact of economic activity and energy prices on energy demand. Further they argued that total energy demand is the sum of demand in the various sectors of the economy. The sectors they considered include; transportation, industry, household and agriculture sectors.

MacRae (1994) gave similar factors to the one used earlier by Baltagi and Griffin (1983) to facilitate comparison. According to him, Gasoline demand is a function of distance traveled per vehicle, number of vehicles and efficiency (efficiency is distance traveled per unit of gasoline). Moreover, gasoline demand (gas) is normalized on a per vehicle basis, and utilization is hypothesized to depend upon the real price of gasoline (P_{gas}/P_{GDP}) and real per capita income (Y/N_{pop}).

More generally, Gately and Streifel (1997) analyzed the growth in oil demand. They observed that much of the growth in world oil demand is affected by GDP, population and price of oil. They also 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.

Wohlgemuth (1997) gave some insight regarding the determinant of demand for transportation fuels. Accordingly, income, both in absolute and in per capita terms, is the most important determinant of demand for transportation fuels. In general, transport demand rises with income, although this relation is not consistent across countries. When comparing countries with similar per capita GDP, the corresponding per capita transport energy consumption can vary considerably. He also argued that changes in fuel prices are also important for the determination of transport fuel efficiencies and energy consumption. For instance, gasoline and diesel prices vary substantially across countries and account for part of the difference in per-capita fuel consumption. Moreover, he explained that the determinants of transportation are grouped into economic, socio-demographic, and geographic factors, which, of course, interact. Economic determinants are principally income and the cost of transport. Socio-demographic factors include the links between family size and structure, gender, work status, and age distribution of the population. Finally, geographical condition also influences transport demand through population density and distances between destinations.

According to Barnes, et.al (1984) a country's demand for energy is linked with factors such as size of population, degree of urbanization and industrialization, patterns and levels of technological development.

Likewise, Hosier, R. et.al (1993) argued that the demand for energy is determined by the price of fuel used, the price of other alternative or competing fuels, income and other characteristics of the residents and climatic variables. In addition, CESEN (1986), the variation in the price of fuel overtime depends on a multitude factors such as: variation in the production and distribution costs of the existing energy sources, supply status, competitiveness of prices in relation with other substitute fuels, social characteristics and income level of the users.

In line with this, Balabanoff (1994) argued that the two most widely important factors determining energy demand are income and its rate of change. Energy consumption and its related costs may affect the path of economic growth, while it is also a function of growth. He further stated that income elasticity of demand for energy in LDCs is larger than in industrialized countries, while price elasticity is smaller, due to the structural effects of development on the demand for oil and the availability of energy sources. Therefore, with a fall in economic growth, price increases may have a depressing effect on economies and reduce energy use. With higher economic activity, the demand for energy increases. On the other hand, a greater availability of energy may raise the level of production and generate higher income and employment. Many factors affect this relationship - for example, demographic factors, such as population and urbanization, the price of energy, the state of technology, the level of activity in the different economic sectors and environmental constraints.

Consistent with the above argument, Arimah (1994) examined the relation between energy and economic growth. Energy-economic growth relationship within a given country is a reflection of that country's level of economic growth. Similarly, commercial energy consumption per capita increases at a faster rate than per capita income, thereby resulting in an increasing value of the income elasticity of energy consumption. With high levels of economic growth, it is expected that commercial energy per capita will rise at a much slower rate than per capita income, thereby displaying a decline in the income elasticity of energy consumption.

Despite the fact that gasoline and diesel demand is determined by the above major fundamentals of economic factors like price of gasoline and diesel and income, gasoline and diesel demand is not free from the influences of government regulation. For example, in most of the developing countries oil is imported and marketed by the government. This makes the consumer to use the oil inefficiently which has a cross effect on the environment and the resource allocation of the country (World Bank, 1999).

Not only the marketing by government makes the oil market in developing countries inefficient, but also the institutional framework and the transport system of these countries are weak. The institutions responsibility for importing and price settings of oil are themselves inefficient. The price of oil is usually set above the cost due to the rent-seeking behavior of governments (World Bank, 1999).

Based on the principles of markets, we can view the world oil market from two angles. These are the classical view (neoclassical view) and the Keynesian (neo-keynesian view).
The classical view naturally proposes that, like any other commodity, oil should be left to the forces of demand and supply. However, the problem with oil market is that the oil reserve is owned by few and hence the supply is monopolized in most cases. For instance, OPEC has about 70% crude oil reserve share and 40% average oil market share (Energy Information Administration, 1999).

The classical view, therefore, could not be a solution, as the oil market is very small and hence not competitive due to the monopolistic nature of the market as seen from the supply side.

The Keynesian view states that when the market becomes uncompetitive and persists, government (or some external force) should intervene in the market with the objective of removing the obstacles of the market. Particularly, the Keynesian view implies that the oil market should be intervened to decartelize it.

It is recognized that energy prices in many developing countries including Ethiopia are fixed by the government, and do not reflect the real opportunity cost of using resources (in this case gasoline and diesel). This suggests that the price level may not influence gasoline and diesel consumption in the way the theory suggests.

2.2 Empirical Literature

In this subsection we critically review some empirical studies which have been used in analyzing the demand for gasoline and diesel. Most econometric demand models of gasoline and diesel are formulated by static and dynamic as well as by the above mentioned framework, tend to be based on simple or multiple regression models where gasoline and diesel demand is a function of one or more independent variables.

The hypothesis that price of gasoline, income and vehicle stocks are mainly determine gasoline demand, has been tested by several economists mainly in the context of developed countries. One such model (the simplest static model) was developed by Sterner and Dahl (1990) analyzed the demand for gasoline using yearly data for Sweden, and found that the mean long-run elasticities are 1.16 for income and -0.53 for price. These lower income and price elasticities prove the argument that less adjustment is captured much more easily, when the periodicity of data is shorter because it shows that, monthly or quarterly elasticities for the same model have an average of roughly half the yearly values.

Based on log-linear static model, the study on the demand for gasoline in the OECD countries was done by Sterner et al (1991) using time series data from 1960 to 1985. It was found that different models tend to give very different estimates, showing the need for careful model specification and interpretation of elasticities. Together with other studies, the analysis showed that average price elasticities range between -0.3 and -0.5. Income elasticities are, however, much more like the long-run estimates found by Baltagi and Griffin (1983).

Cross-sectional data do, however, give much higher income elasticity values (around 1) for average OECD countries (Dahl and Sterner, 1991). This suggests that these data reflect adjustment to long-run changes in prices. However, a significant problem with the simple static model is that there may not be enough time for total adjustment to changes in prices and incomes within the unit time period of data.

Similarly, Rogat and Sterner (1997) used time series, cross-sections and pooled estimators to estimate gasoline demand in some Latin American countries on yearly data covered from 1960 to 1994. Individual country results in lagged endogenous model were found that the long-run price elasticities range from -0.16 to -1.71 with an average of -0.58 and the income elasticities ranging from 0.06 to 1.63 with an average of 0.64. Compared to the typical OECD results, that of the Latin American countries are somewhat lower particularly for income and show perhaps somewhat greater variability (See Dahl and Sterner, 1991).

The inter country results (cross sections between countries for various years) found that price elasticities were with in the range of -0.41 and -0.50 with an average of -3.1 and the income elasticities with in 0.99 and 1.23 with an average of 5.7. The cross sectional data give higher values for price elasticities in spite of the fact that we use a simple static model. This is because we capture the result of very low adaptation process when we compare between countries. As shown in Sterner (1991), however, the elasticities in cross-sectional estimates tend to be lower with smaller and more homogenous group of countries.

Moreover, the long-run elasticity pooled estimates for gasoline demand in some Latin American countries found that the price elasticities range from -0.5 in the pooled OLS to -0.8 in the cross-section. All were lower than the corresponding values for OECD which was shown by Franzen and Sterner (1995). There are two likely explanations. One plausible reason is lower flexibility to local prices since cars are not generally made to Latin American relative prices but to the relative prices in OECD or other car producing countries. Another reason would be that income elasticities should be high at lower income levels. It is in fact more difficult to say what the income elasticity is since estimates vary so greatly between models.

There are also few studies found in Latin American countries by different economists. Berndt and Botero (1985) found price and income elasticities for Mexico to be -0.33 and 1.41, respectively. These results were based on time-series data from 1960-79. Dunkerly and Hoch (1985), found price and income elasticities for Argentina to be -0.03 and 0.84 respectively, and for Chile -0.30 and 1.08, based on time-series data covering the period 1970-1981. Toto and Johnson (1983), found the corresponding elasticities for Venezuela to be -0.09 and 1.23 respectively. Both Dunkerly and Hoch (1985), and Toto and Johansson (1983), used basic static OLS method.

The econometric model discussed by Baltagi and Griffin (1983) on yearly data from 1960-1978 employed the static model to facilitate comparison among OECD countries and developing Asian countries. The individual country results for the OECD reported in Baltagi and Graffin (1983) showed that the short-run real price elasticities ranged from -0.04 to -0.79 with an average of -0.28 and short-run GDP per capita elasticities ranging from 0.11 to

1.14 with an average of 0.58. It was also found that the average GDP elasticity for the OECD countries was only about 50% of that for the developing Asian countries.

Pooling the analysis for OECD countries together, Baltagi and Graffin (1983) reported the following elastiities for the static model: a price elasticity of -0.32 and income elasticity of 0.66, and vehicle per capita elasticity of 0.64.

When the countries were grouped into - low and medium income, the income elasticities of the low-income countries were larger than the middle-income countries in the static model, but not in the dynamic model. However, price elasticities of the low-income countries were smaller (in absolute value) than the middle-income countries for both types of the models. This is because, energy is a necessary ingredient in development so the low-income countries are less sensitive to price changes. The elasticity with respect to the number of vehicles per capita is lower (in absolute term) for the low-income countries, than the middle-income countries. This confirms the fact that low-income countries have fewer vehicles per capita and hence there is less spare capacity in the vehicle utilization.

When we came to the dynamic model, Drollas L.P. (1984) estimatd the lagged endogenous model using time series data on the OECD countries, the average long-run price elasticity found to be -0.80 and 1.31 for income. Similarly, vehicle and vehicle characteristic (efficiency) models capture short-run adjustment by inclusion of vehicle stock. The study done on OECD countries used the annual data by Drollas found that the average price elasticity and vehicle elasticities were -0.31 and 0.52, respectively. If these results are compared to simpler static model, they roughly imply that half of the annual adjustment comes through utilization or changes in vehicles characteristics, rather than changes in number of vehicle.

Charemza and Deadman (1992), using an Error Correction Model (ECM), showed that short and long-run price elasticities were -0.32 and -0.41 respectively, while short and long-run elasticities for vehicles per capita were 0.89 and 1.04, respectively. The estimates for the whole sample period depicted that the short-run elasticities do not differ much from the long-run levels.

Bacon (1992) undertook a study on the possibility of whether fuel taxes can reduce air pollution cheaply through fuel substitution i.e. measuring the possibility of inter-fuel substitution. He found out that these depended on how flexible activities are with regard to fuel used.

Kimuyu P.K. (1996) analyzing the demand for diesel in Kenya used time series, estimated the long-run structural relationship between the demand for diesel and its arguments among which the trend factor was found insignificant. He also found insignificant long-run price elasticity of demand for diesel suggesting that a price policy is unlikely to influence the demand for diesel even in the long-run unless it is combined with other policies. The number of vehicles with current road licensing show the greatest elasticity followed by gross domestic product and proportion of people resident in Nairobi. Vehicle ownership and spatial population distribution therefore offer greatest policy potential regarding regulation of diesel consumption.

Employing an error correction model on the same estimation, he found that diesel demand, in contrast, was responsive to gross domestic product, to number of vehicles with current road licenses, and to the proportion of Kenya's residents in Nairobi. Diesel demand is, therefore, growth elastic and will continue to increase with income. The results further revealed insignificant price elasticity of diesel demand indicating that diesel taxes have only limited potential for regulating diesel utilization and in mitigating undesirable environmental consequences associated with rapidly increasing diesel consumption.

Studying on urbanization and consumption of petroleum products in Kenya, Kimuyu (1993) employed ordinary least squares on log-linear functions. He found that, the urbanization elasticities of the consumption of motor spirit and diesel, the two alternative fuels are slightly less than unity, indicating that an increase in urbanization, other factors remain the same, increases the consumption of these fuels by about the same proportion. The estimated gross domestic product elasticities ranged from 0.08 for motor spirit to 0.476 for diesel. The consumption process is, therefore, not GDP elastic.

Mureithi, Kimuyu and Ikiara (1982) conducted a study to analyze the impact of increased energy costs on balance of payments, choice of production technology and real incomes in Kenya using time series data for the period 1964-1976. Their study revealed the existence of possibilities for substitution between different fuels and between energy and capital. They observed that most of the manufactured goods which Kenya imports use energy in their production. These products come from countries, which are equally affected by the international oil prices hence are highly priced. They contend that it is the direct costs of raw materials, rather than that of energy, which increased most rapidly over the period under study, suggesting that energy was not the major contributor of economic problems[3] in Kenya.

[3] It is widely believed that oil crisis have been the cause of economic problems in Kenya.

Adegbulugbe and Dayo (1986) reviewed the demand analysis of gasoline consumption in Nigeria using time series from 1965 to 1980. In their analysis they used two static, one dynamic and one effective stocks of automobiles models to estimate gasoline demand in Nigeria. The model was estimated by the OLS technique using the multiple regression. Accordingly, the estimated income elasticity from the static model was 1.165, while the dynamic model gave 0.475 and 1.365 as the short and long-term income elasticities, respectively. The estimated effective stock of automobiles elasticity was 0.77. This and the related statistical result showed a good statistical fit between gasoline consumption and the effective stock of automobiles. However, they have not estimated the price elasticity because of data problems.

Coming to Ethiopia, Asmerom Kidane (1991) proceeded by analyzing energy demand in rural and urban centers of Ethiopia using a two stage least square methodology. The model used to estimate demand for energy in rural and urban Ethiopia is based on the general household framework of microeconomic theory. The model is closed by equating the demand for energy with the supply. He specified three demand function for energy, namely, two demand functions for traditional energy sources and one for modern energy sources. The empirical results tend to support the theoretical predictions of the model. However, there is considerable variation in the direction and size of the elasticities depending on the type of energy source and on the urban or rural residence. Still the estimates suggested that economic variables, namely, prices and wealth are important in explaining observed variation in demand for energy. Most importantly, the major finding of the study was that price of traditional energy plays an important role in the consumption of fuel wood and other traditional energy sources.

In a nutshell, the literature reveals that studies done in various countries have identified a multiplicity of factors determining the demand for gasoline and diesel. However, it is mostly determined by the level of income, price and vehicle stock. One important finding that the income elasticities of the low income countries were larger than the middle income countries; where as the price elasticities of the low income countries were smaller than middle income countries.

This study uses gasoline and diesel demand models synthesized from other models. But it differs from other studies by including additional variables (determinants) in the models, namely, level of urbanization, population growth and foreign exchange earnings; and also try to show the relationship of the two models. Although demand for gasoline and diesel is relevant for the assessment of the effects of new policy initiatives, to the best of my knowledge there is no enough information about empirical estimates for gasoline and diesel demand undertaken in Ethiopia. Hence, this study is attempt to fill the research gap.

CHAPTER THREE

COMMERCIAL ENERGY AND THE ETHIOPIAN ECONOMY

3.1 The Structure and Characteristics of the Ethiopian Economy

According to the recent World Development indicator (2002) by the World Bank, in GNI per capita terms measured by the Purchasing Power Party (PPP), Ethiopia ranks 202 out of the total of 207 countries. A similar ranking has been reported by the United Nations Development Program (UNDP), which indicated that, in terms of human development indices, Ethiopia stands at 158 out of 162 countries (Human Development Report, 2001).

Likewise in 2000, Ethiopia's GNI per capita, calculated in terms of US dollars was $100. In terms of PPP, which is more indicative of the individuals' purchasing power in their own countries, and the real GNI per capita for the same year was $660, lowest figure in Africa (World Development indicators, 2002:18).

The Ethiopian economy is fundamentally based on agricultural activities that is dominated by small scale farming practices and production is mostly for subsistence purposes. The agricultural sector is the major sources of production and employment for larger proportion of the population (EEA, 2000). From it's economic contribution, the sector has the major share in terms of GDP. For instance in 1999/2000 as a percentage of GDP, on average, the sector constituted about 50% (See Appendix 2).

Before the political change which brought the present government of Ethiopia to power in May 1991, the massive state control of the productive sectors, trade, financial services and infrastructure severely restricted the country's productive capacity. An overvalued national currency (Birr), scarcity of foreign exchange, limited access to credit, discriminatory policies in different economic activities and high profit taxation made difficulty for the initiative of the investment activity and discouraged export oriented production.

Presently the Ethiopian Government has adopted stabilization and reform program that aimed at correcting price distortions and encourage the participation of private sector in the economy. Accordingly, taxes and subsidies were rationalized, positive real interest rates were introduced and the devaluation of the Birr, which was followed by the introduction of a foreign exchange auction system under which the currency has been moving toward a market determined rate was introduced (Energy Sector Management Assistance Program, 1996:1). More importantly, on October 12, 2001, the foreign exchange auction system is seized and since after a new system of inter-bank foreign exchange market is introduced between Banks which lead to a more free market economy.

The country economic performance in the Imperial era, that is, during 1960/61-1973/74 characterized that agriculture was the dominant sector as compared with other sectors. As a percentage of GDP, agriculture on average, has constituted 68.1% while industry, distributive service and other service were constituted 9.2%, 11.6% and 11.1%, respectively. In this period, GDP, on average, grew by 3.7%. Similarly in the same period agriculture, industry, distributive service and other services on average grew by 2.0%, 6.9%, 8.0% and 7.2%, respectively. This implies that the growth rate of distributive service was higher than other sectors. Consistently the per capita income on average grew by 1.4% with only a one year negative growth which was the period of political instability (Appendix 2).

If we see the trends of the Ethiopian Economy during 1974/75-1990/91, the sectoral basis of agricultural production grew by 1.6% per annum during the period while industry, distributive services and other services grew by 1.4%, 1.0% and 4.1% per year, on average, respectively. Of the five years negative growth rates of GDP, three of them were years of negative growth in agriculture whereas the last year of the Derge saw a reasonably high growth rate in agriculture, while all other sectors declined sharply leading to a negative growth rate in GDP and per capita income. As compared with the Imperial era, the growth rate of all sectors were lower in the Derge regime. Contrary the share of industry, distributive service and other service to GDP were higher in the Derge period while the share of agriculture was lower. It can also be observed that the average real GDP growth of the Derge regime was 1.9% per year compared with an average population growth of 3% leading to a net decline in per capita income of 0.7% per year (Appendix 2). The growth of both real GDP and per capita income in the Derge regime was lower as compared with the Imperial era. The declined of the per capita income is mainly attributed by increase of the number and rate of population.

When we see the economic performance of the country under EPRDF, agriculture has remained the dominant sector and takes the highest share in terms of contribution to GDP. The average growth rate of agriculture in the period was 1.8%, while in the Imperial and pre-reform period it was 2% and 1.6%, respectively. Therefore, this indicates that agriculture has performed better during the Imperial era. In contrast, industry and services (trade, transport, etc . . .) were growing by about 7.3% each while other services (banking, insurance, public administration and social services) were growing by 8.1%. This shows that industry, distributive services and other services during the post reform have performed better than the

Derge period (Appendix 2). In terms of real GDP and per capita income growth, the present government is well performed as compared with the last two governments.

In general, the statistical evidences listed above show that Ethiopia is one of the poorest countries in the world. Nevertheless, recent assessments of the performance of the economy have indicated some promising figures with respect to the growth rate of the economy. Between 1991/92 and 1999/2000, the real GDP of Ethiopia grew at an average rate of 4.6%. Excluding the year 1991/92, which was the year of heightened political instability in the country, the average growth rate registered 5.7%, with a per capita GDP growth rate of 2.7% on average. In 1992/93, the highest GDP growth rate of 12% was registered (Appendix 2).

3.2 The Impact of Energy in Economic Development

The need to determine the relationship between energy and economic growth derives from the increasing realization of the importance of energy to the economic development of nations. "Energy is vital to economic development; without fuels, power, cars, trains, and planes, and without electricity, light, and heating, life in industrialized countries would be considerably less comfortable" (World Bank, 2000). In developing countries (like Ethiopia), however, it is not just a question of comfort. Poverty cannot be reduced without the greater use of modern form of energy. For instance, even now, around two billion people have no access to electricity, relying instead on traditional fuels such as dung and fuel wood. Those who are fortunate enough to have electricity spend an average of 12% of their income on energy-more than five times average for people living in OECD countries (World Bank, 2000).

Hence, several studies undertaken for the developing countries have indicated strong relationships between energy and economic growth (Leach et al, 1986; Ang, B.W 1987; Dunkerley, 1986; Desai, 1986; Pearson, 1987; Arima, 1994). Common to these studies is finding that income elasticity of energy demand generally tends to be highly elastic and greater than unity, where as estimated price elasticity have been insignificantly different from zero and very inelastic. The implication being that it takes more energy consumption to produce more national income. Analogously price elasticity of energy demand is very inelastic since the quantity of energy demand is far less responsive to price changes (Obas John.E, 1996).

In as much as agricultural products are basic necessities of life, oil products are basic necessities for the economic life of a country. This is especially true in the economic sectors of industry, transport and agriculture.

Petroleum is one of the valuable commodities in the world, useful and prerequisite to mankind. Its economic value is to generate energy to the science-invented tools of Transport, Industry, Agriculture and Communication touching every aspect of our daily life (World Bank, 1999).

The level of petroleum consumption is directly related with economic development and the number of population. Table 3.1 shows that, from 1973/74 to 1999/2000, on average, the Ethiopia's economy grew by 2.8%. In addition, Agriculture, Industry, Transport and Communication and the rest economy sectors grew by 1.6%, 3.3%, 4.9% and 4.8%, respectively. Similarly, the number of population went up from 32.7 millions to 65.3

millions, and, on average, it increased by 2.7%; while the per capita income, on average, grew by 3.0%

Table 3.1 - GDP Economic Classification, Total Population and Refined and Imported Petroleum

GDP by Economic Sector, Population and Refined and Imported Petroleum	1973/74	1981/82	1989/90	1999/2000	Average annual growth in % (1973/74-1999/2000)
Agriculture (in millions of birr)	5,059.1	5,189.8	5,814.4	7,035.4	1.61
Industry (in millions of birr)	846.5	1,097.6	1,265.3	1,870.9	3.33
Transport & communication (in millions of birr)	297.8	390.5	588.0	1,026.5	4.89
Others (in millions of birr)*	1,991.5	2637.6	3,682.0	6,351.6	4.83
Gross Domestic product (in millions of birr)	8,194.9	9,315.5	11,349.6	16,284.4	2.79
Per capita GDP (in millions of birr)	256.1	250.0	238.2	271.6	3.0
No. of population (in million)	32.7	37.3	47.6	65.3	2.67
Total refined and imported petroleum (in metric tons)[4]	551,110	730,143	810,911	1,094,884	70.85

Source: Own computation

* included Trade, Hotels and Restaurants.

Therefore, an increase in the level of economy and population has an impact on petroleum consumption, and due to this petroleum consumption, on average, increased by 70.85% during 1973/74-1999/2000.

3.3 Commercial Energy Consumption in Ethiopia

Import and processing of crude oil and the task of wholesale distribution was the responsibility of the Ethiopian Petroleum Corporation (EPC) during the pre-reform period. Its operations were under the supervision of the Ministry of Mines and Energy. In the post-reform period, it was given a status of public enterprise to be managed and supervised by a

[4] 1Metric tons equivalent to 1,404 liters for gasoline and 1,203 liters for diesel

Board of Management and EPC has been renamed as the Ethiopian Petroleum Enterprise (EPE).

EPE played a very important and prominent role in the national economy. Within its capacity, it has done everything possible to ensure adequate and reliable supply of petroleum to satisfy consumer's need. Until 1978, all the oil need of the country was covered by Assab refinery at an average production rate of 450,000 metric tons of products per year. However, from 1978 to 1991 the country's demand for oil became beyond the capacity of the refinery and the balance was imported as refined products. During this period, the balance was 700,000 metric tons per annum on average (EPE, 2000).

For a long time, EPE had been producing a number of products when the Assab refinery was running under the enterprise's supervision. The products were liquefied petroleum gas (LPG), motor gasoline, jet fuel, kerosene, automotive diesel oil (gas oil), inland fuel oil, export fuel oil, marine fuel oil and asphalt used for road and construction activities within the country, and heavy fuel oil for export when surplus was produced.

However, the types of petroleum products currently imported for domestic consumption include: liquefied petroleum gas (LPG), motor gasoline, diesel oil, jet fuel and kerosene. Nevertheless, the type and quantity is subject to the requirement of the local users (EPE, 2000).

All petroleum has been imported either as crude or in the form of refined products. The crude that used to be processed at Assab met less than 30% of Ethiopia's needs and hence the balance being covered by imported as refined. This has been true of the case of the pre-July 1997 period (The new MOFED, 1999).

Since July 1997 Ethiopia's petroleum imports have been solely confined to imports of refined petroleum products. The suspension of petroleum refining at Assab is exclusively made for economic reasons and it benefited both Ethiopia and Eritrea. According to one opportunity cost calculation, the net saving by direct import of refined products is around 10 millions USD (The new MOFED, 1999). By so doing, EPE has kept the country from heavy expenditure of foreign currency which would have been spent on importing crude petroleum. Most importantly, to avoid shortage and inconveniences, EPE has built fuel depots in Bahirdar, Gondar, Shashemene, Combolcha, Agaro, Gambella, Adigrat, Wolita and Nekemt.

Ethiopia lacks domestic petroleum source and all its oil need is fulfilled through importation. This importation uses a significant part of its foreign exchange although Ethiopia's petroleum consumption is among the lowest in Africa. For instance, in 1990 the import of petroleum product used up 55% of total export earnings, while in 1997 due to improved export earnings the import was only 24% of total earnings (The new MOFED, 1999). From Table 3.2, the country's petroleum product consumption, that is, diesel and kerosene, was on average, increased during the year 1991/92 to 1999/2000.

As presented in Table 3.2, we compared the average consumption of petroleum products from 1980/81 to 1990/91 and 1991/92 to 1999/2000. During 1980/81- 1990/91 and 1991/92 - 1991/2000 diesel had the largest share followed by gasoline. This shows that diesel and gasoline consuming sectors had constituted the largest share of petroleum products.

Table 3.2 – Consumption of Petroleum Products by product type (in per cent)

Petroleum products	1980/81-1990/91 Average Annual Product in %	1991/92-1999/2000 Average Annual Product in %
Diesel	45.9	48.0
Gasoline	18.0	17.2
Kerosene	5.4	17.0
Jet fuel	14.7	6.8
Fuel oil	12.5	10.0
LPG	1.0	1.0
Others	2.5	-

Source: Own computation

During 1991/92 to 1999/2000, on average, the country's diesel consumption constituted 48.0% of petroleum demand of the country. Similarly, kerosene increased from 5.4% to 17.0% as compared with other petroleum products. Eventhough the average kerosene consumption increased, the share of diesel and gasoline yearly consumption increased during 1991/92 - 1999/2000 as compared with the 1980/81 – 1990/91 consumption (Appendix 3). However, Jet fuel and Fuel oil consumption share depicted a declining trend.

The increased diesel consumption is related with the development of the transport activity, while kerosene is becoming the only preferable household fuel used for cooking purpose by most households. The decline in consumption share of other petroleum products such as Jet fuel is mainly attributed that fuel used by Jet for defense activity is decreased and in addition planes may be get their fuel from abroad these days. In the case of fuel oil, most industries were using electricity.

The distribution of petroleum products is conducted for two categories of consumers, wholesale consumers[5] and retail consumers[6]. The sector uses the largest part of the petroleum

[5] These consumers use the largest part of the oil by purchasing oil from oil distributors on wholesale basis; for instance, defense, EELPA etc.
[6] Individual households purchasing from fuel stations.

by purchasing petroleum products from petroleum distributors on a wholesale basis. From 1985/86 to 1990/91 and 1991/92 to 1999/2000, the consumption pattern of petroleum by wholesale consumers (economic sectors) is shown in Table 3.3.

Table 3.3 - Petroleum Consumption by Sectors

Sectors	1985/86-1990/91 Average Annual consumption in %	1991/92-1999/2000 Average Annual consumption in %
Industry	18	30
Transport	23	24
Construction	9	15
Agriculture	7	8
Defense	21	6
EELPA	10	5
Others	12	12

Source: Own computation

From Table 3.3, except defense and EELPA, other sectors' consumption, on average, increased from 1985/86 – 1990/91 to 1991/92 – 1999/2000. Specially, construction and industry sectors' consumption showed a significant increase. The main reason for that is the rise of construction work in both government and private sectors since 1991. Moreover, the private sector investment on industrial activity increased the consumption of petroleum. EELPA decreased its oil consumption as many towns were electrified by hydropower. Since 1991 the oil consumption of national defense has also decreased significantly (Appendix 4). This is because of the ending of the civil war and the reduction of the national army. The petroleum consumption under the "others" includes mines, water works, ministries, diplomatic and international organization, and above all the households. The major consumers of kerosene are the households, the number of which increases proportionally to the population growth.

Different practitioners involved or interested in the area made a number of attempts to estimate sectoral consumption and ended up with varying estimates. However, they all agree that the transport sector is the largest consumer of petroleum (i.e. diesel and gasoline), road transport accounting for the bulk of sectoral consumption followed by industrial sector.

Table 3.4 show regional distribution of petroleum consumption in retail sale. The retail sale of petroleum is categorized under six business regions of the country as used by EPE and the companies. These are Addis Ababa, North, South, East, West and Central regions.

Table 3.4 - Regional Consumption of Petroleum (in Per cent)

Regions	1985/86-1990/91 Average Annual Consumption in %	1991/92-1999/2000 Average Annual Consumption in %
A.A	38	43
Central	19	20
Eastern	20	12
Northern	10	9
Western	8	9
Southern	5	7

Source: Own computation

From Table 3.4, we observe the following for the two periods. The consumption of petroleum in Addis Ababa on average, increased from 38 % to 43 % followed by the central region whose share increased from 19 % to 20 %. Southern and Western region consumption, on average, increased by 2 % and 1%, respectively while that of Northern decreased by 1%. On average, in the two periods the Eastern region consumption decreased from 20 % to 12 % (Appendix 5). This was because of the limited number of petroleum stations during the periods. In line with this, there is unequal infrastructure and economic development among the regions and this shows that petroleum consumption (specially gasoline and diesel) have an important impact on economic development.

In terms of petroleum station, the four petroleum companies (Shell, Mobile, Agip and Total) has installed their stations in different parts of the country. For instance, in 1997 the four retail companies had 485 petroleum stations. Shell, Mobil, Agip and Total have 154, 124, 111 and 98 petroleum stations, respectively; and the distribution depends on economic and infrastructural development of the regions.

The two most important petroleum products are gasoline and diesel. The consumption of the products are increasing from time to time in the transport sectors. Table 3.5 shows gasoline and diesel consumption growth by regions.

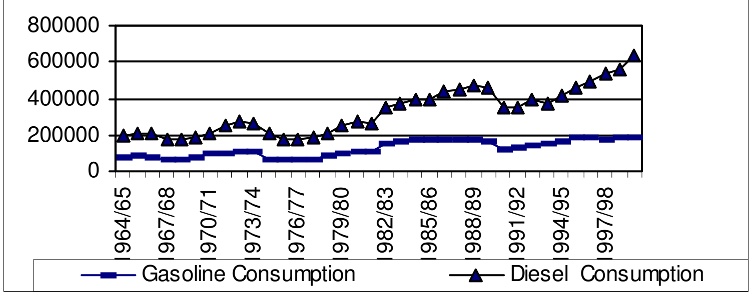
Gasoline consumption of Southern region registered the largest growth. Gasoline consumption grew at the least pace of 8.4 % per year as compared to the 18.3 % growth rate of diesel oil (Appendix 6). This implies that gasoline consumption is being less than that of diesel oil. The South's high gasoline consumption implies that either new consumption boosting factors have turned up or the market is yet to saturate in South. Diesel oil consumption growth is largest for North followed by West (Table 3.5).

Table 3.5 - Gasoline and Diesel Consumption Growth by Regions

Regions	Gasoline (in MC)			Diesel (in MC)		
	1992/93	1999/2000	Average Annual Growth in%	1992/93	1999/2000	Average Annual Growth in %
A.A	84048	114687	5.0	64477	111217	8.9
Central	14538	17438	6.1	54037	83709	13.4
Eastern	10313	13435	9.5	29845	81862	16.7
Northern	5444	6852	5.8	42684	64791	26.0
Western	5487	8611	9.3	24038	49163	24.2
Southern	4018	11290	14.9	12141	42778	20.7
Total	123848	172313	8.4	227222	433520	18.3

Source: Own computation

Fig. 1 Gasoline and Diesel Consumption (in MC)*



* 1 MC equivalent to 1,000 liters

A trend in the consumption of gasoline and diesel is presented in Fig. 1. The consumption of both fuel type decreased between the period 1974/75-1975/76. The period was characterized that the Derge regime came to power and the downfall of the Imperial era. Later on, the consumption of both were increasing until up to 1988/89. Between the period 1989/90-1991/92, the consumption of both fuel were decreased (Appendix 3). The main reason that there were intensive civil war and the downfall of the Derge regime. When the EPRDF came to power, both fuel type consumption were increased. The year after 1991/92 is characterized by economic reconstruction and liberalization of economic activity and hence a higher consumption was occurred.

The percentage change of gasoline consumption during the period 1964/65 to 1999/2000 had been 142%, whereas that of diesel was 222%. During all those years, diesel oil has been the dominant fuel demand of the total consumption (Appendix 3).

In general, gasoline and diesel consumption represents a major proportion of commercial energy use in Ethiopia. As the general economic recovery turns to sustainable growth, the demand for gasoline and diesel is expected to continue rising rapidly. As shown in Table 3.6 for the last three years (1997-2000) and the coming ten years (2001-2010) the demand for gasoline and diesel is expected to increase by an average of 10.19 % and 6.13 % , respectively.

Table 3.6 – Projection Demand for Gasoline and Diesel 1997-2010 (In '000 metric tons)

Product	2000	2005	2010	Rate of Growth in %, 1997-2010
Gasoline *	249.17	368.18	544.00	10.19
Diesel	456.60	674.8	997.0	6.13

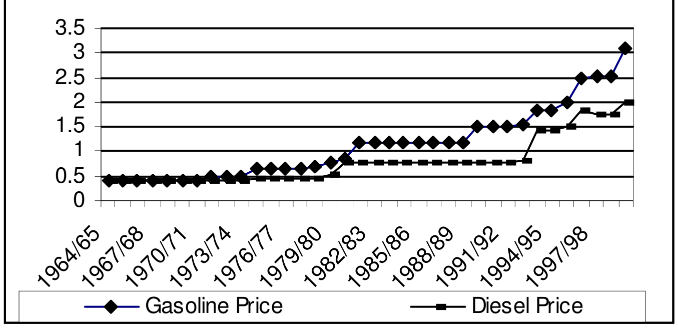
Source: IRG (Petroleum pricing and market structure study, 1997)
* Including Aviation Gasoline

3.4 Effects of Increase in Price of Petroleum on Economic Growth and Balance of Payments

Energy pricing in Ethiopia, as in any other countries, is an effective instrument for implementing energy policy. In the energy pricing policy, an important consideration is that energy must be delivered to the point of end use and made to the consumers. However, it is recognized that a prohibitive price may lead to substitution by other energy sources. Also a price that is too low may lead to inefficient utilization of resources or may make future investment in the resource un-economic. Energy pricing is used as a tool to affect energy conservation, environmental protection, and as a means of encouraging exploitation and use of natural resources. For instance, biomass energy prices depend on supply and demand conditions. Charcoal and fuel-wood prices in urban areas fluctuate with availability of these resources. But the general observation is that the prices of these sources are generally rising over time.

Before 1991 supply of petroleum products was characterized by severe shortfalls. Specially between 1984/85 to 1988/89 rationing system introduced to manage the supply shortfalls created black markets where products fetched several times their official prices. Institutionally determined prices meant under pricing and cross subsidies (The new MOFED, 1999:268). Cross subsidization is used as a deliberate means to influence the pattern of energy demand and stimulate production in different sectors of the economy. In fact the main objective of the pricing system was to keep prices stable. Once product prices were set, they were not adjusted in response to changes in procurement and distribution costs.

Fig. 2 Gasoline and Diesel Price (Cents/lit.)



From Fig. 2, on average, the price of both fuel type was increasing from year to year. The domestic price change is mainly depend on the price of world oil market. In all years the price of gasoline was higher than diesel (Appendix 3). Prices are tightly controlled. Retail prices are controlled by the ministry of trade which fixes transportation charges and distribution margins.

Prior to October 1992, petroleum prices including gasoline and diesel in Ethiopia had been almost fixed (Appendix 3). The prices that were fixed in 1981 were adjusted in 1992. The price structure in 1992 was effected following the devaluation of Birr. The October 1992 price revision enabled product prices reflect actual costs for the first time; this is shown in Table 3.7. Prices revisions were made to reflect economic values of the respective products.

Table 3.7 - Gasoline and Diesel Retail Price Structure (Birr/Liter)*

Product type	1981 to Sept. 1992	Oct. 1992	May 1994	Oct. 1996	March 1997	Nov. 1997	Dec. 1999	July 2000	Percentage change of price Oct, 1992 - July, 2000
Gasoline	1.19	1.85	2.0	2.33	2.64	2.51	2.95	3.79	104.86
Diesel	0.79	1.42	1.5	1.73	1.95	1.76	1.98	2.20	54.93

Source: EPE, Ministry of Commerce and Industry and own computation.
* Addis Ababa Retail Price

In line with the Government of Ethiopia shift towards a market economy, there have been two price adjustments in 1992 alone. These adjustments reflect first, an increase in the transportation allowance to distributors, to reflect the 70 % increase in road tariff rates effected in April 1992, and second, the currency devaluation from Birr 2.07/US dollar to Birr 5.0/US dollar on October 1,1992, the first devaluation in over 20 years (Ministry of Mines and Energy, 1997:12). The government has already started to revise petroleum price every three months. The recent revised prices are based on import parity price, transportation and distribution costs.

Petroleum prices were again revised in May 1994. This remained in effect up to October 1996. The main objective of the pricing system during this period has been to set prices so that it reflects economic values of the respective products and facilitate the supply and distribution of petroleum products (The new MOFED, 1999).

The main objective of the price system during March and November 1997 was to adjust prices to changes in international prices and procurement costs. Petroleum products (such as gasoline and diesel) are in adequate supply at prices that reflected economic costs. To facilitate the availability of products in rural areas and to effectively meet the rapidly growing needs of both urban and rural areas, the 1997 pricing system has been also working smoothly on the basis of biannual revision (The new MOFED, 1999).

In September 1998 the government opened an account called "Petroleum Stabilization Fund" account. The main objective was to put excess money in this account when the world oil market price became lower, while to be paid from it when the price goes up. It is believed that this account helps to stabilize the rise of the domestic price and make stable for some period.

In short, starting October 1992 to July 2000 the government changed the domestic petroleum price for seven times. Accordingly, the percentage change of gasoline price and diesel was 104.86% and 54.93%, respectively (Table 3.7). This implies that the world market price of Commercial energy is increasing from time to time and its demand is also increasing. In addition higher petroleum price also produce higher price on domestic product and service sectors. For instance, in the transport sector, passenger tariff is increasing from time to time.

Increasing of petroleum price negatively affect the economy of developing countries like Ethiopia. To import petroleum products, we need large amount of foreign exchange and this brings a problem in trade balance.

For instance, the country's balance of payment deficit was increasing from 1979/80 to 1999/2000 (Appendix 7). The deficit was covered by foreign borrowing or decreasing the foreign exchange reserve balance.

Table 3.8 - The Impact of Petroleum Import on Ethiopian Foreign Trade Balance
(In '000 of Birr)

Description	1979/80	1983/84	1987/88	1991/92	1995/96	1999/2000
Values of Goods imported	1,432,858	2,067,005	2,274,651	1,810,897	7,708,246	11,438,681
Share of imported petroleum in %	23.7	18.3	9.5	10.7	12.1	17.6
Value of Goods Exported	950,667	929,625	773,642	279,026	2,539,056	3,957,802
Trade Balance	-482,191	-1,137,380	-1,501,009	-1,531,871	-5,169,190	-7,480,879

Source: NBE, Annual Bulletin and own computation.

As shown in Table 3.8, during the period 1979/80 to 1999/2000, the payment for imported petroleum was 23.7%, 18.3%, 9.5%, 10.7%, 12.1%, and 17.6%, respectively. This implies that imported petroleum share (like gasoline and diesel) has an impact on the country-imported goods. Therefore, high petroleum price implies high foreign exchange requirement to import it. In addition, it has a negative impact on the trade balance and depletes the foreign exchange reserve of the country.

Petroleum product prices in many developing countries (hence in Ethiopia) have not followed conventional marginal cost or opportunity cost pricing rules but rather been set with much regard for income distribution goals and with the avowed purpose of promoting transport.

3.5 Energy and Environmental Interaction

The relationship between man and the environment in which he lives is one of interdependence. Man survives when the wider environment is conductive to his survival. It is true also that the atmosphere plays a key role in the exchange of radiation energy between the earth and the sun. However, this important function of the atmosphere is being threatened by the rapidly increasing concentration of greenhouse gases (GHGs) in the atmosphere as a result of human interference.

Today, in the entire world, the energy sector is increasingly recognized as an important component of the economy. Energy technologies as well have great ecological and human health impacts. For instance, vehicle fuels in developed countries are a significant source of air-born toxic pollutants, accounting for up to 95% of lead emissions (World Bank, 1992). The situation is even more precarious in developing countries, given the old condition of most vehicles. This follows the realization that the energy sector is the major source of emission.

Emissions from commercial energy use are the single largest contribution to global warming. Energy related activities, such as transportation, contribute both directly and indirectly to generation of carbon dioxide (CO_2) and other GHGs. Emission from agriculture and energy use, methane emissions from natural gas leaks and coal mines are significant and harmful as well. It is known that most of the historical and current emissions of greenhouse gases originate from developed countries. Ethiopia's greenhouse gas emission is very small compared even to most developing countries.

As economic activities in the country grow, energy consumption and environmental hazards continue through carbon dioxide emissions. According to world band indicators report of 2001, the GDP per unit of energy use (which measure energy efficiency) of Ethiopia in 1980 and 1998 was 1.4% and 2.1%, respectively. The carbon dioxide emission per capita metric tons was 0 and 0.1 in 1980 and 1997, respectively. When we compared with Kenya, 0.4 and 0.3 in 1980 and 1997, respectively, the carbon dioxide emission per capita in Ethiopia was very low. In addition, it was very low in Ethiopia as compared with world wide emission level of 3.5 and 4.1 for the same period, respectively.

Sector wise Ethiopia's GHG emissions profile is dominated by emissions from agriculture, contributing 80% of the total, while gas wise it is dominated by methane, contributing 80% of the total CO_2 equivalent emissions in 1994. Similarly, for the same year emission from energy contributed 15% of the total emission (Table 3.9).

Table 3.9 -1994 Emission in Absolute Values (Gg) and Aggregated Emission of CO_2 equivalent Emission (Gg)

Greenhouse Gas source & sink Categories	**Emission in absolute Values (G_g)***			**CO_2-equivalent Emission (Gg)**				
	CO_2 Emission	***CH_4***	***N_2O***	***CO_2***	***CH_4***	***N_2O***	***Aggre-gated***	***%***
Energy (Fuel Combustion)	2,285	194	3.0	2,285	4,074	930	7,289	15
Industrial process	310	0	0	310	0	0	310	1
Agriculture		1,540	19.7		32,340	6,116	38,455	80
Land use change & Forestry		28	0.2		594	60	654	1
Waste		46	1.5		963	454	1,418	3
Total National Emissions	2,595	1,808	24	2,595	37,968	7,440	48,003	100
%				5	79	16	100	

Source: Ministry of Water Resources; National Meteorological Services Agency, 2001

* G_g is Gigagram and 1 Gigagram equal to 10^9 Grams

Where: CO_2 = Carbon Dioxide, CH_4 = Methane, N_2O = Nitrous Oxide

There was a general increasing trend of GHG emissions in Ethiopia in the period 1990-1995. The relative comparison of GHG emissions for the year 1990 and 1995 showed that total (gross) CO_2 emissions (i.e. emissions from the energy and industrial process sector) increased by about 24% while emission of CH_4 and N_2O went up by 1% and 119%, respectively (Table 3.10). Similarly, aggregate emissions of GHG_s in terms of CO_2-equivalents increased by 12%.

Table 3.10 - Greenhouse Gases Emissions for the period 1990-1995 in terms of CO_2-equivalent (Gg).

Emissions	1990	1991	1992	1993	1994	1995	% change 1990-95
Carbon Dioxide (CO_2)	2,300	1,879	2,073	2,402	2,595	2,862	24
Methane (CH_4)	37,800	38,661	37,320	37,498	37,968	38,235	1
Nitrous Oxide (N_2O)	3,430	4,579	4,705	4,818	7,440	7,498	119
Total	43,537	45,119	44,098	44,718	48,003	48,595	12

Source: Ministry of Water Resources, National Metrological Services Agency, 2001

Where: CO_2 = Carbon Dioxide, CH_4 = Methane, N_2O = Nitrous Oxide

Globally, transportation is one of the most rapidly growing energy consuming sectors and a large and growing contributor of greenhouse gas emissions. The main reason why fuels are regarded as an important source of CO_2 emission is that the transportation sector as a whole and many industries in Ethiopia are highly dependent on fuel/petroleum products for their energy supply. In other words, although Ethiopia is one of the least developed country, it uses fuels for operating various economic sectors. This phenomenon causes the national CO_2 emission from liquid fuels to be higher (Table 3.11).

It is also believed that, environmental pollution is more often related to urbanization and increases in transport activities. The direct relationship of transport to urban development has been accompanied with the increase in motor vehicle emission and hence pollution at local levels.

Table 3.11 - Greenhouse Gas Emission from Gasoline and Diesel 1987/88 - 1992/93[7]

Year	Gasoline Emission		Diesel Emission	
	Actual CO emission	Actual CO_2 emission	Actual CO emission	Actual CO_2 emission
1987/88	16.1426	59.1897	156.4569	573.6752
1988/89	6.7011	24.5706	173.3853	635.7460
1989/90	6.1861	22.6822	154.5728	566.7668
1990/91	9.3938	34.4441	150.4747	551.7405
1991/92	46.9026	171.9762	190.1217	697.1128
1992/93	23.1177	84.7648	216.8690	795.1863

Source: EPE and own computation.

Where: CO = Carbon Monoxide, CO_2 = Carbon Dioxide

The emission from both fluctuate from year to year. When we compared the two, diesel had a great impact on environmental pollution. This implies that even in terms of price, diesel is cheaper than gasoline. From Table 3.11, in 1992/93 gasoline emission depicted a decrease (both carbon monoxide and carbon dioxide), whereas diesel emission showed an increase.

[7] There is, however, considerable variations among the estimates and measurements because of differences in cycle conditions, differences in the sample population, and different estimation techniques. This indicates again the importance of actual emission measurements on the population of interest in order to develop realistic emission systems.

CHAPTER FOUR

THE DATA AND METHODOLOGY

Given the objective of estimating the determinants of gasoline and diesel, the methodology employed in the study including model specification and the econometric approach is discussed in this chapter.

4.1 The Data: Sources and Types

Before directly undertaking the estimation of our model, it is important to highlight the sources and types of the data used in the study. Accordingly, the study employed a time series data from different sources that covered the period from 1964/65 to 1999/2000. The major sources of the data for the analysis are Statistical Abstracts and Journals, Ministry of Mines and Energy of Ethiopia, Ethiopian Petroleum Enterprises (EPE), Ministry of Industry and Trade (MIT), the new Ministry of Finance and Economic Development (MOFED), Ethiopian Road and Transport Authority (ERTA), Ethiopian Rural Energy Development and Promotion Center, Central Statistical Authority (CSA) and National Bank of Ethiopia (NBE).

4.2 Methodology

4.2.1 Model Specification

In this sub section the specification of gasoline and diesel demand functions used in the study is conducted.

4.2.1.1 Gasoline and Diesel Demand Functions

As Hendry (1988) points out, there are no good reasons for accepting a partial adjustment model a priori excluding all lagged exogenous variables. Instead a much more general model should be a starting point which allows various lags on all variables.

The theoretical foundation of gasoline and diesel demand (specially gasoline demand) model used in this study is based on the one developed by Sterner T. (1991), Sterner T. and Dahl C.(1991), Franz'en M.(1994), Franz'en M. and Sterner T. (1995), Baltagi B.H and Griffin J.m(1983); and Rogat. J and Sterner, T (1997). All of them agreed that, gasoline demand (G) is a function of the price of gasoline (P) and income (Y).

Accordingly, the static models are used by Sterner and Dahl (1990) and Rogat and Sterner (1997) attempt to analyze the price and income elasticities of demand for gasoline. The model considers gasoline demand (G) as a function of the real price of gasoline (P) and real income (Y).

$$\mathbf{G = f(P, Y)} \text{ - - - - - - - - - - - - - - - - } \mathbf{(4.1)}$$

The authors argued that two variables are the major determinants of gasoline demand.

Similarly, Dahl and Sterner (1991) and Rogat and Sterner (1997) surveyed dynamic models specifically the partial adjustment type where gasoline demand is also a function of its lag as shown below:

$$\mathbf{G = f(P, Y, G_{t-1})} \text{ - - - - - - - - - - - - - - } \mathbf{(4.2)}$$

Considering equation (4.2) above, the implication is that, prices and incomes have similar lag structures. If this assumption is relaxed, the result is a distributed lags dynamic of the general form.

$$\mathbf{G = f(\sum P_{t-i},\ \sum Y_{t-i})} \text{ - } \mathbf{(4.3)}$$

Dahl and Sterner (1992) modeled demand for transport fuel. They began by a simple static model which assuming that demand is homogeneous of degree zero in prices and income and deflected prices and income into real values which yielding a log-linearity simple static model as:

$$\mathbf{\ln G = C + \alpha \ln P + \beta \ln Y + \varepsilon} \text{ - } \mathbf{(4.4)}$$

Where, G is gasoline consumed, P is real price of gasoline, Y is real income and ε is random error term. To distinguish between the effects of a rise in GNP due to an increase in population, they took the number of people into consideration and came up with the equation below:

$$\mathbf{\ln \left(\frac{G}{N}\right) = C + \alpha \ln \ P + \beta \ln \left(\frac{Y}{N}\right) + \varepsilon} \text{ - - - - - - - - - - - - - - - - - } \mathbf{(4.5)}$$

Franzen (1994) in his study also analyzed gasoline demand in OECD countries. His general gasoline demand function was:

$$\mathbf{G_{ti} = \alpha + \sum_{i=0}^{r_1} \beta_i P_{t-i} + \sum_{i=0}^{r_2} \gamma_i Y_{t-i} + \delta V_t + \sum_{i=0}^{r_3} \lambda_i G_{t-i} + \varepsilon} \text{ - - - - - - - - - - - - - } \mathbf{(4.6)}$$

Where, G_t = log (gasoline consumption per capita) at time t.

P_t = log (price of gasoline) at time t

Y_t = log (income (GDP) per capita) at time t

V_t = log (personal vehicle per capita)at time t.

ε = error term

r = degree of polynomial

The author's included vehicle stock affects gasoline consumption. We believe that this is an important variable which influenced gasoline demand specially in OECD countries.

Baltagi and Griffin (1983) employed the static model to facilitate comparison among OECD countries and extended the coverage of the model to include different countries particularly the developing Asian countries. The model starts with the following identity:

$$\textbf{Gasoline demand = Distance per vehicle X Number of vehicles X } \frac{1}{\textbf{Efficiency}} \text{ - - - -} \qquad \textbf{(4.7)}$$

Where, Efficiency (E) equals Distance travelled per unit of gasoline.

Due to data limitations the application of such identity has been difficult. Thus the structure is usually normalized on a per vehicle basis, and the utilization is hypothesised to depend on the real price of gasoline (P_{gas}/P_{gdp}), real per capital income (Y/N_{pop}) and the number of vehicles per capita (N_{veh}/N_{pop}). Then the model is obtained as:

$$\ln\left(\frac{\text{gasoline}}{\text{vehicle}}\right) = \alpha_o + \alpha_1 \ln\left(\frac{Y}{N_{pop}}\right) + \alpha_2 \ln\left(\frac{P_{gas}}{P_{gdp}}\right) + \alpha_3 \ln\left(\frac{N_{veh}}{N_{pop}}\right) + \varepsilon \text{ - - - -} \qquad (4.8)$$

Other studies on the demand for gasoline and diesel have involved variables such as vehicle characteristics and such models are referred to as vehicle characteristics model. They capture a long-run adjustment through the quantity and characteristics of vehicle stock, then the elasticities on income and price represent changes in utilization:

$$G = f(P, Y, V.CHAR) \text{ -} \qquad (4.9)$$

Where, V.CHAR is vehicle characteristics (vehicle efficiency)

In general, Pesaran and Smith (1995) acknowledge the fact that in principle the demand for any particular commodity is determined simultaneously by all other variables of the economy. The implication is that inclusion of additional explanatory variables will improve the realism of the model and its performance at least for forecasting. Therefore, to find a suitable dynamic model specification, our gasoline demand equation can then be given in log-linear form as:

$$\mathbf{LGCPC_t = \alpha_0 + \alpha_1\,(LRP_g)_t + \alpha_2\,(LRP_d)_t^{8} + \alpha_3\,(LRIPC)_t + \alpha_4\,(LPG)_t + \alpha_5\,(LU)_t + \alpha_6\,(LV_gPGC)_t + \alpha_7\,(LRFEE)_t + \varepsilon_t} \quad \text{-------------------} \quad \mathbf{(4.10)}^{9}$$

In Equation (4.10), GCPC is gasoline consumption per capita; RP_g and RP_d are real price of gasoline and diesel, respectively; RIPC is real income per capita, PG is population growth, U is level of urbanization, V_gPGC is gasoline using vehicles per gasoline consumption, RFEE is real foreign exchange earnings and ε_t is the error term.

Similarly, the diesel demand log-linear equation can be given as:

$$\mathbf{LDCPC_t = \beta_0 + \beta_1\,(LRP_d)_t + \beta_2\,(LRP_g)_t^{10} + \beta_3\,(LRIPC)_t + \beta_4\,(LPG)_t + \beta_5\,(LU)_t + \beta_6\,(LV_dPDC)_t + \beta_7\,(LRFEE)_t + \varepsilon_t} \quad \text{-------------------} \quad \mathbf{(4.11)}^{11}$$

Where, DCPC is diesel consumption per capita and V_dPDC is diesel using vehicles per diesel consumption. Other variables are defined as before.

[8], [10] The diesel price (P_d) is included into the gasoline equation to capture the substitution effect between gasoline and diesel. The same case applies to the gasoline price (P_g) in the diesel equation.

[9], [11] The variables are in logarithms since this has to be the most appropriate functional form and furthermore has the convenience of giving constant elasticities (the elasticities of demand are assumed to remain constant).

In the literature review attempt was made to give the variables which influence the demand for energy (gasoline and diesel) in the economy. A fall in consumption of gasoline/diesel is likely to follow higher prices. It would also be expected that gasoline/diesel consumption can increase due to growth in income (GDP), foreign exchange earnings, urbanization, population growth and stock of vehicles. Therefore, the set of relationships described in the literature review and model specification constitute the basis for the hypothesis to be tested in this study.

Generally, the anticipated signs of the coefficients will be $\alpha_1 < 0$, while α_2, α_3, α_4, α_5, α_6 and α_7 are > 0 for gasoline demand. Similarly, $\beta_1<0$, while β_2, β_3, β_4, β_5, β_6 and β_7 are > 0 for diesel demand.

4.2.2 Econometric Methodology

In dealing with time series data it is common practice to test the hypothesis that the process generating a series has a unit autoregressive(AR) root versus that this process is stationary[12] (Leybourne and Newbold, 1999). If the variables are stationary, we can apply the Ordinary Least Square (OLS) method. If variables entering a regression are not stationary, then, results that are obtained using OLS techniques would be “Spurious”.[13]

[12] A variable (a stochastic process) is said to be stationary if it has a zero or at least constant mean, constant variance over time, and if the covariance between observations in two time periods depends only on the distance of the lag between the two time period rather than on the actual time the covariance is computed (See Harris, 1995)

[13] A spurious regression may has a higher R^2, t-statistics that appear to be significant, but the results are without any economic meaning. In this case, it is often recommended that the regression equation be estimated in first differences (Enders, 1995)

Most macroeconomic variables are found to be non-stationary and show trending over time (Johansen, 1992). One can, however, difference or de-trend the variables in order to make them stationary. If variables became stationary through differencing, they are in the class of difference stationary process.[14] On the other hand, if they are de-trend, they are trend stationary.[15] Most economic variables are, however, in the category of difference Stationary Process (Maddala, 1992). Such a procedure gives only the short-run dynamics while one's interest may be in determining the long-run parameters.

In this study we apply the Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) tests to detect the presence of unit roots in the data. Both the DF and the ADF tests are based on the null hypothesis that a unit root exists in the variables against the alternative that the variables are stationary.

The DF test is based on the following regression equations:

$$\Delta Y_t = \alpha Y_{t-1} + \varepsilon_t \text{ - - - - - - - - - - } (4.12)$$

$$\Delta Y_t = a_0 + \alpha y_{t-1} + \varepsilon_t \text{ - - - - - - - } (4.13)$$

$$\Delta Y_t = a_0 + \alpha y_{t-1} + a_2 t + \varepsilon_t \text{ - - - - - } (4.14)$$

Equation (4.12) is a pure random walk model. Equation (4.13) adds a drift and Equation (4.14) includes both a drift and a time trend.

The ADF test is also based on these equations and augmented by the series of lags. The augmentation is required to tackle the possible autocorrelation problem. Therefore, the ADF has the following form:

---

[14] A stochastic trend can be removed by first-differencing, since ΔX_t is then trendless, as $\Delta X_t = \alpha + U_t$. X_t is then referred to as a difference stationary process (Thomas, 1997).

[15] A deterministic trend cannot be removed by first differencing, since this does not remove t from the process. If $X_t = \alpha + \beta_t + U_t$, and X_t subject to such a trend then it is said to be a trend stationary process (Thomas, 1997).

$$\Delta Y_t = a_0 + \alpha y_{t-1} + a_2 t + \sum_{i=1}^{p} \beta_i \, \Delta Y_{t-i} + \varepsilon_t \text{ - - - - - - - } (4.15)$$

In the above equation both the intercept and a linear time trend are included and the augmentation is up to p lags. The unit root test requires that the null hypothesis $\alpha = 0$ (there is a unit root) versus $\alpha < 0$ (the series is stationary). In this case the usual t-test can not be relied upon instead we apply the ADF- test statistic (See Harris, 1995).

In order to obtain both the short-run dynamics and the long-run relationships, one can appeal to what is know as co-integration. The concept of co-integration implies that even if many economic variables are non-stationary, their linear combination may be stationary (Cuthberston, et al, 1992). If this holds, we say there is long-run relationship (co-integration) between the variables involved.

In testing for the existence of co-integration in time series data, the two widely employed methods are the Engle-Granger two step procedure[16] and the Johansen maximum likelihood approach. In the Engle-Granger two-step procedure, variables entering the co-integrating vector are tested for integration of the same order, in fact order one – I(1). This procedure has its own weaknesses. In the first place, the residual that is used as error-correcting term in the second procedure is obtained from the static regression in the first step which is already suspected to be spurious. It also categorizes variables as endogenous and exogenous with an implication of simultaneity problem. This implies that when there are more than two variables in the system, there can be more than one co-integrating vector and hence the Engle

[16] In testing for co-integration in Engle-Granger approach, the first step is to estimate the long-run model and obtain the resulting residuals and the second step involves testing for the stationarity of the residuals. If the residual is stationary the series is co-integrated (Enders, 1995).

Granger procedure does not give consistent estimates of any of the co-integrating vectors (Thomas, 1997). To this effect, the Johansen procedure is far superior to the residual-based Engle-Granger two-step procedure since (Masih, 2000; Harris, 1995):

i. Unlike the Engle-Granger procedure, it does not make a priori assumption about the existence of at most a single co-integrating vector; rather it explicitly tests for the existence of multiple co-integrating vectors.

ii. It is set up on a unified framework for estimating and testing co-integration relationships on the basis of the Vector Error Correction Mechanism (VECM) approach. The VECM contains information on both the short and long-run adjustments to changes in the variables in the model.

iii. It rests upon appropriate statistics for hypotheses testing for the number of co-integrating vectors and test of restrictions upon the coefficients of the vectors.

Therefore, our study applies the Johansen maximum likelihood procedure to test for the existence of a co-integration vector(s). In the Johansen procedure, there is no a priori categorization of variables as exogenous and endogenous. Hence, given Equation (4.10) and (4.11), it is possible to represent our variables by a vector X_t and our model as an unrestricted vector autoregression (VAR) with K lags (Johansen, 1995: 10,45):

$$X_t = \Pi_1 X_{t-1} + \Pi_2 X_{t-2} + \text{-----} \Pi_k X_{t-k} + \Phi D_t + U_t \text{------- ------------} \qquad (4.16)$$

Where X_t is an (n x 1) vector of endogenous variables, Π_i is an (n x n) matrix of parameters, and U_t is independently and normally distributed with mean of null vector 0 and variances of Ω, i.e. $U_t \sim IN(0, \Omega)$. The deterministic terms D_t represent vectors of dummies and constants that are fixed and non-stochastic.

Equation (4.16) can be specified in Vector Error Correction Model (VECM) form as (See Hansen and Johansen, 1999) :

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \Phi D_t + \Pi X_{t-k} + U_t \text{ - - - - - - - - - - - - } (4.17)$$

Here, the estimates of Γ_i define the short-run adjustment, while Π contains the long-run information. D_t represents vectors of dummies, intercepts and predetermined exogenous variables. If the rank (r) of Π is zero, no stationary linear combination can be identified and hence the variables in X_t are not co-integrated. If Π has full rank, that is if r=n where n is the number of variables entering the co-integrating space, it implies that each variable is 'co-integrated' to itself, and hence each variable is I(0), which is in contradiction with the fact that the variables are I(1). The interesting case is, however, where Π has a reduced rank, that is, there are $r \leq (n-1)$ co-integration vectors present in β. Π may be decomposed in to two matrices α and β, such that $\Pi = \alpha\beta'$, where α and β can both be reduced in dimension to (n x r)[17]. In this regards, β represents (n x r) vector of long-run parameters that makes $\beta' X_t$ stationary and the (n x r) α-martix constitutes the speed of adjustment to disequilibrium.

[17] Once we know how many r linearly independent columns there are in Π (i.e., one we know its rank), we then know that the last (n-r) columns of α are zero and thus that the last (n-r) columns of β are non-stationary and do not enter (4.17). Thus, it is in this sense that we can then reduce the dimensions of α and β to (n x r).

Hence , ΠX_{t-k} in Equation (4.17)[18] is equivalent to $\alpha\beta' X_{t-k}$ and $\beta' X_{t-k}$ represents up to (n-1) linear combinations (co-integrating vectors) that ensure the convergence of the vector X_t to their long-run steady-state path (See Charemza and Deadman, 1997; Harris, 1995).

In the Johansen procedure there are two tests that help to identify the number of co-integrating vectors, called the trace (λ_{trace}) and the maximal (λ_{max}) statistics. These tests are given as follows (Harris, 1995):

$$\lambda_{trace}(r) = -T\sum_{i=r+1}^{n} \ln (1-\lambda_i)$$

$$\lambda_{max}(r, r+1) = -T\ln (1-\lambda_{r+1}) \qquad r = 0,1,2, - - - , n-2, n-1.$$

Where λ_i=eigenvectors, T= number of observations and n is the number of variables.

The trace statistics is used to determine whether there are at most r co-integrating relationships while the maximal statistics tests the null hypothesis of r co-integrating vectors against the alternative of r+1. The magnitude of λ_i is a measure of the strength of the co-integration relations (denoted as $\beta'_i X_t$) are correlated with the stationary part of the model.

---

[18] For more analysis, equation (4.17) can be written out in full as:

$$\begin{bmatrix} \Delta X_{1t} \\ \Delta X_{2t} \\ \vdots \\ \Delta X_{nt} \end{bmatrix} = X_i \begin{bmatrix} \Delta X_{1t-i} \\ \Delta X_{2t-i} \\ \vdots \\ \Delta X_{nt-i} \end{bmatrix} + \begin{bmatrix} \alpha_{11} & \alpha_{12} & \cdots & \alpha_{1n} \\ \alpha_{21} & \alpha_{22} & \cdots & \alpha_{2n} \\ \vdots & \vdots & & \vdots \\ \alpha_{n1} & \alpha_{n2} & \cdots & \alpha_{nn} \end{bmatrix} \begin{bmatrix} \beta_{11} & \beta_{21} & \cdots & \beta_{n1} \\ \beta_{12} & \beta_{22} & \cdots & \beta_{n2} \\ \vdots & \vdots & & \vdots \\ \beta_{1n} & \beta_{2n} & \cdots & \beta_{nn} \end{bmatrix} \begin{bmatrix} \Delta X_{1t-1} \\ \Delta X_{2t-1} \\ \vdots \\ \Delta X_{nt-1} \end{bmatrix}$$

α_{11} represents the speed at which ΔX_{1t} , the dependent variable of the VECM, adjusts towards the single long-run co-integration relationship ($\beta_{11}\Delta X_{1t-1} + \beta_{21} \Delta X_{2t-1}$ +- - - $\beta_{n1} \Delta X_{nt-1}$), while α_{21} represents the speed at which ΔX_{2t} adjusts, and ΔX_{nt} shows how fast ΔX_{nt} responds to the disequilibrium changes represented by the coingeration vector. Each of the r non-zero columns of α contain information on which co-integration vector enters which short-run equation, and on the speed of the short-run response to disequilibirum on (Harris, 1995: p.98)

CHAPTER FIVE

ANALYSIS OF EMPIRICAL RESULTS

5.1 Time series properties of the data

5.1.1 Tests for stationarity

Several tests can be used to test for unit root, but the widely acceptable and reliable are the Dickey-Fuller (DF) and the Augmented Dickey-Fuller (ADF) tests. These test help to detect whether a variable is stationary[19] or not. If a variable is stationary in level, i.e. without running any differencing, then that variable is said to be integrated of order zero or I(0). Similarly, if it becomes stationary by differencing once, then the variable is said to be an I(1) variable.

From Table 5.1, both the Dickey-Fuller and Augmented Ducky-Fuller tests for unit root indicate that all the variables are not stationary in levels. If we take the first difference, all variables are stationary. In other word, the finding suggest that all variables are integrated of order one [I(1)][20].

[19] A process is said to be integrated of order d, denoted as I(d), if it has to be differenced d, times before it becomes stationary (Thomas, 1993)

[20] If two I(1) variables are co-integrated, then their dynamic specification can be written as an error correction model (ECM), and vice versa, if the dynamic relationship between two I(1) variables can be written as an ECM, they are co-integrated (Hendry, 1995).

Table 5.1 Results of unit Root Test

Variable[a]	DF with trend and Constant	ADF with trend and constant; and one lag[b]
LGCPC	-1.8227	-2.3504
LRP_g	-2.782	-2.6633
LRP_d	-2.8614	-2.8672
LRIPC	-2.5446	-3.2331
LPG	-2.8125	-3.5223
LU	-0.19726	-0.46621
LV_gPGC	-1.879	-2.3024
LRFEE	-2.7442	-1.2468
LV_dPDC	-1.8971	-2.8634
LDCPC	-1.7347	-2.7706
ΔLGCPC	-4.605**	-4.7465**
ΔLRP_g	-6.0144**	-4.9902**
ΔLRP_d	-5.9892**	-4.7029**
ΔLRIPC	-5.1496**	-6.2601**
ΔLPG	-5.8902**	-6.1085**
ΔLU	-4.9956**	-5.7939**
ΔLV_gPGC	-4.7176**	-3.624*
ΔLRFEE	-8.4828**	-4.3276**
ΔLV_dPDC	-4.0828*	-3.7285*
ΔLDCPC	-3.9408*	-3.5903*
Critical Value 1% 5%	-4.271 -3.556	-4.271 -3.556

[a] All the variables are in log form
Δ 1st difference
[b] we choose lag1 for ADF which has lower probability
** significant at 1%
* significant at 5%

5.1.2 Co-integration Analysis

It is worth examining the data congruency of the VAR before determining the co-integration rank. One problem that can be encountered in estimating the model is the choice of the appropriate lag structure of the variables in the model. If different lag structures produce white noise then the test for rival models will be used to select the best. Thus, the Shwartz Bayesian Criteria (SBC) and Hannan Quinn (HQ) statistics are used, and according to these tests' the first order VAR is selected as an appropriate specification (See Appendix 8).

The next step is to determine the number of co-integration relationships among the variables. In estimating the models, the Johansen maximum likelihood procedure is used in order to test for co-integration and determine the long-run parameters of Equation (4.10) and (4.11), and the result are summarized in Tables (5.2) and (5.3). Here, the dummies for structural break and policy regime entered the estimation unrestricted. If computed λ_{max} and λ_{trace} values exceeds the critical values we may reject the null hypothesis that co-integrating rank r=0. Which means that in the long-run the hypothesis of rank r=0 is rejected. In other words, testing n-1 co-integrating vector is equivalent to testing that the first r=n-1 eigenvalues are non-zero while the remaining (n-r) eigenvalues are zero (Harris, 1995).

Table 5.2 Tests for number of co-integrating Vectors for Gasoline and Diesel Demand

Ho:Rank =r (a) Gasoline Demand	n-r	λ_i	λ_{max}	Reimers adjusted	λ_{max} (95%)	λ_{trace}	Reimers adjusted	λ_{trace} (95%)
r=0	8	0.849078	64.29**	49.17*	48	188.4**	144.1*	141.2
r≤1	7	0.734014	45.03	34.43	41.5	124.1**	94.92	110.0
r≤2	6	0.61204	32.19	24.62	36.4	79.1	60.48	82.5
r≤3	5	0.412375	18.08	13.82	30.0	46.9	35.87	59.5
r≤4	4	0.397561	17.23	13.18	23.8	28.83	22.04	39.9
r≤5	3	0.194636	7.36	5.628	17.9	11.6	8.867	24.3
r≤6	2	0.116961	4.229	3.234	11.4	4.236	3.239	12.5
r≤7	1	0.000198702	0.006757	0.005167	3.8	0.006757	0.005167	3.8
(b) Diesel Demand								
r=0	8	0.88902	76.94**	59.36**	51.4	227**	175.1**	156.0
r≤1	7	0.714991	43.93	33.89	45.3	150.1**	115.8	124.2
r≤2	6	0.631918	34.98	26.99	39.4	106.1**	81.88	94.2
r≤3	5	0.524067	25.99	20.05	33.5	71.16*	54.89	68.5
r≤4	4	0.447428	20.76	16.02	27.1	45.17	34.85	47.2
r≤5	3	0.330348	14.03	10.83	21.0	24.41	18.83	29.7
r≤6	2	0.192347	7.477	5.768	14.1	10.38	8.005	15.4
r≤7	1	0.0795335	2.901	2.238	3.8	2.901	2.238	3.8

* Rejection at 5% level of significance
** Rejection at 1% level of significance

Accordingly, the results of the maximal and the trace tests for multiple co-integrating vectors are summarized in Table 5.2. The result show clearly that the null hypothesis of no co-integration is rejected by both the λ_{max} and the λ_{trace} statistics for both models. On the other hand, while the λ_{trace} rejected the existence of one co-integrating vector, the λ_{max} failed to reject this. The rejection of one co-integrating vector by λ_{trace} is mainly due to small samples and in such a situation the Johansen procedure over-rejects the null hypothesis (See Harris, 1995).

According to Harris (1995), using both Reimers adjusted λ_{trace} and λ_{max} statistics, we could not reject the null of no co-integration. This is attributed by taking account of the number of parameters to be estimated in the model and making an adjustment for degrees of freedom by replacing T in λ_{max} and λ_{trace} by T-nk, where T is the sample size, n is the number of variables in the model and K is the lag length. Hence, the presence of one co-integrating vector is supported using both Reimers adjusted λ_{trace} and λ_{max}. In addition, according to Johansen and Juselius (1990), the power of the trace test is lower than the maximum eigenvale test. Therefore, we can say that one co-integrating vector is maintained for both models.

Table 5.3 Results of co-integration Analysis for Gasoline and Diesel Demand (From PCFIML output)

(a) Gasoline Demand

(i) Standardized β' Eigenvectors

LGCPC	LRP_g	LRP_d	LRIPC	LPG	LU	LV_gPGC	LRFEE
1.000	0.7095	-0.6418	-0.02190	-0.1201	-1.547	0.6958	-0.08814
0.9513	1.000	-0.3721	0.5877	0.03987	-1.398	0.9673	0.02990
-0.9065	-0.2317	1.000	-0.005261	0.09627	0.6052	-0.5847	-0.1789
1.583	0.8152	0.02946	1.000	0.02867	-1.061	1.110	-0.08522
-11.22	6.484	-2.133	-13.82	1.000	4.977	-10.97	2.606
-1.317	-0.1272	0.6260	-0.8350	-0.02118	1.000	-0.9696	0.1361
0.2738	1.915	-0.9475	0.7158	0.08404	-1.106	1.000	0.1862
41.72	-127.8	76.26	67.98	4.464	17.74	44.99	1.000

(ii) Standardized α - Coefficients

LGCPC	-0.1320	0.03385	-0.1973	-0.03507	0.2283	-0.0004988	0.07077	0.01126
LRP_g	-0.04477	-0.6435	-0.08115	-0.00384	-0.002427	0.0017	0.04821	0.001291
LRP_d	-0.03514	-0.7899	-0.145	-0.0003897	-0.5745	-0.0067936	0.04821	0.001291
LRIPC	-0.07979	-0.1233	-0.1015	-0.003629	-0.01219	-0.0003976	-0.03365	0.0004663
LPG	1.047	-0.3182	0.9991	-0.1891	3.715	-0.0181	-0.3237	-0.01523
LU	0.1021	0.03579	-0.01868	0.0001584	-0.02952	0.0002315	-0.007425	0.001309
LV_gPGC	0.2031	0.0331	0.1676	0.03591	-0.2579	0.0004733	-0.06038	-0.01203
LRFEE	-0.7981	1.142	0.09775	-0.1375	-1.493	-0.001631	-0.2553	-0.004019

Vector AR 1-2F (128,34) = 1.2717 (0.2107), Vector Normality x^2 (16) =122.79(0.0000)**
Number of lages used : 1
Varibalbes entered unrestricted: Constant, dummy for structural break and policy regime.

(b) Diesel Demand

(i) Standardized β' Eigenvectors

LDCPC	LRP_g	LRP_d	LRIPC	LPG	LU	LV_dPDC	LRFEE
1.000	-0.9777	1.598	-3.221	-0.05979	-1.835	0.7189	-0.04177
-0.4434	1.000	0.8791	0.1210	0.2133	-0.2806	0.2026	-0.2862
0.0356	-0.3863	1.000	-2.024	-0.01823	-0.1949	0.07708	-0.0407
0.4318	-0.5065	0.3698	1.000	0.01415	-0.06365	0.3549	-0.1348
5.681	-11.11	3.486	-15.35	1.000	-2.614	4.493	-0.209
-1.377	-0.8786	1.479	-0.5057	0.1502	1.000	-0.5894	0.2114
1.337	0.5762	-0.3511	-0.3112	-0.01117	-1.094	1.000	0.1679
-30.37	2.845	0.4416	0.4063	1.778	38.41	-55.89	1.000

(ii) Standardized α - coefficients

LDCPC	-0.1010	-0.04344	0.00333	-0.4294	-0.1735	0.1923	-0.1584	-0.0005547
LRP_g	-0.008413	-0.4307	-0.09052	0.4799	0.005709	-0.006890	-0.02828	0.0001999
LRP_d	0.01297	-0.3079	-0.4569	-0.2358	0.01497	-0.07807	-0.1255	0.002462
LRIPC	-0.03906	-0.07362	0.07494	-0.1338	0.006605	0.02089	-0.05647	-0.0009761
LPG	-0.3123	-0.4734	2.258	0.004956	-0.2863	-1.200	0.2235	-0.02437
LU	0.05859	-0.0144	0.09251	-0.04042	0.0003507	0.01824	-0.01754	0.0005421
LV_dPDC	0.04204	0.03171	-0.01001	0.3901	0.01917	0.1996	0.1474	0.001008
LRFEE	-0.3826	0.3786	0.5531	2.722	0.02692	0.5212	-0.8828	-0.002431

Vector AR 1-2F (128,27) = 1.5195 (0.1033), Vector Normality x^2 (16) = 117.36 (0.0000) **
Number of lages used : 1
Variables entered unrestricted : constant, dummy for structural break and policy regime.

Looking at the diagnostic tests, vector auto-correlation and normality are obtained from the PCFIML output and the former does not detect problem at 1% level for both models. There is normality problem for both models and this may be due to small sample size.

After establishing the existence of one co-integrating vector, the next step is to test for the long-run weak exogeniety. The test for zero restrictions of α matrix is referred to as the test for weak exogeniety[21]. The requirement is to impose linear restrictions on α - coefficients to identify which entries of the first column of α-matrix is statistically zero. In other word a likelihood ratio test (LR - test)[22] for weak exogeneity is employed by imposing a zero-

Table 5.4 Tests for zero restrictions on α-coefficients for Gasoline and Diesel Demand

(a) Gasoline Demand							
	LRP_g	**LRP_d**	**LRIPC**	**LPG**	**LU**	**LV_gPGC**	**LRFEE**
α-coefficient	-0.04477	-0.03514	-0.07979	1.047	0.1021	0.2031	-0.7981
LR-test:$\chi^2(\approx 1)$	0.17696	0.058911	4.1967	1.4733	0.456	2.4381	3.4062
P-Value	0.674	0.8082	0.0405*	0.2248	0.1520	0.1184	0.065
(b) Diesel Demand							
	LRP_d	**LRP_g**	**LRIPC**	**LPG**	**LU**	**LV_dPDC**	**LRFEE**
α-coefficient	0.00333	-0.04344	-0.4294	-0.1735	0.1923	-0.1584	-0.0005547
LR-test: $\chi^2(\approx 1)$	0.0092954	0.019758	1.9993	0.25329	5.321	0.43701	1.6535
P-Value	0.9232	0.8882	0.1574	0.6148	0.0411*	0.5086	0.1985

* Rejection at 5% level of significance

[21] "- - - is defined to fulfill that requirement and concerns conditional inference about parameters of interest without loss of information". A variable is exogenous if it is determined outside the system under analysis (Hendry, 1995).

[22] The LR test requires estimation of both the unrestricted and the restricted model (Hendry and Doornik, 1994)

restriction on the α-coefficients. This helps us to write endogenous variables conditioned on the other variables in the VAR. The results are summarized in Table 5.4.

According to the results reported in Table 5.4, the assumption of weak exogeneity is rejected for income per capita (LRIPC) in the gasoline demand function and urbanization (LU) in the diesel demand. Thus, it is necessary to test whether there is a causality between the variables that are not weakly exogenous. Following Engle and Granger (1987), a variable **y** is said to be Granger caused by another variable **x** if current values of **y** can be predicted with better accuracy by using past values of **x**. In other words, **x** Granger causes **y** implies that **x** has significant incremental predictive power in the evolution of **y**. To this effect, a Granger causality relationship between LGCPC and LRIPC, and LDCPC and LU is examined and the test result suggested that there is no causality between them (See Appendix 9). This implies that we do not have a serious problem of endogeniety and it is possible to normalize with LGCPC and LDCPC by conditioning on the remaining variables.

Therefore, the structural long-run relationship derived from the co-integrating vector normalized with respect to LGCPC can be presented as:

$$\mathbf{LGCPC_t = -0.7095\,(LRP_g)_t + 0.6148\,(LRP_d)_t + 0.0219\,(LRIPC)_t + 0.1201\,(LPG)_t + 1.547(LU)_t - 0.6958\,(LV_gPGC)_t + 0.08814(LRFEE)_t} \quad \text{- - - - - - - - - - -} \quad \mathbf{(5.1)}$$

Similarly the long-run LDCPC equation can be presented as follow:

$$\mathbf{LDCPC_t = -1.598\,(LRP_d)_t + 0.9777\,(LRP_g)_t + 3.221\,(LRIPC)_t + 0.05979\,(LPG)_t + 1.835\,(LU)_t - 0.7189\,(LV_dPDC)_t + 0.04177\,(LRFEE)_t} \quad \text{- - - - - - - - - - -} \quad \mathbf{(5.2)}$$

Given the above co-integrating vectors, there is also a need to test for the significance of the long-run coefficients (β) in order to identify the unique co-integrating vector. Here again, a zero-restriction is imposed on each coefficient and the results for the LR-statistics are given in Table 5.5.

Table 5.5 Tests for zero-restrictions on Long-run coefficients for Gasoline and Diesel Demand

(a) Gasoline Demand							
	LRP_g	**LRP_d**	**LRIPC**	**LPG**	**LU**	**LV_gPGC**	**LRFEE**
β-coefficient	0.7095	-0.6418	-0.0219	-0.1201	-1.547	0.6958	-0.08814
LR-test: $\chi^2(1)$	4.6159	2.0833	0.0042805	6.1103	9.2454	2.5456	1.0311
P-value	0.0317*	0.1489	0.9478	0.0134*	0.0024**	0.1106	0.3099
(b) Diesel Demand							
	LRP_d	**LRP_g**	**LRIPC**	**LPG**	**LU**	**LV_dPDC**	**LRFEE**
β-coefficient	1.598	-0.9777	-3.221	-0.05979	-1.835	0.7189	-0.04177
LR-test: $\chi^2(1)$	12.356	6.2484	14.253	1.7034	28.085	5.5267	0.24917
P-value	0.0004**	0.0124*	0.0002**	0.1918	0.0000**	0.0187*	0.6177

* 5% level of significance
** 1% level of significance

The test result in Table 5.5(a) shows that price of diesel (LRP_d), income per capita (LRIPC), gasoline using vehicle per gasoline consumption (LV_gPGC) and foreign exchange earnings (LRFEE) are not statistically significant in explaining gasoline consumption per capita (LGCPC) in the long-run. The other variables, namely, urbanization (LU) is statistically significant at 1% while price of gasoline (LRP_g) and population growth (LPG) are significant at 5% and the signs are as expected. More importantly, as shown in Table 5.5 (a), gasoline price is negatively related while diesel price (Cross price) is positive as expected. Similarly in table 5.5 (b), diesel price is negative while gasoline price (relative price) is positive and the signs are as expected. This implies that gasoline and diesel substitute each other in the long-run.

In the case of diesel demand, diesel price (LRP_d), income per capital (LRIPC) and urbanization (LU) are statistically significant at 1% while price of gasoline (LRP_g) and diesel using vehicle per diesel consumption (LV_dPDC) are statistically significant at 5% in explaining diesel consumption per capita (LDCPC) in the long-run. The signs are as expected except (LV_dPDC). Population growth (LPG) and real foreign exchange earnings (LRFEE) are statistically insignificant and as the expected signs.

After identifying the long-run relationship, we estimate the coefficient of the short-run dynamics using the Error Correction Model (ECM). Thus, the ECM is estimated by OLS and the result is summarized in Table 5.6

Table 5.6 Modelling ΔLGCPC and ΔLDCPC by OLS

(a) Gasoline Demand					
Variable	**Coefficient**	**S.E**	**t-value**	**t-prob**	**Partial R^2**
Constant	-0.033244	0.059549	-0.558	0.5826	0.0146
ΔLRP_g	-0.82854	0.24371	-3.40	0.0027	0.3550
ΔLRP_d	0.48647	0.27131	1.793	0.0874	0.1328
ΔRIPC	0.32232	0.61627	0.523	0.6064	0.0129
ΔLPG	0.07328	0.027269	2.687	0.0138	0.2559
ΔLU	1.3357	0.96690	1.381	0.1817	0.0833
$\Delta LRFEE_{-2}$	0.093749	0.058373	1.606	0.1232	0.1094
ΔLV_gPGC_{-1}	-0.72348	0.25159	-2.876	0.0090	0.2825
D_1 *	0.0023047	0.053385	0.043	0.9660	0.0001
D_2 *	0.054053	0.064643	0.836	0.4125	0.0322
ECM_{-1}	-0.91720	0.32963	-2.783	0.0112	0.2694
R^2 = 0.612164, F(10,21) = 3.3147 [0.0099], DW = 2.03, RSS = 0.29 AR 1-2F (2,19) = 0.22046 [0.8042], ARCH 1F (1,19) = 0.10252 [0.7523] Normality $\chi 2$ (2) = 16.208 [0.0003] **, RESET F(1,20) = 1.0748 [0.3122]					
(b) Diesel Demand					
Constant	-0.039487	0.045575	-0.866	0.3965	0.0362
ΔLRP_{g-1}	0.04610	0.12998	0.355	0.7265	0.0063
ΔLRP_d	-0.26727	0.13410	-1.993	0.0601	0.1657
ΔRIPC	0.82219	0.43337	1.897	0.0723	0.1525
ΔLPG_{-1}	0.019584	0.015060	1.30	0.2082	0.0780
ΔLU_{-1}	0.92921	0.72283	1.286	0.2133	0.0763
$\Delta LRFEE_{-1}$	0.034850	0.032831	1.061	0.3011	0.0533
ΔLV_dPDC_{-3}	0.28070	0.15392	1.824	0.0832	0.1426
D_1 *	0.0047792	0.041273	0.116	0.9090	0.0007
D_2 *	0.021748	0.047861	0.454	0.6544	0.0102
ECM_{-1}	-0.90756	0.31468	-2.884	0.0092	0.2937

R^2 = 0.623152, F(11,20) = 3.0065 [0.0157], DW = 1.96, RSS = 0.14
AR 1-1F(2,18) = 0.70875 [0.5055], ARCH 1F (1,18) = 0.11401 [0.7395]
Normality $\chi 2$ (2) = 6.097 [0.0474]*, RESET F(1,19) = 3.465 [0.0782]

*D_1 and D_2 represent dummy variables for policy regime and structural breaks, respectively.

From Table 5.6, some variables are significant while some are insignificant. Hence, following Hendry from general to specific model setting the insignificant variables to zero, the following final result were obtained for both gasoline and diesel demand. The final gasoline demand result is:

$$\Delta LGCPC_t = \underset{(0.974)}{0.02} - \underset{(-2.794)}{0.53}\,(\Delta LRP_g)_t + \underset{(1.876)}{0.95}\,(\Delta RIPC)_t - \underset{(-3.512)}{0.84}\,(\Delta LV_gPGC)_{t-1} - \underset{(-3.117)}{0.96}\,(ECM)_{t-1} \quad (5.3)$$

R^2= 0.43, F (4,28) = 5.3043 [0.0026], DW = 2.11, RSS = 0.43, AR 1-2F(2,26) = 0.39459 [0.6779]
ARCH 1F (1,26) = 0.54374 [0.4675], Normality $\chi 2$ (2)= 6.1804 [0.0514], $\chi 2$ F (8,19) =0.7607 [0.6403], RESET F (1,27) = 3.8494 [0.0601]

Similarly the final diesel demand result is:

$$\Delta LDCPC_t = \underset{(-0.122)}{-0.0018} - \underset{(-1.862)}{0.22}\,(\Delta LRP_d)_t + \underset{(2.295)}{0.80}\,(\Delta RIPC)_t + \underset{(1.671)}{0.23}\,(\Delta LV_dPDC)_{t-3} - \underset{(-3.208)}{0.93}\,(ECM)_{t-1} \quad (5.4)$$

R^2= 0.53, F (5,26) = 5.9199 [0.0009], DW = 2.10, RSS = 0.18, AR 1-1F(1,25) = 0.2872 [0.5968]
ARCH 1F (1,24) = 0.91284 [0.3489], Normality $\chi 2$ (2)= 3.8865 [0.1432], $\chi 2$ F (10,15) =0.77127 [0.6545], RESET F (1,25) = 1.3753 [0.2520]

In the above short-run dynamics estimation the necessary diagnostic tests are conducted. For both equations, there is no problem of higher order serial correlation (Breush-pagan test) up to one lag, the auto-regressive conditional heterascedastic test, the test for normality based on skiwness and kurtosis, the specification (heteroscedasticity) test and the Ramsey's RESET test of functional form. In other word the test results in both model suggest that the residual can generally be considered to be Guassian. Similarly the coefficient of the error correction term of both models are significant with the expected negative sign and it shows that the speed of adjustment of gasoline/diesel demand to its dis-equilibrium level is (are) about 96% and 93%, respectively.

From short-run gasoline demand result of Equation (5.3), real price of gasoline (ΔLRP_g) is significant at 5%, the first lag of gasoline using vehicle (ΔLV_gPGC) is significant at 1% level and finally real income per capita ($\Delta RIPC$) is significant at 10% level. The signs are as expected except gasoline using vehicle (ΔLV_gPGC). One of the possible causes may be that, if other factors remain constant, while the price of gasoline rises, it will be costly to continue consuming it. Therefore, to maximize utility, individuals may be prefer diesel using vehicles than gasoline using vehicles. In terms of elasticity, their short-run price and income elasticities are –0.53 and 0.95, respectively. These result (price and income in the short-run) are consistent with empirical results of Dahl and Sterner (1990), Rogat and Sterner (1997), Berndt an Botero (1985), Charemza and Deadman (1992), etc. that demand for gasoline is price inelastic while elastic for income.

In the case of diesel demand result of Equation (5.4), real price of gasoline (ΔLRP_d) and the third lag of diesel using vehicle (ΔLV_dPDC_{-3}) are significant at 10% level and real income per capita ($\Delta RIPC$) is significant at 5% level with the expected signs. Their short-run price and income elasticities are –0.22 and 0.80, respectively. When we compare with the empirical result of Kimuyu P.K (1996) for diesel demand in Kenya, diesel price is inelastic while income is marginally elastic in Ethiopia and it is consistent with the result of Kimuyu. The result of diesel using vehicle (LV_dPDC_{-3}) strengthened the theory of Dahl and Sterner (1991) that diesel demand is not only affected by current period but also past time. As a result the change in (LV_dPDC_{-3}) before three years has a positive effect on the change in current diesel consumption per capita (LDCPC). However, the coefficient of (LV_dPDC_{-3}) is low and this confirms the fact that low-income countries (hence Ethiopia) have fewer vehicles and hence there is less spare capacity in the vehicle utilization.

CHAPTER SIX

CONCLUSIONS AND POLICY IMPLICATIONS

6.1 Conclusions

Ethiopia's energy consumption is predominantly based on biomass energy sources. An overwhelming proportion (94%) of the country energy demand is met by traditional energy source such as fuel wood, charcoal, dung and agricultural residues. The balance is met by commercial energy sources such as electricity and petroleum. The major consumer of energy in Ethiopia is the household followed by industry and transport sector. With an exception of hydro-electric power, the country petroleum products' requirements is mainly depends on imports. The consumption of petroleum is mainly driven by demand within the transport sector which accounts above 50% of the total fuel consumption. Therefore, both gasoline and diesel fuel are important inputs for the transport sector.

The study used gasoline and diesel demand models synthesized from other models, such as Dahl and Sterner (1991), Rogat and Sterner (1997) and Franzen and Sterner (1995). Therefore, gasoline consumption per capita as the function of real price of gasoline (own price), real price of diesel, real income per capita, population growth, urbanization, number of gasoline using vehicles and real foreign exchange earnings. Similar definition has been adopted for diesel consumption per capita except it included number of diesel using vehicles instead of gasoline using vehicles.

The estimation procedure was accomplished by resorting time series econometric techniques and appropriate yearly data from different sources that cover the period from 1964/65 to

1999/2000 are used in the analysis. The order of integration of individual variables has been determined employing the commonly used DF and ADF tests. In most cases, the variables entering the regression are found to be integrated of order one [I(1)]. In determining the long-run behaviors of the variables, the Johansen multivariate co-integration test was employed as it has possesses a unique advantage over the residual-based two step Engle-Granger approach.

Applying the Johansen procedure to gasoline and diesel demand functions, the λ_{max} statistics of the likelihood ratio test supported the existence of one co-integrating relationship among the variables (since λ_{max} has more powerful test than λ_{trace}) in the regression. More importantly, using both Reimers adjusted λ_{trace} and λ_{max} statistics, we could not reject the null of no co-integration. Besides, the Parsimonious Error Correction Model (PECM) is formulated from the long-run model using the general to specific modeling approach of David Hendry.

The result shows that price of gasoline (own price), population growth and urbanization determine gasoline demand in the long-run with expected signs while price of diesel (cross price), real income per capita, gasoline using vehicles and real foreign exchange earnings have insignificant implication in determine long-run relationship. As to the coefficient of the short-run dynamics, real income per capita and gasoline using vehicles are marginally significant while price of gasoline is not significant. This implies that, in the short-run, pricing policy is useful to analyse gasoline demand.

For diesel demand, price of diesel (own price), gasoline price (cross price), real income per capita, urbanization and diesel using vehicles are significantly explained in the long-run while population growth and real foreign exchange are do not explained. The short-run coefficient of income is marginally significant while the coefficient of diesel price and diesel using vehicles are insignificant. However, the signs are as expected and this is consistent with the theory that income elasticities of the low-income countries were larger than the middle income countries while price elasticities of the low-income countries were smaller (in absolute value) than the middle income countries. The short-run result also consistent with Dunkerley (1987), Arima (1994), etc., which stated that income elasticity of energy demand tends to be elastic, where as price elasticities are insignificantly different from zero and inelastic.

Therefore, it is conclude that diesel is a substitute to gasoline in the long-run and has no effect on both demand in the short-run.

6.2 Policy Implications

Proper evaluation of transportation fuel policy requires good estimates of demand elasticities. Therefore, from the results of the study, the following policy implications can be derived. In the short-run the coefficient of gasoline and diesel price are inelastic while real income is marginally elastic for both model. The inelastic gasoline and diesel price elasticities suggests that gasoline and diesel prices are tightly controlled and fixed by the government and hence the quantity of gasoline and diesel demand is far less responsive to price changes, while income is marginally elastic suggesting that gasoline and diesel demand continue growing as income of the society increases.

The fact that the absolute value of income elasticities are higher than that for prices indicates that gasoline and diesel prices must rise faster than the rate of income growth if gasoline and diesel demand is to be stabilized at present levels. Contrary to this the general observation at present is that the price of gasoline and diesel are generally rising over time in accordance with the world oil market structure, and the government uses cross subsidization as a deliberate means to influence the pattern of energy demand (facilitate the supply and distribution of petroleum products) and stimulate production in different sectors of the economy.

The other implications of the results in this paper is that since the price of energy including gasoline and diesel is growing and has changed seven times (Starting October 1992 to July 2000), its demand is still growing. For instance the result of equation (5.4) shows that, a 1% increase in the real price of diesel causes about only 0.2% decrease in its demand in the short-run. This implies that the rise in gasoline or diesel price has less impact on gasoline and diesel demand.

Lastly, increasing the energy efficiency of vehicles may be the most effective method of controlling energy consumption growth in the transport sector. Hence, government policies which aimed at affecting transport energy consumption should consists of training programs, energy pricing (taxes and subsidies), transport fees, and regulations. It is important that these policies are coordinated so that consistent signals are given.

B I B L I O G R A P H Y

Adegbulugbe, A.O and Dayo F.B (1986), "Demand analysis of gasoline consumption in Nigeria", ***OPEC Review***, 10 No.2, pp. 131-41.

Adenikinju A.F (1994), "Energy - pricing policy and the environment in an oil-exporting, developing country", ***OPEC Review***, pp. 307-308.

Akiyama, T. and Ishiguro, M (1995), "Energy Demand in five major Asian Developing Countries", ***World Bank Discussion paper*** no. 277, World Bank, Washington, D.C.

Archibald, Robert and Gillingham, Robert (1978), "Consumer Demand for Gasoline : Evidence from Household Diary Data," college of William and Mary and Bureau of labor statistics (mimeo).

___________________ (1980), "An analysis of the short-run consumer Demand for Gasoline using Household Survey Data", ***Review of Economics and Statistics*** 62 (November), pp.622-628.

Arimah B.C (1994), "Energy consumption and Economic growth in Africa: a cross-national analysis" an energy and development forum, ***OPEC Review***, Vol. 18 No. 2 pp.207.

Asmerom Kidane (1991), "Demand for energy in rural and urban centers of Ethiopia: An Econometrics Analysis", ***Energy Economics*** (13) April, pp. 130-134.

Bacon, R. (1992), "Measuring the possibility of Inter-Fuel substitution" ***World Bank Policy and Research working papers,*** World Bank, Country Economics Department.

Balabanoff, S. (1994), "The dynamic of energy demand in Latin America", ***OPEC Review***, Vol. 18, No.4.

Baltagi, Badi H. and Griffin, James M. (1983), "Gasoline Demand in the OECD: An application of pooling and Testing procedures" ***European Economic Review*** 22(2) pp.117-137.

___________________ (1984), "U.S. Gasoline Demand : what Next?" ***The Energy Journal*** 5(1) pp.129-140.

Baranes, C. et.al (1984), "Wood, Energy and Households", The Beijer Institute, Stockholm, Sweden.

Bernat, Ernst R. and Botero, German (1985), "Energy Demand in the Transportation sector of Mexico," ***Journal of Development Economics***, 17, pp. 219-238.

CESEN Ansaldo/Finmeccaic Group (1986), co-ooperation agreement in Energy Sector, main Report.

Charemza, W.W. and Deadman, D.F. (1997), "New directions in Econometric Practice" Edward Elgar publishers, England.

Croose. H. W, Aglin L. D (1985), "Automotive mechanics" New Delhi 9thed. pp. 135

Cuthbertson, Keith, et al (1992), ***Applied Econometric Techniques***, wheatsheaf.

Dahl, Carol A.(1978), "American Energy consumption Extravagant or Economical: A case study of Gasoline Demand", ***Resources and Energy*** 1, pp. 359-373.

Dahl, Carol A. and Sterner, Thomas (1990), "The Pricing of and Demand for Gasoline. A survey of models" Memorandum 132, School of Ecnomics and legal science, Gothenburg University, February.

____________________ (1991), "A survey of Econometrics Gasoline demand Elasticities", ***International Journal of Energy Systems***, Vol. 11, No. 2

David K.W (1998), "Demand for motor sprits in Kenya: An Econometric analysis", A research paper, University of Nairobi.

Dhliwayo, Rogers (1996), The Balance of Payments as a monetary phenomenon: An Economic Study of Zimbabwe is Experience, AERC Reseach Paper 46.

Drollas, L.P. (1984), "The Demand for Gasoline: Further Evidence," ***Energy Economics*** 6(1) January, pp. 71-82.

Dunkerley.J, & Hoch.I (1987), "Energy for transport in developing countries, ***The EnergyJournal***, 8.3

Durkerley. J. and Hock (1985), "Transport Energy Determinants and Policy" ***Resources for the Future***, Washington D.C.

Ebohon, O.J. (1996) "Energy, Economic growth and causality in developing countries", ***Energy policy***, Vol. 24, No. 5

Enders, walter (1995), ***Applied Econometric Time Series***, John wiley and sons, New York.

Energy Sector Management Assistance Program (ESMAP) (1996), report no. 179/96, World Bank, Washington, D.C.

Engle, Robert F., and C.W.J Granger (1987), “Co-integration and Error Correction: Representation, Estimation and Testing,” Econometrica Vol. 55, pp. 251-76.

________________, Hendry, David F., Richard, Jean-Francios (1983), "Exogeneity", Econometrica, pp. 227-304, Reprinted in Ericsson, Neil R. and Irons John S.(eds.), ***Testing Exogeneity***: Advanced Texts in Econometrics, oxford university press.

Ephrem Assey .D (1997), "Gasoline Demand and the Environment in Tanzania - A case study of Dare-Es-Selam" Dissertation, Economics Department, University of Nairobi.

Ethiopian Petroleum Enterprise (1999), Evaluation of Petroleum Energy Subsector, Vol. 1 and 2, A.A.

____________________ (2000), various data, A.A.

Ethiopian Economic Association (EEA) (1999/2000), Annual report on the Ethiopian Economy, Vol.2

Faiz. A, Weaver. C.S, Walgn. M.P (1996), "Air pollution from motor vehicles" Standards and Technologies for controlling Emission, The World Bank, Washington, D.C.

Franz'en M. and Sterner, T. (1995), "Long-run Demand Elasticities for Gasoline" ***Global Warming and Energy Demand*** ed, T.Barker P.Ekins and N.Johnston, Routledge, London.

Gallini, Nancy T. (1983), "Demand for Gasoline in Canada," ***Canadian Journal of Economics*** XVI(2) May, pp. 299-324.

Gately, D. and Streifel, S.S (1997), "The Demand for oil products in Developing countries" World Bank Discussion paper no. 359.

Hansen, Hanrik and Johanson, Soren (1999), "Some tests for parameter consistency in cointegrated VAR model," ***Econometrics Journal*** Vol. 2, pp. 306-333.

Harris R. (1995), “Co-integration Analysis in Econometric Modelling”, University of Portsmouth, London.

Hendry, David F. (1988), "The Encompassing Implications of Feedback versus Feed forward mechanisms in Econometrics ", ***Oxford Economic papers***, pp.132-149, Reprinted in Ericsson, Neil R. and Irons, Johns. (eds.) Ibid.

______________ (1995), “ Dynamic Econometrics”, Advanced Texts in Econometrics, Oxford University Press Inc., New York.

_______________ and Doornik J.A (1994), PcFiml 8.0 Interactive Econometric modeling of Dynamic Systems, Institute of Economics and Statistics, University of Oxford.

Hosier, R. et al., (1993), “Urban Energy and Environment in Africa”, Energy policy, Butteworth – Heineman, Vol. 21 No. 5 May 1993.

IRG and ARD (1998), Ethiopian Petroleum product pricing and Marketing study Report, A.A.

Johansen, soren, and K. Juselius (1990), “Maximum Likelihood Estimation and Inference on Co-integration with Applications to the Demand for Money”, Oxford Bulletin of Economics and Statistics, Vol. 52.

Johansen, soren (1992), "Testing weak Exogeneity and the order of co-integration," ***Journal of policy modeling***, pp.313-334, Reprinted in Ericsson and Irons (1994) (eds.), Ibid.

________________ (1995), ***Likelihood - Based Inference in cointegrated Vector Autoregressive models***, Oxford University Press, New York.

Kimuyu, P.K. (1988), "Demand for Commercial Energy in Kenya : A Structural Investigation" P.hD Dissertation, Economics Department, University of Nairobi.

________________ (1996), "Demand for Gas oil in Kenya, A Time series Analysis", IPAR, Nairobi, Kenya.

________________ (1993), "Urbanization and Consumption of Petroleum Products in Kenya" ***Energy policy***, Vol. 21, No. 4

Kooris, George (1983), "Fuel consumption for Road Transport in the USA" ***Energy Economics*** (April), pp.89-99.

L.Totto and T. Johnson (1983), "OPEC domestic oil demand: product forecasts for 1985 and 1990". ***OPEC Review***, Vol. 7 No.2

Leybourne, Stephan J. and Newbold, paul (1999), "The Behaviour of Dickey-Fuller and Phillips - person tests under Alternative hypothesis," ***Econometrics Journal***, Vol. 2, pp. 92-106.

Maddala, G.S. (1992), "Introduction to Econometrics", Macmillan, New York.

Mashi, Rumi and Masih, Abul M.M (2000), " A Reassessment of Long-run Elasticities of Japanse Import Demand," ***Journal of Policy Modeling***, 22(5) pp. 625-639, Elsevier Science Inc. North Holland.

MOFED (1999), "Survey of The Ethiopian Economy" June, Addis Ababa Ethiopia.

______________(2000), "Energy" Addis Ababa, Ethiopia.

McRae, R. (1994) "Gasoline Demand in Developing Asian countries", ***Energy Journal***, 15:1 pp. 143-155.

Ministry of Water Resources, National Meteorological Services Agency (2001), Initial National Communication of Ethiopia to the United Nations framework convention on climate change (UNFCCC), Addis Ababa.

Ministry of Mines and Energy, Calub Gas Share Company (1997), Prospectus, Addis Ababa, Ethiopia.

Ministry of Mines and Energy (1999): Ethiopian energy studies and research center; LPG stoves, Development and market support study-report.

Mureithi, L.P, Kimuyu, P.K. and Ikiara, G.K 1982, "The effects of higher energy costs on balance of payments, employment, technology choice and real incomes in Kenya," ILO Report, Geneva.

Pesaran and Smith (1995), “Alternative approaches to estimating long-run energy demand lasticities. An application to Asian developing countries”. ed: T. Barker, P. Ekins and N. Johnstone, Routledge, London.

Pindyck R.S (1980), "The structure of world energy demand". M.I.T Press, Cambridge, mass. US.

Rogat .J and Sterner. T (1997), "The Determinants of Gasoline Demand in some Latin American countries" Studies in Environmental Economics and Development, Goteborg, Sweden.

Sterner Thomas (1991), "Gasoline Demand in the OECD: Choise of model and Data Set in pooled Estimations" ***OPEC Review***, No. 155, Gothenburg.

Thomas, RL (1993), “Introductory Econometrics: Theory and Applications, 2nd ed, London and New York.

____________ (1997), "Modern Econometrics, An Introduction", Department of Econometrics, Manchester Metropolitan University.

United State Energy Information Administration (1999), international Energy.

Wohlgemuth, N (1997), "World transport energy demand modeling, Methodology and elasticities", ***Energy policy***, Vol. 25, No. 14-15.

World Bank (1980), "Energy in the Developing Countries", August, Washington D.C, USA.

World Bank (1999), "Energy Market & Reform", Seminar note, no.1

World Bank (2000), Fuel for thought: An environmental strategy for the energy sector, USA.

World Bank (2001), Human Development Report, Washington, D.C.

________________ (2002), World Development Indicators, Washington DC. USA.

Appendix 1: ETHIOPIAN ENERGY BALANCE: 1988 EFY (1995/96 GC) (Terajoules)

	PRIMARY ENERGY										SECONDARY ENERGY													
Heating Valves	14.50	15.50	14.50	10.00	13.80	4.235	42.558	18.90	14.50	29.00	3.60	46.00	45.26	32.10	31.00	34.60	35.30	36.30	38.60	Biomass	petrol	lubes	
Fuel	Woody	Crop	Process	Bagassa	Dung	Hydro	Crude	Bio-	Bri-	Char-	Elec-	Refry	LPG	Gaso-	Avgas	Jet	Kero-	Diesel	Fuel	sub-	Sub-	Asphalt	
	Biomass	Residue	Rasid.				oil	gas	quatte	coal	tricity	Gas		line		Fuel	sene	oil	oil	sub total	total	&	TOTAL
	MJ/KG	MJ/KG	MJ/KG	MJ/KG	MJ/KG	MJ/KWH	MJ/KG	MJ/CM	MJ/KG	MJ/KG	MJ/KWH	MJ/KG	MJ/KG	MJ/LT	MJ/LT	MJ/LT	MJ/LT	MJ/LT	MJ/LT	Fuels	Fuels		
GROSS SUPPLY	644,037.44	222,864.44	3,196.33	4,577.49	425,242.02	6,384.52	27,793.35	0.00	0.00	0.00	0.00		8.55	2,419.73	5,953.95	0.00	0.00	12,213.06	0.00	1,299,917.48	48,388.65	0.00	1,382,484.00
Production	644,037.44	222,864.44	3,196.33	4,577.49	425,242.02	6,384.52														1,299,917.48	0.00		1,306,302.00
Imports							27,796.35						8.55	2,419.73	5,953.95			12,213.06		0.00	48,388.65		76,182.01
Stock Changes																				0.00	0.00		0.00
INPUTS TO CONVERSION	29,494.93	9.85	9.85	0.00	3.95	6,384.52	27,796.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	686.08	0.00	29,518.58	28,479.43	0.00	97,804.17
Petroleum Refining							27,796.35										0.00			0.00	27,793.35		55,586.71
Charcoal Production	29,494.93																			29,494.93	0.00		29,494.93
Electricity Gen. (EELPA)						6,384.52												464.85		0.00	464.85		12,276.21
Electricity Gen.(Non-EELPA)						0.00												221.22		0.00	221.22		422.68
Biogas					3.95															3.95	0.00		3.95
Briquette		9.85	9.85																	19.7	0.00		19.7
OUTPUTS FROM CONVERSION	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.13	18.72	6,783.83	5,628.29	0.00	260.15	2,646.42	0.00	0.00	1,589.52	6,737.82	11,068.63	6,803.68	22,302.55	0.00	34,734.52
Refinary Fuel													260.15	2,646.42	0.00	0.00	1,589.52	6,737.82	11,068.63	0.00	0.00		22,302.55
Thermal											201.46									0.00	0.00		201.46
Hydro											5,426.84									0.00	5,975.42		5,426.84
LOSSES FROM CONVERSION	22,711.09	0.49	0.49		2.82	957.68	5,491.00											484.62		22,714.90	0.00		35,138.80
TRANSMISSION & DIST. LOSS											1,021.69									0.00	0.00		1,021.69
TRANSFER																				0.00	0.00		0.00
EXPORTS																				0.00	0.00		0.00
FERTILIZER		58,338.49			314,284.63															372,623.13	0.00		372,623.13
OTHER AND NON-ENERGY USES	59,829.95	109,156.46	3,186.48	0.00	49,008.20	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00	221,181.10	0.00	0.00	221,181.10
Cattle Reed		82,307.02																		82,307.02	0.00		82,307.02
Construction	59,829.95	26,849.44			49,008.20															135,687.60	0.00		135,687.60
Other			3,186.48																	3,186.48			3,186.48
NET ENERGY SUPPLY	554,712.32	55,359.63	0.00	4,577.49	61,194,523.00	0.00	0.00	1.13	18.72	6,783.83	4,606.61	0.00	268.71	5,066.15	5,953.95	0.00	1,589.52	18,264.81	11,068.63	683,398.36	36,236.35	0.00	724,241.31
Statistical Difference*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	56.53	-852.38	5,947.88	-1,864.49	-5,460.45	2,231.69	7,288.18	0.00	1,371.53	0.00	1,371.53
FINAL ENERGY CONSUMPTION	554,712.32	55,359.63	0.00	4,577.49	61,945.23	0.00	0.00	1.13	18.72	6,783.83	4606.61	0.00	212.18	5,918.53	6.08	1864.49	7,049.97	16,033.12	3,780.45	683,398.36	34,864.82	0.00	722,869.79
Household	516,918.60	52,911.08	0.00	0.00	59,291.53			1.13	0.00	6,571.85	2,020.44	0.00	166.59	0.00	0.00	0.00	6,579.13	288.70	0.00	635,694.19	7,034.43	0.00	644,749.06
Urban	23,576.90	2,872.59			3,589.85			0.23		3,969.55	2,020.44		166.59				6,250.17	118.37		34,009.12	6,535.14		42,564.70
Rural	493,341.70	50,038.49			55,701.68					2,602.30			0.00				328.96	170.33		601,685.07	499.29		602,184.36
Agriculture	0.00	0.00	0.00	0.00	0.00				0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.04	816.28	0.00	0.00	816.44		816.44
Transport	0.00	0.00	0.00	0.00	0.00				0.00	0.00	0.00	0.00	0.00	5,918.53		1,637.48	0.00	10,356.78	0.00	0.00	17,918.03	0.00	17,918.03
Road														5,918.53				10,260.59		0.00	16,179.12		16,179.12
Rail																		96.20		0.00	96.20		96.2
Air															5.24	1,637.48				0.00	1,642.72		1,642.72
Marine																			0.00	0.00	0.00		0.00
Industry	16,432.44	1,415.06	0.00	4,577.49	1,517.81			0.00	0.00	108.78	1,975.72	0.00	37.34	0.00	0.00	0.00	91.69	3,396.22	3,766.63	24,051.58	7,291.88	0.00	33,319.19
Large and Medium	992.58			4,577.49							1,963.86		35.66		0.00	0.00	68.48	516.19	3,735.71	5,570.18	4,356.03		11,890.06
Small	192.58										2.12		1.68				4.22	2.03		192.58	7.94		202.64
Cottage	15,247.17	1,415.17	1,415.06		1,517.81					108.78	9.75						12.46	7.78		18,288.82	20.24		18,318.81
Mining																0.00	0.00	155.07	28.87	0.00	183.95		183.95
Construction															0.00		6.53	1,962.05	2.05	0.00	1,970.63		1,970.63
Grain Mills																		753.1		0.00	753.10		753.1
Services and Other	21,361.29	1,033.49	0.00	0.00	1,135.89			0.00	18.72	103.21	610.44	0.00	8.12	0.00	0.84	227.01	379.12	1,175.14	13.82	23,652.59	1,271.94	0.00	26,067.07
Government											3.68		0.54		0.59	226.60	11.26	1,026.86	6.1	0.00	336.67		1,275.63
Commercial	21,361.29	1,033.49			1,135.89				18.72	103.21	580.44		7.08				329.59			23,552.59	195.42		24,569.70
Other											26.32		0.49		0.25	0.42	38.27	148.29	7.72	0.00			221.74

Source: Ethiopian Rural Energy Promotion Center

Appendix 2 - Growth Rates of GDP and Value Added in the various sectors (1960/61-1999/2000)

Year	Growth Rate of Real GDP	Agriculture		Industry		Distributive Service		Other Service		Growth Rate of per Capita Income
		As% of GDP	Growth Rate	As% of GDP	Growth Rate	As% of GDP	Growth Rate	As% of GDP	Growth Rate	
1960/61	-	75.8	-	7.0	-	8.4	-	8.8	-	-
1961/62	3.7	74.3	1.8	7.4	9.6	8.9	9.8	9.4	10.4	1.5
1962/63	3.8	73.7	2.9	7.6	6.4	9.2	7.3	9.5	5.3	1.6
1963/64	4.3	72.3	2.3	8.0	10.6	10.0	13.9	9.6	5.8	2.1
1964/65	6.3	70.6	3.7	8.3	10.3	10.9	15.3	10.2	12.7	4.0
1965/66	3.3	68.9	0.8	9.1	12.8	11.4	8.4	10.6	7.5	1.0
1966/67	4.1	68.4	3.4	9.7	11.1	11.1	0.7	10.8	6.0	1.7
1967/68	3.3	66.9	1.1	9.9	5.5	12	11.9	11.2	7.1	1.0
1968/69	3.7	66.0	2.2	10.1	5.7	12.4	7.4	11.6	6.7	1.3
1969/70	3.4	65.3	2.4	9.9	1.9	13.0	8.6	11.8	5.2	1.1
1970/71	3.7	64.2	2	10.4	9.1	13.4	6.3	12.0	5.8	1.5
1971/72	3.1	63.3	1.6	10.6	4.4	13.7	5.5	12.5	7.7	0.8
1972/73	2.7	62.5	1.4	10.6	3.1	13.9	4.1	13.1	7.3	0.4
1973/74	2.2	61.7	1.0	10.3	-0.3	14.3	5.4	13.6	6.7	-0.3
Average	**3.7**	**68.1**	**2.0**	**9.2**	**6.9**	**11.6**	**8.0**	**11.1**	**7.2**	**1.4**
1974/75	1.1	61.3	0.5	10.1	-1.6	14.1	-0.4	14.5	7.6	-1.0
1975/76	0.7	61.4	0.8	9.4	-6.2	14.0	0.3	15.2	5.3	-1.7
1976/77	1.0	61.0	0.4	9.5	2.9	13.8	-0.6	15.6	3.9	-1.6
1977/78	-0.6	61.6	0.3	9.3	-3.1	12.5	-9.8	16.6	5.6	-3.1
1978/79	4.8	59.3	0.9	10.2	14.5	13.5	13.2	17.0	7.5	2.2
1979/80	4.8	59.2	4.6	10.6	9.7	13.6	5.4	16.6	2.3	2.1
1980/81	0.6	58.1	-1.2	10.9	3.4	14.0	3.3	17.0	3.2	0.6
1981/82	0.5	55.7	-3.6	11.8	8.5	14.5	4.4	18.0	6.3	0.3
1982/83	10.1	57.5	13.6	11.3	5.9	13.5	2.8	17.6	7.8	6.9
1983/84	-6.3	53.7	-12.5	12.8	6.0	14.5	0.3	19.0	1.1	-9.0
1984/85	-9.7	47.0	-20.9	14.8	4.3	16.2	0.9	22.0	4.4	-12.5
1985/86	9.9	49.6	16.0	14.4	6.6	15.2	3.5	20.8	3.8	6.4
1986/87	14.0	51.7	18.8	13.6	8.0	15.4	15.1	19.3	6.2	10.4
1987/88	-0.1	50.3	-2.8	13.1	-3.8	15.9	3.4	20.7	7.1	-3.0
1988/89	0.3	50.6	1.0	12.2	-6.7	15.0	-5.5	22.2	7.5	-2.7
1989/90	4.1	51.2	5.3	11.1	-4.7	15.0	4.4	22.6	5.8	0.9
1990/91	-3.6	56.0	5.2	9.4	-19.1	12.0	-23.5	22.8	-2.7	-6.6
Average	**1.9**	**55.6**	**1.6**	**11.4**	**1.4**	**14.3**	**1.0**	**18.7**	**4.9**	**-0.7**
1991/92	-3.7	56.5	-2.7	9.0	-7.1	12.1	-2.5	22.4	-5.2	-6.7
1992/93	12.0	53.5	6.1	10.4	28.4	13.2	22.2	23.0	14.8	8.5
1993/94	1.7	50.7	-3.7	10.9	7.0	13.8	6.2	24.7	9.2	-0.4
1994/95	5.4	49.7	3.4	11.2	8.1	13.9	6.4	25.2	7.7	3.1
1995/96	10.6	51.5	14.7	10.6	5.4	13.7	9.0	24.1	5.9	7.2
1996/97	5.2	50.7	3.4	10.8	7.0	14.0	7.7	24.5	6.7	2.0
1997/98	-1.2	45.7	-10.8	11.2	2.3	15.0	5.6	28.1	13.3	-4.1
1998/99	6.3	44.7	3.8	11.7	11.4	14.6	3.5	29.0	9.8	3.2
1999/00	5.3	43.2	1.9	11.5	3.0	14.9	7.5	30.4	10.4	2.3
Average	**4.6***	**49.6**	**1.8**	**10.8**	**7.3**	**13.9**	**7.3**	**25.7**	**8.1**	**1.7***

Source: **NBE**

* The average growth rate of real GDP for the year 1992/93-99/00 (i.e excluding the year 1991/92 which was a year of political instability) is 5.7% and the corresponding per capita GDP growth rate is about 2.7%

Appendix 3

Consumption of Petroleum Products by Product type (In mc)

Year	Gasoline price	Gasoline	% Share	Diesel price	Diesel	% Share	Kerosene	%Share	Inland fuel oil	% Share	Jet fuel	% Share	Lpg	% Share	others*	% Share	Total
1964/65	0.42	76700	0.17	0.39	195900	0.45	6000	0.01	94500	0.22	62600	0.14	2600	0.006	0	0	438300
1965/66	0.42	83300	0.18	0.39	212800	0.45	6800	0.01	100800	0.21	67700	0.14	2900	0.006	0	0	474300
1966/67	0.42	77000	0.17	0.39	205800	0.46	4500	0.01	99100	0.22	58400	0.13	2900	0.006	0	0	447700
1967/68	0.42	70000	0.18	0.39	176100	0.46	4800	0.01	73000	0.19	48200	0.12	2800	0.007	11617	0.0301	386517
1968/69	0.42	70700	0.18	0.39	178800	0.45	6100	0.02	78700	0.20	49800	0.12	2700	0.007	13114	0.0328	399914
1969/70	0.42	74700	0.19	0.39	186600	0.46	7800	0.02	64600	0.16	54800	0.14	3000	0.007	12072	0.0299	403572
1970/71	0.42	93500	0.20	0.39	212700	0.46	2200	0.00	56900	0.12	77500	0.17	3400	0.007	15449	0.0335	461649
1971/72	0.5	99100	0.19	0.42	248500	0.48	1900	0.00	70900	0.14	71300	0.14	4200	0.008	21613	0.0418	517513
1972/73	0.5	106700	0.19	0.42	270600	0.49	1800	0.00	80500	0.15	65800	0.12	4200	0.008	24273	0.0438	553873
1973/74	0.5	105700	0.19	0.42	268400	0.48	5400	0.01	96500	0.17	59300	0.11	4500	0.008	19350	0.0346	559150
1974/75	0.65	63948	0.14	0.44	205820	0.45	4464	0.01	99078	0.22	58393	0.13	2875	0.006	24527	0.0534	459105
1975/76	0.65	60466	0.16	0.44	176057	0.46	4836	0.01	73020	0.19	48232	0.13	2875	0.008	17520	0.0457	383006
1976/77	0.65	62695	0.16	0.44	178807	0.45	6102	0.02	78748	0.20	49792	0.13	2747	0.007	16328	0.0413	395219
1977/78	0.67	60386	0.15	0.45	186628	0.47	7789	0.02	64579	0.16	54814	0.14	2975	0.008	19039	0.0481	396210
1978/79	0.71	90189	0.20	0.45	212691	0.46	2183	0.00	56855	0.12	77485	0.17	3357	0.007	18843	0.0408	461603
1979/80	0.76	98313	0.19	0.53	248505	0.48	1916	0.00	70928	0.14	71267	0.14	4214	0.008	27700	0.0530	522843
1980/81	0.85	105344	0.19	0.79	270592	0.48	1849	0.00	80472	0.14	65839	0.12	4191	0.007	32851	0.0585	561138
1981/82	1.19	105626	0.19	0.79	268420	0.48	5589	0.01	96455	0.17	59302	0.11	4500	0.008	24113	0.0428	564005
1982/83	1.19	158000	0.21	0.79	352400	0.48	16000	0.02	97500	0.13	82400	0.11	9000	0.012	25461	0.0344	740761
1983/84	1.19	169200	0.21	0.79	374000	0.47	21000	0.03	95200	0.12	99300	0.13	10000	0.013	24854	0.0313	793554
1984/85	1.19	174000	0.19	0.79	392400	0.42	35800	0.04	110400	0.12	183300	0.20	9000	0.010	28861	0.0309	933761
1985/86	1.19	174640	0.19	0.79	394039	0.43	47092	0.05	112907	0.12	145969	0.16	9462	0.010	30307	0.0331	914416
1986/87	1.19	172491	0.18	0.79	436242	0.45	62980	0.07	122149	0.13	126354	0.13	11164	0.012	31700	0.0329	963080
1987/88	1.19	174164	0.18	0.79	449998	0.45	80440	0.08	119084	0.12	154219	0.16	10457	0.011	4392	0.0044	992754
1988/89	1.19	170408	0.16	0.79	472600	0.46	93266	0.09	132111	0.13	154341	0.15	11883	0.011	3094	0.0030	1037703
1989/90	1.5	162412	0.16	0.79	454834	0.46	98097	0.10	113328	0.11	144606	0.15	10563	0.011	1754	0.0018	985594
1990/91	1.5	124671	0.17	0.79	349175	0.47	38398	0.05	70194	0.09	151424	0.20	7324	0.010	5331	0.0071	746517
1991/92	1.5	130687	0.19	0.79	349647	0.52	71634	0.11	56246	0.08	61065	0.09	4562	0.007	100	0.0001	673941
1992/93	1.53	145930	0.18	0.82	396731	0.48	102979	0.13	80138	0.10	83910	0.10	8163	0.010	459	0.0006	818310
1993/94	1.85	152322	0.18	1.42	374391	0.45	136207	0.17	91961	0.11	59727	0.07	8831	0.011	307	0.0004	823746
1994/95	1.85	166812	0.18	1.42	414184	0.45	165263	0.18	106609	0.12	63504	0.07	9132	0.010	186	0.0002	925690
1995/96	2	184378	0.18	1.5	460584	0.46	199716	0.20	97739	0.10	53887	0.05	8227	0.008	196	0.0002	1004727
1996/97	2.49	182757	0.17	1.84	495141	0.47	213382	0.20	105746	0.10	54938	0.05	7950	0.007	247	0.0002	1060161
1997/98	2.51	180355	0.16	1.76	539998	0.49	209101	0.19	109204	0.10	62415	0.06	4558	0.004	297	0.0003	1105928
1998/99	2.51	181724	0.16	1.76	561309	0.50	196794	0.18	109148	0.10	71421	0.06	2054	0.002	0	0	1122450
1999/00	3.08	185368	0.15	1.98	631133	0.52	199671	0.17	117541	0.10	68252	0.06	2060	0.002	0	0	1204025

Source: EPE, 2001/2002 and own computation

* Includes Asphalt, AV gasoline and Lubricants

Appendix 4

Consumption of Petroleum Products by Sector (In mc)

Year	Industries	% Share	Transport	% Share	Construction	% Share	Agriculture	% Share	Defence	% Share	EELPA	% Share	Others*	% Share	Total
1985/86	93873	0.18	106256	0.20	46838	0.09	34139	0.06	124627	0.23	59185	0.11	66822	0.13	531740
1986/87	104522	0.19	114781	0.21	51713	0.09	39861	0.07	101985	0.19	66139	0.12	70321	0.13	549322
1987/88	105071	0.18	129549	0.22	53125	0.09	43059	0.07	131738	0.22	68469	0.12	62810	0.11	593821
1988/89	109133	0.18	140294	0.23	53201	0.09	41942	0.07	118162	0.20	69692	0.12	73277	0.12	605701
1989/90	101729	0.18	122867	0.22	51172	0.09	39255	0.07	122976	0.22	55409	0.10	73513	0.13	566921
1990/91	77777	0.18	126572	0.29	24462	0.06	23505	0.05	91183	0.21	20799	0.05	72133	0.17	436431
1991/92	70778	0.25	79866	0.28	18295	0.06	27291	0.10	18499	0.06	13662	0.05	58551	0.20	286942
1992/93	89546	0.25	106335	0.30	25182	0.07	26696	0.07	22070	0.06	25215	0.07	64117	0.18	359161
1993/94	102138	0.31	82039	0.25	32235	0.10	30029	0.09	18898	0.06	16054	0.05	43617	0.13	325010
1994/95	118175	0.34	80833	0.23	48149	0.14	29297	0.08	16889	0.05	15146	0.04	40415	0.12	348904
1995/96	115512	0.34	71076	0.21	58659	0.17	24239	0.07	19209	0.06	16288	0.05	30885	0.09	335868
1996/97	122922	0.35	72092	0.21	71982	0.21	25948	0.07	18516	0.05	19210	0.05	18934	0.05	349604
1997/98	119538	0.33	85479	0.24	70686	0.20	26325	0.07	22228	0.06	20132	0.06	17513	0.05	361901
1998/99	115563	0.29	87165	0.22	77468	0.19	25550	0.06	54778	0.14	17582	0.04	23476	0.06	401582
1999/00	117343	0.28	75899	0.18	91396	0.22	28604	0.07	28530	0.07	11054	0.03	60607	0.15	413433

Source: EPE, 2001/2002 and own computation

* includes mininig, water resource, ministrie, RRC and international organization

Appendix 5

Consumption of Petroleum Products by Region (In mc)

Year	Addis Ababa						North						South						East						West						Central						Total petrolum product				
	Gasoline	Diesel	Kerosene	Lpg	Total	% share	Gasoline	Diesel	Kerosene	Lpg	Total	% share	Gasoline	Diesel	Kerosene	Lpg	Total	% share	Gasoline	Diesel	Kerosene	Lpg	Total	% share	Gasoline	Diesel	Kerosene	Lpg	Total	% share	Gasoline	Diesel	Kerosene	Lpg	Total	% share	Gasoline	Diesel	Kerosene	Lpg	Grand Total
1985/86	58953	47103	15813	4034	125903	0.35	10086	27225	11097	287	48695	0.14	4623	6837	2603	-	14063	0.04	10828	54745	5723	421	71717	0.20	6774	19774	1215	-	27763	0.08	15855	46492	6808	-	69155	0.19	107119	202176	43259	4742	357296
1986/87	58102	50815	22895	4789	136601	0.35	11043	23587	12826	285	47741	0.12	4855	8044	3247	-	16146	0.04	10633	52847	7679	347	71506	0.19	7079	24984	1928	-	33991	0.09	16267	54315	9682	-	80264	0.21	107979	214592	58257	5421	386249
1987/88	58623	49778	27936	6301	142638	0.36	10957	22596	15199	196	48948	0.12	5106	9118	4697	76	18997	0.05	11277	53363	9182	251	74073	0.19	7616	26129	2171	53	35969	0.09	15361	52809	9832	306	78308	0.20	108940	213793	69017	7184	398934
1988/89	58113	53828	35878	9336	157155	0.36	10704	21741	17831	119	50395	0.12	4842	9561	6099	368	20870	0.05	13178	57149	14789	26	85142	0.20	7067	28524	2513	53	38157	0.09	14624	52282	12642	731	80279	0.19	108528	223085	89752	10633	431998
1989/90	62805	50439	40677	8501	162422	0.39	7049	14333	11794	198	33374	0.08	4744	12185	5869	19	22817	0.05	11688	60191	17503	377	89759	0.21	6132	26230	2790	14	35166	0.08	12795	46506	15095	768	75164	0.18	105213	209884	93728	9878	418703
1990/91	64399	52477	28303	6071	151250	0.50	722	3294	339	32	4387	0.01	3191	9698	852	212	13953	0.05	10997	53691	3829	11	68528	0.22	3717	16949	675	7	21348	0.07	7945	34317	3298	377	45937	0.15	90971	170426	37296	6710	305403
1991/92	77455	66973	41572	3844	189844	0.49	4973	33895	7247	83	46198	0.12	4042	11540	3715	2	19299	0.05	7305	33800	3992	25	45122	0.12	4426	16993	2000	-	23419	0.06	11213	41664	10135	104	63116	0.16	109414	204865	68661	4058	386998
1992/93	84048	64477	53855	6687	209067	0.46	5444	42684	7820	264	56212	0.12	4018	12141	6363	28	22550	0.05	10313	29845	10841	57	51056	0.11	5487	24038	3387	7	32919	0.07	14538	54038	18422	349	87346	0.19	123848	227222	100688	7391	459149
1993/94	89498	62652	61866	7804	221820	0.44	3680	20942	5625	-	30247	0.06	5210	14542	9902	25	29679	0.06	13375	33897	21489	71	68832	0.14	6585	29608	6527	7	42727	0.09	14855	61990	28353	230	105428	0.21	133203	223631	133762	8136	498732
1994/95	99427	71010	64367	7915	242719	0.42	4113	24638	7901	4	36656	0.06	7401	21117	12915	30	41463	0.07	14357	34683	27042	57	76139	0.13	7652	36816	10501	5	54974	0.10	15905	70747	37932	251	124835	0.22	148855	259011	160658	8262	576786
1995/96	110321	81386	78716	6604	277027	0.41	4945	32115	11258	-	48318	0.07	8881	27822	19550	37	56290	0.08	17507	40052	28597	48	86204	0.13	8696	40137	12175	-	61008	0.09	17810	76200	45891	110	140011	0.21	168160	297712	196187	6798	668857
1996/97	112339	92010	84045	6185	294579	0.41	5389	43389	15853	-	64631	0.09	8819	29634	19329	17	57799	0.08	14401	34994	30351	31	79777	0.11	9098	43139	15761	-	67998	0.10	17571	82581	45540	82	145774	0.21	167617	325747	210879	6315	710558
1997/98	110733	74789	100057	6934	292513	0.39	5118	16679	48793	-	70590	0.09	9631	21028	32902	22	63583	0.09	14576	30596	54996	36	100204	0.13	8745	17277	44799	-	70821	0.09	17962	47080	84340	68	149450	0.20	166765	207449	365887	7060	747161
1998/99	113082	123912	79473	1085	317552	0.44	5258	44228	12728	9	63223	0.09	8803	31713	16626	4	57146	0.08	13768	65604	24469	5	103846	0.14	7635	37588	11652	-	56875	0.08	17142	81409	31824	-	130375	0.18	165688	384454	176772	1103	728017
1999/00	114687	111217	75795	946	302645	0.38	6852	64791	15962	-	87605	0.11	11290	42778	20656	-	74724	0.09	13435	81862	27393	-	122690	0.15	8611	49163	15820	-	73594	0.09	17438	83709	36731	-	137878	0.17	172313	433520	192357	946	799136

Source: EPE, 2001/2002 and own computation

Appendix 6

Gasoline and Diesel Consumption by Region (In MC)

	Addis Ababa				North				South				East				West				Central				Total			
Year	Gasoline	Growth	Diesel	Growth	Gasoline	Growth	Diesel	Growth	Gasoline	Growth	Diesel	Growth	Gasoline	Growth	Diesel	Growth	Gasoline	Growth	Diesel	Growth	Gasoline	Growth	Diesel	Growth	Gasoline	Growth	Diesel	Growth
1985/86	58953		47103		10086		27225		4623		6837		10828		54745		6774		19774		15855		46492		107119		202176	
1986/87	58102	-0.014	50815	0.079	11043	0.095	23587	-0.134	4855	0.050	8044	0.177	10633	-0.018	52847	-0.035	7079	0.045	24984	0.263	16267	0.026	54315	0.168	107979	0.008	214592	0.061
1987/88	58623	0.009	49778	-0.020	10957	-0.008	22596	-0.042	5106	0.052	9118	0.134	11277	0.061	53363	0.010	7616	0.076	26129	0.046	15361	-0.056	52809	-0.028	108940	0.009	213793	-0.004
1988/89	58113	-0.009	53828	0.081	10704	-0.023	21741	-0.038	4842	-0.052	9561	0.049	13178	0.169	57149	0.071	7067	-0.072	28524	0.092	14624	-0.048	52282	-0.010	108528	-0.004	223085	0.043
1989/90	62805	0.081	50439	-0.063	7049	-0.341	14333	-0.341	4744	-0.020	12185	0.274	11688	-0.113	60191	0.053	6132	-0.132	26230	-0.080	12795	-0.125	46506	-0.110	105213	-0.031	209884	-0.059
1990/91	64399	0.025	52477	0.040	722	-0.898	3294	-0.770	3191	-0.327	9698	-0.204	10997	-0.059	53691	-0.108	3717	-0.394	16949	-0.354	7945	-0.379	34317	-0.262	90971	-0.135	170426	-0.188
1991/92	77455	0.203	66973	0.276	4973	5.888	33895	9.290	4042	0.267	11540	0.190	7305	-0.336	33800	-0.370	4426	0.191	16993	0.003	11213	0.411	41664	0.214	109414	0.203	204865	0.202
1992/93	84048	0.085	64477	-0.037	5444	0.095	42684	0.259	4018	-0.006	12141	0.052	10313	0.412	29845	-0.117	5487	0.240	24038	0.415	14538	0.297	54038	0.297	123848	0.132	227222	0.109
1993/94	89498	0.065	62652	-0.028	3680	-0.324	20942	-0.509	5210	0.297	14542	0.198	13375	0.297	33897	0.136	6585	0.200	29608	0.232	14855	0.022	61990	0.147	133203	0.076	223631	-0.016
1994/95	99427	0.111	71010	0.133	4113	0.118	24638	0.176	7401	0.421	21117	0.452	14357	0.073	34683	0.023	7652	0.162	36816	0.243	15905	0.071	70747	0.141	148855	0.118	259011	0.158
1995/96	110321	0.110	81386	0.146	4945	0.202	32115	0.303	8881	0.200	27822	0.318	17507	0.219	40052	0.155	8696	0.136	40137	0.090	17810	0.120	76200	0.077	168160	0.130	297712	0.149
1996/97	112339	0.018	92010	0.131	5389	0.090	43389	0.351	8819	-0.007	29634	0.065	14401	-0.177	34994	-0.126	9098	0.046	43139	0.075	17571	-0.013	82581	0.084	167617	-0.003	325747	0.094
1997/98	110733	-0.014	74789	-0.187	5118	-0.050	16679	-0.616	9631	0.092	21028	-0.290	14576	0.012	30596	-0.126	8745	-0.039	17277	-0.600	17962	0.022	47080	-0.430	166765	-0.005	207449	-0.363
1998/99	113082	0.021	123912	0.657	5258	0.027	44228	1.652	8803	-0.086	31713	0.508	13768	-0.055	65604	1.144	7635	-0.127	37588	1.176	17142	-0.046	81409	0.729	165688	-0.006	384454	0.853
1999/00	114687	0.014	111217	-0.102	6852	0.303	64791	0.465	11290	0.283	42778	0.349	13435	-0.024	81862	0.248	8611	0.128	49163	0.308	17438	0.017	83709	0.028	172313	0.040	433520	0.128

Source: EPE, 2001/2002 and own computation

Appendix 7

Value of import, export and crued and Refined Petroleum

Year	Value of Import	Value of Export	Value of Crued and Refined Petroleum	Growth of Import	Growth of Export	% of Crued & Refined Petroleum as Import	Trade Balance
1979/80	1432858	950667	339384			23.7	-482191
1980/81	1384234	851509	345322	-0.0339	-0.1043	24.9	-532725
1981/82	1641661	778083	361453	0.1860	-0.0862	22.0	-863578
1982/83	1752945	809625	396992	0.0678	0.0405	22.6	-943320
1983/84	2067005	929625	378388	0.1792	0.1482	18.3	-1137380
1984/85	1770433	744572	317925	-0.1435	-0.1991	18.0	-1025861
1985/86	2201265	923816	252534	0.2433	0.2407	11.5	-1277449
1986/87	2236946	795284	225824	0.0162	-0.1391	10.1	-1441662
1987/88	2274651	773642	216570	0.0169	-0.0272	9.5	-1501009
1988/89	2110353	902753	212851	-0.0722	0.1669	10.1	-1207600
1989/90	1824119	736806	225081	-0.1356	-0.1838	12.3	-1087313
1990/91	2130305	542485	210426	0.1679	-0.2637	9.9	-1587820
1991/92	1810897	279026	193153	-0.1499	-0.4857	10.7	-1531871
1992/93	3618718	800814	821090	0.9983	1.8700	22.7	-2817904
1993/94	4739967	1238729	737567	0.3098	0.5468	15.6	-3501238
1994/95	6546274	2732046	993914	0.3811	1.2055	15.2	-3814228
1995/96	7708246	2539056	931865	0.1775	-0.0706	12.1	-5169190
1996/97	8505200	3485626	1504100	0.1034	0.3728	17.7	-5019574
1997/98	9338459	4141582	2265515	0.0980	0.1882	24.3	-5196877
1998/99	11702004	3637260	1308988	0.2531	-0.1218	11.2	-8064744
1999/00	11438681	3957802	2012220	-0.0225	0.0881	17.6	-7480879

Source: NBE Annual Bulletin and own computation

Appendix - 8 Determination of lag length of GCPC and DCPC Model

```
F-tests on retained regressors, F(9, 9)
    LDCPC_1     1.38144 [0.3190]      LDCPC_2    0.567087 [0.7945]

     LRPg_1    0.814464 [0.6176]       LRPg_2     1.14213 [0.4232]
     LRPd_1    0.853749 [0.5912]       LRPd_2    0.869393 [0.5809]
    LRPCI_1     1.76929 [0.2041]      LRPCI_2    0.262363 [0.9705]
      LPG_1     1.67797 [0.2263]        LPG_2     2.26161 [0.1200]
       LU_1    0.867235 [0.5823]         LU_2    0.108138 [0.9986]
   LVdPDC_1     1.44976 [0.2945]     LVdPDC_2    0.733750 [0.6739]
     LFEE_1     1.51327 [0.2735]       LFEE_2     1.22381 [0.3842]

F-tests on retained regressors, F(9, 17)
    LDCPC_1     237.900 [0.0000] **    LRPg_1     1.44174 [0.2465]
     LRPd_1    0.871151 [0.5674]      LRPCI_1     3.96151 [0.0071]**
      LPG_1     1.91091 [0.1196]         LU_1     56.5219 [0.0000]**
   LVdPDC_1     423.759  [0.0000] **     LFEE_1    0.962135
[0.5017]
```

System 2 ⟶ System 3: F(64, 64) = 1.2512 [0.1862]

```
F-tests on retained regressors, F(8, 10)
    LGCPC_1     8.95409 [0.0011] **   LGCPC_2     1.43148 [0.2921]
     LRPg_1    0.579664 [0.7743]       LRPg_2     1.68099 [0.2173]
     LRPd_1    0.456616 [0.8605]       LRPd_2     1.43060 [0.2924]
    LRPCI_1     1.57643 [0.2458]      LRPCI_2    0.707287 [0.6817]
      LPG_1     1.96189 [0.1574]        LPG_2     2.36317 [0.1015]
       LU_1    0.802872 [0.6147]         LU_2   0.0501918 [0.9999]
   LVgPGC_1     9.54642 [0.0009] **  LVgPGC_2     1.42060 [0.2959]
     LFEE_1    0.474169 [0.8487]       LFEE_2     2.10791 [0.1337]


F-tests on retained regressors, F(8, 18)

    LGCPC_1     39.7551 [0.0000] **    LRPg_1     1.11704 [0.3976]
     LRPd_1    0.762683 [0.6390]      LRPCI_1     11.8463 [0.0000]**
      LPG_1     3.00138 [0.0251] *       LU_1     18.0500 [0.0000]**
   LVgPGC_1     58.2847 [0.0000] **    LFEE_1    0.355768 [0.9306]
```

System 4 ⟶ System 5: F(72, 62) = 1.1541 [0.2825]

Appendix - 9 Result of Granger-causality test for GCPC and DCPC

```
Autoregressive-distributed lag model of LGCPC on LRPCI
Autoregression  part has lags 1 to 1
Distributed Lag part has lags 0 to 1
        The present sample is:  2 to 36
Autoregression
             Lag  1
Coeff.      0.8165
Std.Err     0.1052

Distributed Lag
           Constant     Lag  0     Lag  1
Coeff.      0.1462     0.8198    -0.8108
Std.Err      2.761     0.5823     0.5857

RSS = 0.6441021413    å = 0.144144    Rý = 0.663274
F(3, 31) = 20.3543 [0.0000] **

Granger-Causality test for adding LRPCI to LGCPC:
F(2, 31) = 1.1944 [0.3164]


Autoregressive-distributed lag model of LDCPC on LU
Autoregression  part has lags 1 to 1
Distributed Lag part has lags 0 to 1
        The present sample is:  2 to 36
Autoregression
             Lag  1
Coeff.      0.7933
Std.Err     0.1049

Distributed Lag
           Constant     Lag  0     Lag  1
Coeff.      0.8293      1.492     -1.291
Std.Err     0.3456     0.9797     0.9085

RSS = 0.351973113    å = 0.106555    Rý = 0.733576
F(3, 31) = 28.452 [0.0000] **

Granger-Causality test for adding LU to LDCPC:
F(2, 31) = 1.9495 [0.1594]
```

Appendix 10 - Interpretation of the Estimated Variables

- GCPC and DCPC : Gasoline and Diesel consumption per capita income, respectively. Data on these variables are recorded in metric cubic. These were however converted to litters by use of the conversion factors (multiplying the metric cubic by 1000). The data obtained from Ethiopian Petroleum Enterprises.

  The per capita consumption is obtained by dividing the litters by the population for the respective year. The board category of gasoline was identified as premium and regular. However, for our study we have taken the regular gasoline which is used by most vehicles.

- RP_g and RP_d : Real price of gasoline and diesel, respectively. Since there was no common unit price for gasoline and diesel in the country, we have taken Addis Ababa retail price for gasoline and diesel. This price is taken to represent the retail price for the whole country in this study. This is then divided by GDP deflator (Nominal GDP divided by Real GDP) to obtain the real price. Gasoline and diesel price data also obtained from EPE and Ministry of Trade and Industry.

- RIPC: Real income per capita. The income is proxied by the real GDP. We shall also take note of the influence of population growth to real GDP by using per capita income instead of aggregate figures (dividing real GDP by total population). The data of GDP is obtained from the newly Ministry of Finance and Economic Development.

- PG (Population growth) : Higher population densities (usually high population growth rate) exerts pressure on gasoline and diesel use due to increase in demand for the transport services. So that we took population growth as one determinant factor for gasoline and diesel demand. The data is obtained from central statistics office and the new Ministry of Finance and Economic Development.

- U(level of urbanization): Urbanization is anticipated to precipitate increased gasoline and diesel consumption because it increases the demand for intra-urban and inter-urban movement. The rate of urbanization may affect gasoline and diesel use in both the short and long-run. This is obtained by dividing urban population by total population.

- V_gPGC and V_dPDC: Number of gasoline and diesel using vehicles per gasoline and diesel consumption, respectively. Other categories of vehicles e.g. Motor cycles that use gasoline or diesel are left out here considering the fact that their consumption is negligible. We divided the number of vehicles by gasoline and diesel consumption, and obtained gasoline and diesel using vehicles per gasoline and diesel consumption, respectively.

- RFEE : Real foreign exchange earnings (this includes export of goods and service, net capital inflow, net transfer, government and private (net income) and errors and omissions). The real value is obtained by dividing the nominal exports by export unit value index.

Appendix 11 Calculation of Actual CO and CO_2 Emissions from Gasoline and Diesel Consumption (1987/88-1992/93)

Actual CO Emissions = Gasoline/Diesel consumption X Conversion Factor X

Emission Factor X 10^{-6} X Fraction of Carbon Monoxide

Actual CO_2 Emissions = Gasoline/Diesel consumption X Conversion Factor X

Emission Factor X 10^{-6} X Fraction of Carbon Monoxide X 44/12

Where, Gasoline and Diesel consumption = Production + Imports – Exports – Stock change.

Conversion Factor (GJ/t) for Gasoline and Diesel is 43.97 and 42.71, respectively.

Emission Factor (kgc/Gg) for Gasoline and Diesel is 18.9 and 20, respectively

Fraction of carbon monoxide is 0.99 for both fuel type.