Multiyear Sectoral Model for the Libyan Economy

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I hereby certify that this material, which I now submit for assessment of the programme of study leading to the award of Doctor of Philosophy is entirely my own work and has not been taken from the work of others save and to the extent such work has been citied and acknowledged within the text of my work.

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Abstract

The dissertation develops a number of models of relevance to the development of the Libyan economy.

A Box-Jenkins model of the oil sector of the economy is developed. This shows that Libyan oil prices are highly correlated with Brent data.

A Social Accounting model is developed for the economy. The model extends the Hercules model proposed by the World Bank. The underlying nonlinear programming problem is solved using GAMS.

The dissertation develops a multi-year dynamic programming model for electricity generation in Libya. This complements the demand for energy identified by the Social Accounting model.

The dissertation demonstrates the role that mathematical modelling can play in economic planning in Libya.

Key Words: Dynamic Programming, Linear Programming, Multiyear Planning, Sensitivity analysis.

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TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

CHAPTER 2: BACKGROUND RESEARCH

CHAPTER 3: RESEARCH METHODOLOGY

CHAPTER 4: BOX & JENKINS MOEL FOR LIBTAN OIL SECTOR

CHAPTER 5: A MULTIYEAR ELECTRICITY OPTIMISATION MODEL FOR LIBYA

CHAPTER 6: SOCIAL ACCOUNTING MATRIX

APPENDICES

LIST OF TABLES

LIST OF FIGURES

ABBREVIATION

Auto-Correlation Function	ACF
Auto-Regressive	AR
Auto-Regressive Integrated Moving-Average	ARIMA
Auto-Regressive Moving-Average	ARMA
Dynamic Programming	DP
General Algebraic Modelling System	GAMS
General Electricity Company of Libya	GECOL
Libyan Dinar	LD
Libyan Pound	L£
Moving-Average	MA
Multiyear Electricity Optimisation Model	MEOM
National Oil Corporation	NOC
Organisation for Economic Co-operation and Development	OECD
Organisation of Petroleum Exporting Countries	OPEC
Partial Auto-Correlation Function	PACF
Social Accounting Matrix	SAM
System of National Accounts	SNA
World Trade Organisation	WTO

Chapter 1

Introduction

1.1 Introduction

The Libyan economy depends primarily upon revenues from the oil sector, which contribute practically all export earnings and about one-quarter of GDP.

Since 1969, reducing Libya's dependence on oil has been the major objective of the government economic policy. Its inability to achieve this goal stems from ill-advised policy decisions as well as the many obstacles to economic diversification in a land lacking in both basic infrastructure and water resources.

In 1986, the UN Security council imposed sanctions on Libya. These sanctions, expanded in 1993, included the halting of arms sales, severing air transport, and freezing Libyan funds overseas. Sanctions also included a ban on the import of spare parts needed for the maintenance and enhancement of Libya's oil and gas facilities, a sector that was not included in the embargo. In addition to a unilateral embargo imposed on Libya in 1986, the US enacted the Iran and Libya Sanctions Act (ILSA) in 1996, which threatens foreign firms that invest over $20 million annually in Libya's energy sector.

Libya's economic policy in the 1980's and 1990's focused on softening the impact of US and UN sanctions. In 1988, a series of economic liberalization measures were designed to encourage privatization of public sector companies and broaden the scope of private sector activities to include retail trade, small-scale industries, and agricultural businesses.

In 1999, the UN Security Council suspended the sanctions. Since then, the Libyan government has been working on reforms to make the business environment more attractive for foreign investors. Toward this end, the government passed the Foreign Currency Investment Law of 1997 and the Free Trade Act in 1999.

In 2000, Libya asked local and foreign investors to take a larger role in the five-year plan that will help to privatize its state-run industries. High on the list of priorities are the telecommunications industry and road infrastructure, especially a 1,400 kilometre road leading from Libya to its sub-Saharan neighbours.

In the past three years Libya has been actively marketing its economic strengths, especially in the hydrocarbons sector. Hoping to attract foreign capital and knowledge, Libya has sought to exploit advanced recovery techniques and upgrade its downstream facilities. In addition, the Libyan government plans to open up new exploration areas in anticipation of growing investor interest.

Authorities are also formulating a new investment law under which oil profits would be shared between foreign oil operators and the government's National Oil Company (NOC). For the first time, the law will also cover natural gas, which is expected to become an increasingly important source of revenue for Libya The country has been successful in attracting European firms who are keen to establish or expand their activities in Libya's oil industry.

Libya faces a long road ahead in liberalizing the socialist-oriented economy, but initial steps – such as applying for WTO membership, reducing some subsidies, rebuilding effective state institutions and encouraging the private sector to resume business activity (euphemistically called 'expanding the popular sector' or "popular capitalism.") are all helping to lay the groundwork for a transition to a more market-based economy.

Libyan oil reserves are not expected to last beyond the second decade of the next century; diversification is thus an important issue because at current rates of production. Thus, the long-term health of the Libyan economy hinges on developing a self-sustaining nonpetroleum sector. Otherwise, once oil reserves are depleted, Libya will become as poor as it was before its current oil boom.

The Libyan central bank has introduced a series of measures aimed at attracting foreign and local investment. It linked the Libyan dinar to the dollar and settled the country's $5.7 billion public debt. The central bank opened the country's first stock brokerage firm and signed contracts with international companies to modernize local banks.

The state allocated a $4.28 million in 2005 to help introduce changes to integrate Libya's economy with the rest of the world and to achieve an average growth of 5.3 percent in gross domestic product, excluding oil revenues, and a 6.7 percent increase in investment.

Although economic controls are giving way to market forces as the main vehicle of development, the government continues to exercise a degree of economic management and direction which will accelerate the growth process beyond what might be achieved by market forces alone. For this reason the Libyan government is seeking to set several multi-year plans (development planning) in order to fulfil some functions. By providing an analytical framework of the economy's structure, it allows the policy maker to evaluate the prospects for, and constraints on, economic growth and structural change. By assembling a consistent and integrated set of relationships for the whole economy, it enables the policy maker to identify the direct and indirect effects of particular policy changes.

The government believes that planning will bring rapid social and economic development. correct the structural inadequacies in the economy. and modernise the static traditional sector.

Multi-year planning incorporating a significant set of analytical techniques for economic decision making and policy formulation, is central theme in the strategy of the government.

The role of the state in the development process is one of the oldest topics in the economics literature. and controversy continues over the relative merits of the market mechanism as opposed to state intervention. Indeed. the relationship between governments and markets is perhaps the central issue in economic development.

According to Chowdhury, A & Kirkpatrick, C (1994), in all economies the government must exercise some degree of economic management and control. The important question, therefore, is about the nature and quality, rather than the extent, of the state's intervention in the economy.

Planning bridges the gap from "where we are" to "where we want to go." It makes it possible for things to occur which would not otherwise happen. Development planning can be defined as 'the conscious effort of a central organization to influence, direct, and, in some cases, even control changes in the principal economic variables (e.g. GDP, consumption, investment, saving, etc.) of a certain country and region over the course of time in accordance with a predetermined set of objectives'. Todaro, M. (1971).

The purpose of planning is to provide management with a framework in which decisions can be made which will have an impact on the economy. The basic planning problem is how to allocate the country's limited resources. The major benefits to be expected from planning include an improved sense of direction for the economy, better performance, increased understanding of the organization and its purpose, earlier awareness of problems and more effective decisions making.

A development planning exercise typically involves the use of a planning model, which specifies in quantitative terms the relationships between objectives, constraints and policy instrument variables. The model is then used to calculate a feasible or consistent solution, defined as a set of values for the policy instruments that satisfies the specified objectives and does not exceed the predetermined constraints Chowdhury, A & Kirkpatrick, C (1994).

Modern development planning models incorporate sophisticated modelling techniques. For example, Input-Output techniques allowed the planner to consider intersectoral resource allocations. The social accounting matrix approach has provided a method of modelling the effects of various policy interventions on income distribution.

The process of planning involves the examination of a host of social and economic variables. These socio-economic variables are normally related to one another in a very intricate and complex manner and our understanding of the long chain of interaction becomes hazy without the aid of an analytical model. Models are needed, therefore, to analyse complex interactions between various elements which may appear to be unrelated. Chowdhury, A & Kirkpatrick, C (1994).

1.2 Research Objective

The aim of this study is to develop and evaluate multi-year planning models of relevance to the Libyan economy.

A Box-Jenkins model is developed for the Libyan oil sector. A Social Accounting model is built to analyse the distribution of resources within the economy. Finally, a multi-year dynamic programming is proposed for energy generation.

1.3 Research Questions

1- What insights into the Libyan oil sector can be gained from Box-Jenkins models?
2- How can the Social Accounting Matrix methodology be extended to model the Libyan economy?
3- What methodology should be used to build a multi-year model of electricity generation?

1.4 Research Plan

We present a brief outline of the content of the chapters of the dissertation:

In chapter 2, we review literature relating to economic planning, with particular reference to energy modelling.

In Chapter 3, we review the underlying methodology of the research instruments. It justifies the use of the quantitative approach for economic planning. It examines in detail the different quantitative analysis tools used in the study and some of the problems faced by the researcher during the study.

In chapter 4, we review some basic facts about the Libyan economy. We give a brief review of the Libyan geography and population. We discuss the Italian occupation of Libya. We cover the economic situation from 1951 until 1969. Finally, we deal with the current economic situation. This chapter also examine the box-Jenkins technique as a significant tool of forecasting univariate and multivariate data. We applied the technique to Libyan oil sector prices.

In Chapter 5, we apply a dynamic programming model to the optimisation of electricity supply in Libya. A linear programming transhipment algorithm is embedded in the dynamic programme.

In chapter 6, we propose a nonlinear combinatorial model for the analysis of social accounting, national data. The model is derived from the Hercules model and is implemented in GAMS.

1.5 Significance of This Research

We list in this section the main contributions of this thesis.

- The dissertation shows how the Box-Jenkins methodology could be used to model Libyan oil prices over time.
- We show how dynamic programming could be used for multi-year modelling of the Libyan energy sector.
- We build the first social accounting matrix for the Libyan economy.

Chapter 2

Background Research

2.1 Introduction

Dynamic programming was the brainchild of an American Mathematician, Richard Bellman, who described the way of solving problems where you need to find the best decisions one after another. In the forty-odd years since this development, the number of uses and applications of dynamic programming has increased enormously.

Dynamic programming was introduced by Bellman, based on a concept known as the principle of optimality. The principle states that an optimal decision (policy) has the property that whatever the initial state and initial decisions are, the remaining decisions must constitute an optimal decision (policy) with regard to the state resulting from the first decision. Bellman, R. E & Dreyfus, S. E. (1962). This simply means that no matter what the initial states or decisions are, the remaining decisions will constitute an optimal decision (policy) with regard to the information derived from the first decision. Another way of stating the principle is to suggest that if an incorrect decision has been made in the first or second stage, it does not prevent a decision maker from making the correct decision in future stages. Aman, K (2000:pp.243).

Thierauf, R. J (1978:pp249) defined Dynamic programming as a mathematical technique which solves for a series of sequential decisions, each of which affects future decisions. According to Lawrenc, L (1981:pp671) dynamic programming is a quantitative method that is similar in scope to linear programming. The goal of both procedures is the efficient allocation of resources. Thus, either programming approach is designed to determine the values that minimise cost, maximise profit or optimise any one of a variety of other kinds of payoffs. Lawrenc. L (1981:pp672) added we use the word dynamic because time is explicitly incorporated into the model.

Lawrenc, L (1981:pp695) highlighted that dynamic programming is a very useful quantitative method that can be applied to a wide variety of multi-stage decision problems occurring over time or when choices may be made sequentially. According to Hamdy, A (1992:pp345) dynamic programming is a mathematical procedure designed primarily to improve the computational efficiency of select mathematical programming problems by decomposing them into smaller, and hence computationally simpler, sub-problems.

2.2 Dynamic Programming

The word Programming in the name has nothing to do with computer programs. Mathematicians use the word to describe a set of rules which anyone can follow to solve a problem. They do not have to be written in a computer language.

Hamdy, A (1992:pp345) explained that the name dynamic programming probably evolved because of its use with applications involving decision making over time (such as inventory problem). Hamdy, A (1992:pp345) added that other problems, in which time is not a factor, can also be solved by this technique. For this reason, a more apt name may be multistage programming, since the procedure typically determines the solution in stages. Thierauf, R. J (1978:pp.250) stated that dynamic programming is concerned with problems in which time is not a relevant variable. For example, a decision must be made which involves an allocation of a fixed quantity of resources among a number of alternative uses. This type of problem can be solved by breaking it down into several steps. In this manner, the final decision is handled as if it were a series of dependent decisions over time. Even though this type of problem is not concerned with the time factor per se, it still adheres to the fundamental characteristic of dynamic programming--a multistage process of decision making.

Maurice, S et al.(1959:pp270) mentioned that Dynamic programming is a newly developed mathematical technique which is useful in many types of decision problems . Thierauf, R. J (1978:pp249) highlighted that Linear programming problems have one common characteristic: they are static. Problems are stated and solved in terms of a specific situation occurring at a certain moment. When a problem is concerned with variations over time, another Operations Research technique must be utilized which includes the time element. Like linear and integer programming, dynamic programming attempts to optimize an objective function subject to a set of constraints but, unlike the first two, it divides a problem into several interrelated components, called stages, where each stage produces an optimal solution. Lawrenc, L (1981:pp671) claimed that a variety of similar situation involving sequential decision making can be evaluated by dynamic programming.

2.3 Formulating a Dynamic programming

Thierauf, R. J (1978:pp250) discussed that Dynamic programming may be thought of as an approach for breaking large, complex problems into a series of smaller problems that are individually easier to solve. Unlike linear programming, dynamic programming has no standard format, but rather is a general approach to problem solving. The format of any given dynamic-programming formulation can vary widely in nature and complexity, depending on the problem's structure. David, S & William, F (1981:pp325) stated that Dynamic programming deals directly with the combinatorial problem that a set of decisions in year t affects the options, and hence the decisions, in year $t + 1$, etc. This mathematical and computational procedure is the most general and powerful of any of the approaches for feedback control under uncertainty. According to Thierauf, R. J (1978:pp250) to illustrate its essential nature, several basic concepts, i.e., requirements, for formulating a dynamic programming problem are set forth:

1-The first concept is a *state variable* whose value specifies the condition of the process. The values of these variables tell us all we need to know about the system for the purpose of making decisions. For example, in a production problem, we might require state variables that relate to plant capacity and present inventory levels. Although the number of state variables can be large, the difficulty in solving a problem increases considerably as the number of these variables increase. It is important to minimize their number.

2- The concept of *decisions or decision variables*, which are opportunities to change the state variables (possibly in a probabilistic manner). The net change in the state variables over some time period may be subject to considerable uncertainty. The returns generated by each decision depend on the starting and ending states for that decision, thereby adding up as a sequence of decisions. Typically, the task is to make decisions that maximize total return.

3-The last important concept for formulating a dynamic programming problem is the ability to make decisions about the problem at various stages or points in time. At each step in the problem, a decision is made to change the state and thereby maximize the gain. At the next stage, decisions are made using the values of the state variables that result from the preceding decision, and so forth. Thus the time component is considered in only two ways: the present and its immediate preceding period. Aman, K (2000:pp243-244) stated that like linear programming, the procedure for solving a dynamic programming problem involves several basic steps. They are: (1) determining what decision variables to include and setting up the objective function to be optimized (subject to a set of constraints); (2) specifying the stages of the problem and determining the variables, called states, whose values constitute the basis of decisions at each stage; (3) identifying the recursive relationship between different stages, and finding the optimal solution; and (4) presenting the results of computation in a table. Thierauf, R. J (1978:pp251) added that one last point should be noted when formulating a dynamic programming problem. No matter what the initial state(s) and decision(s) were, the remaining decisions will constitute an optimal policy. For example, if wrong decisions have been made for the first week and second week, this does not prevent one from making the right decisions in the future -- third week, fourth week, and remaining weeks. Thus, dynamic programming enables one to arrive at optimal decisions for the periods or stages that still lie ahead despite bad decisions made in the past. David. S & William. F (1981:pp325) argued that suppose there are 100 options in year t and that each of these generates 100 more options at $t + 1$, and so forth, in five years there will be $100^5 = 10^{10}$ possibilities. The number of alternatives in any practical problem is far too large to evaluate by enumeration, so some kind of special procedure is required. Dynamic programming provides one such procedure. David, S & William, F (1981:pp325-326) highlighted that Dynamic programming can be used when the controls are linear functions of the state variables and there are no restrictions on the coefficients of these functions. The solution algorithm finds the best values for these coefficients, where "best" is defined in terms of the expected present value of a quadratic objective function. David. S & William, F (1981:pp325-326) explained that the objective function can be developed with the desiderata given earlier, though for dynamic programming we must restrict ourselves to a quadratic form.) Two other key points should be remembered: (a) there can be no restrictions on the coefficients; (b) optimization of the present discounted value of an objective function is used in place of a set of terminal constraints. Aman, K (2000:pp243) explained that because of the way in which a problem is structured into interrelated components, the decision made at one stage has a direct bearing on the decision made at the next stage. Furthermore, the decision made at a given stage must not only take into consideration its effects on the next stage, but also on all subsequent stages in a recursive manner. The term *recursive* means what happens in one stage has a direct consequence on all future stages, but has no effect on what took place in previous stages. The latter is called recycling. The ultimate objective of dynamic programming is to find an optimum combination of decisions that will, over time, optimize the overall outcome. According to Lawrenc, L (1981:pp674) the objective of any dynamic program is to find the value of the cost function for the initial state and the corresponding optimal choices. Lawrenc, L (1981:pp695) suggested that dynamic programming can serve as an alternative to linear programming although dynamic programming can also be used to solve integer and nonlinear programming problems.

Most of the problem for which dynamic programming has been used to obtain numerical solutions can be formulated as deterministic discrete-time variational control problems. The general case of this problem is formulated as follows:

Given:

1- A system described by the nonlinear difference equation

$$x(k+1)=\Phi\left[x(k),u(k),k\right] \qquad (1)$$

where x is an n-dimensional state vector, u is an m-dimensional control vector, k is an index for stage variable, and Φ is an n-dimensional vector function.

2- A variational performance criterion

$$J=\sum_{k=0}^{k}L\left[x\left(x(k),u(k),k\right)\right] \qquad (2)$$

where J is the total cost and L the cost for a single stage.

3- Constraints

$$x\in X(k) \qquad (3)$$

$$u \in U(x,k) \tag{4}$$

where $X(k)$ is a set of admissible states at stage k, and $U(x,k)$ a set of admissible control at stage x, stage k.

4- An initialStat

$$x(0) = c \tag{5}$$

Find:

The control sequence $u(0),.......,u(k)$ such that J in (2) is minimised subject to the system equation (1) , the constraint equations (3) and (4), and the initial condition (5).

The dynamic programming solution to the above problem is obtained buy using an iterative functional equation that determines the optimal control for any admissible state at any stage. This equation follows immediately from Bellman`s principle of optimality.

The first step in the derivation is to define the minimum cost function for all $x \in X$ and all k, k =0,1,......., k, as

$$I(x,k) = \min_{\substack{u(j) \\ j=k,k+1,\ldots,k}} \left\{ \sum_{j=k}^{k} L\left[x(j),u(j),j\right] \right\} \tag{6}$$

where

$$x(k) = x$$

The summation is then split into two parts, the term evaluated for $j = k$ and the summation over $j = k+1$ to $j = k$. The minimisation is similarly split into to parts. The result is

$$I(x,k) = \min_{u(k)} \min_{\substack{u(j) \\ j=k+1,\ldots,k}} \left\{ L\left[x,u(k),k\right] \right\} + \sum_{j=k+1}^{k} L\left[x(j),u(j),j\right] \tag{7}$$

The first term in brackets in (7) is not affected by the second minimisation. Thus. (7) becomes

$$I(x,k)=\min_{u(k)}\left\{L\left[x,u(k),k\right]+\min_{\substack{u(j)\\ j=k+1,\dots,k}}\left[\sum_{j=k+1}^{k}L\left[x(j),u(j),j\right]\right]\right\} \tag{8}$$

The second term in brackets in (8) is exactly analogous to the definition in (6), where the argument of I is $\left(\Phi\left[x,u(k),k\right],k+1\right)$. Abbreviating $u(k)$ as (4), the iterative functional equation becomes.

$$I(x,k)=\min_{u}\left\{L(x,u,k)+I\left[\Phi(x,u,k),k+1\right]\right\} \tag{9}$$

This equation is a mathematical statement of Bellman's principle of optimality. It states that the minimum cost for state x at stage k is found by choosing the control that minimise the sum of the cost to be paid at the present stage and the minimum cost in going to the end from the state at stage $k+1$ which results from applying this control. The optimal control at state x and stage k, denoted by $u(x,k)$, is directly obtained as the value of u for which the minimum (9) is attained. Since (9) determines $I(x,k)$ and $u(x,k)$ in term of $I(x,k+1)$, it must be solved backward in k. As a terminal boundary condition.

$$I(x,k)=\min_{u}\left[L(x,u,k)\right]$$

The optimisation over a sequence of controls is thus reduce to a sequence of optimisations over a single control vector. Larson, R. (1982: pp.224-227).

2.4 Differences between Dynamic programming and Linear programming

Thierauf, R. J (1978):pp263) claimed that the preceding problems are not sophisticated examples of dynamic programming, but they do present some of its basic concepts. Generally, both linear programming and dynamic programming make use of an algorithm, although their mathematical procedures are different. Thierauf. R. J (1978):pp263) added that the basic characteristic of dynamic programming involves a multistage process of decision making where there are generally time intervals. However, these stages may be only an order in which the problem is solved.

On the other hand, linear programming gives a solution as of one time period based upon certain capacity, quantity, and contribution (or cost) constraints. According to Thierauf, R. J (1978):pp263) Dynamic programming is more powerful in concept, but computationally more difficukt than linear programming. Thierauf, R. J (1978:pp263) concluded that Dynamic programming is quite different in form from linear programming. While certain rules must be followed in the iterative process of linear programming, dynamic programming utilizes the appropriate mathematics necessary for the problem's solution. Aman, K (2000:pp251) said that Dynamic programming, on the other hand, is considered just as versatile as linear programming. It can be used in almost any situation and relationship: linear, nonlinear, deterministic, stochastic, continuous, and discontinuous. There are certain advantages to using this type of model in that it allows a problem to be serially structured without any recycling or going back, which means that there are several optimal points from which a decision maker could make a choice. This apparent flexibility has an advantage over other programming models where the solution is restricted to a single optimal value. Lawrenc, L (1981:pp672) considered that dynamic programming differs from the other allocation model in that it considers decision making over time.

2.5 Dynamic program solution

Thierauf, R. J (1978:pp249) showed that dynamic programming can solve problems referred to as stochastic linear programming or linear programming problems dealing with uncertainty. Today, dynamic programming has been developed as a quantitative technique to solve a wide range of business problems. David, S & William, F (1981:pp326) argued that we have already noted that the dynamic programming approach produces results that are difficult to explain to those who are not expert in operations research. Therefore, it would have to offer very significant advantages in order to be a serious candidate for adoption. David, S & William, F (1981:pp327) added that we see dynamic programming as a way to gain insight that may be useful in developing practical rules of thumb for dynamic control under uncertainty, but we do not advocate it for direct application. Thierauf, R. J (1978:pp263) mentioned that wrong decisions in the past, under dynamic programming, do not prevent the making of correct decisions now and in the future. In essence, regardless of earlier decisions, dynamic programming enables one to find optimal decisions for future periods. Aman, K (2000:pp246) suggests that numerous situations where a dynamic programming model would be appropriate, such as finding an optimal route at a minimum cost or determining the optimum output plan by adjusting seasonal fluctuations in demand for services (such as water or electricity), as in production smoothing. Aman, K (2000:pp246) added that even government inventories could be treated as a dynamic programming problem if the objective could be couched in terms of determining a policy that would minimize the expected cost resulting from situations, such as shortages or stockout. All of these problems have one thing in common: they are all multistage problems that can be solved through a sequence of decisions similar to the problem discussed here.

2.6 Existing energy system models

When analysing energy, or other social and economic systems, a large number of factors needs to be taken into account. It is not uncommon for an energy model to have thousands of data entries. As humans are unable to deal with all this information themselves they use computer based models to assist them. These models are abstractions. They are simplified mathematical representations of some real world system or problem. It is this simplification that makes them so useful, as it puts the problem into a form that it is possible to comprehend. As a tool, computer models are comprehensive and able to inter-relate a great number of factors simultaneously. Moreover, they do not make computational or logical errors.

Models are not constructed for the sake of modelling itself; rather, they are tools designed to help with the analysis of some real life situation. That is, a model is created for a distinct purpose and is meant to be applied to a particular problem. It follows that the modelling approach should be determined by this purpose.

There is a wide range of options and techniques available to energy analysts who wish to use such models. Here, we will focus on the most widely used modelling frameworks, with different areas of application, namely MARKAL, EFOM, MESSAGE and TIMES. They are all predeveloped, ready-to-use model-building tools that save the user the trouble of programming themselves.

2.6.1 MARKAL

MARKAL (MARKet ALlocation) is a linear, multi-period, bottom-up optimisation model of a national level energy system. The model has been widely used in almost 40 countries, including developed, transitional and developing economies. MARKAL was originally designed to develop a strategy for research, development and demonstration for the International Energy Agency (IEA). The characteristics of future energy technologies were estimated and the influence of these technologies was analyses for several countries through various scenarios. MARKAL was developed at the Brookhaven National Laboratory in the USA and at Kernforschungsanlage Jülich in Germany. Currently, two user interfaces exist for MARKAL: MUSS is an older, DOS-based interface, whereas ANSWER is a more recent Windows-based interface.

MARKAL is a demand-driven model, which means that all the specified useful energy demands have to be satisfied. Optimising the objective function, the model selects the most favourable energy carriers and processes to supply the given demands. Available resources, economic, technical and environmental characteristics of technologies together with useful energy demands are the main input parameters in a MARKAL model. Five main classes are distinguished in MARKAL: resources (e.g., mining), energy carriers (e.g., coal, wind), processes, conversion systems and demand devices. Fishbone, L.G. et al (1983). Processes transform one energy carrier into another; thus, for example, oil refineries are modelled as processes. Conversion systems (e.g.. power plants. cars) convert energy carriers into commodities with end-use demand (e.g., electricity. traveled distance). With demand devices, energy saving measures such as improved insulation can be introduced to a MARKAL model. For processes, conversion systems and demand devices, parameters including efficiency, availability factor, lifetime as well as investment, fixed and variable costs are defined, and import costs are assigned to primary energy carriers. The salvage values of existing capacities at the end of the time horizon are taken into account. and all costs are discounted to their present value by a given discount rate.

The modelling horizon in MARKAL can be divided in up to sixteen periods of equal lengths. Due to new installations and decommissioning of old capacity, the market shares of different technologies vary throughout the periods. Diurnal storage technologies, e.g. hydroelectric pumped power plants that consume electricity during the night and produce it during the day, can be included in models. Model constraints include annual energy carrier balances, seasonal district heating balances, diurnal electricity balances and annual availability and demand equations. Through a peak-load production relation, the supply system is secured to have enough capacity, and possibly a desired reserve margin, during the maximum load. The growth of such factors as installed capacity of a technology, utilisation of a certain resource or total investments can be limited by user constraints in a MARKAL model.

A multi-objective analysis is enabled through eight functions, which can be used either as objective, constraints or for accounting. These functions are discounted total system cost, cost for renewable technologies excluded, environmental impact, fossil energy use, non-renewable energy use, nuclear energy use, security-weighted summation of primary energy resources and a combination of cost and security. When a function is acting as a constraint, it is given a value that defines either the lower or the upper limit. Functions used for accounting do not influence the optimal solution. Security function can be used to limit the dependence on imported energy carriers. Optimal solution includes installed capacities in the beginning of every period, (energy-) commodity flows, activities of processes and conversion technologies, total costs and total emissions. Electricity production from conversion plants can be solved for day and night load for three seasons (winter, summer and intermediate). Heat plants are assumed to operate at constant power through a season. Heat production for extraction turbines, for which the proportion of heat and electricity production can vary, is solved on a diurnal level. Uncertainties can be included and analysed through model's stochastic programming feature.

MARKAL has been expanded to be a family of modelling systems. It has been linked to the top-down model MACRO, allowing the evaluation of the interaction between technology policies and market instruments. MACRO is a two-sector (production and consumption) aggregated model of long-term economic growth, whose inputs include capital, labour and energy. Instead of minimising the total cost, MACRO maximises the discounted utility of consumption. MARKAL-MACRO is a simplified energy-economy model, with detailed description of technologies. MARKAL-MICRO and MARKAL-ELASTIC_DEMAND (MED) are steps closer towards a partial equilibrium model, in which useful energy demand has been replaced, respectively, with non-linear and step-wise demand curves. The equilibrium between supply and demand is calculated by maximising the sum of consumer and producer surplus. Goldstein, G (1999). The MARKAL family of models is unique, benefiting from application in wide variety of settings and global technical support from the international research community.

As with most energy system models, energy carriers in MARKAL interconnect the conversion and consumption of energy. This user-defined network includes all energy carriers involved with primary supplies (e.g., mining, petroleum extraction, etc.), conversion and processing (e.g., power plants, refineries, etc.), and end-use demand for energy services (e.g., boilers, automobiles, residential space conditioning, etc.). The demand for energy services may be disaggregated by sector (i.e., residential, manufacturing, transportation, and commercial) and by specific functions within a sector (e.g., residential air conditioning, heating, lighting, hot water, etc.). The building blocks depicted in Figure (2.1) represent this network, referred to as a Reference Energy System (RES).

The optimization routine used in the model's solution selects from each of the sources, energy carriers, and transformation technologies to produce the least-cost solution subject to a variety of constraints. The user defines technology costs, technical characteristics (e.g., conversion efficiencies), and energy service demands. As a result of this integrated approach, supply-side technologies are matched to energy service demands. The specification of new technologies, which are less energy or carbon-intensive, allows the user to explore the effects of these choices on total system costs, changes in fuel and technology mix, and the levels of greenhouse gases and other emissions. Therefore, MARKAL is highly useful for understanding the role of technology in carbon mitigation efforts and other energy system planning settings.

A variety of different constraints may be applied to the least-cost solution. These constraints include those related to a consistent representation of the energy system, such as balancing energy inputs and outputs, utilization of capacity, replacement of expended capacity by new investments and satisfaction of demand.

In addition, environmental or policy issues, such as greenhouse gas emissions may be examined in several ways, including sectoral or system-wide emissions limits on an annual basis or cumulatively over time. Alternatively, the imposition of a carbon tax or other fee structure could be modeled if desired. As a result, various costs for carbon may be generated for different levels of emission reductions. In this way, future technology configurations are generated and may be compared. If constraints are also placed on the types of technologies and rates of penetration, the configuration of the entire energy system will change. In all cases, MARKAL will produce the least-cost solution which meets the provided set of constraints.

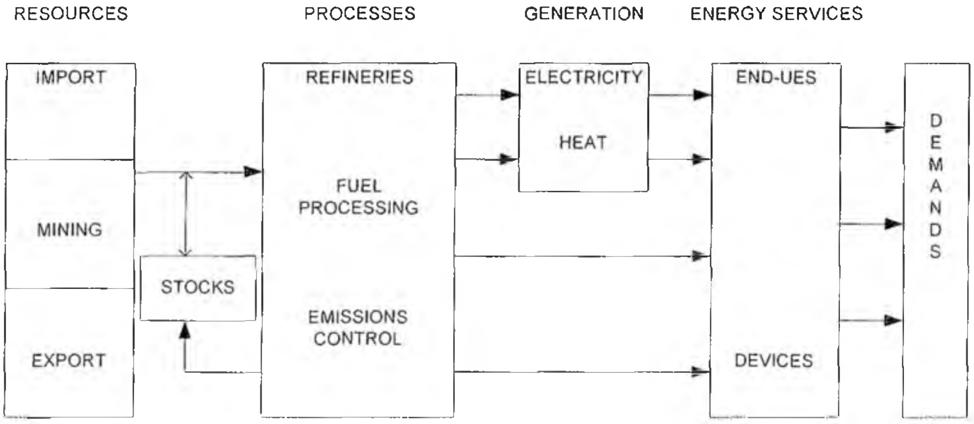


Figure (2.1): MARKAL Building Blocks

2.6.2 EFOM

EFOM, Energy Flow Optimisation Model. was originally developed in a European Community research program in the 1970s. It is a bottom-up linear programming optimisation model that can be used to describe the whole energy system from primary energy supply to demand sectors. EFOM has been applied to all member countries of the European Union (except Austria) as well as many other countries, including Russia, Mexico and China. Employment rates, polluting factors, technical and economical lifetimes and export possibilities can be included in model inputs. Upper and lower bounds on flows and capacities can be given, and total imports and costs may be limited. Availability factors for processes set upper constraints on annual plant utilisation times, which are computed by the model. In addition to diurnal storage, also seasonal storage processes are allowed.

The EFOM is a multi-period model, which can cover a study time span of 40 years. The time span is divided into periods defined by their ending years, and the periods may vary in length .van der Voort et al (1984). Moreover, annual capacity and flow constraints, as well as total cost constraints may be addressed for each period. Total costs include investment and fixed costs, which are proportional to capacity, and variable costs, which are proportional to energy or material flow. Investment costs, including interest payments, are divided over the economical lifetime of the technology with the annuity method. Cogeneration plants with variable electricity to heat ratio can be modelled as a process with electricity output, of which a varying share can be transformed into heat with a given conversion factor (for example, with one unit of electricity can five units of heat be produced).

EFOM has been extended by an environmental module (EFOM-ENV), which includes emission reduction technologies with negative emission coefficients. Annual pollutant limits considering technology, sector or the whole system have been introduced. Also the cumulative CO2 emissions can be calculated and constrained, in which case the model can self determine the optimum pace for emission reductions. For SO2 and NOx, which stay much shorter time in the atmosphere than CO2, the annual emissions are normally limited. The annual time division in EFOM-ENV was extended to three seasons (winter, spring & autumn and summer) with three diurnal periods (peak, intermediate and base load). Production units can be set to be peak, intermediate or base load units. In EFOM-ENV, final energy demand may be influenced by energy saving measures, but useful energy demand remains exogenously defined. To model price-induced changes in energy demand, an iterative algorithm connecting useful energy demand with the shadow prices of previous solution has been added.

2.6.3 MESSAGE

MESSAGE, Model for Energy Supply Strategy Alternatives and their General Environmental impact, was created at IIASA (International Institute for Applied Systems Analysis) in Austria. MESSAGE was originally used for a study, in which seven world regions were analysed for a 50-year time horizon, divided into several periods. Like MARKAL and EFOM, also MESSAGE can be used to describe the overall energy supply system with resource extraction, import and export, commodity flows, conversion, distribution and end-use of energy. The modelling horizon is divided into periods, which can vary in length. Each period is represented by a typical year, which can be divided into load regions. In the model version MESSAGE III, up to 10 load regions can be included in a year. A typical division includes winter, intermediate and summer days, which each subdivides into three load regions of arbitrary length.

In MESSAGE, technologies may be assigned certain production patterns. For example, nuclear power plants can be fixed for base load operation and photovoltaic cells may have output only at specific times. Annual and diurnal storage can transfer energy from low-load regions to high-load regions. The production in one period can be limited in relation to the production of previous period. and additional user constraints are allowed. End-use technologies are divided into equipment for thermal conversion, non-substitutable electricity demand, transportation and non-energy use. MESSAGE has been extended with possibilities to use integer variables, non-linear functions, multi-criteria optimisation and stochastic future investment costs. In addition to total cost minimisation, the model can be used for finding the marginal costs as well as optimal technology and dimensions for investments.

2.6.4 TIMES

TIMES (The Integrated MARKAL-EFOM System) is a recent development in the evolution of the MARKAL framework, created by the Energy Technology System Analysis Program (ETSAP) of the IEA. Like its predecessor, TIMES is a dynamic linear optimisation framework that finds the least-cost solution under given constraints such as annual or cumulative emission levels. It presupposes perfect foresight and parametric data sources. Due to increased model flexibility, TIMES allows for analysis of many problems which required undesirable compromises or were beyond the analytical limits of MARKAL.

Time division in TIMES is flexible: the modelling horizon can be divided into an unlimited number of periods with varying period lengths, and a year can be further subdivided into an arbitrary number of time slices up to 3 hierarchy levels. Through interregional linkage feature, multi-regional models can be developed, for example, to analyse the future needs for transmission capacity as well as the effects of carbon permit trading. Vintaged processes allow for varying attribute values depending on both the year of commissioning and the age of a process. For instance, the investment costs for new wind power plants may decrease every period, or the fixed operating and maintenance costs of an existing power plant may grow due to increasing need for maintenance as the power plant ages. Moreover, attribute values can change depending on the model year. This feature may be used to reflect the increment in fixed operating and maintenance costs due to higher labour costs.

Standard naming conventions for attributes of all technology types make TIMES more transparent than its predecessor. The representation of processes with more than one input or output commodity is easier and more flexible; fuel-dependent efficiencies can be specified within a process, whereas in MARKAL additional processes and a dummy commodity are necessary. Modelling of regulating hydropower production is remarkably improved by the introduction of seasonal storage in addition with diurnal storage. Seasonal storage can be charged by both within a model produced commodities and seasonally specified flows of primary energy carriers, such as inflow of water filling the reservoirs for hydropower production.

In TIMES, economic and technical lifetime of a process can be defined separately, which enables, for example, different amortisation times for private households and companies. The investment of a large project (e.g., power plant) is divided equally over the construction time, and the costs for each portion of investment are annualised over the economic lifetime of the technology. The investment of projects with short construction time takes place in annual increments during the period (e.g., the number of cars increases yearly, not only once in a period). The useful energy demand can be specified in TIMES by the user, or it can be determined by the model based on elastic supply and demand curves.

2.7 Conclusions

The dominant concept employed in energy modelling systems is that of a dynamic programming framework encapsulating an annual optimisation model. The annual optimisation model is typically a linear program or a model with linear constraints and a piecewise linear objective function (that is amenable for solution by parametric linear programming); more sophisticated models incorporate stochastic linear programming for modelling uncertainty.

We propose to build such a model for the Libyan energy sector. By building the model, many managerial insights into energy modelling can be gained.

Chapter 3

Research Methodology

3.1 Introduction

This chapter describes the research methodology used in the dissertation and justifies its use.

3.2 Research Methods

What is research? Many definitions have been given, including a systematic of gaining new information, or a way to answer questions .Jeffrey, A & George, A (2000: pp4). Smith, M. (1981:pp.585) states that the research must be conducted and reported so that its logical argument can be carfully examined. Sekaran, U. (1992) Suggests that research is *organised, systematic, data based, critical scientific inquiry or investigation into a specific problem, undertaken with the objective of finding answers or soluations to it*". Ghauri, P et al (1995) stated that research methods refer to the systematic, focused and orderly collection of data for the purpose of obtaining information from them to solve/ answer out research problems or questions.

There is a debate on which methods or techniques are more suitable for scientific research. On one hand, it is sometimes stated that structured and quantitative methods are more suitable and scientific. On the other hand, Cassell, C & Symon, C (1994) said that "it is argued that adopting qualitative (phenomenological) approach implies taking a different perspective on human behaviour from that adopted in utilising quantitative (positivist) approaches". However, Ghauri, P et al (1995) highlighted that methods or techniques are not better or scientific only because they are quantitative. "which methods and techniques are most suitable for which research (project) depends on the research problem and its purpose".

The distinction between quantitative and qualitative research methods in economics studies is generally perceived as being that while the quantitative approach is objective and relies heavily on statistics and figures, the qualitative approach is subjective and uses language and description. Although most researchers emphasis one or the other, qualitative and quantitative methods can be combine and used in the same study .Ghauri, P et al (1995).

Differences between the two approaches are located in the overall form, focus, and emphasis of the study .Ghauri, P et al (1995), Cassel, C & Symon, C (1994).

Table 3.1 shows the differences in the emphasis between qualitative and quantitative methods.

Table 3.1 Differences in the emphasis between qualitative and quantitative methods

Qualitative Methods	Quantitative Methods
• Emphasis on understanding	• Emphasis on testing and verification
• Focus on understanding from respondent's/informant's point of view	• Focus on facts and/or reasons of social events
• Interpretation and rational approach	• Logical and critical approach
• Observation and measurements in natural settings	• Controlled measurement
• Subjective 'insider view' and closeness to data	• Objective 'outsider view' distant from data
○ Exploitative orientation	○ Hypothetical-deductive: focus on hypothesis testing
○ Process oriented	○ Result oriented
○ Holistic perspective	○ Particularistic and analytical
○ Generalisation by comparison of properties and contexts of individual organism	○ Generalisation by population membership

Source: Ghauri et al (1995); based on Reichat and Cook (1979)

3.2.1 Qualitative approach

Qualitative research methods have become increasingly important as ways of developing knowledge for evidence based working practice.

The purpose of qualitative research is to describe, explore, and explain phenomena being studied. Marshall, C & Rossman, G.B (1995). Qualitative research questions often take the form of *what is this?* or *what is happening here?* and are more concerned with the process rather than the outcome. Here we will describes 3 common types of qualitative research.

3.2.1.1 Sampling, data collection, and data analysis

Sampling refers to the process used to select a portion of the population for study. Qualitative research is generally based on non-probabilistic and purposive sampling rather than probability or random approaches. Miles, M & Huberman , M (1994).

Sampling decisions are made for the explicit purpose of obtaining the richest possible source of information to answer the research questions. Purposive sampling decisions influence not only the selection of participants but also settings, incidents, events and activities for data collection. Some of the sampling strategies used in qualitative research are maximum variation sampling, stratified purposeful sampling, and snowball sampling. Miles, M & Huberman , M (1994). Qualitative research usually involves smaller sample sizes than quantitative research. Morese, J. M (1994). Sampling in qualitative research is flexible and often continues until no new themes emerge from the data, a point called *data saturation.*

Many data collection techniques are used in qualitative research, but the most common are interviewing and participant observation. Morse, J. M & Field, P.A (1995). Unstructured interviews are used when the researcher knows little about the topic, whereas semi-structured interviews are used when the researcher has an idea of the questions to ask about a topic.

Participant observation is used to observe research participants in as natural a setting as possible. The types of participant observation range from complete participation to complete observation. Morse, J. M & Field, P. A (1995). To learn more about the topic being studied, qualitative researchers may also use other data sources such as journals, newspapers, letters, books, photographs, and video tapes.

Qualitative data analysis, unlike quantitative data analysis, is not concerned with statistical analysis, but with the analysis of codes, themes, and patterns in the data. Tesch, R (1990). Increasingly, qualitative researchers use computer software programs to assist with the coding and analysis of data. Tesch, R (1990).

The product of qualitative research varies with the approach used. Qualitative research may produce a rich, deep description of the phenomenon being studied or a theory about the phenomenon.

Qualitative research reports often contain direct quotes from participants that provide rich illustrations of the study themes. Qualitative research, unlike its quantitative counterpart, does not lend itself to empirical inference to a population as a whole; rather it allows the researcher to generalise to a theoretical understanding of the phenomenon being examined.

3.2.1.2 Types of qualitative research

There are many different types of qualitative research, such as ethnography, phenomenology, grounded theory, life history, and ethnomethodology. Tesch, R (1990). As in quantitative research, it is important for the researcher to select the qualitative research approach that would best answer the research question. Three of the most commonly used approaches to qualitative research are phenomenology, ethnography, and grounded theory. Morse, J. M & Field, P. A (1995). The goals and methods associated with each approach will be described briefly in the following sections.

3.2.1.2.1 Phenomenology

The aim of a phenomenological approach to qualitative research is to describe accurately the lived experiences of people, and not to generate theories or models of the phenomenon being studied. Van Manen, M (1990).

The origins of phenomenology are in philosophy, particularly the works of Husserl, Heidegger, and Merleau-Ponty. Van Manen M (1990). Because the primary source of data is the life world of the individual being studied, in-depth interviews are the most common means of data collection. Furthermore, emerging themes are frequently validated with participants because their meanings of that lived experience are central in phenomenological study.

3.2.1.2.2 Ethnography

The goal of ethnography is to learn about a culture from the people who actually live in that culture. Sparadley, J.P (1979). A culture can be defined not only as an ethnic population but also as a society, a community, an organisation, a spatial location, or a social world. Hammersley, M (1992).

Ethnography has its roots in cultural anthropology, which aims to describe the values, beliefs, and practices of cultural groups. Sparadley, J.P (1979). The process of ethnography is characterised by intensive, ongoing, face to face involvement with participants of the culture being studied and by participating in their settings and social worlds during a period of fieldwork.

The essential data collection methods of participant observation and in depth interviewing permit the researcher to learn about the meanings that informants attach to their knowledge, behaviours, and activities. Germain, C.P (1993). The context (social, political, and economic) of the culture assumes an important part of an ethnographic study, unlike a phenomenological study.

3.2.1.2.3 Grounded theory

The purpose of a grounded theory approach to qualitative research is to discover social-psychological processes. Strauss, A.L & Corbin, J (1990). Grounded theory was developed by Glaser and Strauss in the 1960s and is founded philosophically on symbolic interactionism. Chenitz, W. C & Swanson, J. M (1986).

Distinct features of grounded theory include theoretical sampling and the constant comparative method.

Theoretical sampling refers to sampling decisions made throughout the entire research process in which participants are selected based on their knowledge of the topic and based on emerging study findings.

In data analysis, the researcher constantly compares incidents, categories, and constructs to determine similarities and differences and to develop a theory that accounts for behavioural variation. Both observation and interviewing are commonly used for data collection.

3.2.2 Quantitative approach

Lawrence, L (1981) stated that theses quantitative methods can be broadly categorised as techniques of management science- a field melding portions of business, economics. statistics, mathematics. and other disciplines into a pragmatic effort to help managers make decisions. According to Babbie, E (1992) Quantitative research is defined as "the numerical representation and manipulation of observations for the purpose of describing and explaining the phenomena that those observations reflect," and qualitative research is described as "the non-numerical examination and interpretation of observations, for the purpose of discovering underlying meanings and patterns of relationships.

Isadore, N et al. (1998) suggest that the quantitative approach is used when one begins with a theory (or hypothesis) and tests for confirmation or disconfirmation of that hypothesis. Isadore, N et al. (1998) also added quantitative research, on the other hand, falls under the category of *empirical studies*, according to some, or *statistical studies*, according to others. These designs include the more traditional ways in which psychology and behavioural science have carried out investigations. Isadore, N et al. (1998) highlighted that quantitative modes have been the dominant methods of research in the social sciences.

Quantitative research tends to present organizational reality as an inert amalgam of facts waiting to be unravelled by an investigator, much as natural scientists are often seen as laying bare the underlying laws of the natural order in their laboratories Alan, B (1995).

Isadore, N et al. (1998) described the quantitative research as:

> *Quantitative research is frequently referred to as hypothesis-testing research (Kerlinger, 1964). Typical of this tradition is the following common pattern of research operations in investigating, for example, the effects of a treatment or an intervention. Characteristically, studies begin with statements of theory from which research hypotheses are derived. Then an experimental design is established in which the variables in question (the dependent variables) are measured while controlling for the effects of selected independent variables. That the subjects included in the study are selected at random is desirable to reduce error and to cancel bias. The sample of subjects is drawn to reflect the population. After the pretest measures are taken, the treatment conducted, and posttest measures taken, a statistical analysis reveals findings about the treatment's effects. To support repeatability of the findings, one experiment usually is conducted and statistical techniques are used to determine the probability of the same differences occurring over and over again. These tests of statistical significance result in findings that confirm or counter the original hypothesis. Theory revision or enhancement follows. This would be a true experiment.*

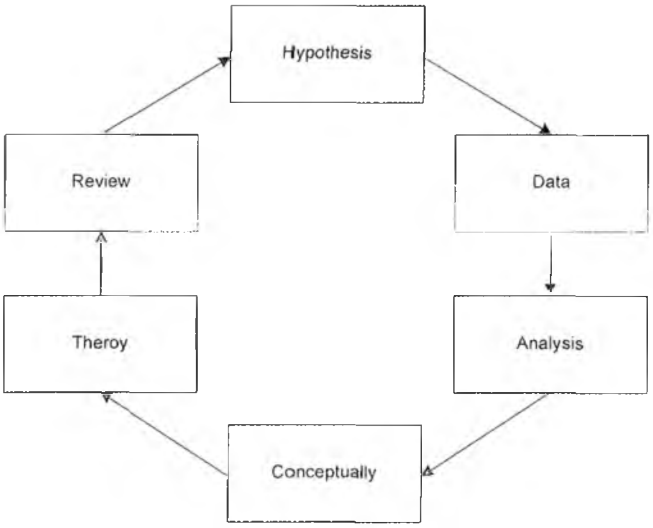
Quantitative designs include experimental studies, quasi-experimental studies, pretest-postest designs, and others, where control of variables, randomization, and valid and reliable measures are required and where generalizability from the sample to the population is the aim. Data in quantitative studies are coded according to a priori operational and standardized definitions.

During the 1940s and 1950s, the quantitative paradigm dominated the social science and the educational research scene. Behaviourists and organizational theorists utilized empirical fact gathering and hypothesis testing almost exclusively in studying educational and social phenomena. . Isadore, N et al. (1998).

In the mid- 1960s, while the quantitative perspective continued to prevail, a shift began as scepticism toward the domination of logical positivism and the evident chasm between human social systems and mathematical logic grew. New epistemologies began to emerge that acknowledged, for example, the value-laden nature of human social interactions. That human beings construct reality for themselves and that knowledge itself is transmitted in social ways were beginning to be assumed. Questions arose about the tenability of applying natural science methodology to these complex human dynamics. Isadore, N et al. (1998).

Quantitative research begins with theory (square 1). From theory, prior research is reviewed (square 2); and from the theoretical frameworks, hypotheses are generated (square 3). These hypotheses lead to data collection and the strategy needed to test them (square 4). The data are analyzed according to the hypotheses (square 5), and Conceptually, in *our* model, the "theory" is neither at the beginning nor at the end-but the square and circle would overlap and continue the cycle .

Figure (3.1): Quantitative Research Methodology



Source: Isadore, N et al. (1998): Qualitative – Quantitative Research Methodology: Exploring the interaction continuum pp:21

Here we will describe some common tools which have been used in quantitative researches

3.2.2.1 Statistics

Statistics play a vital role in the development of economics as an academic discipline and, more importantly, as a practical discipline.

One of the fundamental concepts of statistics is probability. All statistical tests involve the calculation of probabilities, either directly or indirectly. Statistical hypotheses are never said to be true or false. Instead, the probability that they are true or false is stated.

The topics in inferential statistics are the testing of hypotheses, regression, goodness-of-fit tests, the analysis of contingency tables and multivariate techniques such as principal components analysis, multidimensional scaling and hierarchical cluster analysis.

3.2.2.1.1 Descriptive Statistics

The term 'descriptive statistics' refer to a set of methods, procedures and techniques used to represent, summarise, or otherwise communicate the essential characteristics of a set of raw data. Some important aspects of descriptive statistics are tabular and graphical representations and the calculation of a single number representing a particular characteristic of the data in question.

Applying the techniques of descriptive statistics allows one to make statistical inferences, for example, the use of chance models to draw conclusions from data. These conclusions help researchers to solve the problems they are confronted with.

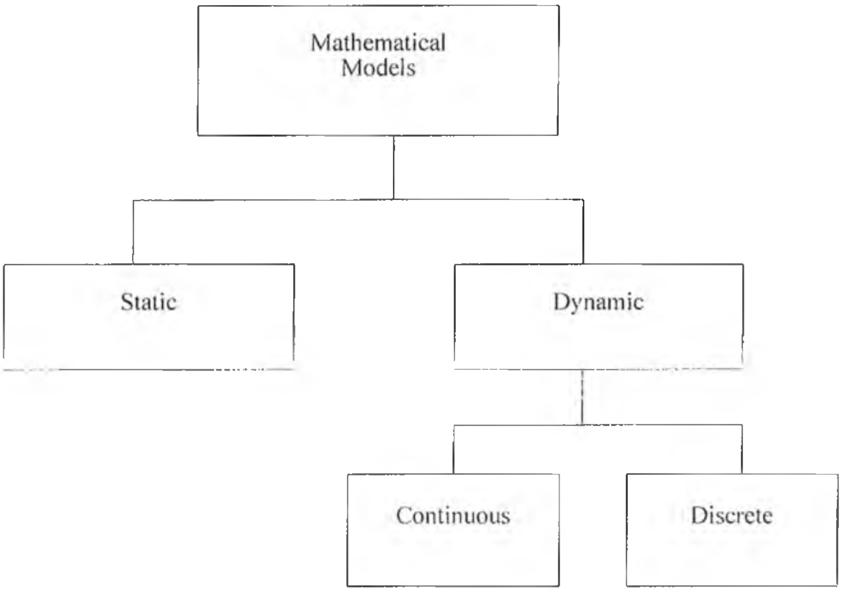
3.2.2.2 Modelling

Models can provide a description of situations or phenomena that are difficult to examine in any other way. There are three types of modelling, the first type is referred to as iconic: we all familiar with how scald-down versions of a car or aeroplane can be used to demonstrate the characteristics to the real things. The second type is called analogue modelling where one factor is used to describe another. The third type of modelling, symbolic, which describes how mathematics and other notation can be used to represent problem situations.

The use of model means that the performance of the business over an extended time period can be observed quickly and under a number of different scenarios.

Models are also classed as either static or dynamic, with dynamic system being modelled using continuous or discrete-event approach.

Figure (3.2): The types of Mathematical Models



Static models include the linear programming technique which is an example of an analytical mathematical technique which can be used to solve management decision –

making problems. Alternatively, a dynamic mathematical model allows change in system attributes to be derived as a function of time.

These socio-economic variables are related to one another in a very intricate and complex manner and our understanding of the long chain of interaction becomes hazy without the aid of an analytical model. Models are needed, therefore, to analyse complex interactions between various elements that may appear to be unrelated.

According to Myrdal, G (1968) Models are essential aids to clear thinking.. The first virtue of models is that they can make explicit and rigorous what might otherwise remain implicit, vague and self-contradictory...since ordinary thinking too often proceeds by fairly simple rule of thumb and uni-causal explanations and rarely ascends to a complex system of interdependent relationships, model-thinking may serve as a kind of thought-therapy, loosening the cramped intellectual muscles, demonstrating the falsity or doubtfulness of generalizations and suggesting the possibility of an interdependence previously excluded. The most justifiable claims for the use of economic models are the modest ones that they are cures for excessive rigidity of thought and exercises in searching for interdependent relationships.

Chowdhury, A & Kirkpatrick, C (1994) stated that Analytical planning models also have 'communication' value. Many different organizations and individual agents interact in the formulation and execution of a country's economic and social policies. Hence the ability of a planner to communicate with politicians, bureaucrats and others involved in the policy formulation process constitutes an important element in any type of planning and such communications can be enhanced by analytical planning models.

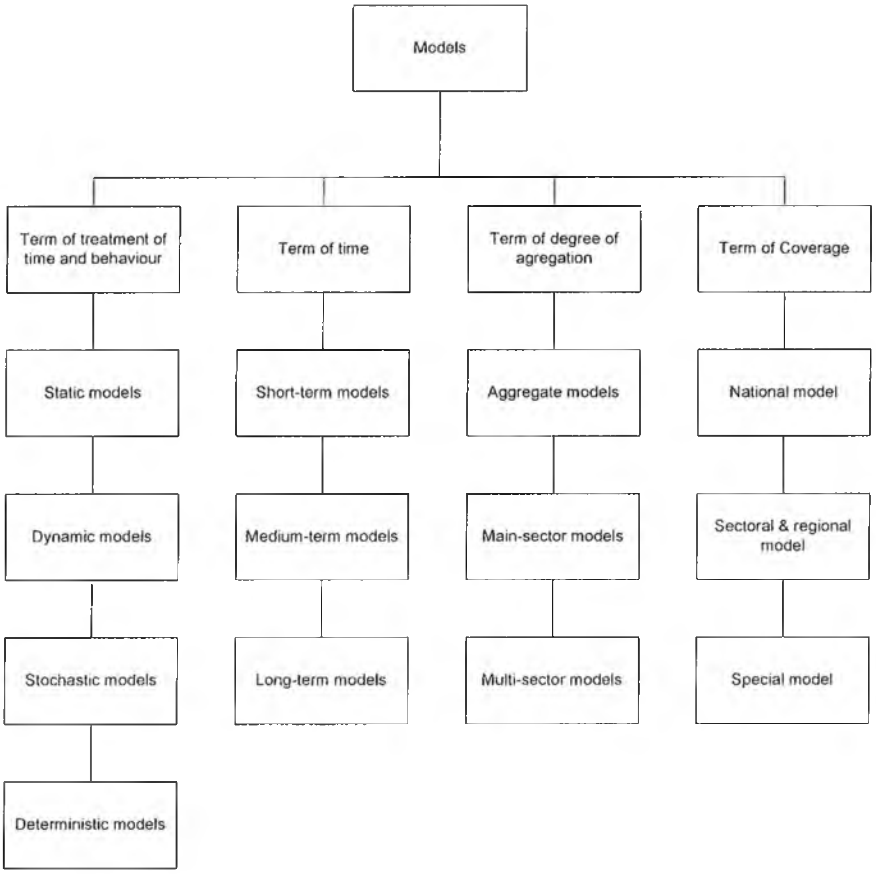
A planning model specifies the relationships between the goals of the society and the instruments that are available to achieve them. By quantifying these relationships, the planners can simulate the effects of alternative policies on the societal objectives and check whether the overall plan or objectives are consistent and feasible in terms of capacity and resource constraints.

Chowdhury, A & Kirkpatrick, C (1994) added that The quantitative planning models therefore provide a framework within which the various agencies involved in the planning process can carry out a fruitful dialogue regarding the possibilities and trade-offs facing the nation. In short, planning models are useful precisely because they force the planners, policy makers and others involved in the planning process to set out the structure of the economy and to focus on the relationships that determine the outcome of policy changes.

On the other hand, planning model can be categorised into (1) overall or national models that deal with the entire economy and within which the nation's development plan is analysed, (2) sectoral or regional models that deal with individual producing sectors and regions can be used examine the feasibility of the overall objective and (3) special models that deal with selected aspects of the overall plan.

Planning models can be also categorised in terms of the degree of aggregation: (1) aggregate models treat the entire economy as one producing sector, (2) main-sector models divide the economy into a few producing sectors and examine the interrelationships between them and (3) multi-sector models divide the economy into a large number of producing sectors. In term of time planning model can be categorised into (1) short –term, usually covering 1-3 years; (2) medium-term, covering a 3-7 year; and (3) long-term, covering 10 years or more.

Figure (3.3): Planning Model categories



Modelling tools can be used to understand the structure of a system, the interconnection between its components and how changes in any area will affect the whole system and its constituent parts over time. Hence these models can be used to measure and predict the behaviours of a system, as well as to facilitate and accelerate group learning. Maani, K & Canava, R(2000).

3.2.2.2.1 Linear Programming (LP)

It is clear that many management decisions are essentially resource allocation decisions and various techniques exist to help management in this area. Programming problems are generally concerned with the optimum allocation of scarce resources among a number of products or activities. These scarce resources may be materials. staff. investment capital or processing time on large or expensive machines.

Linear programming is a mathematical procedure that seeks the optimum allocation of scarce or limited resources to competing products or activities. It is one of the most powerful techniques available to the decision-maker and has found a range of applications in business, government and industry. Curwin, J & Slater, R (1996).

All linear programming problems have three characteristics:
(i) a linear objective function (ii) a set of linear structural constraints and (iii) a set of non-negativity constraints.

Linear programming provides a way of formulating and solving a wide range of problems. If these problems are defined in terms of two variables, then the solution can be found using graphical method. Problems with three or more variables must be solved by techniques such as the Simplex method.

Moreover, linear programming is a very powerful technique for solving allocation problems and has become a standard tool for many businesses and organisations. There are numerous software packages which are dedicated to solving linear programming problems and other types of mathematical programs, of which possibly LINDO, GAMS, XPRESS-MP are the most popular.

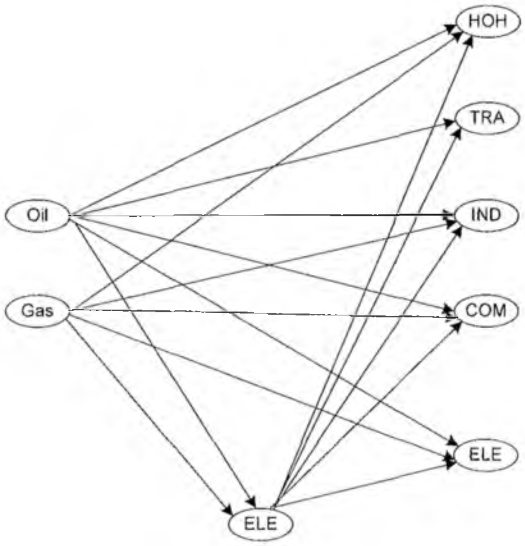
3.2.2.2.2 Transhipment Model

This is a variation on the transportation problem in which shipping via intermediate nodes is allowed. In other words, not all of the nodes in the model are sources or sinks. Some are simple flow conserving nodes. In addition, the sources and sinks may also transship flows.

Figure (3.4) provides a problem to be treated in this study. This network model can be divided into three particular types of nodes. The nodes on the left represent supply nodes, those in the middle are transhipment nodes and those on the right are demand nodes. The arcs connecting a pair of nodes represent paths of transmission or transportation routes between a pair of nodes consisting of supply, transhipment and demand nodes.

The objective of the transhipment problem is to find the minimum cost pattern of the shipment. Constraints are associated with the amount available at each source and the demands at each sink.

Figure (3.4): Transhipment Problem



Supply nodes Transhipment node Demand nodes

In the standard linear programming network, the Simplex algorithm maintains a feasible solution known as a basis, which is gradually improved in small steps until optimality is reached.

For the minimum cost flow problem, the basis is a flow satisfying all capacity constraints. The arcs of the network are divided into three subsets (T, L, U). where L means no flow passes across an arc. U implies that each arc carries flow exactly equal to its capacity and those labelled T from an undirected spanning forest of the network.

Consider $G = (N, A)$ to be a directed network defined by a set N of n nodes and a set A of s directed arcs. Each arc *(i, j)* ε *A* has an associated unit cost value c_{ij}. Each $I \in N$ has an associated number $b_{(i)}$ representing its supply and demand.

A path in $G=(N,A)$ is a sequence of nodes and arcs $i_1,(i_1,i_2).......,(i_{r-1},i_r)$ satisfying the property that either $(i_k,i_{k+1})\in A$ or $(i_{k+1},i_k)\in A$ for each k.

In the minimum cost flow problem, we want to determine a least cost shipment of a commodity through a network that meets the demand at all nodes. The decision variables are the flow x_{ij} on each arc $(i,j)\in A$. This problem can be formulated as an optimisation problem as follows:

Minimize:

$$\sum_{(i,j)\in A} c_{ij}x_{ij}$$

subject to:

$$\sum_{\{j:(i,j)\in V\}} x_{ij} - \sum_{\{j:(j,i)\in V\}} x_{ji} = b_{(i)} \qquad \text{for all } i\in N$$

$$L_{ij}\le X_{ij}\le S_{ij} \qquad \text{for all } (i,j)\in V$$

Where

$$X_{ij}\ge 0 \quad for\ i=1,2,3\ and\ j=1,2,3,4,5$$

3.2.2.2.3 Network Flows

Curwin, J & Slater, R (1996) defined a network as a way of illustrating a set of tasks and showing the relationship between them. Curwin, J & Slater, R (1996) added that a network can be used to show clearly the task or activity that need to completed on time to keep the project on time and also those tasks that can be delayed without affecting the project time.

Network analysis is a collective term for a family of related techniques developed to help management plan and control projects. Curwin, J & Slater, R (1996) stated that the objectives of network analysis are to locate the activities that must be kept to time, manage activities to make the most effective use of resource and look for way of reducing the total project time.

Network analysis is likely to be of most value where the projects are: (i) complex (ii) large, such as high capital investment and (iii) where restrictions exist.

According to Curwin, J & Slater, R (1996) networks provide a planned approach to project management. To be effective, networks require a clear definition of all the tasks that make up the project and pertinent time estimates.

Formulating and solving network problems via linear programming is called network flow programming. Most network flow problem can be cast as a minimum-cost network flow program. A min-cost network flow program has the following characteristics:

1. Variables are the unknown flows in the arcs x_j.
2. The total flow into a node equals the total flow out of a node

$$\underset{\text{(outflow)}}{\sum x_j} - \underset{\text{(inflow)}}{\sum x_j} = 0$$

3. Some nodes are connected to the environment surrounding the network (source node), or a net loss of flow out of the network (sink node)

4. There may be upper and lower bounds on the flows in the arcs

   $x_j \geq b_j$ is a lower bound on an arc flow

   $x_j \leq b_j$ is an upper bound on an arc flow

5. There is a cost per unit of flow c_j associated with each arc
6. In a minimum cost network flow problem, the objective is to find the value of the variables x_j that minimize the total cost of the flow over the network.

Given a properly labeled diagram, the conversion to a minimum cost network flow linear program is straightforward. A network consist of nodes and arcs and there are three parameters associated with each arc; the lower flow bound, the upper flow bound and the cost per unit of flow $\left[l, u, c\right]$.

The parameter l is the lower bound on the flow in the arc with a default value of zero. if not explicitly specified; u is the upper bound on the flow in the arc, with a default value of infinity. If not explicitly specified, c is the cost per unit of flow in the arc with default value of zero. For example, an arc having a lower flow bound of zero, an upper flow bound of 30 and cost per unit of flow of 8 would be labeled $\left[0,30,8\right]$.

Source and sink node behavior is controlled by the label on the phantom arc associated with the node. If the upper and lower flows bound on the phantom arc are identical then the node relationship is an equation. However. if the upper and flow bound on the arc differ then the node relationship is an inequality.

3.3 Research Methodology

Quantitative analysis has been used throughout this study. According to Lawrence. L (1981) quantitative methods can be applied to decision making in general and can be used by individual or group, in deduction, in the professions, and in every type of organisation, including government and non-profit foundations. Lawrence, L

(1981:pp8) stated that every decision–making situation involves alternatives. Quantitative methods are used to select the alterative that best satisfies the decision maker's goal. Lawrence, L (1981) explained that identifying the possible alternative and goals is an important task. Once the alternatives are identified, a problem can be quantitatively analysed by comparing the alternatives in term of how well they meet the decision maker objectives.

3.3.1 Data Collecting

This process covered the collection of secondary data from the main sources (companies and organisations). During this stage the researcher succeeded in attaining several things (1) building good relationships with the people working in the National Oil Corporation (NOC), Central Bank, National Authority for Information and Documentation, Ministry of planning and Public Planning Council, (2) interviewing executives in those companies and organisations and (3) collecting a large part of relevant data from those sources.

Several problems faced the researcher in the data collection process, as already expected: (1) Travel to and Libya from time to time took a significant time and effort, (2) co-operation of the executives and staff was not ensured merely on a letter from the College confirming that the data will be handled confidentially: it was necessary to obtain their interest in the research and (3) the people to be interviewed were senior executive who are always engaged in meetings and other business either inside the country or abroad.

Table (3.2): Summary of main sources of the research

National Authority for Information and Documentation Publications
Ministry of Planning Publications
National Oil Corporation Publications
Central Bank of Libya Publications
Public Planning Council Publications
General Electricity Corporation Publications

3.3.2 Software

The first software we will use in order to calculate the time series of the Libyan crude oil is Minitab. Minitab is a package for the statistical analysis of time series data. The second software package was GAMS (General Algebraic Modelling System), which implemented the model of Social Accounting Matrix (SAM). GAMS supports linear and nonlinear simulation and optimisation models written in algebraic form and has report writing and extensive data manipulation capabilities.

3.4 Validation

Validation is the process of checking whether initial model results agree with known situations; it is an important final step before the model results are use in support of a real-world decision. Two situations may occur:

1- A methodology already exists with the same purpose as the new model
In order to be credible, you will have to prove that the results of the new model are at least as good as the results produced with an existing method, since the old method is probable known to be accurate (or its weaknesses are known) you can compare the old and new method side by side, your model should at a minimum reproduce the old results and should aim for better results.

2- There is no existing methodology
In this case, you should use historical data and try to reproduce the past in essence, you try to predict what you already know.

3.5 Conclusion

This chapter has discussed research methodology used in this research. It resolves the issue of why the quantitative method and modeling methodology have been used. Data collection and related problems have been covered in this chapter as well.

Chapter 4

Box-Jenkins

4.1 Introduction

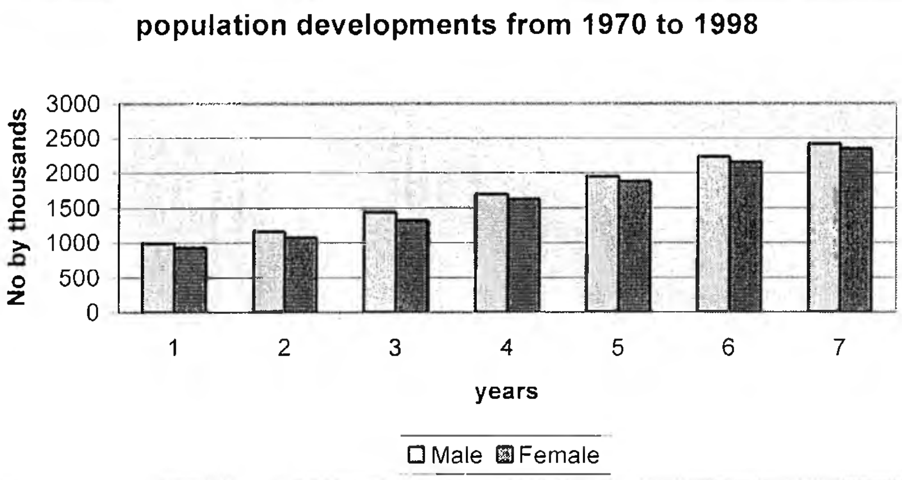
Libya is a North African country, which embraces a vast area of 1,759,540 square Kilometres; it is the fourth largest state on the African continent, and is seven times the size of the United Kingdom. The southern frontiers are bounded by Niger and Chad; the country is also bounded by Sudan in the South East, while it is bounded by Egypt in the East and Tunisia and Algeria in the West. Libya boasts 1,900 Kilometres of coastline with the Mediterranean Sea to the North. The Western coastal part of the country contains the capital Tripoli as well as the highly fertile plain. The Eastern coastal strip contains another valuable agricultural area and the permanent green mountain (al-Jebel al-Akhder). Libya's oil and gas reserves are located well outside the economically productive area, in the Sirt basin and in the South-West, near the border with Algeria. Also, major hydrocarbon reserves are located in the central Hamada al-Hamrah zone, and offshore west of Tripoli, where the large Bouri field has been developed. The first official census of Libya in 1954 recorded a population of 1,041,099. Since 1954 regular censuses have been undertaken every ten years, the official census in 2001 recorded a population of 5,290,000. In comparison to its land area, Libya's population is very small, and it suffers currently from a youthful population, see table (4.1).

Table (4.1): Percent Population, by Division of Aged Groups

1975			1998		
Less than 15	15-65	More than 65	Less than 15	15-65	More than 65
46.5	52.0	2.0	43.0	54.0	3.0

Source: Secretariat of Planning

Figure (4.1): Population Development from 1970 to 1998



Source: National Corporation for Information and Documentation

4.2 Libyan Economic History

4.2.1 The Economic Situation during the Italian Occupation

Twentieth-century writers on imperialism and development believed in an enduring link between colonialism and underdevelopment. Tirthankar, R (2002).

The period of Libyan colonial rule was long enough to defy any simple summary. However, in discussing this period, it is useful to focus on a number of features. The Italian government invested lavishly in Libya where a lot of money was spent on roads, ports, railways, public buildings and agriculture. While the Italian development in Libya depended heavily on Italian nationals. the role of Libyans was limited to unskilled jobs.

4.2.2 From independence in 1951 until 1969

By the year 1949, when the United Nation decided the future of Libya. the foreign administrations in the country initiated efforts to involve the Libyans in the management process with a view to handing over responsibilities to them after independence.

The Libyan economy during this period was poor and dependent mainly on agriculture and livestock. The majority of the population led a simple life depending essentially on a subsistence level of food, clothing and housing and enjoying very limited knowledge of twentieth century technology. The other sector of the economy belonged to a minority of foreigners or natives who lived in modern villas. The modern sectors of the dual economy tried to satisfy the needs of a small group for construction, services, consumption, transportation and sophisticated luxuries of imported goods.

The discovery of the oil had a major effect on the economy. Libyan exports between 1958 and 1961 jumped from 4.313 (million L£) to 218.487 (million L£). In contrast, agriculture largely stagnated during this period.

Table (4.2): changing of agriculture contribution in Libyan economy during period 1958-1968

Sectors	1958	1962	1967	1968
Agriculture products	20.0	17.3	21.0	21.7
Agriculture products as percent of national product	26.1	9.4	3.4	2.6
Agriculture exports	2.7	1.8	0.6	0.47
Trade deficit in agriculture goods	2.4	6.6	18.6	28.95
Total employment in agriculture sector as percent of total employment	70%	50%	33.9%	30%
Petroleum exports	0	49.0	417.3	664.3
Petroleum exports as percent of national product	0	28.5%	54.7%	59.7%

Source: planning and development Ministry; Ateiga (1972,P.120)

However, the impact of prosperity of the oil industry was clearly reflected in many respects of society:

1- The gap between the two sectors of the dual economy has gradually narrowed.

2- Libya is self reliant.

3- A rapid growth in gross domestic product has been achieved, jumping from L£ 52.2 million in 1958 to L£ 492.1million in 1965 see table (4.3).

Table (4.3): Gross Domestic Product of Libya during the period 1958-1968

(Million L£)

Sectors	1958		1962		1965		1968	
		%		%		%		%
Agriculture	13.6	26	14.9	9.6	25.2	5.1	33.4	301
Petroleum and natural gas	3.6	6.9	38	24.4	270.1	54.9	648.6	60.5
Mining and quarrying	3.6	6.9	0.6	0.4	1.0	0.2	1.5	0.1
Manufacturing industries	6	11.5	9.0	5.8	12.6	2.6	20.0	1.9
Construction	1.8	3.4	10.3	6.6	34.9	7.1	89.2	8.3
Electricity and gas	0.8	1.5	0.9	0.6	2.0	0.4	3.9	0.4
Transport, storage & communication	2.9	5.5	8.6	5.5	18.5	3.8	39.3	3.7
Trade, restaurants and hotels	7.3	13.9	14.2	9.1	25.1	5.1	45.5	4.2
Banking and insurance			1.7	1.1	3.5	0.7	6.3	0.6
Public administration and defence	9.5	18.1	15.5	10.0	37.0	7.5	77.1	7.2
Educational services	6.7	12.8	5.0	3.2	12.8	2.6	25.6	2.4
Health services			2.1	1.4	4.5	0.9	10.9	1.0
Ownership of dwelling			29.4	18.9	36.4	7.4	59.7	5.5
Other services			5.3	3.4	8.5	1.7	11.6	1.1
	52.2	100	155.5	100	492.1	100	1072.6	100

Source: planning and development Ministry; (1972,P.120)

4.2.3 Libyan economy since 1969

4.2.3.1 Economic situation

Since the 1969 revolution, state intervention in the economy has increased in accordance with the social and economic ideas of Qaddafi. It started in 1973 with the so-called Cultural Revolution and the introduction of peoples' committees to administrate the majority of public organisations. The nationalisation process in the oil sector started at the beginning of the 1970s by nationalising the marketing and distribution of petroleum activities in the country.

In 1978. a large number of private companies were taken over by workers' committees. One year later, all direct importing businesses were transferred to public corporation and the issuing of importing licences was stopped. In 1981, the government cancelled all licences of shops selling food products, clothes, electrical goods, household appliances and spare parts. As an alternative, retail activity came under the control of the state-administrated supermarkets and seven marketing companies.

During the 1980s, the Libyan economy was severely affected by the slump in oil revenues which resulted from the low prices and oil export shrinkage; for example, revenue from sales of petroleum declined from $14,930 million in 1981 to $6,070 million in 1988. OPEC Annual Statistical Bulletin (2001). This situation led to the suspension or cancellation of a number of development projects (with the exception of the Great Man-made River). The estimated cost of this project was 30 billion dollars; it aimed at providing the northern part of Libya with sufficient water supply by piping fresh water from the water tables in the south.

The Libyan economy was based on agriculture during the 1950s. Since the 1960s oil became the main source of Libyan income; however, the fluctuation in oil prices directly affected the GDP growth. Table 2.5.1.1 shows GDP increased from LD 1288.3 million in 1970 to LD 5612.7 million in 1977 due to increased oil prices. In contrast, the decline in oil prices during the 1980s led to a decrease in the GDP. During the 1990s, the GDP reached LD 14285.8 million in 1999, with an annual growth rate of 19.19% (c.f.) Table (4.4).

Table (4.4) Gross Domestic Product by economic sectors for different years (Million LD)

Economic sectors	1970	1974	1977	1980	1986	1989	1990	1995	1999
Agriculture, Forestry and Fishing	33.1	64.7	90.0	183.0	320.0	563.5	612.8	1095.3	1546.5
Oil and Natural Gas	812.6	2385.0	3276.0	6571.0	1784.0	1608.8	2235.8	3063.0	3254.1
Mining and Quarrying	1.7	15.5	28.5	48.8	49.0	65.7	66.5	185.0	215.4
Manufacturing	22.5	55.0	124.7	192.2	401.8	587.0	645.0	764.8	944.0
Electricity, Gas and Water	6.2	12.4	26.1	49.7	112.0	174.8	154.1	232.3	269.3
Constriction	87.8	376.6	602.0	935.7	895.0	1197.5	1205.5	679.0	737.7
Trade, Restaurants and Hotels	47.0	184.2	292.0	489.8	485.9	826.5	925.7	1418.0	1965.9
Transportation. storage and communication	43.2	155.0	220.1	356.1	395.5	628.5	712.5	948.1	1275.8
Finance, Insurance and	13.0	72.8	144.1	246.4	285.4	326.5	345.0	307.1	476.0

Ownership of Dwellings									
Ownership of Houses	59.6	111.3	157.3	210.4	252.4	298.2	304.1	410.1	507.2
Public administration and defence	98.1	209.5	362.2	611.1	920.0	1114.5	1105.5	939.5	1238.7
Education services	39.7	95.4	172.8	220.8	387.5	477.0	505.5	884.1	926.9
Health services	15.8	38.5	79.6	114.7	213.5	292.0	311.0	351.0	488.4
Other services	8.0	19.5	37.4	47.4	75.0	140.5	155.5	354.0	439.9
Total	1288.3	3795.4	5612.8	10277.1	6577.0	8301.0	9284.5	11631.3	14285.8
Oil and natural Gas as percentage of GDP	63.1%	62.8%	58.4%	63.9%	27.1%	19.4%	24.1%	26.3%	22.8%
Other sectors	36.9%	37.2%	41.6%	36.1%	72.9%	80.6%	75.9%	73.7%	77.2%

Source: Central Bank of Libya (1994) (2000)

However, over the past three years, Real Gross Domestic Product (GDP) grew by around 3.2% in 2000 and recorded a slightly decrease in 2001 of 0.1% due to the declining in the contribution of the oil sector, which decreased from LD 6661.0 million in 2000 to LD 6009.0 million in 2001.

4.2.3.2 Economically Active Population

The Economically Active Population has increased from 1383.8 thousand in 1999 to 1445.0 thousand in 2000. Table (4.5) shows the number of the economically active people according to non-national or citizen status.

Table (4.5): Economically Active Population in Libya from 1998 to 2000 (Thousand)

Years	Citizens		Non-nationals		Total
	Number	%	Number	%	
1998	1151.6	87.0	172.1	13.0%	1323.7
1999	1203.9	87.0	179.9	13.0	1383.8
2000	1257.1	87.0	187.9	13.0	1445.0

Source: Central Bank of Libya, annual report 2001

4.2.3.3 Foreign Trade

Libyan imports witnessed a significant increase during the 1970s, from 263 million in 1970 to 4311 million in 1981; the main reason behind this was the increase in Libyan oil exports during the period. The value of imports during the 1980s and 1990s decreased from 4311 million in 1981 to 1928.6 million in 1999. National Corporation for Information and Documentation (2000), due to the decrease in the oil exports, which represent the main source of foreign exchange and as a result of U.S. and U.N. sanctions.

During 2001, the value of exports and imports produced a trade surplus of LD2733.1 million against a corresponding surplus of LD 3310.1 million in 2000. The value of exports during 2001 increased by LD 172.5 million as compared to 2000, whereas the value of imports during the same period decreased by LD 749 million as compared to 2001.

Table (4.6): value of exports, imports and balance of trade during 2000and 2001
Million LD

During	Exports	Imports	Trade balance
2000	5221.5	1911.4	3310.1
2001	5394.0	2660.4	2733.6

Source: National Corporation for Information and Documentation (2001)

4.2.3.4 Oil and Gas

Libya is a major oil exporter, particularly to Europe. Oil export revenues, which account for about 95% of Libya's hard currency earning (and 75% of government receipts), were hurt severely by the dramatic decline in oil price during 1998, as well as by reduced oil exports and production - in part as a result of U.S. and U.N. sanctions. With higher oil prices since 1999, however, Libyan oil export revenues have increased sharply to $11.0 billion in 2001. up from only $6.0 billion in 1998. As a result of strong oil export revenues, Libya's fiscal situation is now significantly in surplus.

Libya's oil industry is run by the state-owned National Oil Corporation (NOC), along with smaller subsidiary companies. NOC and its subsidiaries account for 63% of Libya's production. As of 2000, NOC had an estimated total oil production capacity of around 810,000 bbl/d, accounting for over half the country's total. Several international oil companies are engaged in exploration/production agreements with NOC. The leading foreign oil producer in Libya is Italy's Agip-Eni, which has been operating in the country since 1959.

Overall, Libya would like foreign companies help to increase the country's oil production capacity from 1.5 million bbl/d at present to 2 million bbl/d over the next five years. This would restore Libya's oil production capacity to the level of the early 1970s. In order to achieve its oil sector goals, Libya will require as much as $10 billion in foreign investment over the coming decade.

4.2.3.5 Currency

In January 2002, Libya devalued the official exchange rate on its currency, the Dinar, by 51% as part of a move toward the unification of the country's multi-tier foreign exchange system. The devaluation also aimed to increase the competitiveness of Libyan firms and to help attract foreign investment into the country. Also in January 2002, Libya cut its customs duty rate by 50% on most imports to help offset the effects of its currency devaluation.

4.2.3.6 Future Developments

The need for policy shift had become evident much earlier as many countries achieved high growth and poverty reduction through policies that emphasized greater export orientation and encouragement of the private sector.

Libya is hoping to reduce its dependency on oil as the country's sole source of income and to encourage investment in agriculture, tourism, fisheries, mining and natural gas. The reform of Libya's agricultural sector is a top government priority. There are hopes that Great Man Made River will reduce the country's water shortage and its dependence on food imports. Libya is also attempting to position itself as a key economic intermediary between Europe and Africa. Liberalizing foreign direct investment is another important part of future developments, driven by the belief that this will increase the total volume of investment in the economy, improve production technology and increase access to world markets. This policy will create a different competitive environment for Libyan companies than exists now and will lead to significant changes. However, Libya has been taking some steps in this direction since

1999; therefore, Libya's economic performance in the post-reform period has many positive features.

4.3 Box-Jenkins Model

The model-building methodology of Box and Jenkins relies heavily upon two functions, the Autocorrelation Function (ACF) and the Partial Autocorrelation Function (PACF). The underlying goal is to find an appropriate formula so that the residuals are as small as possible and exhibit no pattern. The model-building process involves three stages, model selection, model estimation and model checking. This is repeated as necessary, terminating with a model that replicates the patterns in the series as closely as possible, is parsimonious in terms of the number of parameters used and also produces accurate forecasts.

The basic Box - Jenkins (1976) ARIMA model is a regressionlike approach: a given observation, Y_t, at time t, is a function of the values of previous observations and the accumulation and retention of residual errors. This approach combines several techniques, such as building equations with autoregressive terms, differencing values, and modelling residuals. Because several major processes are included in one model, the procedure is known as an autoregressive integrated moving average (ARIMA) approach. By modelling residuals into the equations, many problems that plague ordinary least-squares methods can be reduced. Ronald, D. F et al. (1997).

According to Donald. A & Hoi K. (1989) ARIMA methods can be used to analyze data in a simple time series that contains no behavioral intervention. In this case, the objective of the ARIMA analysis is to describe the nature of the serial dependency of the time series in exact mathematical terms. Frequently, a simple time series analysis is conducted for the purpose of forecasting some future event. By identifying the exact nature of the serial dependency in the past, one can project the series into the future, assuming that the serial dependency will continue in the same fashion.

The basic formula for ARIMA models is:

$$X_t = \delta + \phi_1 X_{t-1} + \phi_2 X_{t-2} + \dots\dots + \phi_p X_{t-p} + \\ A_t - \theta_1 A_{t-1} - \theta_2 A_{t-2} - \dots\dots\dots - \theta_q A_{t-q} \tag{4.1}$$

There are a couple of points to note on Box-Jenkins model:

1- The model assumes that the time series is stationary, and recommend differencing non-stationary series one or more times in order to achieve stationarity.

2- Box-Jenkins models can be extended to include seasonal autoregressive and seasonal moving average terms. Although this complicates the notation and mathematics of the model, the underlying concepts for seasonal autoregressive and seasonal moving average terms are similar to the non-seasonal autoregressive and moving average terms.

3- The most general Box-Jenkins model includes difference operators, autoregressive terms, moving average terms, seasonal difference operators, seasonal autoregressive terms, and seasonal moving average terms. As with modeling in general, however, only necessary terms should be included in the model.

4.3.1 Autoregressive Terms (AR)

The first components in the equation (4.1) is the autoregressive terms (AR), phi (ϕ), which indicate that a given observation can be predicted from past observations

$$X_t = \phi_1 X_{t-1} + \phi_2 X_{t-2} + \dots\dots + \phi_p X_{t-p} + \delta \tag{4.2}$$

There may be no ϕ coefficient in the model; however, in general, there are p different phi coefficients, where p is the number of lagged terms that the researcher will assess. The phi coefficients are regression weights that account for autoregression up to p units behind the present observation. Ronald, D. F et al (1997:187).

4.3.2 Moving Average Terms (MA)

The next components are the moving average (MA), theta (θ)

$$X_t = -\theta_1 A_{t-1} - \theta_2 A_{t-2} - \dots\dots\dots - \theta_q A_{t-q} + \delta \qquad (4.3)$$

Moving average parameters are somewhat more difficult to describe than are the autoregressive parameters. They can be considered as coefficients that represent the degree to which the errors or residuals, *e*, linger in the series and are "remembered" by the series to create a lagged influence. Some time series "drain off " or dissipate their residuals rapidly. Therefore, their theta terms may be small or nonexistent. However, some series have large theta terms because residual errors that linger for a while will influence subsequent observations. There may be no theta coefficients or as many as q theta coefficients, where q is the number of moving average lags. Ronald, D. F et al. (1997).

4.3.3 Stationarity

A common assumption in many time series techniques is that the data are stationary.

Box - Jenkins ARIMA models assume that time series are "stationary." That is, a time series itself should have the same mean level and the same variability around the mean level throughout the entire time series. This means that a series that displays a systematic trend or that has different variances along the series would be unacceptable for analysis unless it was transformed to stationarity. Ronald, D. F et al. (1997).

A stationary process has the property that the mean, variance and autocorrelation structure do not change over time. Stationarity can be defined in precise mathematical terms, but for our purpose we mean a flat looking series, without trend, constant variance over time, a constant autocorrelation structure over time and no periodic fluctuations (seasonality).

For practical purposes, stationarity can usually be determined from a run sequence plot. If the time series is not stationary, we can often transform it to stationarity with one of the following techniques.

1. We can difference the data. That is, given the series Z_t, we create the new series $Y_i = Z_i - Z_{i-1}$
2. The differenced data will contain one less point than the original data. Although you can difference the data more than once, one difference is usually sufficient.
3. For non-constant variance, taking the logarithm or square root of the series may stabilize the variance. For negative data, you can add a suitable constant to make all the data positive before applying the transformation. This constant can then be subtracted from the model to obtain predicted (i.e., the fitted) values and forecasts for future points.

4.3.4 Seasonality

Many time series display seasonality. By seasonality, we mean periodic fluctuations. For example, oil prices tend to increase in the Winter season and decline in the Summer season. So time series of oil prices will typically show increasing prices from September through February and declining prices in July and August.

Seasonality is quite common in economic time series. It is less common in engineering and scientific data.

The following graphical techniques can be used to detect seasonality.

1. A run sequence plot will often show seasonality.
2. A seasonal subseries plot is a specialized technique for showing seasonality.
3. Multiple box plots can be used as an alternative to the seasonal subseries plot to detect seasonality.
4. The autocorrelation plot can help identify seasonality.

The run sequence plot is a recommended first step for analyzing any time series. Although seasonality can sometimes be indicated with this plot. seasonality is shown more clearly by the seasonal subseries plot or the box plot. The seasonal subseries plot does an excellent job of showing both the seasonal differences (between group patterns) and also the within-group patterns. The box plot shows the seasonal difference (between group patterns) quite well, but it does not show within group patterns. However, for large data sets, the box plot is usually easier to read than the seasonal subseries plot.

Both the seasonal subseries plot and the box plot assume that the seasonal periods are known. In most cases, the analyst will in fact know this. For example, for monthly data, the period is 12 since there are 12 months in a year. However, if the period is not known, the autocorrelation plot can help. If there is significant seasonality, the autocorrelation plot should show spikes at lags equal to the period. For example, for monthly data, if there is a seasonality effect, we would expect to see significant peaks at lag 12, 24, 36, and so on (although the intensity may decrease the further out we go).

There are three primary stages in building a Box-Jenkins time series model

4.3.5 Model Identification

The first step in developing a Box-Jenkins model is to determine if the series is stationary and if there is any significant seasonality that needs to be modelled. Stationary can be assessed from a run sequence plot. The run sequence plot should show constant location and scale. It can also be detected from an autocorrelation plot. Specifically, non-stationarity is often indicated by an autocorrelation plot with very slow decay. Seasonality can be assessed from an autocorrelation plot, a seasonal plot, a seasonal subseries plot or a spectral plot.

As a first step in model identification, researchers should plot the time series and examine possible trends and/or uneven variability. Seasonal cycles may also be apparent in the plot. This step will often show that differencing and variance stabilizing transformations will be necessary to create a stationary series. Next, the researcher should obtain the autocorrelation coefficients (ACF) of the series (or differenced series) up to n /4 lags behind, where n = the number of data points in the series. In addition, users should obtain partial autocorrelation coefficients up to n /4 lags behind. Partial autocorrelation coefficients (PACF) are autocorrelations coefficients between any two time periods, in which the influence of all other time periods has been removed. One can start to build a preliminary model of the series by examining the patterns of autocorrelation functions and partial autocorrelations. Different patterns of autocorrelation and moving average terms leave their own tell-tale "signatures" in the ACF and PACF plots, much in the way that burning objects leave their particular patterns of spectral bands on the spectroscope. Ronald, D. F et al. (1997).

According to McCain, L (1979:pp249):

1. If the ACF shows a significant positive peak at lag q and trails off rapidly and/or shows a damped exponential or sine wave and PACF shuts off abruptly, suspect an AR process.
2. If the PACF shows a significant positive peak at lag q and trails off and shows an exponential or damped sine wave (-) and the ACF is small after lag q, suspect an MA process.

4.3.6 Model Estimation

Estimating the parameters for the Box-Jenkins models is a quite complicated non-linear estimation problem. For this reason, the parameter estimation should be left to a high quality software program that fits Box-Jenkins models. Fortunately, many commercial statistical software programs now fit Box-Jenkins models.

The main approaches to fitting Box-Jenkins models are non-linear least squares and maximum likelihood estimation. Maximum likelihood estimation is generally the preferred technique.

4.3.7 Model Diagnostics

That is, the error term A_t is assumed to follow the assumptions for a stationary univariate process. The residuals should be white noise (or independent when their distributions are normal) drawings from a fixed distribution with a constant mean and variance. If the Box-Jenkins model is a good model for the data, the residuals should satisfy these assumptions.

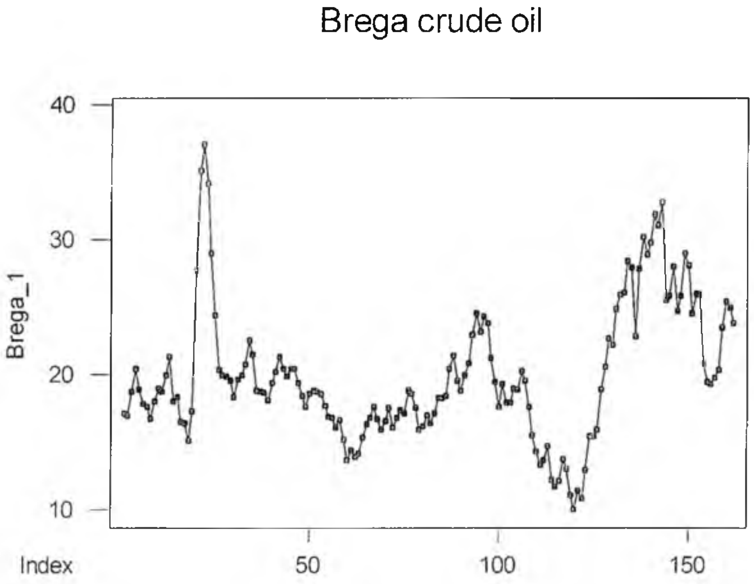
If these assumptions are not satisfied, we need to fit a more appropriate model. That is, we go back to the model identification step and try to develop a better model. Hopefully the analysis of the residuals can provide some clues as to a more appropriate model.

4.4 Modelling Libyan Crude Oil

We will use the previous procedure to model a time series of Libyan crude oil in 2002 as an ARMA (Auto-Regressive Moving-Average) process and produce future forecasts using MINITAB. Libya produces eight types of crude oil; Brega, Zuweitina, Sirtica, Sidra, Abu-Tiffil, Sarir, Alshrara and Amna. The series of monthly crude oil prices for this study covered the period from 1988 to 2002.

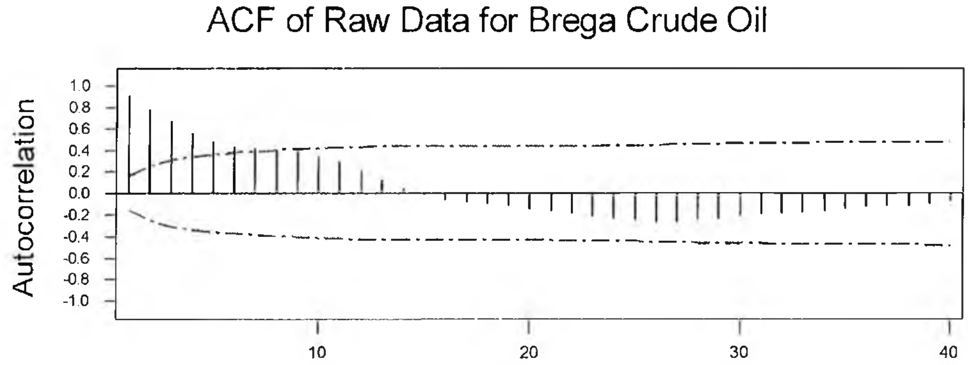
4.4.1 Brega crude oil prices

Figure (4.2): Plot of the Brega Crude Oil



The autocorrelation function (ACF) plot shows a very slow, linear decay pattern, which is typical of non-stationary time series:

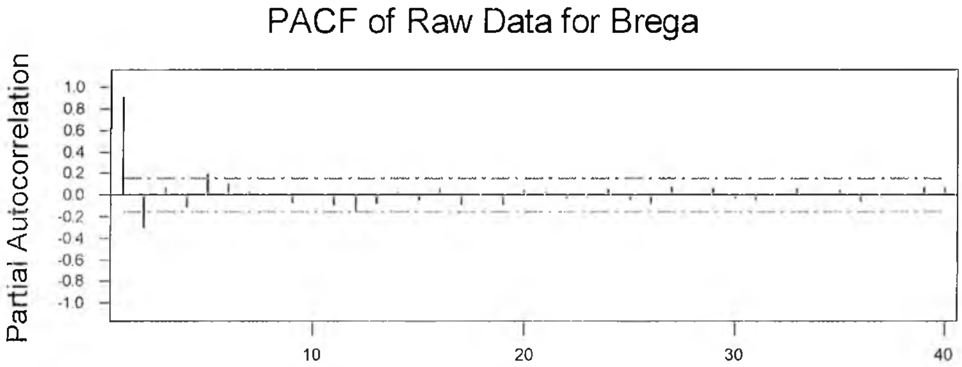
Figure (4.3): ACF of Raw Data for Brega Crude Oil



```
Lag  Corr     T     LBQ    Lag  Corr     T     LBQ    Lag  Corr     T     LBQ    Lag  Corr     T     LBQ

  1  0.92 11.66  138.50     13  0.12  0.55  574.15     25 -0.25 -1.12  632.89     37 -0.12 -0.51  737.25
  2  0.79  6.13  241.79     14  0.04  0.19  574.46     26 -0.27 -1.19  647.25     38 -0.12 -0.49  740.24
  3  0.67  4.32  317.34     15 -0.03 -0.12  574.58     27 -0.27 -1.19  661.95     39 -0.10 -0.42  742.48
  4  0.56  3.23  369.54     16 -0.07 -0.30  575.39     28 -0.26 -1.12  675.28     40 -0.07 -0.29  743.59
  5  0.48  2.60  408.00     17 -0.09 -0.41  576.86     29 -0.24 -1.03  686.82
  6  0.44  2.31  441.00     18 -0.10 -0.47  578.88     30 -0.22 -0.93  696.40
  7  0.42  2.14  471.56     19 -0.13 -0.57  581.84     31 -0.21 -0.87  705.03
  8  0.41  2.02  500.44     20 -0.15 -0.69  586.15     32 -0.20 -0.83  712.97
  9  0.39  1.86  526.20     21 -0.17 -0.78  591.80     33 -0.18 -0.76  719.84
 10  0.35  1.65  547.68     22 -0.20 -0.89  599.21     34 -0.17 -0.71  725.86
 11  0.30  1.38  563.31     23 -0.23 -1.02  609.12     35 -0.15 -0.62  730.57
 12  0.22  0.99  571.55     24 -0.24 -1.08  620.48     36 -0.13 -0.54  734.09
```

Figure (4.4): PACF of Raw Data for Brega Crude Oil



```
Lag   PAC      T     Lag   PAC      T     Lag   PAC      T     Lag   PAC      T

  1  0.92  11.66      13 -0.09  -1.18      25 -0.05  -0.63      37 -0.04  -0.45
  2 -0.31  -4.01      14  0.03   0.34      26 -0.09  -1.11      38 -0.02  -0.28
  3  0.07   0.95      15 -0.06  -0.79      27  0.07   0.94      39  0.07   0.89
  4 -0.12  -1.57      16  0.06   0.80      28  0.00   0.00      40  0.08   0.96
  5  0.20   2.50      17 -0.10  -1.25      29  0.06   0.79
  6  0.10   1.29      18  0.02   0.24      30 -0.04  -0.46
  7  0.03   0.33      19 -0.10  -1.30      31 -0.06  -0.74
  8 -0.01  -0.13      20  0.04   0.53      32  0.01   0.12
  9 -0.08  -0.99      21  0.03   0.36      33  0.06   0.76
 10  0.02   0.21      22 -0.04  -0.49      34 -0.02  -0.20
 11 -0.10  -1.30      23 -0.03  -0.35      35  0.04   0.46
 12 -0.16  -2.01      24  0.06   0.71      36 -0.07  -0.94
```

Clearly at least one of differencing step is needed to make this series stationary. After taking one non-seasonal difference the plot becomes:

Figure (4.5): Plot of Brega Crude Oil after one Non-Seasonal Difference

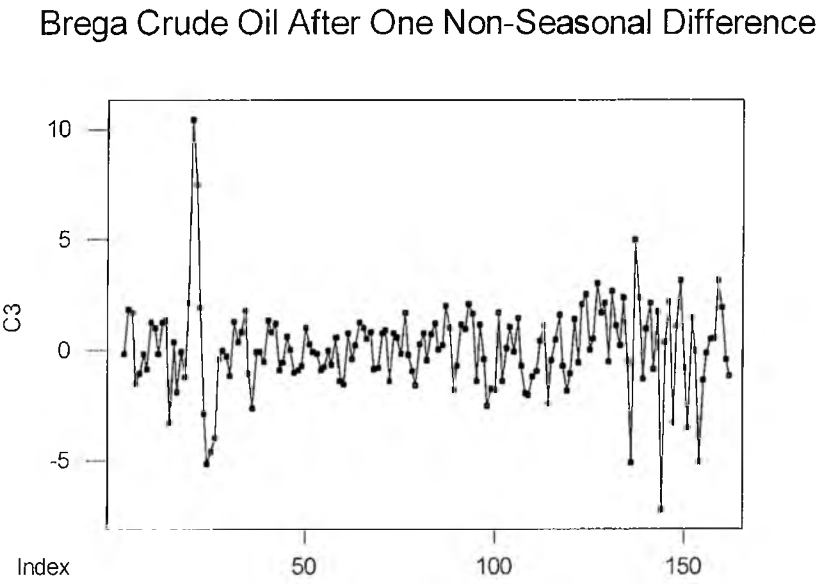
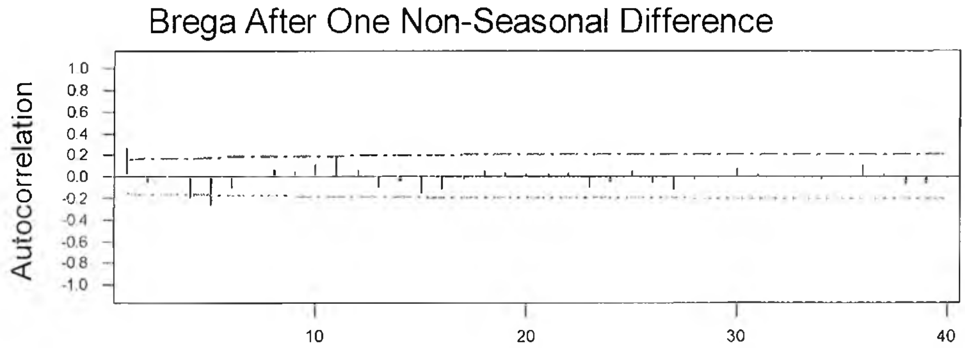


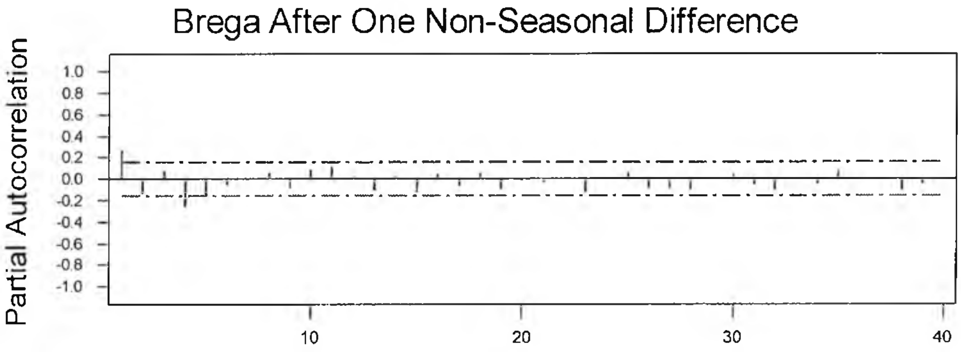
Figure (4.6): ACF of Brega Crude Oil after one Non-Seasonal Difference



```
Lag  Corr     T    LBQ    Lag  Corr     T    LBQ    Lag  Corr     T    LBQ    Lag  Corr     T    LBQ

  1  0.26  3.30  11.12     13 -0.12 -1.20  46.49     25  0.05  0.45  59.76     37  0.02  0.22  68.24
  2 -0.06 -0.76  11.80     14 -0.05 -0.55  47.01     26 -0.07 -0.69  60.73     38 -0.08 -0.74  69.55
  3  0.01  0.15  11.82     15 -0.17 -1.70  52.03     27 -0.13 -1.27  64.09     39 -0.07 -0.64  70.54
  4 -0.20 -2.41  18.72     16 -0.13 -1.30  55.11     28 -0.04 -0.35  64.34     40 -0.02 -0.18  70.61
  5 -0.27 -3.12  31.19     17 -0.04 -0.42  55.45     29 -0.01 -0.11  64.37
  6 -0.11 -1.23  33.36     18  0.05  0.52  55.95     30  0.07  0.68  65.36
  7 -0.03 -0.37  33.57     19  0.03  0.26  56.07     31  0.02  0.23  65.48
  8  0.06  0.69  34.27     20  0.02  0.16  56.12     32 -0.01 -0.14  65.53
  9  0.04  0.41  34.53     21  0.02  0.22  56.22     33  0.02  0.18  65.60
 10  0.11  1.17  36.62     22  0.03  0.34  56.44     34 -0.04 -0.40  65.95
 11  0.20  2.07  43.34     23 -0.11 -1.06  58.64     35 -0.01 -0.05  65.95
 12  0.06  0.66  44.05     24 -0.06 -0.59  59.35     36  0.10  0.97  68.13
```

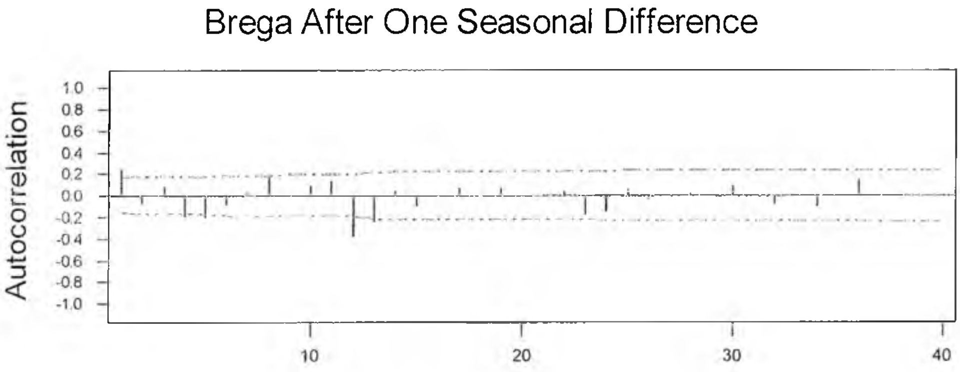
Figure (4.7): PACF of Brega Crude Oil after one Non-Seasonal Difference



Lag	PAC	T	Lag	PAC	T	Lag	PAC	T	Lag	PAC	T
1	0.26	3.30	13	-0.11	-1.45	25	0.05	0.63	37	-0.00	-0.06
2	-0.14	-1.79	14	0.02	0.24	26	-0.10	-1.21	38	-0.11	-1.43
3	0.07	0.95	15	-0.14	-1.72	27	-0.09	-1.19	39	-0.05	-0.67
4	-0.26	-3.31	16	0.04	0.51	28	-0.11	-1.41	40	0.00	0.02
5	-0.15	-1.88	17	-0.07	-0.95	29	-0.01	-0.08			
6	-0.06	-0.74	18	0.05	0.68	30	0.04	0.55			
7	-0.02	-0.30	19	-0.10	-1.23	31	-0.06	-0.75			
8	0.06	0.70	20	-0.03	-0.35	32	-0.11	-1.37			
9	-0.09	-1.13	21	-0.04	-0.47	33	-0.01	-0.14			
10	0.09	1.09	22	-0.01	-0.08	34	-0.05	-0.62			
11	0.11	1.43	23	-0.13	-1.62	35	0.07	0.90			
12	0.02	0.22	24	0.01	0.18	36	-0.00	-0.04			

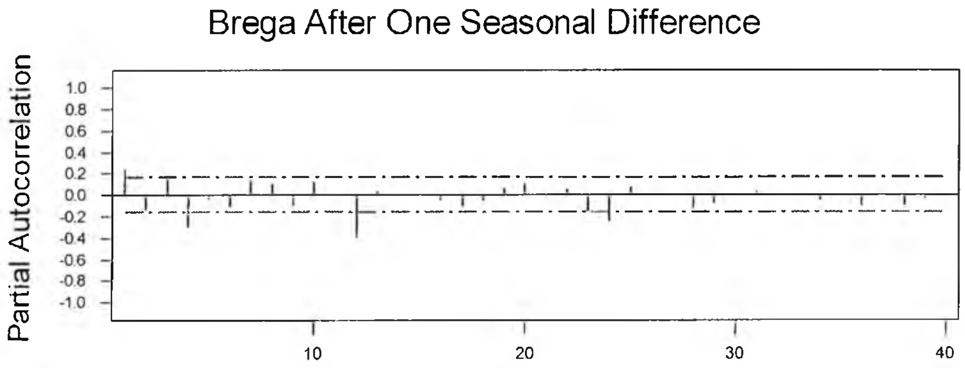
The autocorrelations at the near-seasonal lags (11, 23, 36) fail to die out quickly. This confirms the nonstationary character of the seasonal pattern and calls for seasonal difference.

Figure (4.8): ACF of Brega Crude Oil after one Seasonal Difference



Lag	Corr	T	LBQ	Lag	Corr	T	LBQ	Lag	Corr	T	LBQ	Lag	Corr	T	LBQ
1	0.24	2.98	9.05	13	-0.25	-2.33	70.04	25	0.07	0.56	84.66	37	0.01	0.07	94.72
2	-0.08	-0.90	9.99	14	0.04	0.33	70.27	26	-0.04	-0.37	84.99	38	-0.03	-0.27	94.93
3	0.08	0.88	10.89	15	-0.10	-0.86	71.85	27	-0.01	-0.08	85.01	39	-0.01	-0.05	94.93
4	-0.20	-2.29	17.11	16	0.01	0.11	71.88	28	0.02	0.19	85.10	40	-0.00	-0.03	94.94
5	-0.22	-2.39	24.42	17	0.07	0.62	72.70	29	-0.00	-0.01	85.10				
6	-0.09	-0.96	25.72	18	0.02	0.16	72.75	30	0.09	0.77	86.64				
7	0.03	0.31	25.85	19	0.07	0.59	73.53	31	0.01	0.07	86.66				
8	0.17	1.80	30.49	20	0.01	0.08	73.55	32	-0.08	-0.72	88.04				
9	0.02	0.21	30.56	21	0.01	0.08	73.56	33	-0.01	-0.07	88.05				
10	0.09	0.95	31.94	22	0.05	0.40	73.93	34	-0.10	-0.88	90.16				
11	0.13	1.34	34.69	23	-0.18	-1.61	79.87	35	-0.00	-0.03	90.16				
12	-0.39	-3.95	59.51	24	-0.15	-1.29	83.87	36	0.15	1.27	94.71				

Figure (4.9): PACF of Brega Crude Oil after one Seasonal Difference



```
Lag  PAC     T       Lag  PAC     T       Lag  PAC     T       Lag  PAC     T

  1  0.24   2.98      13  0.03   0.32      25  0.07   0.82      37  0.02   0.24
  2 -0.15  -1.79      14  0.01   0.09      26 -0.00  -0.03      38 -0.10  -1.21
  3  0.15   1.78      15  0.01   0.15      27  0.01   0.13      39 -0.05  -0.55
  4 -0.30  -3.70      16 -0.05  -0.62      28 -0.13  -1.58      40 -0.02  -0.30
  5 -0.04  -0.54      17 -0.12  -1.43      29 -0.08  -0.99
  6 -0.12  -1.42      18 -0.06  -0.70      30  0.02   0.19
  7  0.13   1.58      19  0.06   0.70      31  0.03   0.39
  8  0.11   1.30      20  0.10   1.26      32 -0.02  -0.29
  9 -0.10  -1.23      21 -0.03  -0.34      33 -0.01  -0.17
 10  0.12   1.46      22  0.05   0.65      34 -0.05  -0.60
 11  0.00   0.05      23 -0.16  -1.91      35  0.00   0.01
 12 -0.41  -4.95      24 -0.25  -3.11      36 -0.10  -1.25
```

The autocorrelation function (ACF) plot shows five significant spikes, whereas the partial autocorrelation function shows four significant spikes, Which this suggests a model with both an AR and MA term, the model may be ARMA (5, 5).

Residual Sum of Squares for Various ARMA (P, Q) models for Brega Data with One Seasonal and Non-Seasonal Difference:

Table (4.7): Residual sum of Squares

5	454.92	**395.25**	390.11	386.26	393.24	**341.01**
4	548.45	545.44	551.00	402.82	368.04	426.97
3	564.86	561.38	513.61	511.89	426.80	429.13
2	574.13	548.77	503.63	447.54	463.74	428.48
1	796.71	596.24	597.33	451.13	439.45	465.63
0		603.23	605.15	489.49	486.86	490.74
P/ q	0	1	2	3	4	5

A pattern is evident in the table for the Brega data that is replicated for the tables of Sum Squares for the other time series considered, the Brega table for a minimum value of 341.01 for the ARMA (5,5) model, and (essentially) a local optimum of 395.25 for the ARMA (5,1) model.

However, based on the 'principle of parsimony' in model selection, we will use ARMA (5,1) as the preferred model for the data, with little loss in the residual term.

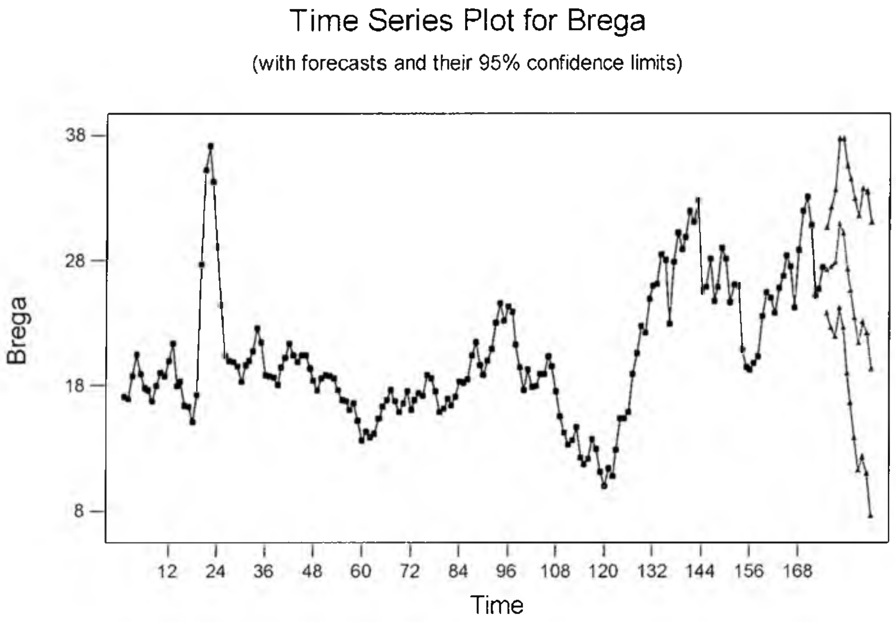
Table (4.8):Forecasts Brega on Raw Data Using the ARMA (5,1) Model:

```
Forecasts from period 162
                                  95 Percent Limits
Period       Forecast        Lower        Upper          Actual
 163          24.9021       21.6429      28.1613          25.71
 164          25.2960       20.6867      29.9052          26.66
 165          26.3761       20.7310      32.0213          28.38
 166          28.0854       21.5670      34.6039          27.48
 167          27.8203       20.5325      35.1082          24.20
 168          29.7005       21.7171      37.6840          28.77
 169          29.5664       20.9433      38.1894          31.87
 170          28.3118       19.0934      37.5303          33.79
 171          28.2771       18.4995      38.0548          30.79
 172          26.9670       16.6605      37.2735          25.10
 173          26.7108       15.9012      37.5204          25.67
 174          26.4754       15.1852      37.765           27.36
```

It appears to be consistent, so we can use this model for forecasting the future

```
Forecasts from period 174
                                  95 Percent Limits
Period       Forecast        Lower        Upper
 175          27.0910       23.7077      30.4744
 176          27.3603       22.5755      32.1451
 177          27.7010       21.8409      33.5611
 178          30.8761       24.1094      37.6428
 179          30.0761       22.5107      37.6415
 180          27.1939       18.9065      35.4814
 181          25.4830       16.5315      34.4345
 182          23.3126       13.7430      32.8821
 183          21.2911       11.1411      31.4412
 184          22.9615       12.2624      33.6605
 185          22.1380       10.9167      33.3593
 186          19.2435        7.5232      30.9638
```

Figure (4.10): Time Series Plot Brega



4.4.2 Analysis of the other time series

Much of the analysis of the remaining time series is very similar to that of the Brega series.

4.4.2.1 Zuweitina Crude Oil Prices

Figure (4.11): Plot of Zuweitina Crude Oil Prices

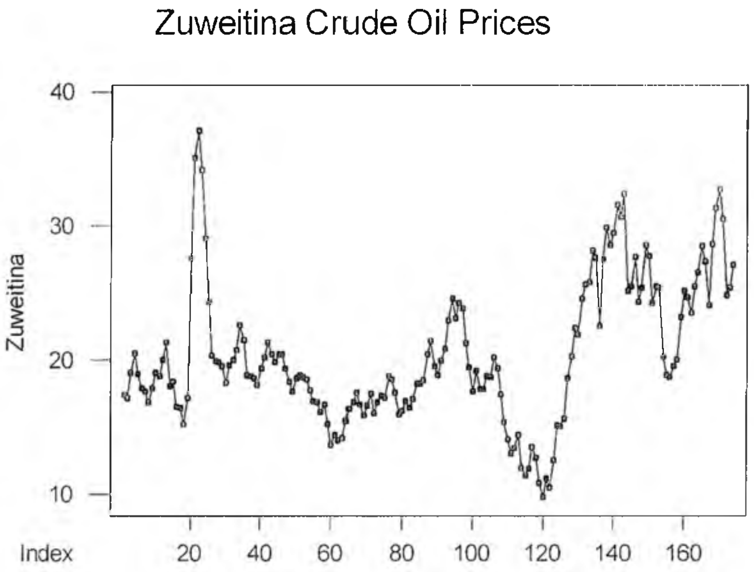


Figure (4.12): ACF of Zuweitina Crude Oil Prices

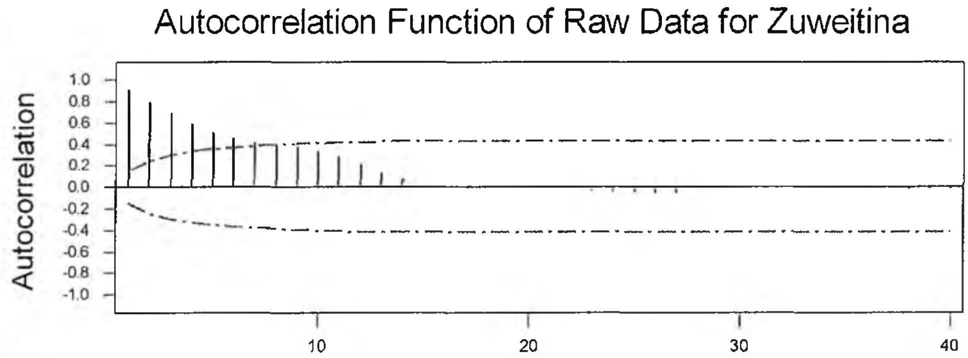


Figure (4.13): PACF of Zuweitina Crude Oil Prices

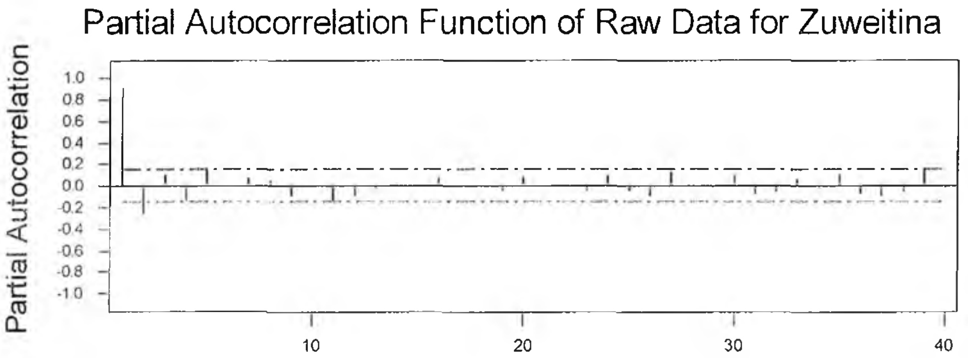


Figure (4.14): ACF of Zuweitina after One seasonal and Non-Seasonal Difference

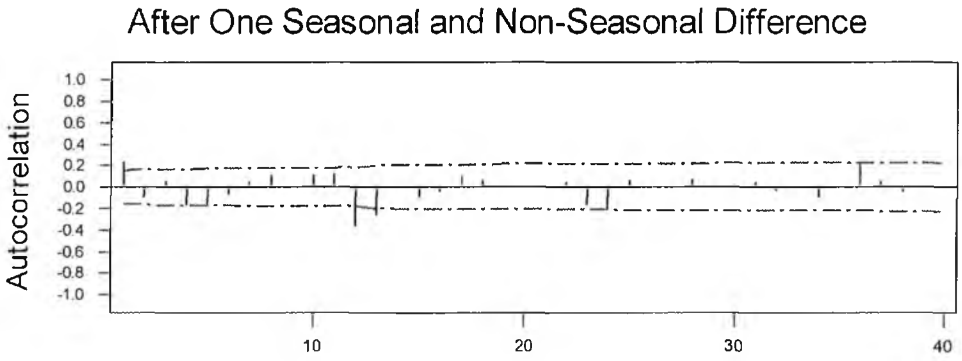
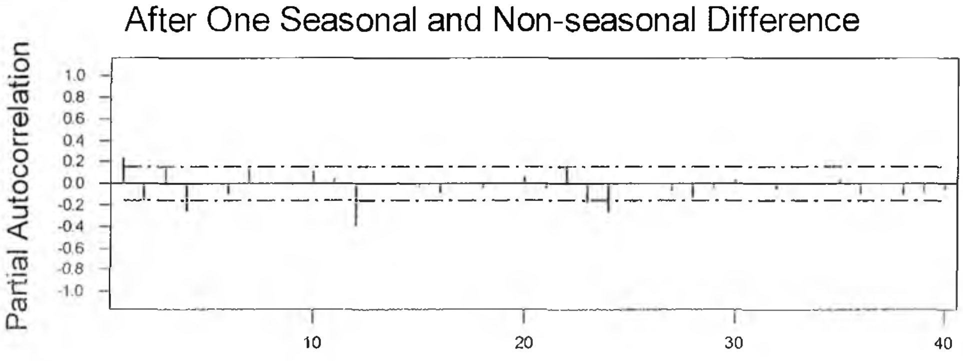


Figure (4.15): PACF of Zuweitina after One seasonal and Non-Seasonal Difference



Residual Sum of Squares for Various ARMA (P, Q) models:

Table (4.9): Residual Sum Squares

5	514.44	**460.10**	465.57	397.48	424.57	**427.27**
4	612.70	496.86	616.67	440.22	432.35	456.55
3	636.73	597.67	573.79	560.60	479.67	465.64
2	638.41	618.49	558.29	569.44	485.44	475.30
1	981.46	709.05	690.51	515.62	540.48	494.17
0		718.35	701.84	578.02	545.30	554.67
P/ q	0	1	2	3	4	5

4.4.2.2 Sirtica Crude Oil Prices

Figure (4.16): Plot of Sirtica Crude Oil Prices

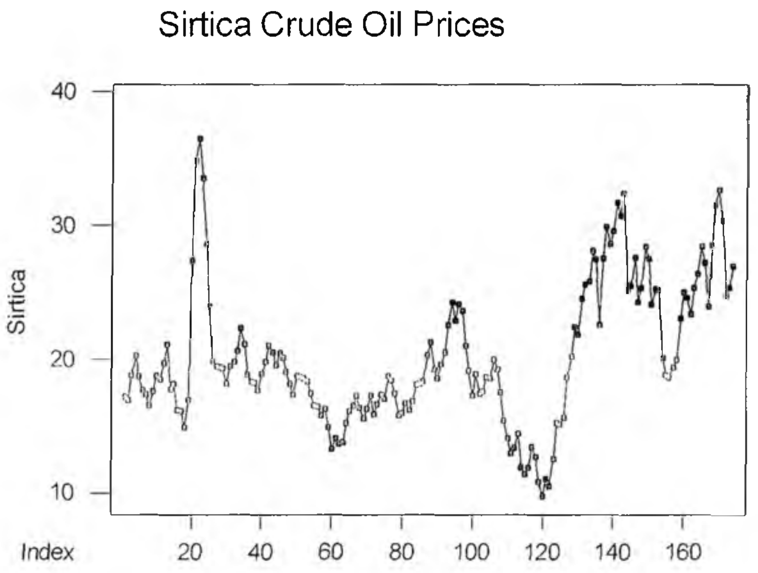


Figure (4.17): ACF of Sirtica after One Seasonal and Non-Seasonal Difference

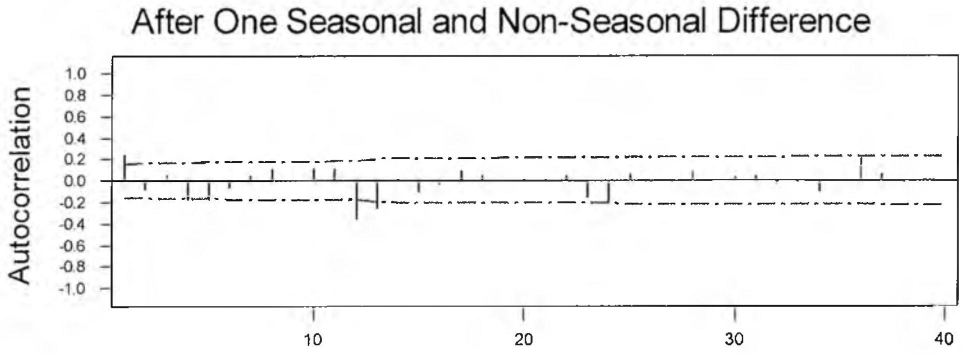
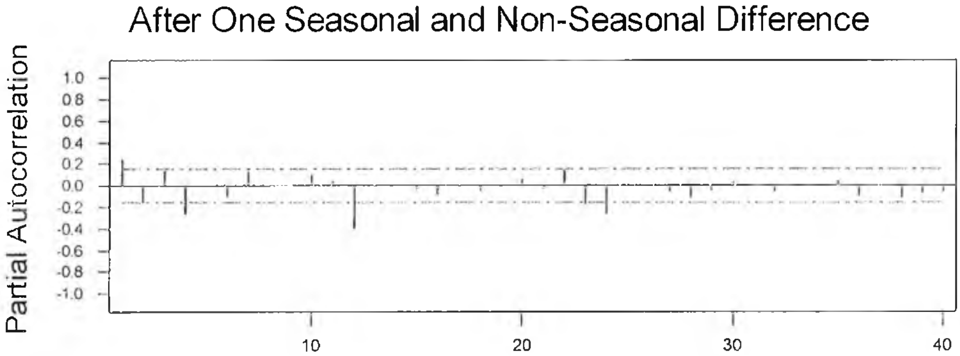


Figure (4.18): PACF of Sirtica after One Seasonal and Non-Seasonal Difference



Residual Sum of Squares for Various ARMA (P, Q) models:

Table (4.10): Residual Sum Squares

5	515.46	**455.24**	449.55	435.95	463.28	**417.75**
4	622.78	491.47	459.18	439.41	425.25	486.39
3	641.64	607.33	583.96	566.76	624.35	478.15
2	643.47	645.47	559.82	570.99	489.36	484.40
1	983.19	708.91	683.10	516.33	546.52	496.88
0		717.61	702.81	571.38	522.88	560.38
P/ q	0	1	2	3	4	5

4.4.2.3 Sidra Crude Oil Prices

Figure (4.19): Plot of Sidra Crude Oil Prices

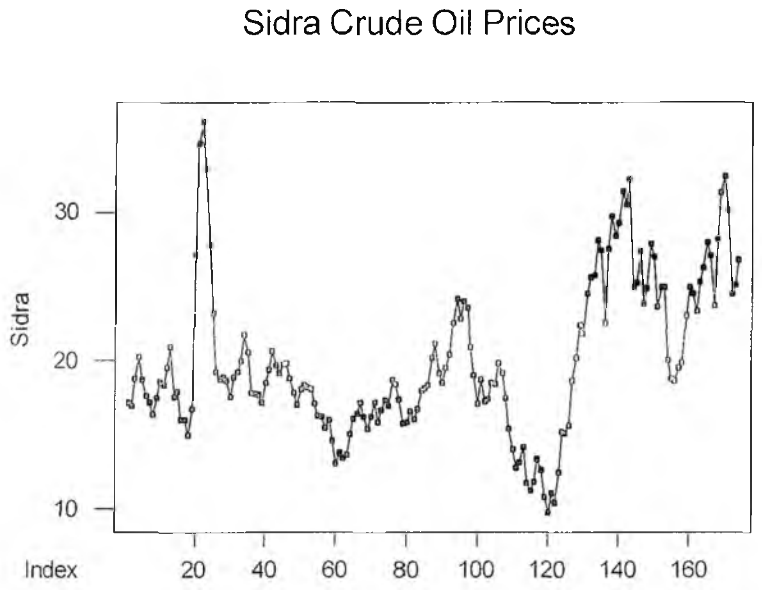


Figure (4.20): ACF of Sidra after One Seasonal and Non-Seasonal Difference

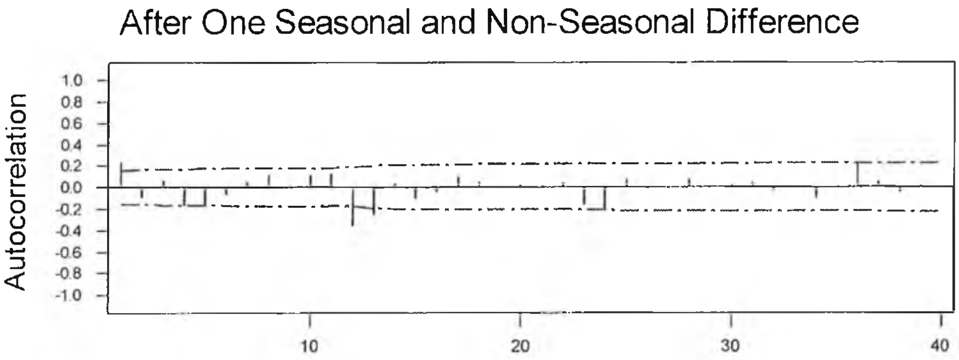
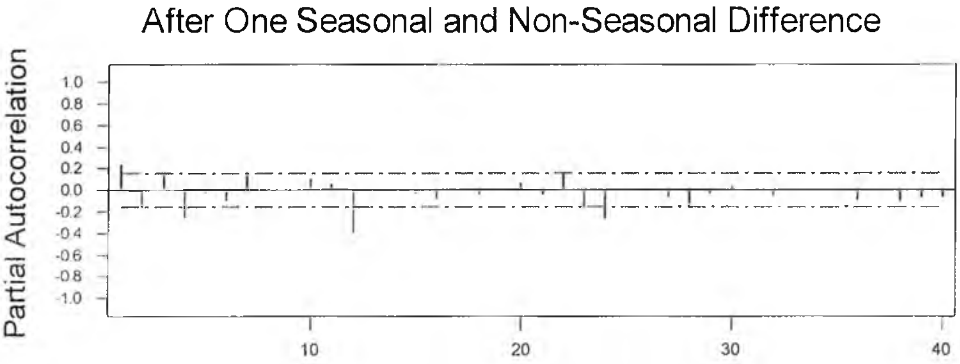


Figure (4.21): PACF of Sidra after One Seasonal and Non-Seasonal Difference



Residual Sum of Squares for Various ARMA (P, Q) models:

Table (4.11): Residual Sum Squares

5	520.51	**455.76**	449.68	454.62	463.37	**375.25**
4	622.29	553.13	459.91	440.07	430.17	485.12
3	642.87	635.90	570.90	546.87	423.45	463.69
2	631.29	630.69	558.45	555.22	486.80	474.29
1	986.05	710.39	685.87	523.33	535.97	505.11
0		719.94	703.26	574.26	559.30	544.72
P/ q	0	1	2	3	4	5

4.4.2.4 Abu-Tiffil Crude Oil Prices

Figure (4.22): Plot of Abu-Tiffil Crude Oil Prices

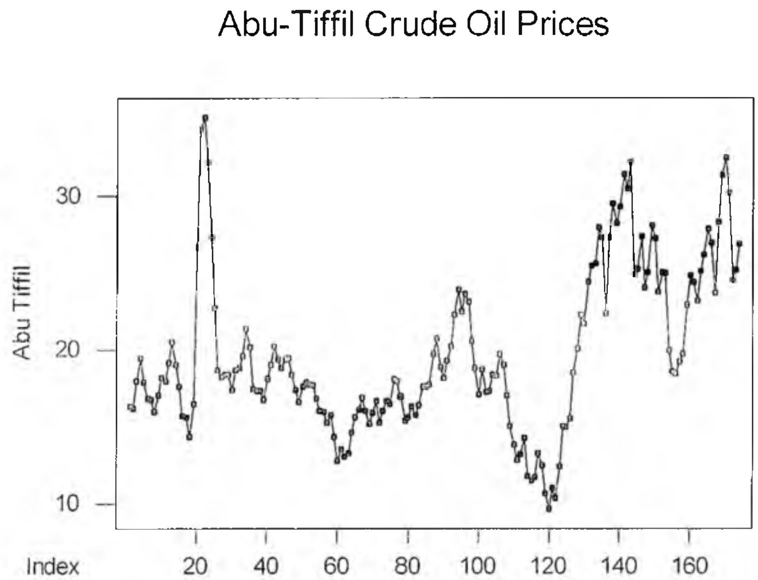


Figure (4.23): ACF of Abu-Tiffil after One Seasonal and Non-Seasonal Difference

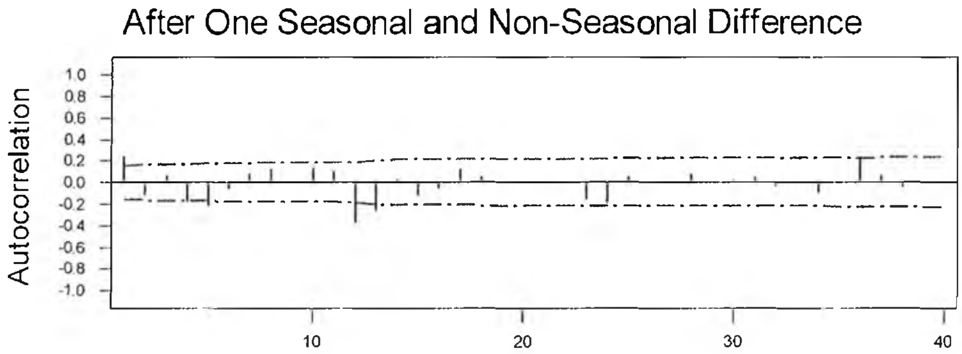
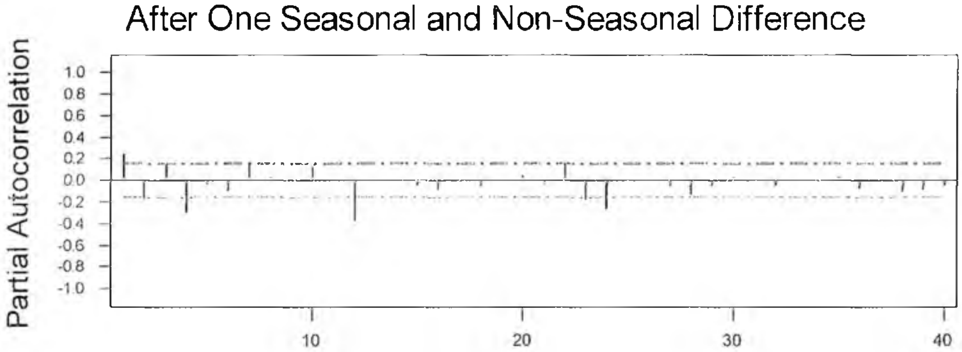


Figure (4.24): PACF of Abu-Tiffil after One Seasonal and Non-Seasonal Difference



Residual Sum of Squares for Various ARMA (P, Q) models:

Table (4.12): Residual Sum Squares

5	513.71	**445.25**	446.20	474.26	415.68	**387.30**
4	607.40	486.29	609.84	427.84	414.03	421.32
3	618.86	548.50	630.47	554.61	494.64	461.92
2	632.47	602.84	540.98	557.41	475.39	459.47
1	968.82	690.76	673.55	497.90	508.82	513.97
0		703.84	682.59	553.90	520.05	522.251
P/ q	0	1	2	3	4	5

4.4.2.5 Sarir Crude Oil Prices

Figure (4.25): Plot of Sarir Crude Oil Prices

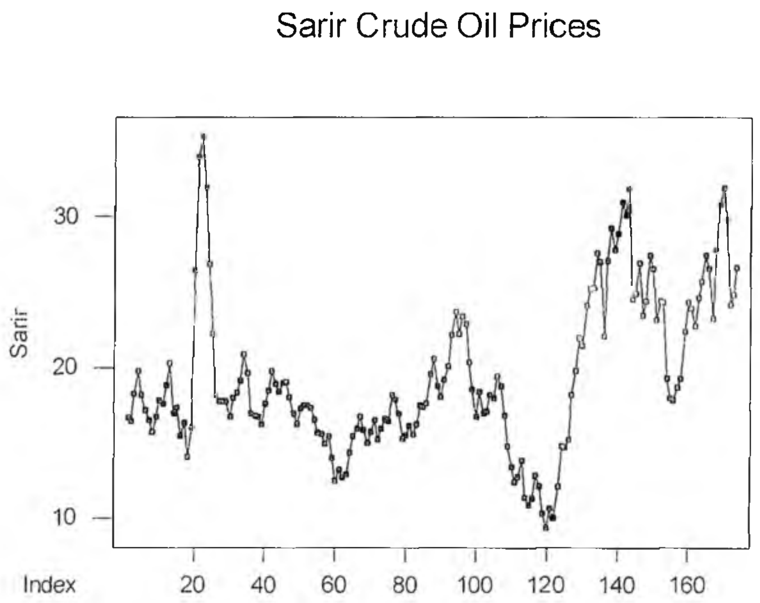


Figure (4.26): ACF of Sarir after One Seasonal and Non-Seasonal Difference

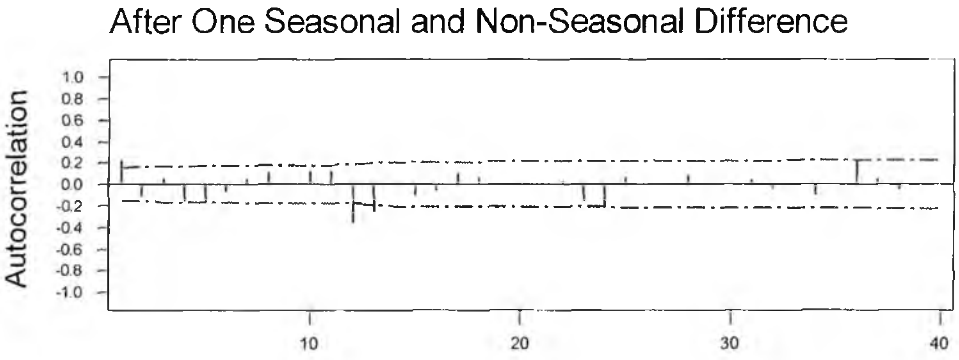
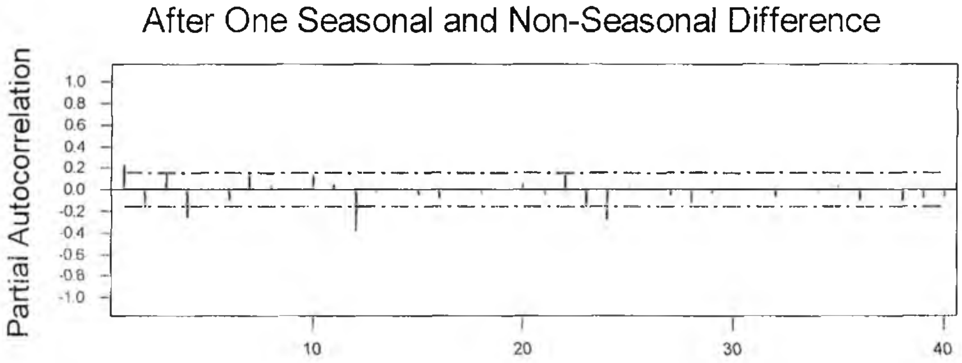


Figure (4.27): PACF of Sarir after One Seasonal and Non-Seasonal Difference



Residual Sum of Squares for Various ARMA (P, Q) models:

Table (4.13): Residual Sum Squares

5	520.41	**454.53**	451.01	438.40	417.69	**374.14**
4	620.02	610.03	622.69	448.22	424.94	460.18
3	638.83	606.94	579.66	548.98	483.69	461.81
2	629.12	617.80	559.92	569.42	490.98	476.46
1	988.13	710.90	690.50	508.07	522.55	508.54
0		721.39	703.27	593.36	497.78	546.12
P/ q	0	1	2	3	4	5

4.4.2.6 Amna Crude Oil Prices

Figure (4.28): Plot of Amna Crude Oil Prices

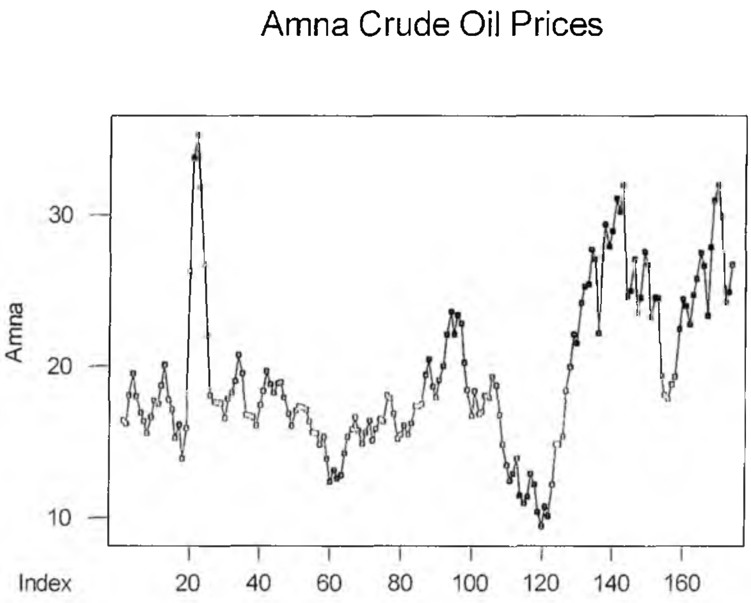


Figure (4.29): ACF of Amna after One Seasonal and Non-Seasonal Difference

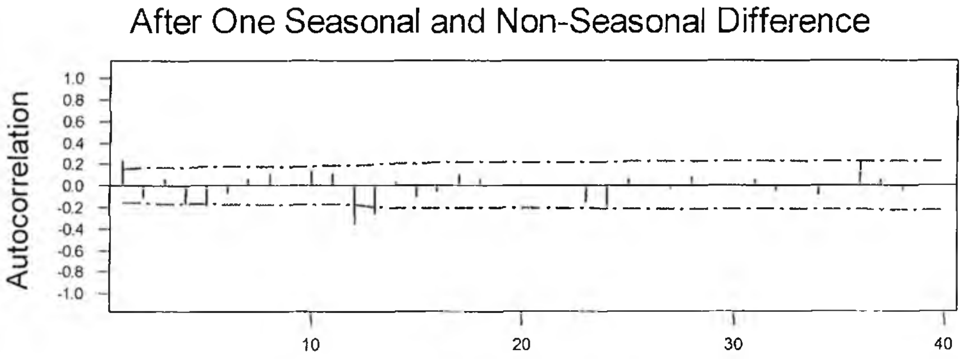
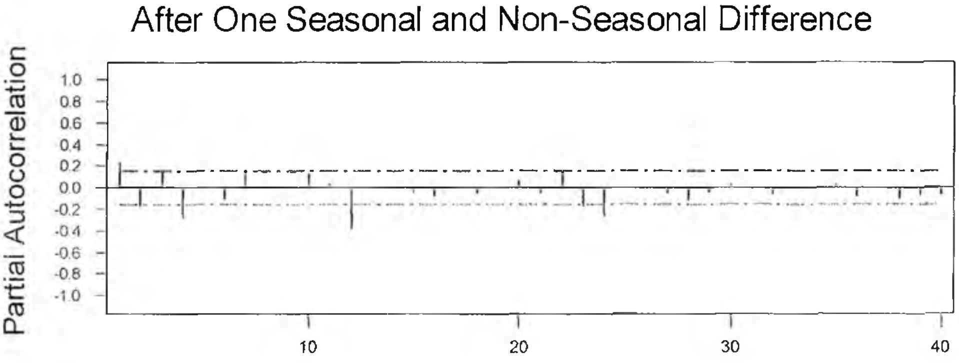


Figure (4.30): PACF of Amna after One Seasonal and Non-Seasonal Difference



Residual Sum of Squares for Various ARMA (P, Q) models:

Table (4.14): Residual Sum Squares

5	521.10	**449.59**	448.88	437.39	452.83	**396.77**
4	612.82	606.77	617.40	435.86	438.06	481.86
3	637.22	610.19	646.96	554.14	474.98	460.99
2	640.58	613.18	555.95	564.59	478.68	469.10
1	984.06	705.76	702.75	505.33	514.87	514.63
0		717.15	697.73	564.89	588.80	545.48
P/ q	0	1	2	3	4	5

4.5 Conclusions

The Box-Jenkins methodology has been shown to be viable for analysing the single time series studied here. However, much experimental work will have to be undertaken to verify this approach. The full oil data involves multiple time series; however, each series is heavily correlated with the Brent series so that a multivariate model is not justified.

Chapter 5

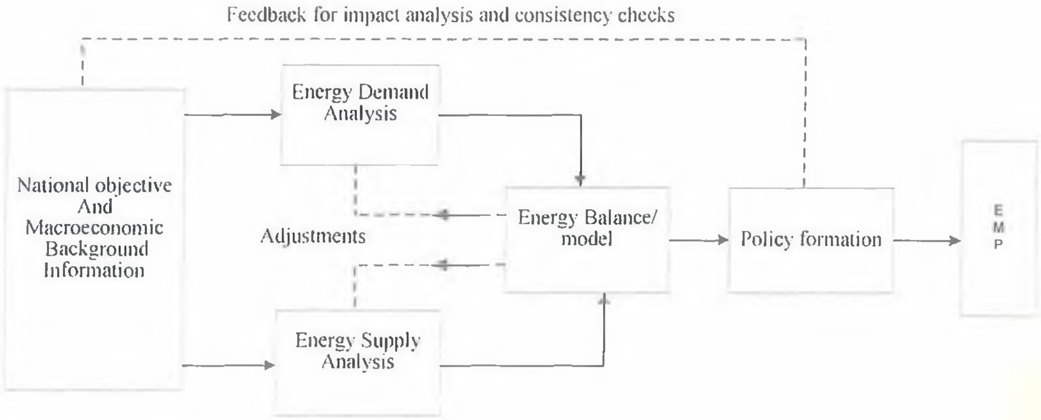
A Multiyear Electricity Optimisation for Libya

5.1 Introduction

The importance of a dependable electrical power system is ever increasing in the modern world of today. Almost all aspects of society are dependent on electrical power in one way or the other to function properly. At the same time, the technical complexity of power delivery increases, as new technologies are being introduced into power systems with growing demand and increasing geographical scope. The technical and societal changes nourish the ongoing debate about how the electrical power system should be organised, in order to best meet the various demands it serves in society.

Different structures for power system organisation are also being implemented in various parts of the world. This chapter will give out some light into some of the long-term challenges regarding the continued reliance on electrical power as a primary energy carrier.

Figure (5.1): Feedback for impact analysis consistency checks



Sources: Ghosh, P.K.(1984.p202).

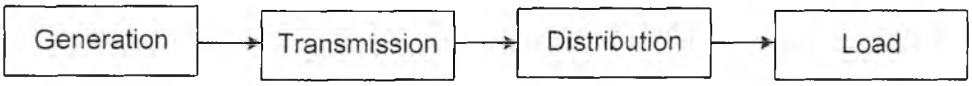
5.2 Operation and Organisation of Power Systems

Electrical power systems are large-scale, integrated and complex engineering systems that need a certain level of centralised coordination to function. Besides, electric power has a set of special features that makes it different from most other commodities that are traded in markets.

The list of special features includes instant and continuous generation and consumption, non-storability, high variability in demand over day and season, and non-traceability (i.e. a unit of consumed electricity can not be traced back to the actual producer). At the same time electricity is an essential good for society and we know that blackouts with huge detrimental effects can occur if the system is not maintained under control. Furthermore, the generation and transmission of electricity are expensive.

The main participants that are typically involved in the planning and operation of a restructured power system are.

Figure (5.2): The Main Power System Components



System operator

The system operator plays a very important role in the coordination and operation of the power system and is responsible for always keeping supply equal to demand. Trading between generators and end users in the power market provides equilibrium between expected supply and demand.

Transmission provider

The transmission provider owns and operates the high voltage transmission grid in the power system. The system operator and the transmission provider can be the same entity, like in Libya. However, the grid can also be owned by separate companies and coordinated through an independent system operator, as is frequently the case in some countries. The costs related to running the transmission grid (investments, operating costs, transmission losses etc.) are recovered from the transmission tariff.

Distribution company

The distribution companies are responsible for operating the lower voltage grids and ensure that end users have access to their local network. This is also a monopoly service and total costs for investment and operation of the distribution grid is reflected in the distribution tariff.

Generators

The generators are responsible for feeding sufficient electricity into the grid. With open access to the network there is wholesale competition between generators of various technologies and ownership. The generators bid their power generation into the market, either through an organised power exchange or via bilateral contracts.

5.3 Scope and Limitation of the Chapter

We discussed so far in this chapter the range of complexities involved in the electrical power system. Naturally, this chapter only covers a limited part of all the challenges that the various participants in the system are facing. The work presented in this chapter focuses on the cost minimisation part of the power system. Our main attention is on investments in new power generation capacity and on long-term balance between supply and demand in an energy sector.

The objective in this chapter is to use a dynamic programming model as a tool to increase the understanding of complex dynamic of multiyear planning in power system. We develop a multiyear electricity optimisation model (MEOM) that generation companies and governments can use to improve their investment strategies in power system. The dynamic programming model can be used to find an optimal strategy for investments in new power generation capacity and it can also simulate the development of supply and demand in the power system over a multiyear period.

The mathematical models presented in this chapter builds on a number of simplifying assumptions. We are mainly concerned with modelling of the economic interaction between cost minimisation and investments in new power generation plants. Decommissioning of existing plants is an important aspect that is not taken into account in our analyses.

Multiyear planning models of the type considered are simplifications of reality. Simplifying assumptions are introduced to help make a model tractable; the model builder is frequently called upon to balance simplifying assumptions against the need to make the model behave in a realistic manner.

One such difficulty arises in the need to commit to the incorporation of large capital projects towards the end of the planning horizon; this is typically overcome by incorporating the net present value NPV (over a specified time period beyond the end of the planning horizon) of all capital items in the model. The net present value of the items will depend on their age at the end of the planning horizon; however, if the age of an item does not have a significant impact on the NPV (and so can be ignored) the amount of computation can be greatly reduced.

5.4 Model for power generation expansion planning

In this section we discuss planning methods and multiyear planning models for expansion planning and long-term analysis of electrical power system.

First, we describe a number of planning methods that developed for the power industry.

5.4.1 The Power Generation Expansion Planning Problem

The general power generation planning problem has at least three important dimensions that must be evaluated during the project assessment phase. Firstly, the project type must be considered, i.e. choice of technology and capacity size for the new plant. Secondly, the timing of the investment must be evaluated. Thirdly, the location of the new plant must also be decided. A full project evaluation is a large and complex task, which requires the use of various planning methods and decision support models.

In this chapter we are mainly concerned with the first two of these dimensions, while the question of optimal location in the electrical power system is not treated in any depth. The focus in our model is on developing mathematical models that are better capable of providing decision support in power system.

5.4.2 Long-Term Planning Methods

Electrical power systems, with stable prices, centralised decision making and access to full information results in low uncertainty for the participants in the system. Under these conditions, forecasting and optimisation are ideal long-term planning methodologies and these methods were also frequently used in the regulated power industry, as pointed out by Dyner and Larsen (2001).

Various planning techniques have been developed in order to optimise electricity supply systems under traditional regulation.

5.4.2.1 Generation Expansion and Integrated Resource planning

The traditional objective in power generation planning was to minimise the cost of accomplishing required expansions of generation capacity. The focus was almost entirely on the supply-side of the power system, while demand was simply assumed to follow a forecasted growth rate. As a response to both increasing cost of electricity supply and also environmental constraints the concept of integrated resource planning was developed. While the objective of the traditional planning process was to meet demand for electricity at least cost, the principal goal in integrated resource planning is to meet the demand for energy services at least cost. Swisher, J et al. (1997) Hence, integrated resource planning also considers options on the demand side, such as energy efficiency programs and demand-side management, in order to find the optimal configuration of the power system. The concept of integrated resource planning was originally developed for the regulated utilities in the US. However, the same methodology can also be applied on different geographical and organisational levels. Integrated resource planning has been used for planning purposes from the local distribution level to national analyses of regulatory policies for the energy sector.

5.4.2.2 Multi-Criteria Trade-Off Analysis

The provision of energy services has a fundamental impact not only on the economy, but also on the environment and on the society in general. Conflicting objectives frequently arise in long-term infrastructure planning within the energy sector, since many interest groups are affected by the resource decisions. Planning methods that take into account several of these objectives are referred to as multi-criteria decision making methods. Multicriteria methods are frequently applied for different planning purposes in the electrical power sector, for instance in combination with capacity expansion or integrated resource planning. The objective for the multi-criteria methods is to help decision makers evaluate the trade-offs between different system criteria, such as total costs, emissions and reliability. A systematic comparison of the various criteria makes it easier for the decision makers to make well-informed and appropriate decisions. The least-cost solution is not necessarily the optimal one, when other criteria are also taken into consideration.

5.5 Classification of Multiyear Planning Model

In this section we investigate some important quality of multiyear planning models for long-term planning in electrical power system.

We look at a number of dimensions along which long-term planning models can be classified.

5.5.1 Model Purpose and Algorithm

A multiyear planning model for long-term planning can be either prescriptive or descriptive. Prescriptive models are based on optimisation and their purpose is to identify optimal investment strategies. Most planning models for the regulated industry are prescriptive. In contrast, a descriptive model does not find optimal investment strategies directly. The purpose of descriptive models is to increase decision maker's knowledge, by simulating the future development of the system under a set of different assumptions. Better knowledge will, in turn, result in improved decision making.

The objective function in prescriptive decision support models developed for the regulated power industry is usually minimisation of total cost, or in some cases maximisation of social welfare.

Another important model attribute is the mathematical algorithms that are used to solve the model. A planning model can use more than one solution algorithm.

Several optimisation methods from operations research (linear/non-linear programming, dynamic programming etc.) are frequently used in planning models. The planning model's solution algorithms depend on the purpose of the model and the range of other attributes that are included in it. For instance, the incorporation of uncertainty through the use of stochastic variables can cause considerable difficulties.

5.5.2 Representation of Investment Decisions

Regulated power system are characterised by centralised decision making. Therefore, in traditional prescriptive expansion planning models it is usually assumed that all decisions are made by one centralised decision maker, who controls the entire system.

Another important dimension in the modelling of investment decisions is how the timing of new investments is taken into account. With a static representation it is assumed that a new investment must be undertaken immediately. Hence, the only concern is to decide whether or not to invest, and then decide which project to invest in, if there are several alternatives. In contrast, with a dynamic representation of investment decisions, the timing of new projects is also taken into account. Modelling of uncertainties, construction delays and investor foresight are also important for the investment decision. Long-term trends, such as changes in demand, fuel prices etc., can be represented either as deterministic or stochastic variables.

5.5.3 Representation of Supply and Demand

The level of detail in the representation of supply and demand in the power system is rather limited in most long-term planning models. This is mainly because the gain from adding details in a long-term analysis is usually low, while the increase in computational burden can be substantial. The number of power generation technologies that can be added to the power system is a supply-side attribute that can be very important for the mathematical dimension of the expansion planning problem.

Another important dimension is whether or not price elasticity of demand is represented.

5.6 A Multiyear Electricity Optimisation Model

This section presents a model concept for long-term analysis of the power sector that is based on dynamic programming. The model is a possible tool for increasing the understanding of investment in new power plants. It is specifically suitable for scenario planning and we argue that both energy companies and public authorities could make use of such dynamic models in their long-term strategic planning. In the model we calculate the annual optimum energy cost using a linear optimisation algorithm.

5.6.1 Dynamic Programming

Dynamic programming (DP) is one of the optimisation techniques that is appropriate for solving investment problems in accordance with the real options theory. DP is a general optimisation technique with applications within a range of different areas, including power system planning.

In our models we use dynamic programming as a tool for analysing investment in the power system. The method of dynamic programming was developed in 1950's through the work of Richard Bellman as a policy design tool for complex management problems. (See chapter 2).

Dynamic programming can be used to model interactions within and between social, economic and technological systems. Instead of analysing the detail of individual elements in a system, the emphasis in dynamic programming is on the relationships between the elements that create dynamics in system.

When developing a dynamic model, a substantial amount of time should be spent initially to develop an understanding of the problem that is being investigated. It is very important that the decision makers, which are actually going to utilise the results from the model, are involved at the beginning of the analysis. The most important variables in the model must be identified.

The next step in the analysis is to formalise the causal relations into a mathematical model. Mathematically, dynamic programming is a set of equations. The state variables in the model are referred to as stocks, while the control variables are dependent on the decision strategies and structure of information feedback loops in the system.

A dynamic programming model is usually solved numerically. However, the purpose of developing a dynamic programming model is usually to gain better insight into a real world system. Real decision makers are rarely entirely rational about their decisions. Simulation models based on system dynamics is therefore still a valuable tool for descriptive analysis, which in turn can result in increased knowledge and thereby improved decision making.

5.6.2 The Simulation Model

The model simulates the development of the power system in a country for a long period of time (20-50). We model the investment in new plants with a supply and demand curve. The time resolution in the model is one year, using the simplifying assumption that investment decision can only be made at the beginning of each year. New investments in generation result in a change in the supply and demand for electricity.

The level of detail in the model is aggregated, instead of going into detail on the different parts of the system. We try to focus on the relationships that we see as most important for the long-term development of investment in new power plants. The model is a tool for generating scenarios to analyse what is likely to happen under certain circumstances (e.g. build one power plant, two power plants etc.). Development and use the model can contribute to learning and improved decision making for participants in the power industry.

We assume that investments in the new power generation capacity are based on purely economic argument. A power company invests in new plants if the expected profitability is high enough to cover their required rate of return on capital. The expected profitability on a new investment is dependent on total cost of the project.

5.6.3 Network Simplex Algorithm for the Minimum Cost Flow Problem

In the standard linear programming network. the Simplex algorithm maintains a feasible solution known as a basis. which is gradually improved in small steps until optimality is reached.

For the minimum cost flow problem, the basis is a flow satisfying all capacity constraints. The arcs of the network are divided into three subsets (T, L, U), where L means no flow passes across an arc, U implies that each arc carries flow exactly equal to its capacity and those labelled T from an undirected spanning forest of the network.

Consider $G = (N, A)$ to be a directed network defined by a set N of n nodes and a set A of s directed arcs. Each arc $(i, j) \in A$ has an associated cost C_{ij} denoting the maximum amount of flow that can be sent on the arc. Each $I \in N$ has an associated number $b_{(i)}$ representing its supply and demand.

A path in $G = (N, A)$ is a sequence of nodes and arcs i_1 $(i_1, i_2)......(i_{r-1}, i_r)$ satisfying the property that either $(i_k, i_{k+1}) \in A \; or \; (i_{k+1}, i_k) \in A$ for each k.

In the minimum cost flow problem, we want to determine a least cost shipment of a commodity through a network that meets the demand at certain nodes from the available supplies at each node.

The decision variables are the flow X_{ij} on each arc $(i, j) \in A$. This problem can be formulated as an optimisation problem as follows:

Minimize:

$$\sum_{(i,j)\in A} C_{ij} X_{ij}$$

subject to:

$$\sum_{\{j:(i,j)\in V\}} X_{ij} - \sum_{\{j:(j,i)\in V\}} X_{ji} = b_{(i)} \quad for\ all\ i \in N$$

$$L_{ij} \le X_{ij} \le S_{ij} \quad for\ all\ (i, j) \in V$$

where

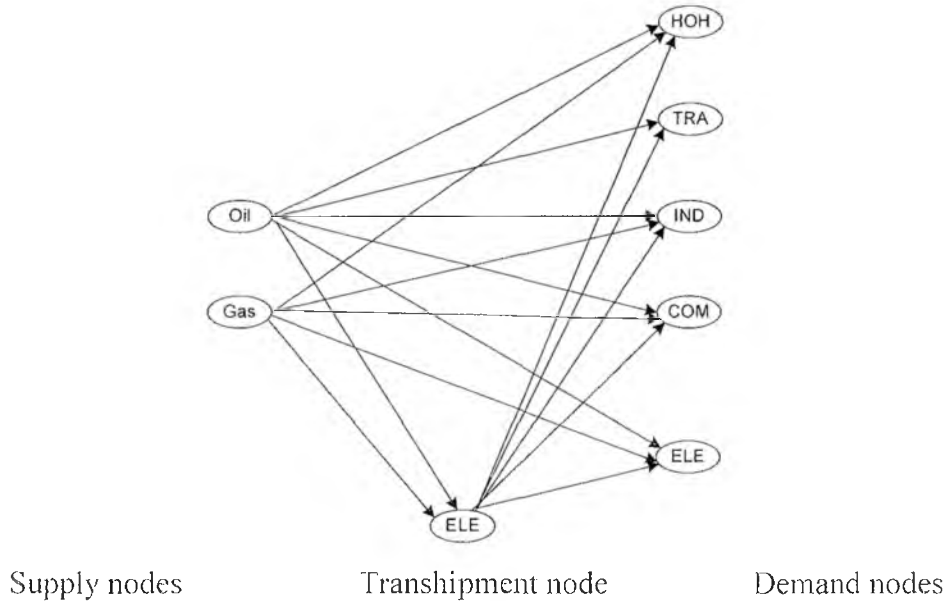
$$X_{ij} \ge 0 \quad for\ i = 1, 2, 3\ and\ j = 1, 2, 3, 4, 5$$

5.7 Illustrative Example: Model 1

To test the model we developed a simple model for the Libyan power system. The initial condition in the model describes year 2003, and the model is simulated for a period of 22 years.

In our network model of the energy resource management problem, supply nodes represent energy capacity nodes (such as oil, natural gas and electricity), the demand nodes are the network formulation corresponding to the consumption sectors: household, industrial, transport, and commercial uses. Our formulation also has transhipment nodes corresponding to electricity.

Figure (5.3): Transhipment problem



The energy management problem is a multiyear (dynamic) problem and the planning period typically consists of ten years or longer. This dynamic problem may be transformed into a static problem by using a special technique. In this technique we first separate the time horizon into a finite number of periods and replicate the underlying network for each period. We then connect the corresponding nodes for different time periods by additional arcs.

An important decision problem in the resulting network model is to determine the optimal quantity of primary energy for each year in the planning horizon. This is the network flow problem described in 5.3.3.

Our model has three main components: demand, supply and shipment cost. The demand sector consists of five sub-sectors: household, industry, transport, commercial and electricity. The historical energy demand behaviors of these sectors are analyzed and projected as separate energy demand variables, such as energy demand of household, energy demand of transport, etc.

Energy demand from each demand sector is transferred from the supply sectors to meet energy needs. Supply sectors consist of oil, natural gas and electricity. Note that electricity is both a source and a destination of energy.

In order to obtain the optimal supply and demand for each energy resource, demand is transferred to the related supply sector using the transshipment method. Table (5.1) shows the basis year 2003 and the units of measurement are Thousand of Tones of Oil Equivalent (KTOE).

Table (5.1): primary Libyan energy in 2003

	Household	Industry	Transport	Commercial	Electricity	Supply
Oil	30	10	50	10	10	10222
Gas	25	10	1000	1000	10	4851
Electricity	25	40	1000	70	0	6286
Demand	2675	6058	2695	3645	6286	

First we solved this problem using a java program for linear programming problem; see Figure (5.2) for the optimal solution for 2003.

Table (5.2): The optimal LP solution; objective function = 298655

	Household	Industry	Transport	Commercial	Electricity	Supply
Oil		3882	2695	3645		10222
Gas	2675	2176				4851
Electricity					6286	6286
Demand	2675	6058	2695	3645	6286	

The dual solution for 2003 is:

Table (5.3): Dual Solution

Oil	-19950
Gas	-19950
Electricity	-19950
Household	-25
Industry	-40
Transport	0.0
Commercial	-40
Electricity	-40

The underlying LP is replicated 22 times in the DP model. We then began developing network flow to solve the minimum cost flow problem see section.

The mathematical description of the model can be stated as follows

Minimise: Total shipment cost,

Subject to:

- For all supply types: allocated capacity must be equal to existing design capacity, and
- For all demand categories: utilized capacity equal energy demand.

The mathematical description of the model can be stated as follows

Minimise:

$$30X_{11} + 10X_{12} + 50X_{13} + 10X_{14} + 10X_{15} + 25X_{21} + 10X_{22} + 1000X_{23} + 1000X_{24} + 10X_{25} + 25X_{31} + 40X_{32} + 1000X_{33} + 70X_{34} + 0X_{35}$$

Subject to:

$X_{11}+X_{12}+X_{13}+X_{14}+X_{15} = 10222$

$X_{21}+X_{22}+X_{23}+X_{24}+X_{25} = 4851$

$X_{31}+X_{32}+X_{33}+X_{34}+X_{35} = 6286$

$$X_{11}+X_{21}+X_{31} = 2675$$
$$X_{12}+X_{22}+X_{32} = 6058$$
$$X_{13}+X_{23}+X_{33} = 2695$$
$$X_{14}+X_{24}+X_{34} = 3645$$
$$X_{15}+X_{25}+X_{35} = 6286$$

$X_{ij} \geq 0$ for $i = 1, 2, 3$ and $j = 1, 2, 3, 4, 5$.

5.7.1 The future value of having the plants

The cost of an electricity investment in economic terms is the value of the resources that must be consumed to bring the project about. What must be estimated is the total value of the construction costs and any additional operating and maintenance costs. It is important to note that the analysis does not distinguish between who incurs the cost, but rather aims to include any and all costs that are involved in bringing about the project.

In calculating the future value of the generating plants, certain assumptions are made as follows:

1. Inflation does not exist
2. The appropriate discount rate is 2%
3. Plants are decommissioned after 30 years.

The new plants are assumed to be a Gas-fired plant at a cost 107 million L.D in order to produce 500 MW, and a Hydro plant which would cost 213 million L.D in order to produce 600 MW. The two plants derive income by selling electricity to the government at a certain price (.20 L.D in our simple model) each year, totaling 6500000 L.D for the gas-fired plant and 11500000 for the hydro plant. Additionally, the plants would incur maintenance and other costs throughout their remaining life at an amount of 500000 L.D and 60000 L.D respectively see table (5.4).

Table (5.4): maintenance cost and income from selling electricity

Type of plant	maintenance and other cost	income from selling electricity	Net income
Gas –fired	50000	6500000	6000000
Hydro	60000	11500000	11440000

According to the scenario 1 we are not going to build neither of the plants. Therefore, the future of having the plants is equal to zero, and the income will be 1365160000 L.D a year, which comes from selling the electricity of existing plants (86258 GWh) in 2025. In scenario 2 we will build a gas-fired plant in 2025, and the income will be increased by the contribution of the plant to reach 1371160000 L.D a year. In Scenario 3 we will build a hydro plant and the income will be 1376600000 D.L a year. As for the scenario 4 we will build the two plants, the gas-fired plant and the hydro plant, with an income of 1382600000a year. The future value of having the plants in the scenarios listed above for 30 years is shown in table (5.5).

Table (5.5): The future value of having the plants

Scenarios	Total annual income from selling electricity	Age of plant	The future value of having the plants
Scenario 1	1365160000	30	40954800000
Scenario 2	1371160000	30	41134800000
Scenario 3	1376600000	30	41298000000
Scenario 4	1382600000	30	41478000000

5.7.2 Dynamic Network Flow for Model I

We assume that the electricity demand grows by 6%, all construction costs are paid in the final year of construction, and cost includes construction, maintenance and operation. It is assumed also that the discount cash flow value is 1.02.

We assume that new investments in design capacity are under consideration in order to meet an increase in electricity demand in 2024. When the new capacity is installed, it remains available for a lifespan of 30 years.

In the dynamic programming model below, each year under consideration corresponds to a stage (on the horizontal axis) $t = 0,1,\ldots,T$, and the states (on the vertical axis) correspond to the electricity generation plants commissioned. The electricity generation plants are denoted by $x(t)$ and the sequence of states is $x = \{ x(0), x(1), \ldots, x(T) \}$.

The motion of the system is governed by the dynamic equation (the equation of motion) of the system:

$x(t) = A[x(t-1), u(t), t] \qquad t = 1,\ldots,T$

For every t, $A[.,t]$ is a given function between the appropriate spaces. The state $x(t-1)$ at the end of stage $t-1$ (at the beginning of stage t) contains all information of the development of the system until the beginning of stage t (the cost of commissioned plan, the maintenance and the optimal objective function value for the stage). The state $x(t-1)$ and the transformation function $A[.,t]$ determine the new state $x(t)$ at the end of stage t according to the dynamic equation above .

For stage t we consider all possible initial states y at the beginning of the stage. For every t and every y we examine the partial decision processes, starting from $x(t-1) = y$ at the beginning of stage t, and satisfying the equation of motion in the remaining stage $s = t, t+1, \ldots T$.

Assume that these problems have optimal solutions for every y and t. Then the optimal value of the partial objective functions:

$\sum_{s=t}^{T} c [x(s), u(s), s]$ for all y and t is a real valued function G on the set $\{y\}$

x[1,....., T] with the value G (y,t) at (y,t). The function G thus defined is called the value function. Therefore, the optimum solution consists of a sequence of optimal decisions on a path from the initial to the final stage.

In the network below, the figures above the nodes refer to the sum of the partial objective function value and the cost of the commissioned plant including the maintenance and operation cost at the end of the stage, those on the arcs, the cost of the commissioned plant and the cost of maintenance and operation, and those below the nodes are the partial objective function value. Thus, the figures for 2004 show that the cost of the commissioned plants is 118 Million L.D, the cost of maintenance and operation is 5 million L.D, and the the value of the partial objective function is 310.53 million L.D, and the total cost at the previous stage (2003) is 289.66. Therefore, the total cost at the end of the stage (2004) is 732.19 million L.D.

At the final year, the negative costs on the arcs represent the total objective function value for all possible decisions (scenarios) as follows:
Scnario1 represents the possible decision for doing nothing and the total cost is 13145.50 million L.D. Scenario 2 represents the possible decision for building one gas-fired plant in 2025 (Z). Scenario 3 represents building one hydro plant in 2025 and the total cost is 13375.60 million L.D. Scenario 4 represents building one hydro plant in 2025 and one gas-fired plant at a total cost of 13497.45 million L.D.

Then we calculated the future value of the plants as it has shown in section (5.6.2). .

Figure (5.4) Network Flow for Model 1

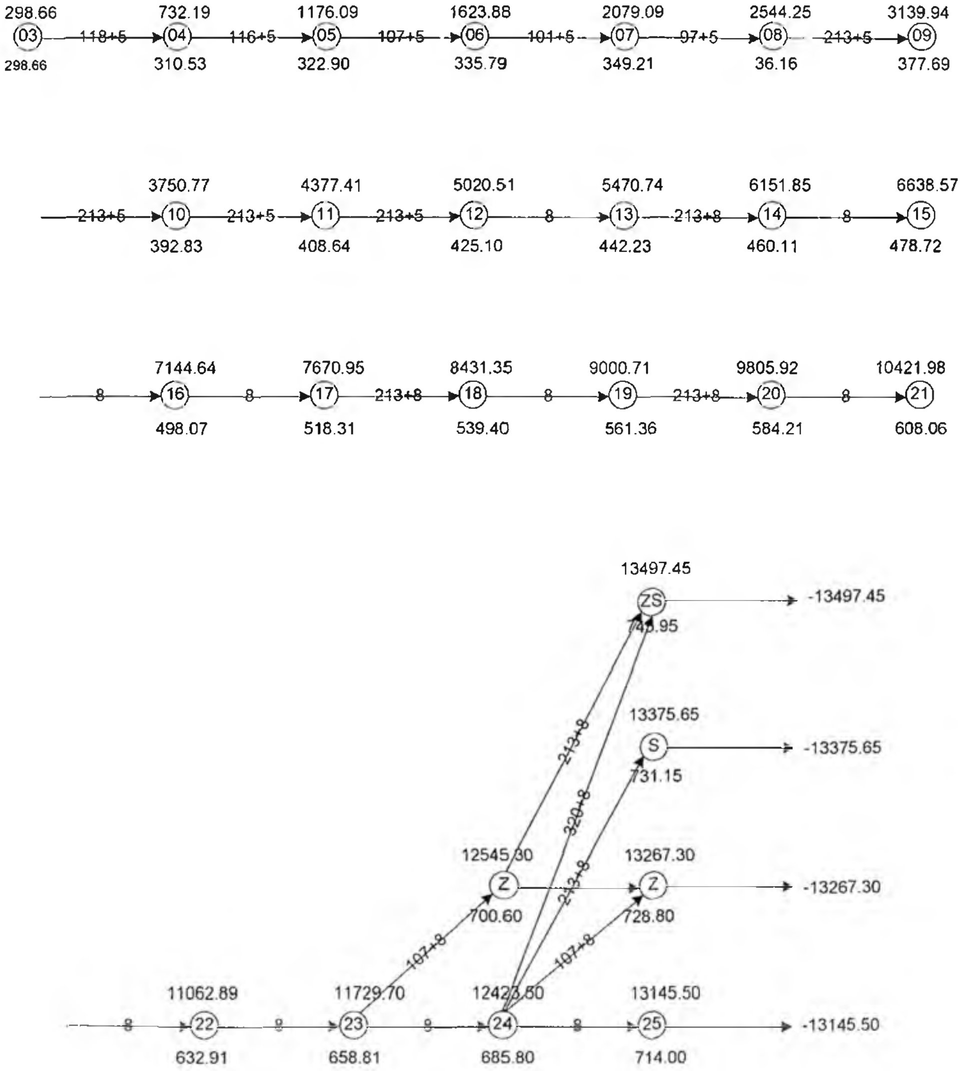


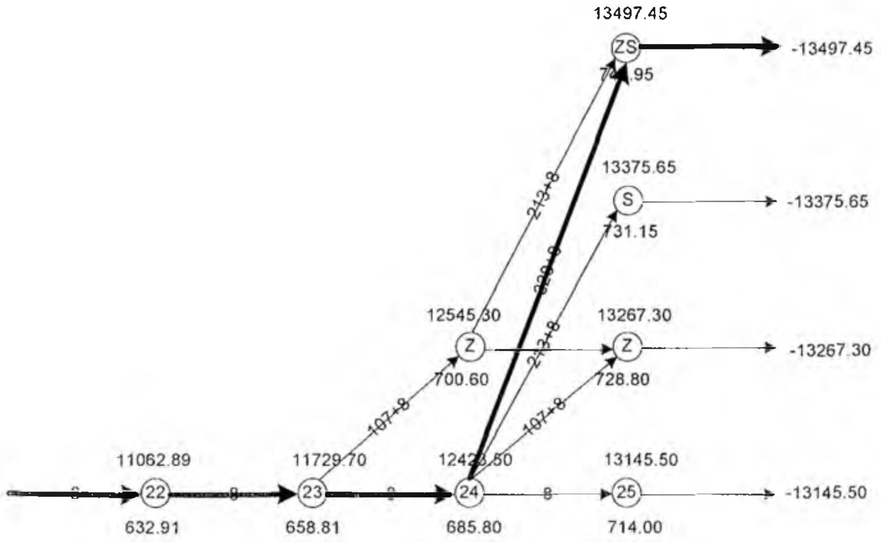
Table (5.6): Cost /Benefit analysis

Scenarios	Total Cost	Net benefit	Contribution
Scenario 1	-13145.50	40954.80	27809.30
Scenario 2	-13267.30	41134.80	27867.50
Scenario 3	-13375.65	41298.00	27922.35
Scenario 4	-13497.45	41478.00	27980.55

The results show that all the alternatives are very close, although the fourth scenario seams to be much better. However we should take the third and the second alternatives into consideration as well. It may be that there are some social reasons that cause the government to construct the power stations in 2025.

However, from our results, the optimal scenario is the fourth one and we will adopt a backward formulation. We will cross the net work from right to left and build up the optimal decision path sequentially as follows.

Figure (5.5) Network Flow for Model 1



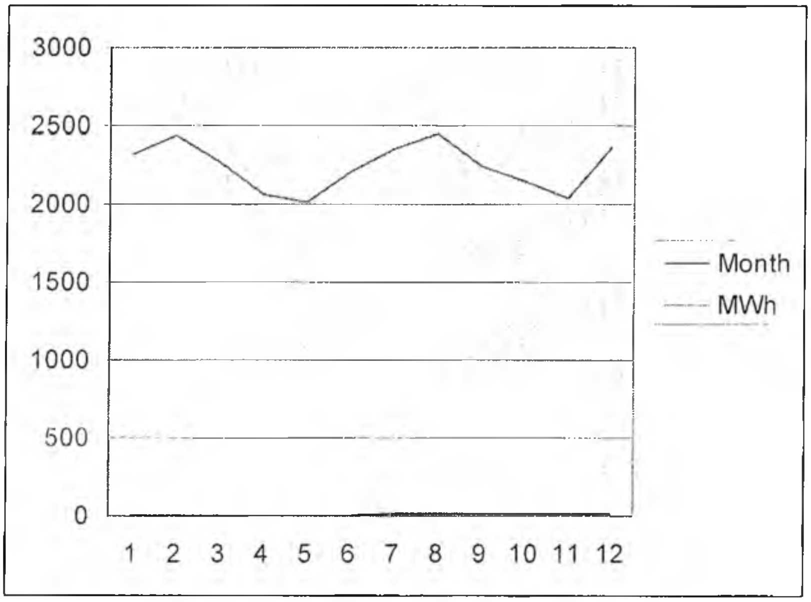
5.8 Cost of Electricity throughout the Day

The current analysis does not take into account the varying cost of electricity generation throughout the day or the week. However, the nonlinear cost models that arise from this should be incorporated into a national energy planning model for the Libyan economy. A more comprehensive model would break the day into segments, consider optimal allocations for each segment and then aggregate the results within an annual framework. The resulting model is an extension of the model we propose, but it does not involve any additional major modeling components.

Electricity is like few other commodities, because it can not be stored in large quantities except as potential energy. For example, water behind a dam or in a natural gas storage tank. It must be generated at the instant it is needed. Additionally, as more power is demanded by consumers, more expensive generating plants have to be brought on line to meet that demand. Generating plants need regular maintenance and work most efficiently at C.75% of their capacity; as we begin to operate plants above this value, the cost of generating electricity rises in a nonlinear manner. Thus, the total demand for electricity at any point in time determines the associated production cost.

Demand for electricity varies by time, it fluctuates within a year, a week, and a day. Within a year, figure 6.1 shows that demand is highest in summer, where as in spring and autumn there has traditionally been lower demand periods. Winter has tended to be a relatively higher demand period. When looking at the demand for electricity within a week, it is highest during a weekday

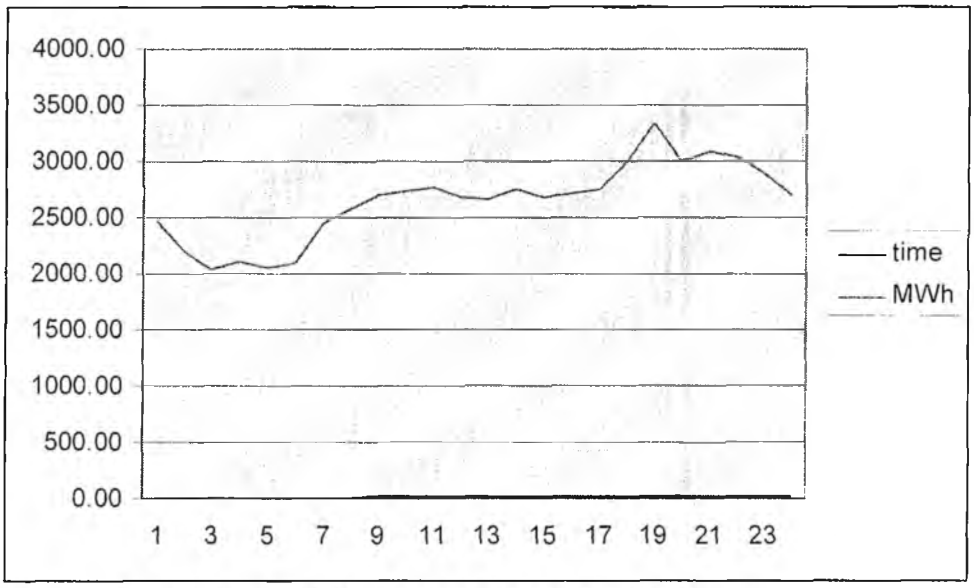
Figure (5.6): electricity demand throughout a year



Source: General Electricity Corporation annual report 2003

Within a day (see figure 5.7) power demand varies in a wide range. For example, between 1 am and 7 am demand is relatively low because less power is demanded. As people get up cook breakfast and head to work, the demand increases and cost around increases as well due to the more expensive generation that is brought on line. About 10 am demand hits its morning peak. There is usually a slight decrease in demand until 5 pm when demand begins to increase again. Demand for electricity is highest between 6 pm and 11 pm then drops again until the next morning.

Figure (5.7): electricity demand throughout a day



Source: General Electricity Corporation annual report 2003

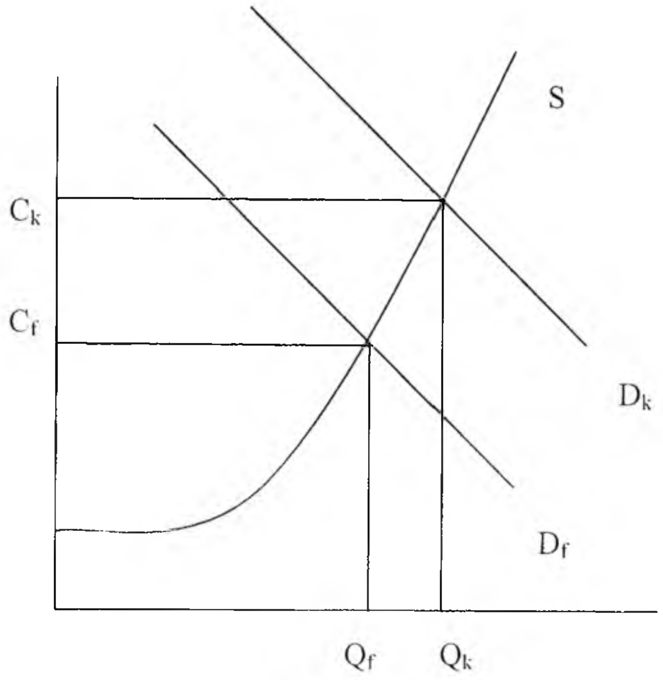
Therefore, the cost of electricity is determined by the forces of supply and demand. As a result, the cost of electricity rises and falls based on a variety of factors such as demand and types of generation available. Cost is generally lower on weekend and late at night due to lower demand and the cost of electricity usually peaks in the early evening as people arrive home from work.

To understand the effects of various demand on the cost of electricity we assume for each period t, end user demand $D_t(C_t)$ depend on the suppler cost, in each period given the market supply curve $S_t(C_t)$. Therefore, the equilibrium in the market is determined by $S_t(C_t) = D_t(C_t)$ this market equilibrium is shown in figure (5.8) for two time periods: peak demand (K) and off-peak demand (F).

We can see from the figure (5.8) once demand goes up to hit its peak, supply goes up to meet it, which then results in the cost of electricity going up. Therefore, utilities are forced to bring their most expensive generating units on line or to buy additional power from grid at peak rate. Producing electricity during hours of particularly high demand is often more expensive because back-up generators and less efficient facilities need to be put into use.

Currently in Libya, all consumers pay prices that reflect the average cost of electricity rather than prices that reflect the cost of the unit they are actually using at the time. With the average cost of electricity, household and commercial consumer have little incentive to manage their consumption and use less electricity during peak hours when demand is exceptionally high. Therefore, the government should introduce various prices throughout the day to reflect the real cost of electricity and encourage people to make informed choices about how and when they will use electricity.

Figure (5.8): Example of switching from low cost to high cost for the high peak period (k) and low off-peak period (f) of demand



5.9 The Main Model

In this section we develop a multiyear electricity optimisation model for Libya. The multiyear planning model in this section calculates optimal planning strategies for the Libyan electricity sector. When developing the model we first assume that the investor has an exclusive permission to construct a new power plant. Under this assumption we develop the mathematical framework of the optimisation model, which is based on dynamic programming. More realistic assumptions are added to the model, by also representing the investment decisions of other participants in the system.

We use the model to identify at which scenario it is optimal to invest in new power plants in Libya.

The objective of long-term optimisation of electricity generation capacity is the minimisation of the total costs (expected investment and operational costs) considering the reliability constraints.

The structure of generating units has to be optimal: it is optimal if the requirements of power balance, reserve capacity, reliability, security, and other constraints are fulfilled with minimum total costs.

The optimisation task is to determine the optimal unit commitment and the economic scheduling of unit and energy production during the planning period. The objective is to minimise the sum of operational costs and expected investment costs for the each year of planning period considering the reliability and environmental constraints.

We use the model to analyse a multiyear electricity model that is similar to projects currently under consideration in the Libyan power system. The analysis is concerned with identifying optimal investment combinations for an investor with permission to construct new power plants.

We use the model to analyse an investment in 6 power plants. It is assumed that the planer wants to optimise the cost of his investment decision. Technical specifications for the new power plants are presented in table (5.7). Furthermore, a planning horizon of 20 years (T=20years) and we assume that the investor can only construct one plant a year.

Table (5.7): Technical specification for the new power plants

Plant	Type	Location	Cost (Million L.D)	Capacity (MW)
A	Al Zuwiya power plant (gas-fired)	AlZuwiya	118	600
B	West mountain power plant (Gas-fired)	West Mountain	107	650
C	Gulf stream station Hydro	Sirte	500	1400
D	Massrata power plant	Massrata	192	750
E	Expand the Tubrok power plant	Tubrok	213	600
F	East Tripoli power plant	Tripoli	213	600

Table (5.8): the maintenance & operation cost for the new Plants

Plant	Capacity (MWh)	Maintenance cost (Million L.D)	Operation cost (Million L.D)
A	2414100	2	15
B	2615275	2	15
C	5632900	3	15
D	3017625	1.5	15
E	2414100	2	15
F	2414100	2	15

We developed an input dataset for the Libyan power sector. The initial conditions in the model describe year 2005, and the model is simulated for a period of 20 years. On the supply side the initial generation capacity consists hydropower and gas-power. 6 different power plants can be added to the system (Al zuwiya power plant, West mountain power plant, Gulf stream station, Massrata power plant, Tobrok power plant and East Tripoli power plant), we labelled them A, B, C, D, E, and F respectively see table (5.7). Investments in all of these plants are currently under consideration in the Libyan power system. The demand side is described by a few key variables, and we assume a reference high growth in demand of 6%. 65 different scenarios are considered as described below.

We first run a business as usual scenario (doing nothing), where we assume that the authorities take a passive approach. In the second scenario (having one plant built by 2025) we assume that the authorities take a more active approach and invest in one plant A, B, C, D,E or F. in the second scenario (having two power plants built by 2025) and so on , table (5.9) shows the scenarios and the action that assumed to be taken by the authorities.

Table (5.9) : The scenarios and the action that assumed to be taken

Scenario	Plant built by 2025
1	Nothing
2	A
3	B
4	C
5	D
6	E
7	F
8	EF
9	DF
10	DE
11	CF
12	CE
13	CD

14	BF
15	BE
16	BD
17	BC
18	AF
19	AE
20	AD
21	AC
22	AB
23	DEF
24	CEF
25	CDF
26	CDE
27	BEF
28	BDF
29	BDE
30	BCF
31	BCE
32	BCD
33	AEF
34	ADF
35	ADE
36	ACF
37	ACE
38	ACD
39	ABF
40	ABE
41	ABD
42	ABC
43	CDEF
44	BDEF
45	BCEF

46	BCDF
47	BCDE
48	ACEF
49	ADEF
50	ACDF
51	ACDE
52	ABEF
53	ABDF
54	ABDE
55	ABCF
56	ABCE
57	ABCD
58	BCDEF
59	ACDEF
60	ABDEF
61	ABCEF
62	ABCDF
63	ABCDE
64	ABCDEF

5.9.1 Current Electricity System in Libya

Some of the main characteristic of the current and historical energy supply and demand in Libya is presented in this section.

Libya currently has electric power production capacity of about 4.7 gigawatts (GW), with peak load of around 3.3 GW. Tables (5.10) and (5.11) show the development of power production capacity and peak load respectively.

Most of Libya's existing power stations are oil-fired, though several have been converted to natural gas. Libya's power demand is growing rapidly (around 6%-8% annually), and is expected to reach 5.8 GW in 2010 and 8 GW in 2020. During the summer of 2004, Libya was hit by widespread blackouts as power plants could not keep up with demand. To prevent such blackouts in the future and to meet surging power consumption, Libya's state-owned General Electricity Company (GECOL) has plans to spend 1.4 billion L.D through 2025 building six new combined cycle and steam cycle power plants.

The Libyan power projects include an 600-MW power plant in Al Zuwiya on the west coast, an 650-megawatt (MW) Western Mountain Power Project, a 1,400-MW "Gulfsteam" combined power and desalination complex in Sirte , an 750-MW power plant in Massrata, expend the Tubrok power plant with a 600-MW, and the 600-MW Western Tripoli power plant.

Aside from building new generation capacity, GECOL also has a program to upgrade and expand the country's power transmission grid. Currently, Libya's power grid consists of around 7,500 miles of 220-kV lines, 13,000 miles of 66-kV and 30kV lines, and 20,000 miles of 11 kV lines.

Table (5.10): The development of power production capacity (MW)

Year	Power production capacity
1980	1460
1985	2435
1990	3092
1995	4602
2000	4716
2001	4601
2002	4708
2003	4708

Source: General Electricity Corporation of Libya annual report 2003

Figure (5.9): **The development of power production capacity (MW)**

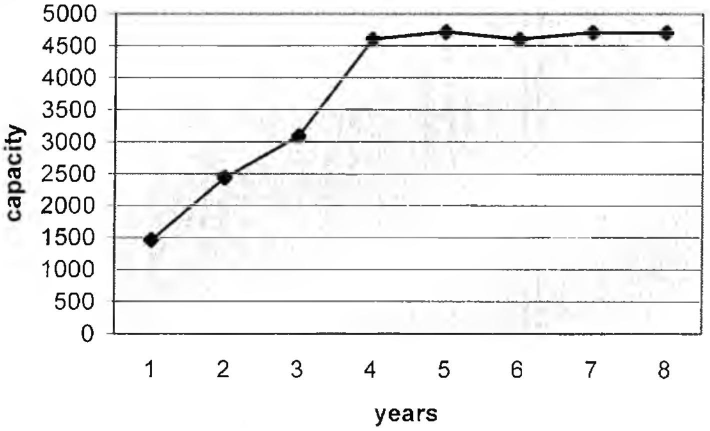


Table (5.11): The development of peak load (MW)

Year	Peak load	Growth rate
1996	1977	-
1997	2140	8.24
1998	2360	10.28
1999	2448	3.73
2000	2630	7.43
2001	2934	11.56
2002	3081	5.01
2003	3341	8.44

Source: General Electricity Corporation of Libya annual report 2003

5.9.2 Main Assumptions in the Model

The model builds on a set of simplifying assumptions. The most important assumptions are listed below.

1. The user's objective is to minimise the expected cost from new investments, on the other hand to maximise the expected profit from new investment. Income is earned by selling electricity into the market.
2. The user's risk preference is represented by using a risk-adjusted discount rate.
3. The user does not take into account the possible negative price effect on existing generation assets when new investments are considered.

4. Investment costs are adjusted according to the length of the planning period. Furthermore, it is assumed that the investment cost is spread out evenly over the construction period, so that the cash flow can be represented by one single outlay half way into the construction period.
5. Investment decisions can be made once a year, i.e. the time resolution of the optimisation model is one year.
6. No decommissioning of existing capacity within the planning horizon.
7. We assume that the user can never have more than one new plant under construction at the same time.
8. All facilities built by the year 2025 can be maintained for 20 years and will contribute electricity to the Libyan economic over this period.

5.9.3 Mathematical Description of the Model

The overall problem for an investor considering investing in a new generation plant can be stated as a dynamic optimisation problem over a planning horizon of T years, as shown below. The planer's objective is to minimise the total cost over the planning horizon. We use a one year time resolution and assume that investments can only take place at the beginning of each year. Furthermore, we adjust the total cost according to the length of the planning period, so that the termination Ct, is simply the expected cost in the last period under the condition that no new investment is made. In the basic formulation we assume that the investor has an excusive right to invest in new power plants.

$$C_0(x_0) \min \sum_{k=0}^{T-1} f(x_k, u_k)$$

$$x_{k+1} = x_k + u_{k-k+1}$$

$$x_k \in \Omega_{x,k} \quad u_k \in \Omega_{u,k}$$

where

$C_0(x_0)$	min.expected total cost over planning period at initial states
$f(x_k, u_k)$	expected cost function, time step k

x_k total new installed capacity (state variable)
u_k new capacity (decision /control variable)
$\Omega_{u,k}$ discrete feasible sets for x,u

The planer's new installed capacity x_k is the state variable in this dynamic optimisation problem.

Since the annual expected costs are additive we can solve the planning problem using dynamic programming. We use a backward SDP algorithm with discrete time and states, as described by Bertsekas (2000), to find solution to the problem.

$$C_k(x_k) = \min_{u_k \in u_k} f_k(x_k, u_k)$$

5.9.4 The future value of having the plants

In calculating the future value of the generation plants, we will use the same assumptions that have mentioned in section (5.6.2)

The six plants derive income by selling electricity to the government at certain prices each year. Totalling 38.71 L.D for the A plant , 41.93 LD for the B plant, 90.32 L.D for the C plant , 48.38 L.D for the D plant, 38.81 L.D for the E plant and 38.71 L.D for the F plant. Table (5.12) shows the income from selling electricity for one year and for 20 years for each plant.

Table (5.12) : Income from selling electricity

Plant	Income from selling electricity for one year (Million L.D)	Income from selling electricity for 20 years (Million L.D)
A	38.71	774.15
B	41.93	838.67
C	90.32	1806.36
D	48.38	967.69
E	38.71	774.15
F	38.71	774.15

The future value of having a plant = annual income from selling electricity × expected age of the plant

Table (5.13) shows the future value of having the plants under each scenario

Table (5.13) the future value of having the plants

Plant	Income from selling electricity (Million L.D)	Total annual income from selling electricity (Million L.D)	Age of plant (year)	The total value of having the plants (million L.D)
ABCDEF	296.76	1661.92	20	33238.40
ABCDE	258.05	1623.21	20	32464.20
ABCDF	258.05	1623.21	20	32464.20
ABCEF	248.38	1613.54	20	32270.80
ABDEF	206.44	1571.60	20	31432.00
ACDEF	254.83	1619.99	20	32399.80
BCDEF	258.05	1623.21	20	32464.20
ABCD	219.34	1584.50	20	31690.00
ABCE	209.67	1574.83	20	31496.60
ABCF	209.67	1574.83	20	31496.60
ABDE	167.73	1532.89	20	30657.80
ABDF	167.73	1532.89	20	30657.80
ABEF	158.06	1523.22	20	30464.40
ACDE	216.12	1581.28	20	31625.60
ACDF	216.12	1581.28	20	31625.60
ADEF	164.51	1529.67	20	30593.40
ACEF	206.45	1571.61	20	31432.20
BCDE	219.34	1584.50	20	31690.00
BCDF	219.34	1584.50	20	31690.00
BCEF	209.67	1574.83	20	31496.60
BDEF	167.73	1532.89	20	30657.80
CDEF	216.12	1581.28	20	31625.60
ABC	170.96	1536.12	20	30722.40
ABD	129.02	1494.18	20	29883.60
ABE	119.35	1484.51	20	29690.20
ABF	119.35	1484.51	20	29690.20
ACD	177.41	1542.57	20	30851.40
ACE	167.74	1532.90	20	30658.00
ACF	167.74	1532.90	20	30658.00
ADE	125.80	1490.96	20	29819.20
ADF	125.80	1490.96	20	29819.20
AEF	116.13	1481.29	20	29625.80
BCD	180.63	1545.79	20	30915.80
BCE	170.96	1536.12	20	30722.40
BCF	170.96	1536.12	20	30722.40
BDE	129.02	1494.18	20	29883.60
BDF	129.02	1494.18	20	29883.60
BEF	119.35	1484.51	20	29690.20
CDE	177.41	1542.57	20	30851.40

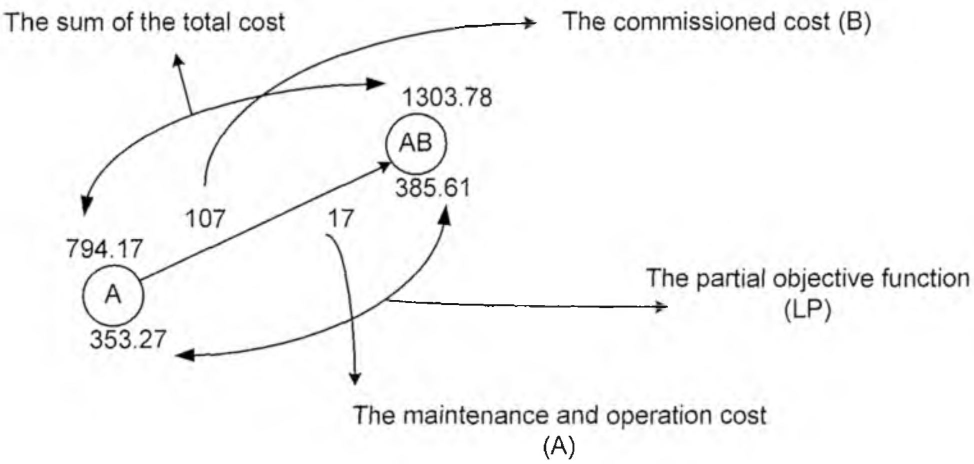
CDF	177.41	1542.57	20	30851.40
CEF	167.74	1532.90	20	30658.00
DEF	125.80	1490.96	20	29819.20
AB	80.64	1445.80	20	28916.00
AC	129.03	1494.19	20	29883.80
AD	87.09	1452.25	20	29045.00
AE	77.42	1442.58	20	28851.60
AF	77.42	1442.58	20	28851.60
BC	132.25	1497.41	20	29948.20
BD	90.31	1455.47	20	29109.40
BE	80.64	1445.80	20	28916.00
BF	80.64	1445.80	20	28916.00
CD	138.70	1503.86	20	30077.20
CE	129.03	1494.19	20	29883.80
CF	129.03	1494.19	20	29883.80
DE	87.09	1452.25	20	29045.00
DF	87.09	1452.25	20	29045.00
EF	77.42	1442.58	20	28851.60
A	38.71	1403.87	20	28077.40
B	41.93	1407.09	20	28141.80
C	90.32	1455.48	20	29109.60
D	48.38	1413.54	20	28270.80
E	38.71	1403.87	20	28077.40
F	38.71	1403.87	20	28077.40
doing nothing		1365.16	20	27303.20

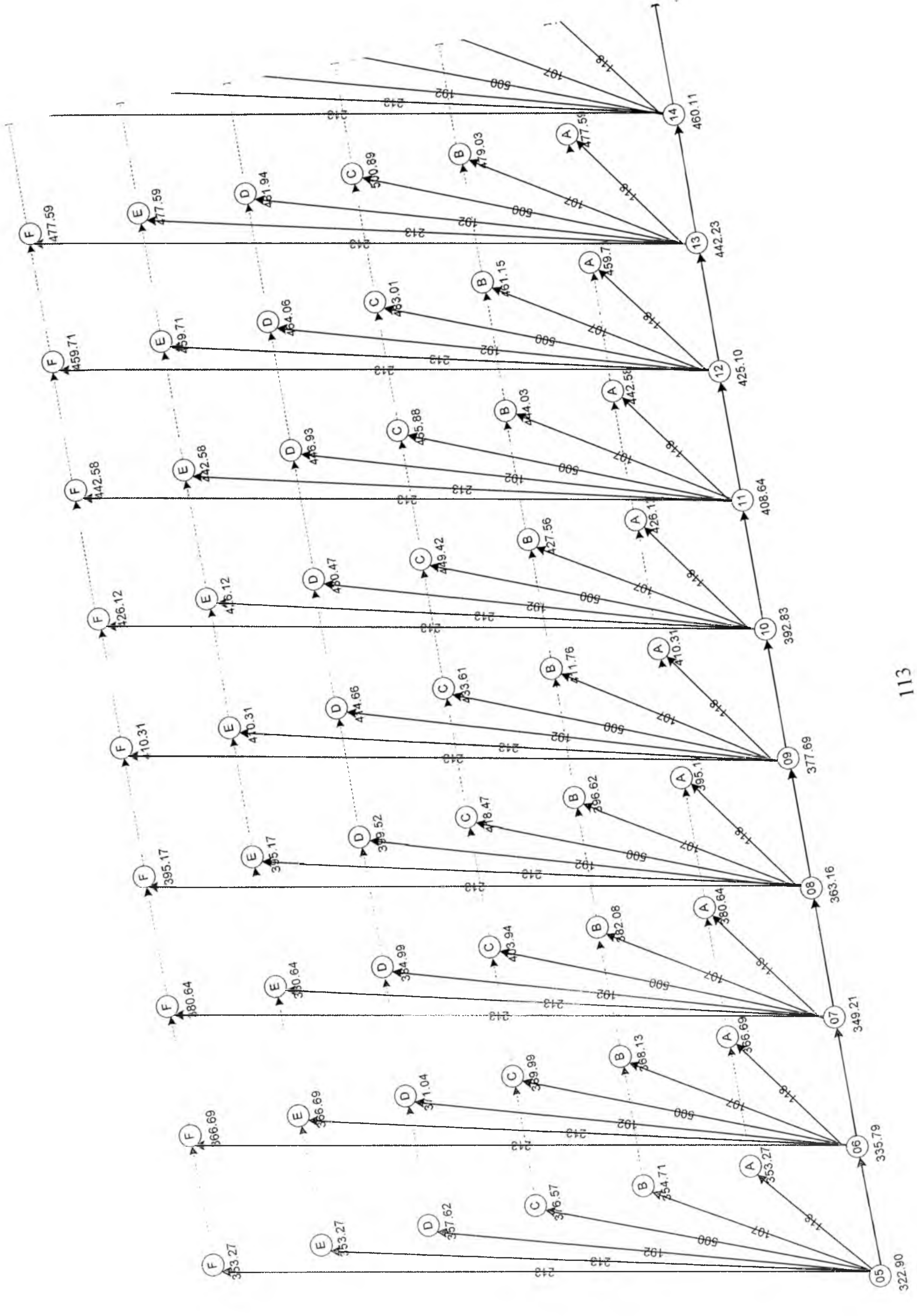
5.9.5 Dynamic Network Flow – Main Model

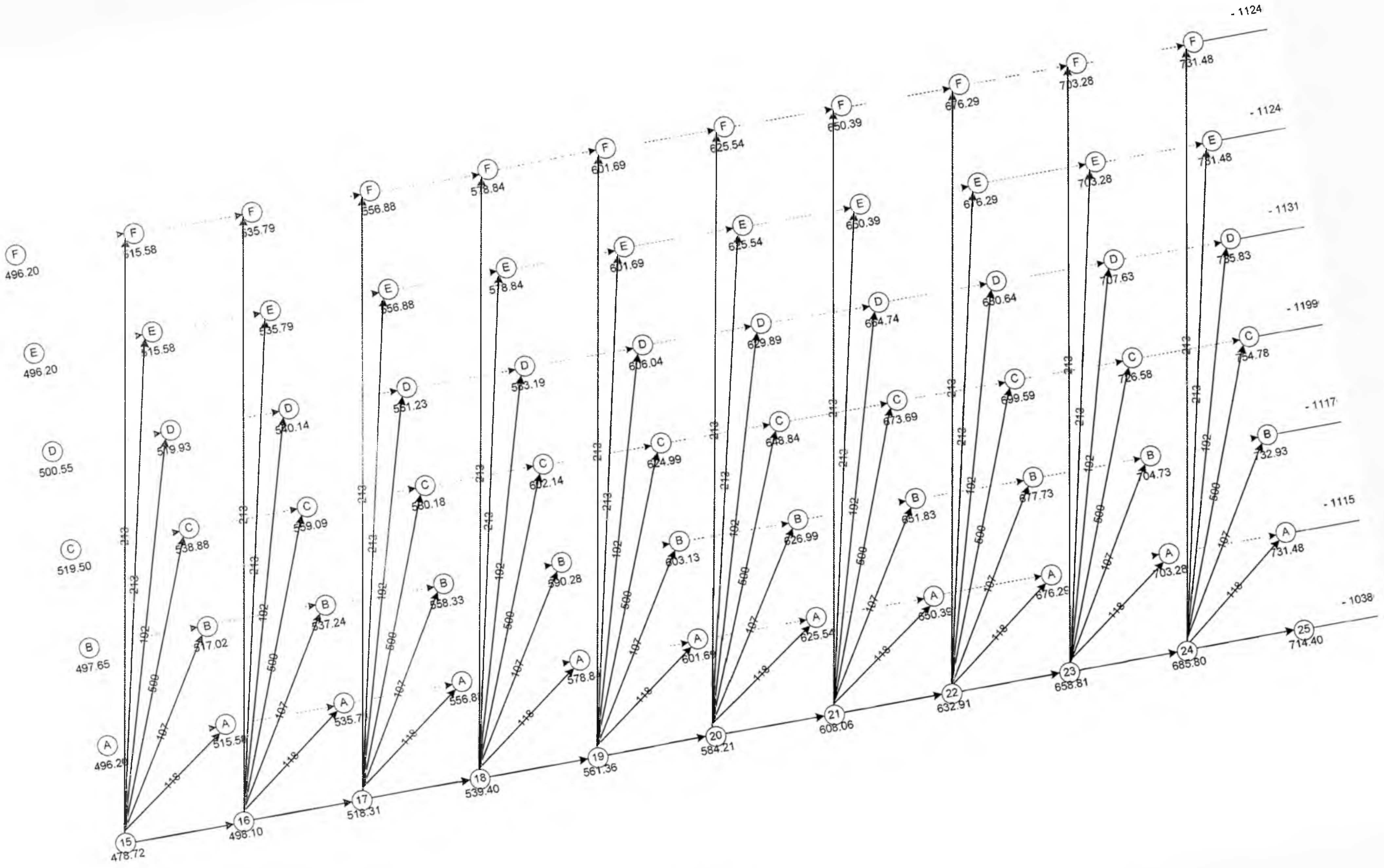
Due to the large size of the network flow of the main model, which contents 1280 nodes (states) and 20 stages. we divided it into sub-network flow in order to explain the analysis and we will provide the complete network flow at the end of this chapter.

Figure (5.11) shows the network flow for scenarios 1-6. As we mentioned before the figure above the node refer to the sum of (the partial objective function LP + the cost of the commissioned plant + the maintenance and operation cost). Those on the arcs refer to the cost of the commissioned plant and the cost of maintenance and operation, and those below the nodes are the partial objective function value LPs.

Figure (5.10): Network flow




05
322.90
A 353.27
B 354.71
C 376.57
D 357.62
E 353.27
F 353.27
06
335.79
A 366.69
B 368.13
C 389.99
D 371.04
E 366.69
F 366.69
07
349.21
A 380.64
B 382.08
C 403.94
D 384.99
E 380.64
F 380.64
08
363.16
A 395.1
B 396.62
C 418.47
D 399.52
E 395.17
F 395.17
09
377.69
A 410.31
B 411.76
C 433.61
D 414.66
E 410.31
F 410.31
10
392.83
A 426.1
B 427.56
C 449.42
D 430.47
E 426.12
F 426.12
11
408.64
A 442.58
B 444.03
C 465.88
D 446.93
E 442.58
F 442.58
12
425.10
A 459.7
B 461.15
C 483.01
D 464.06
E 459.71
F 459.71
13
442.23
A 477.59
B 479.03
C 500.89
D 481.94
E 477.59
F 477.59
14
460.11
118
107
600
192
213
213


F 496.20
E 496.20
D 500.55
C 519.50
B 497.65
A 496.20
15 478.72
F 515.58
E 515.58
D 519.93
C 538.88
B 517.02
A 515.58
213
213
192
500
107
118
16 498.10
F 535.79
E 535.79
D 540.14
C 559.09
B 537.24
A 535.7
17 518.31
F 556.88
E 556.88
D 561.23
C 580.18
B 558.33
A 556.8
18 539.40
F 578.84
E 578.84
D 583.19
C 602.14
B 590.28
A 578.8
19 561.36
F 601.69
E 601.69
D 606.04
C 624.99
B 603.13
A 601.6
20 584.21
F 625.54
E 625.54
D 629.89
C 648.84
B 626.99
A 625.54
21 608.06
F 650.39
E 650.39
D 654.74
C 673.69
B 651.83
A 650.39
22 632.91
F 676.29
E 676.29
D 680.64
C 699.59
B 677.73
A 676.29
23 658.81
F 703.28
E 703.28
D 707.63
C 726.58
B 704.73
A 703.28
24 685.80
F 731.48
E 731.48
D 735.83
C 754.78
B 732.93
A 731.48
25 714.40
- 1124
- 1124
- 1131
- 1199
- 1117
- 1115
- 1038

The contribution = - total cost (total value of the construction cost + operating and maintenance costs) + total income from selling electricity

$$f_k\left(x_k, u_k\right) = -\Pi_{cost,k}\left(x_k, u_k\right) + \Pi_{energy,k}\left(x_k\right)$$

Where

$(\Pi_{cost,k})$ = the total expected cost

$(\Pi_{energy,k})$ = the total income from selling electricity

Table (5.14) shows the cost/benefit analysis that derived from the complete network flows for each scenario.

Table (5.14): Cost /Benefit analysis

Plant	Total cost (Million L.D)	Benefit (Million L.D)	Contribution
ABCDEF	15591.54	33238.40	17646.86
ABCDE	14940.64	32464.20	17523.56
ABCDF	14922.64	32464.20	17541.56
ABCEF	14686.34	32270.80	17584.46
ABDEF	14245.81	31432.00	17186.19
ACDEF	15002.26	32399.80	17397.54
BCDEF	15017.64	32464.20	17446.56
ABCD	14459.73	31690.00	17230.27
ABCE	14170.81	31496.60	17325.79
ABCF	14170.81	31496.60	17325.79
ABDE	13518.16	30657.80	17139.64
ABDF	13518.16	30657.80	17139.64
ABEF	13471.10	30464.40	16993.30
ACDE	14300.11	31625.60	17325.49
ACDF	14300.11	31625.60	17325.49
ADEF	13598.32	30593.40	16995.08
ACEF	14250.37	31432.20	17181.83
BCDE	14316.73	31690.00	17373.27
BCDF	14316.73	31690.00	17373.27
BCEF	14265.81	31496.60	17230.79
BDEF	13613.16	30657.80	17044.64
CDEF	14415.53	31625.60	17210.07
ABC	13431.40	30722.40	17291.00
ABD	12758.30	29883.60	17125.30
ABE	12707.36	29690.20	16982.84

ABF	12707.36	29690.20	16982.84
ACD	13573.22	30851.40	17278.18
ACE	13509.50	30658.00	17148.50
ACF	13509.50	30658.00	17148.50
ADE	12836.83	29819.20	16982.37
ADF	12836.83	29819.20	16982.37
AEF	12787.40	29625.80	16838.40
BCD	13581.20	30915.80	17334.60
BCE	13526.40	30722.40	17196.00
BCF	13526.40	30722.40	17196.00
BDE	12853.30	29883.60	17030.30
BDF	12853.30	29883.60	17030.30
BEF	12802.36	29690.20	16887.84
CDE	13668.22	30851.40	17183.18
CDF	13668.22	30851.40	17183.18
CEF	13604.50	30658.00	17053.50
DEF	12931.83	29819.20	16887.37
AB	11909.36	28916.00	17006.64
AC	12734.13	29883.80	17149.67
AD	12041.06	29045.00	17003.94
AE	11997.86	28851.60	16853.74
AF	11997.86	28851.60	16853.74
BC	12752.50	29948.20	17195.70
BD	12059.43	29109.40	17049.97
BE	12004.36	28916.00	16911.64
BF	12004.36	28916.00	16911.64
CD	12869.80	30077.20	17207.40
CE	12829.13	29883.80	17054.67
CF	12829.13	29883.80	17054.67
DE	12136.06	29045.00	16908.94
DF	12136.06	29045.00	16908.94
EF	12092.86	28851.60	16758.74
A	11153.79	28077.40	16923.61
B	11171.68	28141.80	16970.12
C	12019.79	29109.60	17089.81
D	11315.79	28270.80	16955.01
E	11248.79	28077.40	16828.61
F	11248.79	28077.40	16828.61
doing nothing	10380.59	27303.20	16922.61

The results show that all the alternatives are very close. although the scenario of having ABCDEF built by 2025 seams to be much better. However we should take all the closed alternatives into consideration as well. It may be that there are some social reasons that cause the government to construct those power stations. Table (5.15) shows the most identical options that should be taken into consideration.

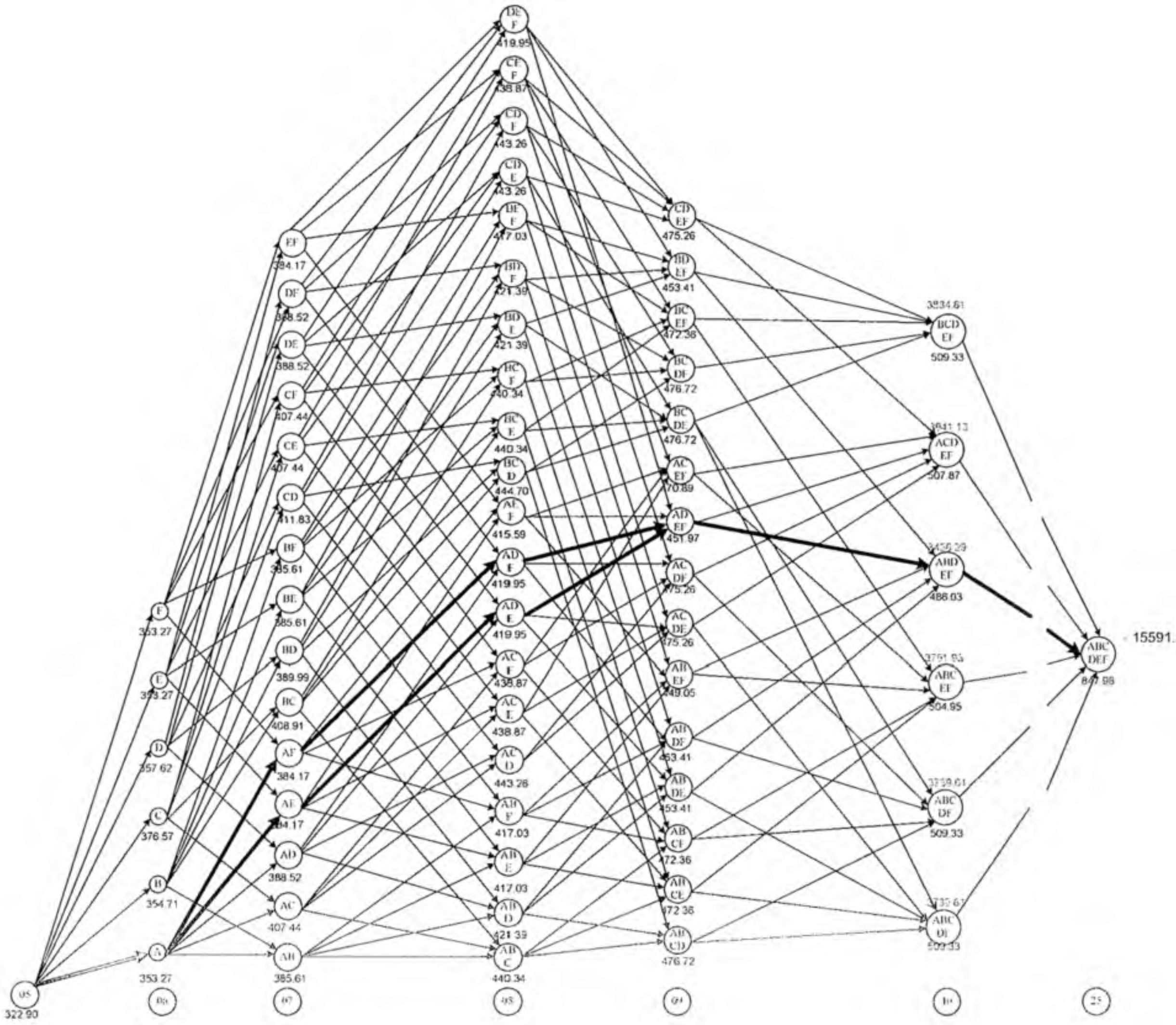
Table (5.15): The most identical options

Plant	Total cost (Million L.D)	Benefit (Million L.D)	Contribution
ABCDEF	15591.54	33238.40	17646.86
ABCEF	14686.34	32270.80	17584.46
ABCDF	14922.64	32464.20	17541.56
ABCDE	14940.64	32464.20	17523.56
BCDEF	15017.64	32464.20	17446.56
ACDEF	15002.26	32399.80	17397.54
BCDE	14316.73	31690.00	17373.27
BCDF	14316.73	31690.00	17373.27
BCD	13581.20	30915.80	17334.60
ABCE	14170.81	31496.60	17325.79
ABCF	14170.81	31496.60	17325.79
ACDE	14300.11	31625.60	17325.49
ACDF	14300.11	31625.60	17325.49
ABC	13431.40	30722.40	17291.00
ACD	13573.22	30851.40	17278.18
BCEF	14265.81	31496.60	17230.79
ABCD	14459.73	31690.00	17230.27
CDEF	14415.53	31625.60	17210.07
CD	12869.80	30077.20	17207.40
BCE	13526.40	30722.40	17196.00
BCF	13526.40	30722.40	17196.00
BC	12752.50	29948.20	17195.70
ABDEF	14245.81	31432.00	17186.19
CDE	13668.22	30851.40	17183.18
CDF	13668.22	30851.40	17183.18
ACEF	14250.37	31432.20	17181.83

A cursory look at the contribution value for each scenario would suggest that decision maker should go with the scenario 64, (having ABCDEF built by 2025), since it has a higher expected value or contribution L.D 17646.86 million as opposed to the rest of the other options, for examples. L.D17584.46 for scenario 63.

However, from our results, the optimal scenario is building ABCDEF and we will adopt a backward formulation. We will cross the net work from right to left and build up the optimal decision path sequentially as follows.

Figure (5.12) The Optimal Scenario



5.10 Conclusion

In this chapter we have presented an optimisation model for long-term analysis of the power sector. The model is based on the dynamic programming technique. In the model we have tried to include the main casual relationships that give rise to the long-term investment dynamics in the power system. The dynamic programming model can serve as a tool for learning and decision support for participates in the planning department and power sector. The strength of the modelling approach lies in its ability to dynamically simulate systems where decisions are centralised.

The model is well suited for scenario planning. The results from the Libyan case study show that the model is able to capture at least of the long-term dynamic that is likely to occur on multiyear planning of the electricity.

Dynamic programming model is mainly a tool for improving decision makers' qualitative understanding about a complex problem. Increased insight will, in turn, result in better decision making. However, improving knowledge can only to a limited extent be achieved by studying the results from the simulation model. In order to obtain the best results from using the dynamic programming for planning purpose, decision makers should be involve in all the stage of the model development.

The model simulates the development of the power system in Libya for a period of 20 years. We modeled the investment in new plants with a supply and demand curve. The time resolution in the model is one year, using the simplifying assumption that investment decision can only be made at the beginning of each year. New investments in generation result in a change in the supply and demand for electricity.

The level of detail in the model is aggregated. instead of going into detail on the different parts of the system. We tried to focus on the relationships that we saw as most important for the long-term development of investment in new power plants. The model is a tool for generating scenarios to analyse what is likely to happen under certain circumstances (e.g. build one power plant, two power plants etc.). Development and use the model can contribute to learning and improved decision making for participants in the power industry.

We assumed that investments in the new power generation capacity are based on purely economic arguments.

Chapter 6

Social Accounting Matrix

6.1 Introduction

Social accounting and national accounting have a great deal in common. Both are frameworks or systems that encompass every transaction of an economy within a given period of time, usually a year. The main difference between social accounting and national accounting is one of emphasis. The primary intent of national accounts is to analyse the production of goods and services, whereas in social accounting the emphasis is on the distribution and redistribution of income generated by the production process.

The development of social accounting went hand-in-hand with the development of planning models that used this data. Timothy, J.K (1996). A SAM is a particular representation of the macro and meso economic accounts of a socio-economic system, which capture the transactions and transfers between all economic agents in the system (Pyatt, G & Round, J (1985); Reinert, K & Roland-Holst, D (1997)). Therefore, a Social Accounting Matrix (SAM) is a matrix representation of the social accounts of the nation. It records transactions taking place during an accounting period, usually one year.

The main features of a SAM are:

- The accounts are represented as a *square matrix*; where the incomes and outgoings for each account are shown in the corresponding row and column of the matrix.
- It provides a comprehensive oversight of the economy and clearly sets out the inter-relationships between different agents.
- It is flexible, in that, although it is usually set up in a standard, basic framework there is a large measure of flexibility both in the degree of

disaggregation and in the emphasis placed on different parts of the economic system.

- It brings together data from many disparate sources that help to describe the structural characteristics of an economy.
- It shows clearly the linkage between income distribution and economic structure.
- It represents a useful analytical framework for modeling with links to other combinatorial paradigms.
- It shows much more detail about the circular flow of income, including transactions between different institutions (including different household groups) and between production activities, and in particular it records the interactions between both these sets of agents via the factor and product markets.

6.2 Data Need and Construction of a SAM

There is no fixed design for a SAM, it depends uniquely on the purposes to be served and the data that is available. Typically, it includes institutional sectors, productive activities, current account, capital accounts for institutional sectors, financial assets/ claims and accounts with the rest of the world. It is also the general practice to include separate accounts for commodities and the activities that produce them.

The idea of a SAM is to provide a detailed framework for the better understanding of the economy. It requires the disaggregation of all these accounts in accordance with the circumstances and needs of the country.

Social Accounting Matrices have been criticised in that the approach requires a significant amount of data; this can cause problems for countries with relatively undeveloped statistical systems. However, the data required is no more than that required for economic planning and social policy. One way to deal with insufficient data for an "ideal" SAM is to compromise by reducing the scope of the SAM, probably by some aggregation, and introducing new data collection programmes.

The SAM records the transactions between the accounts in the cells of the matrix (Tij). A payment from the jth account to the ith account is shown in cell Tij according to the standard accounting convention in an input-output table. The ordering of the rows and columns is not crucial, although the rows are always ordered in the same way as the columns. In many SAMs and SAM-based analyses the leading accounts are chosen to reflect our primary interest in living standards and distributional issues; so that institutions (households) or factors of production are ordered first. The ordering begins with production, as it does in an input-output table, although this does not affect the data structure or the modelling techniques in any other way. Round, J (1988).

6.3 Presentation of the Accounts

In Libya until 2003, National accounts where accumulated using the United Nation system of National Accounts 1968 (SNA68), and it is planned to introduce the SNA 93 in the coming year. The main modification introduced by the SNA93 is that of presenting the economic data as a sequence of accounts starting from the production account through income creation and distribution and ending with consumption and accumulation. A goods and services account with the rest of the world is also included.

The System is modeled as a nonlinear flow problem. It is build around a sequence of interconnected flow accounts linked to different types of economic activity taking place within a given period of time, together with balance sheets that record the values of the stocks of assets and liabilities held... at the beginning and end of the period (SNA93, para. 1.3) .

6.3.1 A Matrix Representation (SNA) Framework

In the SNA 1968 we can find these accounts in the following framework, which will allow us to present the previous accounts into a matrix form.

Table (6.1): A Matrix Representation (SNA) Framework

	Production	**Consumption**	**Accumulation**	**Rest of the world**
Production		Consumption	Investment	Exports
Consumption	GDP		Less: Consumption fixed capital	Net distributed factor income payments
Accumulation		Saving		
Rest of the world	Imports		Surplus of the nation current transactions	

SNA 1968 for Libya in 1999

Table (6.2) System of National Accounts (1968) for Libya in 1999

	Production	**Consumption**	**Accumulation**	**Rest of the world**	**Total**
Production		11615.1	1581.7	3374.3	16571.1
Consumption	14138.2		(-) 1292.2	42.3	12888.3
Accumulation		1273.2			1273.2
Rest of the world	2432.9		983.7		3416.6
Total	16571.1	12888.3	1273.2	3416.6	

SNA 1993 for Libya in 1999

Table (6.3) System of National Accounts (1993) for Libya in 1999

	Production	Consumption	Accumulation	Rest of the world	Total
Production		11615.1	1581.7	3374.3	16571.1
Consumption	12846 NDP			42.3	12888.3
Accumulation	1292.2	1273.2			2565.4
Rest of the world	2432.9		983.7		3416.6
Total	16571.1	12888.3	2565.4	3416.6	

6.4 Social Accounting Matrix for Libya in 1999

A SAM is a square matrix whose rows and columns respectively correspond to the supply and deposition of goods and services. Each cell represents a transaction between two accounts. In the simplest SAMs there are six core accounts (1) Activities (oil and non-oil sectors);(2) Production (oil and non-oil sectors); (3) Factors of Production (labour and capital); (4) Institutions (e.g. household and government); (5) Capital (e.g. saving and investment); (6) Rest of the world (transactions with other countries). More complex variations involve further desegregation of these accounts.

Table (6.4): Social Accounting Matrix for Libya in 1999

		Activities		Products		Factors		Institutions		Saving & Investment	Rest of
		Oil	Non-oil	Oil	Non-oil	Labour	Capital	Household	Stats		
Activities	Oil			4549 8							
	Non-oil				16105.6						
Products	Oil	553.9						486.3	179 9	200.9	3128 8
	Non-oil		6026 3					8027.2	2921 7	1380.8	245.5
Factors	Labour	195.2	5060.2								
	Capital	3636 6	3891								253.7
Institutions	Household					5157.7	4223.2				
	Stats				63		3444.4	685			
Saving& Investment		164 1	1128.1					182 4	1090 8		
Rest of					2432.9	97.7	113.7			983.7	

Source: by the author

To facilitate the building of a large economy-wide model for Libya, the new framework and data we firstly established a social accounting matrix for the year 1999 using the (World Bank) Hercules model. This matrix is extremely useful, both to verify the coherence of our set of equations and to help us in the model building.

HERCULES is both an approach to organizing and building economic models and a supporting software system (Arne Drud, David Kendrick, 1986). The model is described by a set of nonlinear equations that simultaneously determine prices, quantities, and money flow (Arne Drud, David Kendrick, 1986).

It can be seen from the table above (SAM for Libya in 1999) that total Factors of Production (13036.7) is divided, with 9390.9 of it going to household sector, 3444.4 to government, and 211.4 to the rest of the world. Total income of household is 9380.9, and is used to purchase 8513.5 of goods and services; the Production activities (producers) take 23151.3 they have received from the household, government, capital and the rest of the world sectors and pay 20718.4 to factors of production and 2432.9 to the rest of the world.

6.5 Mathematical Model

6.5.1 The Economy

In our first model (Model I), the economy consists of two producers, which produce two goods, using labour and capital inputs. The labour and capital inputs are supplied by two sets of households, all output is consumed by the households, which use their wage and dividend income to pay their consumption expenditure.

An economy like this is normally described by a set of nonlinear equations that simultaneously determine prices, quantities and money flows. We shall distinguish between two types of equations :(1) set of equation or submodels that describe economic agents such as producers, factors and households, and (2) linkage equations that describe the connections between the agents through, e.g., material balance or income-expenditure balance.

6.5.2 Local and Global Variables

The price of goods and factors will, in general, appear in the submodels of all users of the good or factor and are therefore global variables. In Model I, the following are global variables:

P_s = price of out put sector s,
P_f = price of factor f.
P_h = consumer price index for household h.

The sector index z is used to denote discrete categories, oil (oil sector) , non-oil (non-oil sector). Similarly, f can take the value l (labor) and c (capital). There is no overlap between the three prices. Although we have assumed that there are two sectors, two factors and one household group the model development will still be valid for z sectors. f factors, and h households and we shall use Z. F. and X_P when we count variables and equations. We will ensure that total supply is equal to total demand. and they will do so without matching individual suppliers with individual consumers.

6.5.3 Producers

The equations for a producer relate prices, quantities and total revenue of the goods produced to the prices, quantities and total costs of inputs and therefore, total cost. It is assumed here that the feasible combinations of inputs and outputs for each producer are represented by Cobb-Douglas production functions of form.

(1q) $$q_s = b_f \pi_f C_{fs}^{a_{fs}}$$

Out put Factor input

Where

q_s = quantity of output in sector s,

C_{fs} = quantity of factor input into sector s,

a_{fs} = share parameter for factor f in sector s, satisfying $\sum_f a_{fs} = 1$, and

b_f = scale parameter.

All equations defining quantities have the letter q appended, equations defining payments (or derived from ones defining payments) have a latter y appended and definitional equations relating payments to quantities and prices have a letter d appended.

It is assumed that the producer chooses the quantities of inputs and outputs in order to maximize profits under the assumption of perfect competition, such as, under the assumption that the producer can not influence prices. This mean, that although prices are endogenous in the overall model, they are considered exogenous by the producer. Maximization of the profit function subject to the production function constraint yields a set of first order optimality conditions that define demands for factor inputs. Dixon. Bowles. and Kendrick (1980).

(2q)
$$C_{fs} = a_{fs} - p_s \times \frac{q_s}{p^f}$$

all f , s

(factor demand)	(share parameter)	(output price,	output quantity	factor price)

The demand for each factor varies directly with the price and quantity of the commodity being produced and inversely with the price of the factor. Equation (1q), and (2q), defiles quantities. The corresponding payments can be determined from the following identities:

(1d)
$$y_s = p_s \times q_s \qquad \text{all } s$$

(revenue) (price times quantity)

(2d)
$$t_{fs} = p_f \times c_{fs} \qquad \text{all } f, s$$

Where y_s = total revenue in sector s,

t_{fs} = factor payment from sector s to factor f.

Equation (1q), (2q) define the quantity submodel because the key relationships, (1q) and (2q) , define quantities. Now we shall derive a payment submodel. The factor demand equation (2y) combined with (2q) gives the following factor payments equation:

(2y)
$$t_{fs} = a_{fs} \times y_s \qquad \text{all } f, s$$

The payments version of the production function (1q) is

$$y_s = p_s b_s \pi_f \left({}^{t_{fs}} \Big/ {}_{p_{fs}} \right)^{a_{fs}} \qquad \text{all} \quad s$$

That by introduction of (2q) can be reduced to

$$\text{(1y)} \qquad p_s = \beta_s \pi_f p_f^{a_{fs}} \qquad \text{all s}$$

where,

$$\beta_s = \pi_f a_{fs}^{-a_{fs} / b_s} \qquad \text{all s}$$

Thus, the "payment version" of the production function turns out to be the cost equation that determines the price of the output from the prices of the inputs.

6.5.4 Factor of Production

The model assumes that the total amount of each factor, q_f is fixed and that the price of factor, q_f will adjust to reach full employment. Implicit in the assumption of a single price per factor is an assumption that each factor is homogenous and perfectly mobile between sectors. We shall assume that the household group gets a share of each type of factor income proportional to the household's ownership of the factor.

The definitional equations that describe the relationship between factor variables are:

$$\text{(3d)} \qquad y_f = p_f \times q_f \qquad \text{all } f$$

(factor income) (factor prices times total factor input)

Where y_f = total income of factor f.

The payment equations describing the distribution of income are

(4d) $$t_{hf} = a_{hf} \times y_f \qquad \text{all } f,h$$

(factor income paid to households) (share of total factor income)

Where, t_{hf} = payment from factor f to household h, and

a_{hf} = share of factor f owned by household h.

6.5.5 Household

The equations for households describe their consumption pattern and define consumer price indices and real consumption. It is customary to assume that households consume so as to maximize their utility, subject to their budget constraint.

$$\max \; U_h(c_{sh})$$

$$\text{s.t.} \; \sum_s p_s \times c_{sh} < y_h$$

Where,

$U_h(.)$ = utility function for household h,

c_{sh} = quantity of good s consumed by household h

y_h = income for household h.

The first order optimality conditions for this optimization problem give the consumption system that defines consumption as a function of income and prices.
In our particular model we shall assume that the utility function is

$$U_h(.) = \sum_s a_{sh} \log(c_{sh})$$

Where a_{sh} = weight of good s. We assume for convenience that

$$\sum_{s} a_{sh} = 1 \text{ for all h.}$$

The consumption system derived from this utility function is

(5q) $$c_{sh} = a_{sh} \times y_h / p_s$$

The quantity consumed of each commodity varies directly with income and inversely with the price of the commodity. The definitional equation relating price and quantity to expenditure is

(5d) $$t_{sh} = p_s \times c_{sh}$$

(expenditure) (price times quantity consumed)

where, t_{sh} = expenditure on good s by household h.

The consumption system can be derived in payments instead of quantities, in which case we get

(5y) $$t_{sh} = a_{sh} \times y_h$$

The expenditure on each good is a fixed share of total income. Since the shares add to one, all income is used. A consumer price index and a real consumption equation are also associated with a utility function and the corresponding consumption system. For our utility function these equations are:

(6y) $$p_h = \pi_s \quad p_s^{a_{sh}} \qquad \text{all } h$$

And

(6q) $$q_h = \alpha_h \quad \pi_s \quad c_{sh}^{a_{sh}}$$

Where, q_h = real consumption for household h, and

$$\alpha_h = \pi_s \ a_{sh}^{-\alpha_{sh}}$$

p_h and q_h satisfy the standard definitional equation

(6d) $$y_h = p_h \times q_h$$

6.5.6 Linkages or Balance Equations

We shall now relate the three groups of agents (producers, factors and households) by defining the equations that characterize the linkages. In this model there are three groups of linkage equations corresponding to each of the three groups of agents.
For the producers, total supply of each commodity must be equal to total demand:

(7d) $$q_s = \sum_h c_{sh} \qquad \text{all s}$$

(Production) (Consumption)

This equation is relatively simple in this model, since there is only one category of demander (households). but the same type of material balance equation exists in models with many demanders. Equation (7q) is the quantity linkage equation corresponding to the arrow from producers to households, the payments linkage equation that corresponds to the arrow from household to producers statistics: for each good the total receipts of the suppliers must be equal expenditures of the demanders.

(7y) $$y_s = \sum_h t_{sh}$$

(revenue) (consumption)

give the definitions in Eqs. (1d) and (5d).

(1d) $$y_s = p_s \times q_s$$

(5d) $$t_{sh} = p_s \times c_{sh}$$

Equations (7q) and (7y) are dependent, so only one of them can be included in the overall model. The producer –household linkages will therefore add one equation, a quantity or a payments equation, for each sector or commodity. The quantity equations for factors are similar: total supply of each factor must be equal to total demand.

(8q) $$q_f = \sum_s c_{fs} \qquad \text{all } f$$

(total factor quantity) (sum over factor inputs in each sector)

The total income of each factor must also be equal to the sum of the factor payments:

(8y) $$y_f = \sum_s t_{fs}$$

(factor income) (sum over factor cost in each sector)

Equations (8q) and (8y) are dependent, so only one can be included in the final model for each factor. The production-factor linkages will therefore add one equation for each factor of production. The last linkage equation relates factor payments to household incomes. It corresponding to the arrow from factors to households; there is no corresponding physical flow, so there is only a monetary version of the equation.

(9y) $$y_h = \sum_f t_{hf} \qquad \text{all } f$$

(household income) (sum over factors of factor transfers)

And there is therefore one linkage equation for each household.

There are only linkage equations for quantities and payments where the linkage equations correspond to material balance equations. There are no linkage equations for prices.

6.6 The Conceptual Basic of the Model

In the previous section we provided a mathematical statement of a simple model, in this section we will formulate, estimate, and find solution of this type of model, using the Social Accounting Matrix SAM as a data base.

Our simple model in the previous section consists of two sectors agriculture and industry, which produce food and clothing respectively, using two factors labor and capital which supplied by household. Consider table (6.5), which is the SAM for our simple model.

Table (6.5) Social Accounting Matrix

	Food	Clothing	Capital	Labor	Household	Total
Food					30	30
Clothing					70	70
Capital	10	40				50
Labor	20	30				50
Household			50	50		100
Total	30	70	50	50	100	

Table (6.5) shows that factors turn over labor and capital income to their owners, the household, the household uses the income to purchase food and clothing from the agriculture and industry sectors (food and clothing), which in turn pay wage and profit to labor and capital. Total labor income of 50 is going to household; total capital income of 50 is also going to household. Total income of household is thus 100, and is used to purchase 30 of food and 70 of clothing. the food producers then take the 30 they have received from the household and pay 20 to labor and 10 to capital. Similarly the clothing producers use the 70 they received from household to pay 30 to labor and 40 to capital.

6.6.1 The Relationship between the SAM and the Model Variables and Equations

There is a strong relationship between the SAM and the variables and equations of the model constructed in the previous section. The payments variables for the simple model are y_s ,t_{fs} , y_f, t_{hf} , y_h and t_{hs} . Table (6.6) shows the arrangement of these variables in the cells or as account totals of the SAM.

Table (6.6) :the payment variables in the SAM

	Food	Clothing	Capital	Labor	Household	Total
Food					t_{fh}	y_f
Clothing					t_{ch}	y_c
Capital	t_{cf}	t_{cc}				y_c
Labor	t_{lf}	t_{lc}				y_l
Household			t_{hc}	t_{hl}		y_h
Total	y_f	y_c	y_c	y_l	y_h	

The quantity variables of the model are q_s. c_{fs}. q_f. q_h. and c_{sh} and table (6.7) shows the arrangement of these variables in the cells or as account totals of the SAM.

Table (6.7): the physical flow variables in the SAM

	Food	Clothing	Capital	Labor	Household	Total
Food					c_{fh}	q_f
Clothing					c_{ch}	q_c
Capital	c_{cf}	c_{cc}				q_c
Labor	c_{lf}	c_{lc}				q_l
Household						q_h
Total	q_f	q_c	q_c	q_l	q_h	

It can be seen from the tables (6.6) and (6.7) some of the payments in table (6.6) do not have a corresponding physical flow in Table (6.7). Note that all prices are price indices that we calibrate to be 1 in the base case. The measurement units for physical flows or quantities are therefore such the physical flows are equal to their value when the price index is one, for example, at base case prices. Table (6.8) is also called (constant-price SAM). It can be used to analyze change in the economy in real terms. However, the price can be associated with the accounts of the SAM as shown below.

Table (6.8): prices and Associated Accounts of The SAM

Accounts	Prices
Food	p_f
Clothing	p_c
Capital	p_c p c
Labor	p_l p l
Household	p_h p h

Next consider the relations between the SAM and the equations constructed in section 6.5 . The simplest equations are those labeled d, in which the payment is defined as being equal to a physical flow times a price. There is exactly one physical flow and one of these equations for each account, and one for each of the non-empty cells in table (6.7). The price is the price of the row, and the payment is the payment in the corresponding cell in table (6.6). an example of a cell equation is Eq.(2d) for the labor row and food column of both table (6.6) and table 3.3 $t_{lf} = p_l \quad c_{lf}$. an example of an account equation is the capital version of Eq. (3d),

$$y_c = p_c \quad q_c$$

The payments versions of the linkage equations are shown in table (6.9). These equations are accounting identities in the rows of the SAM. They simply say that the row total is equal to the sum of the elements in the row. There is one linkage equation for each row of the SAM.

Table (6.9): The Accounting Identities and the Behavioral Equations in the SAM

	Food	Clothing	Capital	Labor	Household	Total
Food					$(5y)$	$(9y)$
Clothing					$(5y)$	$(9y)$
Capital	$(2y)$	$(2y)$				$(7y)$
Labor	$(2y)$	$(2y)$				$(7y)$
Household			$(4y)$	$(4y)$		$(8y)$
Total	$(1y)$	$(1y)$			$(6y)$	

The remaining equations are the behavioral equations. All these equations can be thought of as belonging either to cells or to columns of the SAM.as we said before, one can often choose between a payments version or a quantity version of an equation, but the models are mathematically equivalent: in what follows, therefore, we shall work with the payments version only.

6.7 Model 1

The previous two sections provided the mathematical statement and the conceptual framework for our first model and this section will describe the complete representation of the model. We will run the simple model as a subsystem of the General Algebraic Modeling System, GAMS. Gams supports linear and nonlinear simulation and optimization models written in algebraic form. and has report writing and extensive data manipulation capabilities.

The main components of the GAMS input file for our simple model are:
Account list
Cell Array
Social Accounting Matrix
Parameters
Variables
Equations
Model statement

Solve statement
Experiment information
In the rest of this section, these components will first be discussed one by one; then the complete model representation will be presented.

6.7.1 The Account Set

The first component is the set of accounts. For our model the set is

Food
Clothing
Capital
Labor
Household

The GAMS statement needed to input this set is

```
        SET         u          SAM entry   /FOO,CLO,CAP,LAB,HOH/
                    i(u)       goods        / FOO,CLO/
                    h(u)       factor       /CAP,LAB/;
  Alias  (u ,v) , (i , j), (h , k);
```

Note that:

- Input can be in a mixture of lower case and upper case
- The word SET is a GAMS keyword therefore, must be entered exactly as shown, which it indicates that we are going to declare one or more sets.
- The latter u is an identifier and the modeler chooses it freely.
- The text string SAM is a documentation text that becomes associated with the set u.
- The next five names, FOO, CLO… define the element of the set u. elements of sets and indices in general are called GAMS labels. The modeler can choose labels freely.
- There are several levels of separators in the GAMS language. At the highest level is the semicolon (;), which is used to separate GAMS statements. (the

semicolon is not necessary if the next statement starts on a new line and starts with a GAMS keyword). The second level of separators contains the slash (/). That demarcates a list, such as a list of element in a SET. The third level of separators comprises the comma (,) and ‘end –of-line’ the type of separator is used between elements in a set, and between multiple identifiers in a SET, ACRONYM, PARAMETERS.

- In order to access both rows and columns of the SAM independently, one needs a copy of the set u. this copy is created with the next GAMS statement Alias (u , v) , (i , j) , (h , k); Alias is a GAMS keyword that is followed by a list of identifiers in parenthesis.

6.7.2 The Cell Array

In the previous section the model was essentially defined through the SAM table, and we must therefore enter this table. The SAM is entered as shown below:

```
Table  SAM ( u , v )          social accounting matrix

       FOO   CLO   CAP   LAB   HOH
FOO                            30
CLO                            70
CAP    10    40
LAB    20    30
HOH                50    50
;
```

The word TABLE is a GAMS keyword. The TABLE statement has two functions. It defines a parameter, i.e., a multidimensional array, and it initializes it with numbers read in a tabular form. The name SAM is an identifier. it is not a keyword and any other identifier can be used. The characters in parentheses, (u , v), are the domain of the table . That is, labels defining the rows and the columns of the table must both belong to the set of accounts, u. the use of domain is not mandatory in GAMS; it is highly recommended. however. If the domain is defined, the GAMS system will check the labels and flag the error if the user misspells one of the account labels across the top or along the side of the table. The table are not checked if the domain is not defined or if it is represented by a *.

The input is free format, so the data entries do not have to be in specific columns as long as they are in the field under the column heading. The field is initially the columns occupied by the column heading and it is widened if some of the material extends beyond the right or left edge of the field. The fields of adjacent columns must not grow so much that they start to overlap; if they do, GAMS will flag the error.

6.7.3 Parameter

The word Paramcter is a GAMS keyword. It defines a multi-dimensional array in the same way as table, but it does not initialize the array. The names xpo(i), fo(h), zo(j), and ff(h) are identifiers, and any legal identifier can be used instead.

Xp0(i)	household consumption of the i-th good
F0(h,j)	the h-th factor input by the j-th firm
Z0(j)	output of the j-the good
FC(j)	the fixed cost in the j-th factor
Un(i)	share of fixed costs in capital costs

The statements are used to define the identifiers are
Xpo(i) = SAM(i , “HOH”);
Fo(h,j) = SAM(h,j):
Zo(j) = sum (h, fo(h,j));
Ff(h) =SAM(“HOH”,h);

The remaining parameters are parameter values associated with the functional specifications. Examples of such parameters are the exponents in Cobb-Douglas production functions.

In our example. alpha(i) is a share parameter in utility function. beta (h,j) is a share parameter in production function and b(j) is a scale parameter in prouduction function. And they are defined using these statements:

```
Alpha(i) = Xp0(i) / sum (j,Xp0(j));
Beta(h,j) = F0(h,j) / sum(k,F0(k,j));
b(j) = Z0(j) / prod (h,F0(h,j)**beta(h,j));
```

6.7.4 Variables

The word Variable is a GAMS keyword. The names Xp(i), F(h,j), Z(j), px(i), pz(i)and pf(h) are identifiers. For example, Xp(i) is the household consumption of the i-the good z(j) is the output of the j-th good and px(i) is the demand price of the i-th good, UU is the utility (fictitious). Therefore, in our model there are six variables.

6.7.5 Equations

The word equation is also a GAMS keyword, and usual the model has the same number of variable as equations, the names eqpX(i), eqpZ(i), eqF(h,j), eqpqd(i), eqpf(h) and eqz(i) are identifiers as follows:

eqpX(i)	household demand function
eqpZ(i)	production function
eqF(h,j)	factor demand function
eqpqd(i)	good market clearing condition
eqpf(h)	factor market clearing condition
eqZ(i)	price equation

and they are defined using the these statements

```
eqpX(i)...   Xp(i)  =e= alpha(i) *sum (h,pf(h)*FF(h))/px(i);
eqpZ(j)..    Z(j)  =e= b(j)*prod(h,  F(h,j)**beta (h,j));
eqF(h,j)..   F(h,j)  =e= beta(h,j)*pz(j)*Z(j)/pf(h);
eqpqd(i)..    Xp(i) =e= Z(i);
eqpf(h)..    sum(j,  F(h,j))  =e= FF(h);
eqZ(i)..     px(i)      =e= pz(i);

obj..        UU       =e= prod(i  .x(i) **alpha(i));
```

6.7.6 Model Statement

Next the model is specified by defining its five components: the account list, the cell table, the parameter, the variables, and the equations. This is done with the model statement as follows:

Model Nasia /all/;

Model is a GAMS keyword. The name of the model, which is Nasia, can be any identifier. The list of elements of the model is enclosed between slashes. Any legal identifiers can be used for the name of the elements of the model.

6.7.7 Solve Statement

After the model has been defined it can be solved using the statement

Solve Nasia maximizing UU using nlp;

SOLVE, MAXIMIZING, USING and NLP are GAMS keywords and Nasia is the name of the model. Using NLP is used to indicate the type of model and the solution method.

Appendix 1 Lists the full GAMS syntax and the results of the model experiment of Model 1.

6.8 Model 2 (Government and Taxes)

In this section and the following we will gradually add new components to our small two sector economy, and we will use the same producer with each addition.

Governments play an important role in all economies, so the first expansion of our simple model is the addition of a government sector. This sector has a direct influence on disposable household income (through direct taxes), on price of goods (through indirect taxes), and on overall demand (through its consumption of goods). Therefore, we will look at the government as a collector of direct and in direct taxes, and as a consumer of goods.

6.8.1 The Data SAM

The SAM describing our two sectors two factor economy with a government sector added is shown in table (6.10)

Table (6.10) The SAM for a small economy with a government

	FOO	CLO	CAB	LAB	HOH	GOV	IDT	Total
FOO					20	13		33
CLO					50	22		72
CAP	10	40						50
LAB	20	30						50
HOH			50	50				100
GOV					30		5	35
IDT	3	2						5
Total	33	72	50	50	100	35	5	

The economy still has the same structure, but the numerical values have been changed slightly so the overall SAM is balanced. The payment from household to the government, 30: shows direct taxes paid by household, and it appears as one of the items on which the household spend its income, food and clothing to government, 10 and 20 respectively: these two payments represent the government consumption of goods. The payments from food and clothing to indirect taxes, 3, 2 respectively: these two payments represent indirect taxes on food and clothing, and they are shown as part of the expenditures incurred in bringing the goods to the market.

In order to build a model that reproduces this economy, we will make the following assumptions:

- The household sector pays a fixed percentage of its income indirect taxes, and the remaining disposable income is used for consumption.
- Producers must pay a fixed percentage of their sales revenues as indirect taxes.
- We will assume that the government (like the household sector) spend all its income on goods in fixed value share which we will omit saving and investment at this stage.

6.8.2 The Parameter and Variables

The parameter for the new model is shown below, we saw the household account of the previous model. The government account is of the same type because the government spends all its income on consumption.

The other new account type is tax found in the indirect tax account. It defines the account as an indirect tax account, which means that it can only receive income in the form of indirect taxes; it must pay its income to an institutions account, in our case to the government account.

The modeling of expenditure for the household consumption account, the factor accounts, and the activity accounts is exactly as in our previous model, and the government consumption is modeled in the same way as household consumption.
The only new features are in the indirect tax account and direct tax account.

Xg0(i)	government consumption
Td0	direct tax
Tz0(j)	production tax
tauz(i)	production tax rate

And they are defined using the these statements

```
Td0         = SAM("GOV". "HOH");
TZ0(j)      = SAM("IDT",j);
Xg0(i)      = SAM(i, "GOV");
tauz(i)     = Tz0(j)  /  Z0(j);
```

As we mentioned before, the remaining parameters are parameter values associated with the functional specifications. An example of such parameter is the exponents in Cobb-Douglas production functions.

In this model, we added mu(i) as a government consumption share and taud as a direct tax rate, and they are defined using these statements:

```
mu(i) = Xg0(i) / sum (j,Xg0(j));
taud  = Td0/(sum(h, FF(h)) + sum(j, FC(j));
```

As for the variables, we added four more variables to our model, as follows

Xg(i)	government consumption
Pq(i)	Armington's composite good price
Td	direct tax
Tz(j)	production tax

Therefore, we now have ten variables.

6.8.3 Equations

The equations of household demand function eqpX, production function eqpZ, factor demand function eqF(h,j), good market clearing condition eqpqd(i), factor market clearing condition eqpf(h), and price equation eqZ are exactly as in our previous model, the only new features are in the direct tax revenue function eqTd, production tax revenue function eqTz, and government demand function eqXg.

```
eqTd..          Td     =e= taud*(sum(h, pf(h)*FF(h)) +sum(j, FC(j)));
eqTz..          Tz    =e= tauz(j)*pz(j)*Z(j);
eqXg(i)         Xg(i) =e= mu(i)*(Td + sum (j, Tz(j))/pq(i));
```

6.8.4 Model Statement and Solve Statement

There is nothing new in the model statement and solve statement, they are exactly as in our previous model

Appendix 2 Lists the full GAMS syntax the results of the model experiment of Model 2.

6.9 Model 3 (Intermediate Input)

One common of describing SAMs is to characterize them as Leontief input-output matrices, therefore, we will start by showing a data SAM that includes the new flows, flows of goods into the production sectors and we will make assumption about the mechanisms determining the new flows themselves and their relationships to some old flows.

6.9.1 The Date SAM

The basis for this section is the SAM in table (6.11). The new payments are those in the submatrix where the rows and columns of the food and clothing accounts intersect; some of the other payments have been adjusted so that the overall SAM remains balanced, but the matrix has the same accounts and the same basic feature as the SAM in table (6.10).

Table (6.11) The SAM for a small economy with intermediate input

	FOO	CLO	CAB	LAB	HOH	GOV	IDT	Total
FOO	15	10			20	8		53
CLO	5	20			50	27		102
CAP	10	40						50
LAB	20	30						50
HOH			50	50				100
GOV					30		5	35
IDT	3	2						5
Total	53	102	50	50	100	35	5	

The food sector purchases 15 units from itself to be used as inputs and it purchases 5 units of inputs from the clothing sector. So far we have assumed that each sector produces one good. In practice, however, we always work with bundles of similar goods. Therefore, when building models we assume that each account covers on good only or that the goods within each account are homogenous for the purposes of the model.

6.9.2 Model Assumption and the Model SAM

Before we can build a model we will make the following reasonable assumptions:

- We need to assume that intermediate inputs are bought in the market for final goods and therefore that their price includes taxes, and on the quantity side, we assume that the quantity of intermediate inputs is proportional to the quantity of output.
- The indirect taxes are computed as a percentage of the factory gate value of output, which will in turn reflect the value of all inputs (intermediate, labor and capital)
- We will maintain the assumption that capital and labor can be substituted for each other, and augment it with an assumption that the aggregate factor input must be combined with an assumption that the aggregate factor input must be combined with intermediate inputs infixed proportions, measured in quantity units.

These assumptions have been used to disaggregate the data SAM into the model SAM shown in table (6.11). Most of the table is similar to table (6.10).

6.9.3 The GAMS Implementation of the Model

The GAMS implementation of the model is shown in the appendix to the section.
The definition of the account set is exactly as before, and the first new feature appears in the SAM: we added new payments in the submatrix where the rows and columns of the food and clothing accounts intersect.
We have also added three parameters and made a change on defining Z0(j) (output of the j-th good)as follows :

Y0(j)	composite factor
X0(i)	intermediate input

ax(i, j)	intermediate input requirement coefficient.
ay(j)	composite fact, input requirement coefficient.

And we defined them as following

Y0(j) = sum (h, F0(h,j));

X0(i) = SAM(i, j) :

ax(i, j) = X0(i, j) / Z0(j);

ay(j) = Y0(j) / Z0(j);

Z0(j) = Y0(j) + sum (i, X0(i,j)) + FC(j);

As for the variables and the equations, we added four more variables and three equations as follow:

Variables:

Y(j)	value added
X(I, j)	intermediate input
Py(j)	value added price
Q(i)	Armington's composite good

Equations:

eqpy(j)	composite factor aggregation function
eqX(i, j)	intermediate demand function
eqY(j)	value added demand function

Appendix 3 Lists the full GAMS syntax the results of the model experiment of Model 3.

6.10 Model 4 (Foreign, Saving and Investment)

This section will add two more components to our model, namely foreign trade, savings, import tariff, and investment. The reason both components are added at the same time is that one of the important sources of savings in many countries is foreign savings, which in turn is closely related to the foreign trade account.

The numbers presenting indirect taxes in earlier SAMs must now be reinterpreted. In the previous SAMs, we only had one source of supply and two sources of demand, and. In this SAM, we have two sources of supply, domestic production and imports, and two different types of demand, domestic demand and export demand. Therefore, for model building; we need extra figures that split the tax payments into their components. This is done in the Data SAM in table 6.1 below, where indirect taxes are distributed between two accounts, IDT for taxes on domestic production and TRF for import duties.

6.10.1 The Data SAM

Table (6.12) shows a SAM that includes foreign trade, savings, import tariff, and investment. Foreign trade is presented by the rest of the world account (labeled EXT), import tariff is presented by an account labeled TRF, and savings and investment are represented by one account labeled INV.

Table (6.12) The SAM with foreign trade, import tariff, savings, and investment

	FOO	CLO	CAB	LAB	HOH	GOV	INV	IDT	TRF	EXT	Total
FOO	15	10			20	8	6			8	67
CLO	5	20			45	27	10			5	112
CAP	10	40									50
LAB	20	30									50
HOH			50	50							100
GOV					30			5	3		38
INV					5	3				8	16
IDT	3	2									5
TRF	1	2									3
EXT	13	8									21
Total	67	112	50	50	100	38	16	5	3	21	

The foreign trade cells in the SAM are:

- Food and Clothing to The Rest of the world: these two entries, 13 and 8 respectively, represent payments for goods to the rest of the world, i.e. imports. Imports increase the pool of goods available in the domestic economy.
- The Rest of the world to Food and Clothing: these two entries, 8 and 5 respectively, represent payments from the rest of the world for goods, i.e.

exports. Exports decrease the pool of goods available in the domestic economy.

The savings and investment cells in the SAM are:

- Household and Government to Investment: these two entries 5 and 3 respectively, represent savings by household and government.
- Investment to Food and Clothing: these entries, 6 and 10 respectively, represent investment, and since the numbers show purchases from the food and clothing sectors, they represent investment by sector of origin.

The import tariff cells in the SAM are:

- Food and Clothing to The Rest of the world: these entries 1 and 2 respectively, represent payments from food and clothing for import tariff
- Import tariff to Government: the 3 in the cell represent the payment to the government.

The last new cell is related to both the rest of the world account and the saving account: the 8 in the cell represent foreign savings, i.e. savings by foreign institutions and individuals in our economy. Foreign savings are equal to payments for imports (13+8=21) minus payments for exports (8+5=13). It is also equal to total nominal investment (16) minus domestic savings (5+3=8).

Investment can be measured on a gross or net basis, the difference being the value of depreciation of existing capital stock. Input-output tables and SAMs normally measure gross investment.

6.10.2 Model Assumption and Model SAM

We will make the following assumptions:

- Import supply: this variable is assumed to be elastic, i.e. any amount can be bought at a fixed world price, measured in foreign exchange. The landed price reflects the world price converted at a given exchange rate, plus import duties.

- Import demand: the SAM has no data that describe the use of import in detail. We know for example that total food imports 13 and import duties are 1, so the landed value of imports is 14. But we do not know how these 14 are distributed among household consumption (20), government consumption (8), investment (6), and intermediate inputs (15, 10) respectively. We will therefore, assume that the import share is the same in all components of demand (except in exports, where it is zero).
- Export supply: we will assume that demand from the rest of the world depends on the price of exported goods measured in foreign exchange units.
- Household consumption and savings: we will assume that total disposable income is split between consumption, taxes, and savings in fixed proportions.
- Government consumption and savings: the government is assumed to have an activity plan for period, and the quantity of consumption is therefore fixed, independent of prices. Saving is a residual, namely total income from direct and indirect taxes minus consumption expenditures.
- Investment: total quantity of investment is assumed to be exogenous, and investment by sector of origin is derived from total investment using fixed coefficient model, measured in quantity units.
- Foreign savings: the foreign savings variable is a residual, derived both as the difference between fixed investment and domestic savings, and as the different between imports and exports.

Looking at the accounts in the (6.8). Table, many of them are similar to the ones we had in the previous models. the main difference is in the import tariff. Rest of the world (imports and exports), in addition, savings and investment are included as one new account.

Due to the size of the model, we will refer to the GAMS implementation shown in the appendix at the end of the section.

6.10.3 The GAMS Implementation

The parameters for the model are shown in lines 35-61 of the computer listing. It shows many parameters, all of which are declared prior, the new parameter as follows

Xv0(i)	investment demand
E0(i)	exports
M0(i)	imports
Q0(i)	Armington's composite good
D0(i)	domestic good
Sp0	private saving
Sg0	government saving
Tm0(j)	import tariff
Sf	foreign saving in euro
Pwe(i)	export price in euro
Pwm(i)	import price in euro
Taum(i)	import tariff rate

The parameters are defined in lines 63-91.

The specific parameters are shown in lines 96 – 121, and the new ones are

Lambda(i)	investment demand share
deltam(i)	share parameter in Armington function
deltad(i)	share parameter in Armington function
gamma(i)	scale parameter in Armington function
xid(i)	share parameter in transformation function
xie(i)	share parameter in transformation function
theta(i)	scale parameter in transformation function
ssp	average propensity for private saving
ssg	average propensity for government saving

Also all the parameters above are defined in lines 124 – 146.

The variables for the model are shown in lines 153 – 180, and the new variables are

Xv(i)	investment demand

E(i)	exports
M(i)	imports
D(i)	domestic good
Pe(i)	export price in local currency
Pm(i)	import price in local currency
Pd(i)	the i-th domestic good price
epsilon	exchange rate
Sp	private saving
Sg	government saving
Tm(i)	import tariff

Lines 183 - 261 show the model equations, which they are classified to eight groups, domestic production, government behavior, investment behavior, household consumption, international trade, Armington function, transformation function, and market clearing condition. The new equations are:

- Import tariff revenue function.. Tm(i) =e= taum(i) * Pm(i) * M(i)
- Investment demand function.. Xv(i) =e= lambda(i) * (Sp + Sg + epsilon * Sf) / pq(i)
- Private saving function.. Sp =e= ssp * (sum(h, Pf(h)*FF(h)) + sum(j, FC(j)))
- Government saving function.. Sg =e= ssg * (Td + sum(j, Tz(j)) + sum(j, Tm(j))).
- World export price equation.. Pe(i) =e= epsilon * Pwe(i)
- World import price equation..Pm(i) =e= epsilon * Pwm(i)
- Palance of payments epsilon.. sum (i, Pwe(i) * E(i)) + Sf =e= sum (I, Pwm(i) * M(i)
- Armington function Q(i) =e= gamma(i) * (deltam(i) * M(i)**eta(i) + deltad(i) *D(i) ** eta(i)) ** (1/eta(i))
- Import demand function..M(i) =e= (gamma(i)**eta(i) * deltam(i)*pq(i)/((1+taum(i)) *pm(i))) ** (1/(1-eta(i))) * Q(i)
- Domestic good demand function..D(i) =e= (gama(i) ** eta(i) * deltad(i) *pq(i) /pd(i)) ** (1/(1-eta(i))) * Q(i)

- Transformation function ..Z(i) =e= theta(i) * (xie(i) * E(i) ** phi(i)+xid(i) *D(i) **phi(i))**(1/phi(i))
- Export supply function..E(i) =e=(theta(i) **phi(i)*xie(i)*(1+tauz(i))*pz(i) /pe(i)) ** (1/(1-phi(i)))*Z(i)
- Domestic good supply function.. D(i) =e= (theta(i) ** phi(i) * xid(i) * (1+tauz(i)) *pz(i) / pd(i)) ** (1/ (1-phi(i))) * Z(i)

The Model statement in line 321-322 finalizes the definition of the model.

Appendix 4 Lists the full GAMS syntax the results of the model experiment of Model 4.

6.11 Conclusion

The SAM is potentially a valuable tool for a wide variety of purposes; for the statistician it provides a consistency check for all macro-economic statistics.

The approach proposed in this chapter for the study of combinatorial optimization and geometric programming provides an insightful understanding of the ways in which the structural components of the economy and into the interpretation of marginal cost variables.

Conclusion

The objectives of the most nations of the world, developed as well as devolving, market economies as well as those that are now shifting from a centrally planned system to market economy such as Libya, are full employment of domestic resource, an acceptably low rate of inflation, a sensible rate growth, and a fair distribution of income. The tools to achieve these objectives are fiscal and monetary policies based on significant planning.

In chapter 4 we applied the Box-Jenkins methodology to analyse the Libyan oil sector prices and the usefulness of the methodology was demonstrated on practical time series.

In chapter 5 we have presented an optimisation model for long-term analysis of the power sector. The model is based on the dynamic programming technique. In the model we included the main casual relationships that arise in the long-term investment dynamics of the power system. The dynamic programming model can also serve as a tool for learning and decision support for participates in the planning department and power sector.

The model is well suited for scenario planning. The results from the Libyan case study show that the model is able to capture the long-term dynamics that are likely to occur on multiyear planning of the electricity.

The model simulates the development of the power system in Libya for a 20 year period. We modelled the investment in new plants with a supply and demand curve. The time resolution in the model is one year, using the simplifying assumption that investment decision can only be made at the beginning of each year. New investments in generation result in a change in the supply and demand for electricity.

The level of detail in the model is aggregated. Instead of going into detail on the different parts of the system. We try to focus on the relationships that we see as most important for the long-term development of investment in new power plants. The model is a tool for generating scenarios to analyse what is likely to happen under certain circumstances (e.g. build one power plant, two power plants etc.). The model can be developed as a learning tool and an aid for improved decision making in the power industry.

In chapter 6, we constructed a Social Accounting Matrix for Libya for 1999. The SAM is potentially a valuable tool for a wide variety of purposes; for the statistician it provides a consistency check for all macro-economic statistics.

Appendices

Appendix 1

```
 Set    u      SAM entry    /FOO, CLO, CAP, LAB, HOH/
        i(u)   goods        /FOO, CLO/
        h(u)   factor       /CAP, LAB/;
Alias (u,v), (i,j), (h,k);
* ---------------------------------------------------------------

* Loading data ------------------------------------------------
Table  SAM(u,v)       social accounting matrix
        FOO    CLO    CAP    LAB    HOH
FOO                                  30
CLO                                  70
CAP     10     40
LAB     20     30
HOH                   50     50
;
* ---------------------------------------------------------------

* Loading the initial values -----------------------------------
Parameter     nu(i)        share of fixed costs in capital costs;
nu(i)=0.1;

Parameter     Xp0(i)       household consumption of the i-th good
              F0(h,j)      the h-th factor input by the j-th firm
              Z0(j)        output of the j-th good
              FC(j)        the fixed costs in the j-th firm
              FF(h)        factor endowment of the h-th factor
;

Xp0(i)   =SAM(i,"HOH");
F0(h,j)  =(1-nu(j))*SAM(h,j)$(ord(h) eq 1)
      +SAM(h,j)$(ord(h) ne 1);
FC(j)   =nu(j)*SAM("CAP",j);
Z0(j)   =sum(h, F0(h,j));
FF(h)   =sum(j, F0(h,j));
Display Xp0, F0, Z0, FF;
* Calibration -------------------------------------------------

Parameters     alpha(i)      share parameter in utility function
               beta(h,j)     share parameter in production function
               b(j)          scale parameter in production function
;
alpha(i)=Xp0(i)/sum(j, Xp0(j));
beta(h,j)=F0(h,j)/sum(k, F0(k,j));
b(j)   =Z0(j)/prod(h, F0(h,j)**beta(h,j));
Display alpha, beta, b;
* ---------------------------------------------------------------
```

```
* Defining model system --------------------------------------------
Variable      Xp(i)         household consumption of the i-th good
              F(h,j)        the h-th factor input by the j-th firm
              Z(j)          output of the j-th good
              px(i)         demand price of the i-th good
              pz(j)         supply price of the i-th good
              pf(h)         the h-th factor price

              UU            utility [fictitious]
;

Equation      eqpX(i)       household demand function
              eqpz(i)       production function
              eqF(h,j)      factor demand function
              eqpqd(i)      good market clearing condition
              eqpf(h)       factor market clearing condition
              eqZ(i)        price equation

              obj           utility function [fictitious]
;

eqpX(i)..     Xp(i)   =e= alpha(i)*sum(h, pf(h)*FF(h))/px(i);
eqpz(j)..     Z(j)    =e= b(j)*prod(h, F(h,j)**beta(h,j));
eqF(h,j)..    F(h,j)  =e= beta(h,j)*pz(j)*Z(j)/pf(h);
eqpqd(i)..    Xp(i)   =e= Z(i);
eqpf(h)..     sum(j, F(h,j)) =e= FF(h);
eqZ(i)..      px(i)   =e= pz(i);

obj..         UU      =e= prod(i, Xp(i)**alpha(i));
* ----------------------------------------------------------------

* Initializing variables --------------------------------------------
Xp.l(i) =Xp0(i);
F.l(h,j)=F0(h,j);
Z.l(j)  =Z0(j);
px.l(i) =1;
pz.l(j) =1;
pf.l(h) =1;
* ----------------------------------------------------------------

* Setting lower bounds to avoid division by zero --------------------
Xp.lo(i) =0.001;
F.lo(h,j)=0.001;
Z.lo(j) =0.001;
px.lo(i)=0.001;
pz.lo(j)=0.001;
pf.lo(h)=0.001;
* ----------------------------------------------------------------
pf.fx("LAB")=1;
```

```
* Defining and solving the model ------------------------------------
Model Nasia /all/;
Solve Nasia maximizing UU using nlp;
* -------------------------------------------------------------------
* end of model ------------------------------------------------------
* -------------------------------------------------------------------
```

Experiment Information and results of the model experiment

We are now ready to experiment with the model. Experiments with nlp mostly involve maximizing the objective function.
The detail results of the model experiment can be seen by displaying all after the SOLVE. To start with, we will look at the solution summary. It is shown below

Parameter:

Parameter alpha (share parameter in utility function)

Food 0.300	clothing 0.700

Parameter beta (share parameter in production function)

	Food	Clothing
Capital	0.310	0.545
Labor	0.690	0.455

And the parameter b (scale parameter in production function)

Food	1.858	Clothing	1.992

Equations:

- Household demand function
  In our model, household consume two goods; food and clothing, therefore, the household demand function for food is... eqpX(food)... Xp (food) + (28.5) * px (food) - (13.5) * pf (capital) - (15) * pf (labor) =E= 0.
  (LHS = 1.5, INFES = 1.5)
  household consumption of food + (28.5) * demand price of food- (13.5) * capital factor price – (15)*labor factor price
  and the household demand function for clothing is...
  eqpX (clothing)....Xp(clothing) + (66.5)* px (clothing) – (31.5)* pf (capital) – (35) * pf (labor) =E= 0. (LHS = 3.5, INFES = 3.5)
- Production function
  our model contents two sectors (food and clothing) and two factors (capital nd labor), the production function for the food sector is
  eqpz (food).. – (1) * F(Capital , food) – (1) * F (labor , food) + Z (food) =E=0 (LHS=0) due to intermediate input = 0
  and the production function for the clothing sector is
  eqpz (clothing).. – (1) * (capital, clothing) – (1) * F (labor, clothing) + Z (clothing) =E= 0.
- Factor demand function
  the capital demand input by the food sector is
  eqF (capital , Food) .. F(capital , food) – (0.310) * Z(food) – (9) * pz (food) + (9) * pf (capital) =E= 0

the capital demand input by the clothing sectors is
eqF (capital , clothing).. F (capital , clothing) – (0.545) * Z (clothing) – (36) * pz (clothing) + (36) * pf (capital) =E= 0
the labor demand input by the food sector is
eqF (labor , food).. F (labor , food) – (0.689) * Z (food) – (20) * pz (food) + (20) * pf (labor) =E= 0.

- *Objective function*
  obj.. – (0.5428) * X (food) – (0.5428) * X (clothing) + UU =E=0.

Solution Reports

Now we are interested in examining the result of the optimization, the results are first presented in as stranded mathematical programming output format, which there is a line of printout for each row and column giving the lower limit, level or primal value, upper limit, and marginal or dual value. As follows:

Household demand function

	Lower	Level	Upper	Marginal
Food	0	0	0	0.542
Clothing	0	0	0	0.543

In each row of the table above, the marginal cost number is the change in household demand that results from changing the household demand by one unit.

Production function

	Lower	Level	Upper	Marginal
Food	0	0	0	0.542
Clothing	0	0	0	0.543

Factor demand

	Lower	Level	Upper	Marginal
Capital. Food	0	0	0	0.544
Capital. Clothing	0	0	0	0.544
Labor. Food	0	0	0	0.542
Labor. Clothing	0	0	0	0.542

Good market clearing condition

	Lower	Level	Upper	Marginal
Food	0	0	0	EPS
Clothing	0	0	0	0

EPS is a GAMS keyword means very small but nonzero.

Factor market clearing condition

	Lower	Level	Upper	Marginal
Capital	45.000	45.000	45.000	EPS
Labor	50.000	50.000	50.000	EPS

Price equation

	Lower	Level	Upper	Marginal
Food	0	0	0	-15.448
Clothing	0	0	0	-36.004

Utility function

	Lower	Level	Upper	Marginal
Obj	0	0	0	1.000

Household consumption of the i-th good (variable)

	Lower	Level	Upper	Marginal
Food	0.001	28.523	+INF	0
Clothing	0.001	66.477	+INF	0

+INF is a GAMS keyword; it means plus infinity, a very large positive number.

The h-th factor input by the j-th firm (variable)

	Lower	Level	Upper	Marginal
Capital. Food	0.001	8.822	+INF	0
Capital. Clothing	0.001	36.178	+INF	0
Labor. Food	0.001	19.701	+INF	0
Labor. Clothing	0.001	30.299	+INF	0

Output of the i-th good (variable)

	Lower	Level	Upper	Marginal
Food	0.001	28.523	+INF	0
Clothing	0.001	66.477	+INF	0

Demand price of the I-th good (variable)

	Lower	Level	Upper	Marginal
Food	0.001	1.002	+INF	0
Clothing	0.001	1.003	+INF	0

Supply price of the i-th good (variable)

	Lower	Level	Upper	Marginal
Food	0.001	1.002	+INF	0
Clothing	0.001	1.003	+INF	0

```
The h-th factor price (variable)

              Lower        Level        Upper        Marginal
Capital       0.001        1.005        +INF         0
Labor         1.000        1.000        1.000        EPS

UU utility [fictitious]

              Lower        Level        Upper        Marginal
UU            -INF         51.574       +INF         0
```

Appendix 2

```
Set    u      SAM entry    /FOO, CLO, CAP, LAB, HOH,GOV,IDT/
       i(u)   goods        /FOO, CLO/
       h(u)   factor       /CAP, LAB/;
Alias (u,v), (i,j), (h,k);
* ----------------------------------------------------------------------

* Loading data -----------------------------------------------------------
Table  SAM(u,v)      social accounting matrix
        FOO    CLO    CAP    LAB    HOH    GOV    IDT
FOO                                  20     13
CLO                                  50     22
CAP     10     40
LAB     20     30
HOH                   50     50
GOV                                         30        5
IDT      3      2
;
* ----------------------------------------------------------------------

* Loading the initial values -----------------------------------------
 Parameter      nu(i)        share of fixed costs in capital costs:
nu(i)=0.1;

Parameter     Xp0(i)         household consumption of the i-th good
              F0(h,j)        the h-th factor input by the j-th firm
              Z0(j)          output of the j-th good
              FF(h)          factor endowment of the h-th factor
              Xg0(i)         government consumption
              FC(j)          the fixed costs in the j-th firm
              Td0            direct tax
              Tz0(j)         production tax
              tauz(i)        production tax rate


;
Td0     =SAM("GOV","HOH");
```

```
TZ0(j)  =SAM("IDT",j);


Xp0(i)  =SAM(i,"HOH");
F0(h,j)  =(1-nu(j))*SAM(h,j)$(ord(h) eq 1)
       +SAM(h,j)$(ord(h) ne 1);
FC(j)  =nu(j)*SAM("CAP",j);
Z0(j)  =sum(h, F0(h,j));
tauz(j) =Tz0(j)/Z0(j);
FF(h)  =sum(j, F0(h,j));
Xg0(i)  =SAM(i,"GOV");

Display  F0,Xp0,Z0,Xg0,Td0,Tz0,FF,tauz;
* Calibration ------------------------------------------------------
Parameter      sigma(i)       elasticity of substitution
               psi(i)         elasticity of transformation
               eta(i)         substitution elasticity parameter
               phi(i)         transformation elasticity parameter
;
sigma(i)=2;
psi(i)  =2;
eta(i)  =(sigma(i)-1)/sigma(i);
phi(i)  =(psi(i)+1)/psi(i);

Parameters     alpha(i)       share parameter in utility function
               beta(h,j)      share parameter in production function
               b(j)           scale parameter in production function
               mu(i)          government consumption share
               taud           direct tax rate


;
alpha(i)=Xp0(i)/sum(j, Xp0(j));
beta(h,j)=F0(h,j)/sum(k, F0(k,j));
b(j)   =Z0(j)/prod(h, F0(h,j)**beta(h,j));
mu(i)  =Xg0(i)/sum(j, Xg0(j));
taud   =Td0/(sum(h, FF(h))+sum(j, FC(j)));

Display  alpha,beta,b,mu,taud;
* ----------------------------------------------------------------------


* Defining model system ----------------------------------------------
Variable       Xp(i)          household consumption of the i-th good
               F(h,j)         the h-th factor input by the j-th firm
               Z(j)           output of the j-th good
               px(i)          demand price of the i-th good
               pz(j)          supply price of the i-th good
               pf(h)          the h-th factor price
               Xg(i)          government consumption
               pq(i)          Armington's composite good price
               Td             direct tax
```

```
          Tz(j)        production tax


          UU           utility [fictitious]
;

Equation      eqpX(i)        household demand function
          eqpz(i)       production function
          eqF(h,j)      factor demand function
          eqpqd(i)       good market clearing condition
          eqpf(h)       factor market clearing condition
          eqZ(i)        price equation
           eqTd         direct tax revenue function
          eqTz(j)       production tax revenue function
          eqXg(i)        government demand function


          obj          utility function [fictitious]
;
eqTd..        Td     =e= taud*(sum(h, pf(h)*FF(h)) +sum(j, FC(j)));
eqTz(j)..      Tz(j)  =e= tauz(j)*pz(j)*Z(j);
eqXg(i)..       Xg(i)  =e= mu(i)*(Td +sum(j, Tz(j))/pq(i));
eqpX(i)..       Xp(i)   =e= alpha(i)*sum(h, pf(h)*FF(h))/px(i);
eqpz(j)..      Z(j)   =e= b(j)*prod(h, F(h,j)**beta(h,j));
eqF(h,j)..      F(h,j)  =e= beta(h,j)*pz(j)*Z(j)/pf(h);
eqpqd(i)..       Xp(i)   =e= Z(i);
eqpf(h)..      sum(j, F(h,j)) =e= FF(h);
eqZ(i)..       px(i)  =e= pz(i);

obj..         UU     =e= prod(i, Xp(i)**alpha(i));
* ---------------------------------------------------------------------

* Initializing variables ---------------------------------------------
Xp.l(i) =Xp0(i);
F.l(h,j)=F0(h,j);
Z.l(j)  =Z0(j);
px.l(i) =1;
pz.l(j) =1;
pf.l(h) =1;
pq.l(i) =1;
Td.l    =Td0;
Tz.l(j) =Tz0(j);
Xg.l(i) =Xg0(i);
* ---------------------------------------------------------------------

* Setting lower bounds to avoid division by zero ----------------------
Xp.lo(i) =0.001;
F.lo(h,j)=0.001;
Z.lo(j) =0.001;
px.lo(i)=0.001;
```

```
pz.lo(j)=0.001;
pf.lo(h)=0.001;
pq.lo(i)=0.00001;
Td.lo  =0.00001;
Tz.lo(j)=0.0000;
Xg.lo(i)=0.00001;
* ------------------------------------------------------------------
pf.fx("LAB")=1;

* Defining and solving the model -----------------------------------
Model Nasia /all/;
Solve Nasia maximizing UU using nlp;
* ------------------------------------------------------------------
* end of model -----------------------------------------------------
* ------------------------------------------------------------------
```

Experiment Information and results of the model experiment

The detail results of the model experiment can be seen by displaying all after the SOLVE. To start with, we will look at the solution summary. It is shown below

Parameter:

Parameter tauz (production tax rate)
Food 0.103 Clothing 0.030
Parameter alpha (share parameter in utility function)
Food 0.286 Clothing 0.714
Parameter beta (share parameter in production function)

	Food	Clothing
Capital	0.310	0.545
Labor	0.690	0.455

Parameter b (scale parameter in production function)
Food 1.585 Clothing 1.992
Parameter mu (government consumption share)
Food 0.371 Clothing 0.629

Equations:

- Household demand function
  eqpX(food)... Xp(food) + (27.1428)*px(food) – (12.8571)*pf (capital) – (14.2857)*pf (labor) =E= 0 (LHS = -7.1428, INFES = 7.1428)
  eqpX(clothing)...Xp(clothing) + (67.8571)*px(clothing) – (32.1428) *pf(capital) – (35.7142) *pf(labor) =E= 0 (LHS=-17.8571, INFES=17.8571).
- Production function
  eqpz(food)... -(1) * F (capital, food) – (1)) F (labor, food) + Z (food) =E=0 eqpz9clothing)... - (1) * (capital, clothing) – (1) * F (labor, clothing) + Z (clothing) =E=0

- Factor demand function
  eqF(capital, food).. F(capital, food) – (0.3103) * Z(food) – (9) * pz(food) + (9)*pf (capital) =E=0
  eqF(capital, clothing)… F(capital, clothing) – (0.5454) *Z(clothing) – (36) * pz(clothing) + (36)* pf (capital) =E=0
  eqF(labor, food)…F(labor, food) – (0.6896) *Z(food) – (20) * pz(food) + (20) *pf(labor) =E=0
- Good market clearing condition
  eqpqd(food).. Xp(food) – Z(food) =E=0 (LHS = -9, INFES = 9)
  eqpqd(clothing).. Xp(clothing) – Z(clothing) =E=0 (LHS = -16, INFES = 16)
- Factor market clearing condition
  eqpf(capital).. F(capital, food) +F(capital, clothing) =E=45 (LHS = 45)
  eqpf(labor).. F(labor, food) +F(labor, clothing) =E=50 (LHS = 50)
- Direct tax revenue function
  eqTd.. –13.5 * pf (capital) – 15 * pf (labor) + Td =E= 1.5 (LHS = 1.5)
- Production tax revenue function
  eqTz(food).. – (0.103) * Z (food) – (3) * pz(food) + Tz (food) =E=0
  eqTz(clothing).. – (0.030) * Z (clothing) – (2) * pz(clothing) + Tz (clothing) =E=0.
- Government demand consumption
  eqXg.. Xg(food) + (1.8571) * pq(food) – 0.3714 * Td – (0.3714) * Tz(food) – (0.3714) *Tz(cloting) =E=0
  eqXg.. Xg(clothing) + (3.1428) * pq(clothing) – 0.6285 * Td – (0.6285) * Tz(food) – (0.6285) *Tz(cloting) =E=0

Objective function
obj… - (0.5497) * Xp (food) – (0.5497) * Xp (clothing) + UU =E=0
(LHS = -38.4833, INFES = 38.4833)

Appendix 3

```
Set   u     SAM entry    /FOO, CLO, CAP, LAB, HOH,GOV,IDT/
      i(u)  goods        /FOO, CLO/
      h(u)  factor       /CAP. LAB/:
Alias (u,v). (i,j). (h,k);
* ----------------------------------------------------------------------

* Loading data -------------------------------------------------------
Table  SAM(u,v)      social accounting matrix
          FOO   CLO   CAP   LAB   HOH   GOV   IDT
FOO        15   10                 20   8
CLO         5   20                 50   27
CAP        10   40
LAB        20   30
HOH                    50    50
GOV                               30         5
IDT         3    2
;
* ----------------------------------------------------------------------
```

```
* Loading the initial values ----------------------------------------
Parameter     nu(i)        share of fixed costs in capital costs;
nu(i)=0.1;

Parameter     Y0(j)        composite factor
              F0(h,j)      the h-th factor input by the j-th firm
              FC(j)        the fixed costs in the j-th firm
              X0(i,j)      intermediate input
              Z0(j)        output of the j-th good
              Xp0(i)       household consumption of the i-th good
              Xg0(i)       government consumption
              Td0          direct tax
              Tz0(j)       production tax
              FF(h)        factor endowment of the h-th factor
              tauz(i)      production tax rate

;
Td0     =SAM("GOV","HOH");
Tz0(j)  =SAM("IDT",j);

F0(h,j) =(1-nu(j))*SAM(h,j)$(ord(h) eq 1)
      +SAM(h,j)$(ord(h) ne 1);
FC(j)   =nu(j)*SAM("CAP",j);
Y0(j)   =sum(h, F0(h,j));
X0(i,j) =SAM(i,j);
Z0(j)   =Y0(j) +sum(i, X0(i,j))+FC(j);

tauz(j) =Tz0(j)/Z0(j);

Xp0(i)  =SAM(i,"HOH");
FF(h)   =sum(j, F0(h,j));
Xg0(i)  =SAM(i,"GOV");


Display Y0,F0,X0,Z0,Xp0,Xg0,Td0,Tz0,FF,tauz;
* Calibration ---------------------------------------------------------
Parameter     sigma(i)     elasticity of substitution
              psi(i)       elasticity of transformation
              eta(i)       substitution elasticity parameter
              phi(i)       transformation elasticity parameter
;
sigma(i)=2;
psi(i)  =2;
eta(i)  =(sigma(i)-1)/sigma(i);
phi(i)  =(psi(i)+1)/psi(i);

Parameter     alpha(i)     share parameter in utility func.
              beta(h,j)    share parameter in production func.
              b(j)         scale parameter in production func.
              ax(i,j)      intermediate input requirement coeff.
```

```
          ay(j)       composite fact. input req. coeff.
          mu(i)        government consumption share
          taud        direct tax rate
;

alpha(i)=Xp0(i)/sum(j, Xp0(j));
beta(h,j)=F0(h,j)/sum(k, F0(k,j));
b(j)   =Y0(j)/prod(h, F0(h,j)**beta(h,j));

ax(i,j) =X0(i,j)/Z0(j);
ay(j)  =Y0(j)/Z0(j);
mu(i)  =Xg0(i)/sum(j, Xg0(j));
taud   =Td0/(sum(h, FF(h))+sum(j, FC(j)));

Display alpha,beta,b,ax,ay,mu,taud;
* ------------------------------------------------------------------

* Defining model system -------------------------------------------
Variable     Y(j)        value added
          F(h,j)      the h-th factor input by the j-th firm
          X(i,j)      intermediate input
          Z(j)        output of the j-th good
          Xp(i)        household consumption of the i-th good
          Xg(i)        government consumption
          pf(h)       the h-th factor price
          py(j)       value added price
          pz(j)       supply price of the i-th good
          pq(i)       Armington's composite good price
          Td          direct tax
          Tz(j)       production tax
          Q(i)        Armington's composite good

          UU           utility [fictitious]
;

Equation     eqpy(j)       composite factor aggregation func.
          eqX(i,j)      intermediate demand function
          eqY(j)        value added demand function
          eqF(h,j)      factor demand function
          eqpzs(j)      unit cost function

          eqTd          direct tax revenue function
          eqTz(j)       production tax revenue function
          eqXg(i)       government demand function



          eqXp(i)       household demand function
          eqpqd(i)      market clearing cond. for comp. good
          eqpf(h)       factor market clearing condition
```

```
           obj          utility function [fictitious]
;
*[domestic production] ----
eqpy(j)..      Y(j)    =e= b(j)*prod(h, F(h,j)**beta(h,j));
eqX(i,j)..     X(i,j)  =e= ax(i,j)*Z(j);
eqY(j)..       Y(j)    =e= ay(j)*Z(j);
eqF(h,j)..     F(h,j)  =e= beta(h,j)*py(j)*Y(j)/pf(h);
eqpzs(j)..     pz(j)   =e= ay(j)*py(j) +sum(i, ax(i,j)*pq(i))
                   +FC(j)/Z(j);
*[government behavior] ----
eqTd..         Td      =e= taud*(sum(h, pf(h)*FF(h)) +sum(j, FC(j)));
eqTz(j)..      Tz(j)   =e= tauz(j)*pz(j)*Z(j);
eqXg(i)..      Xg(i)   =e= mu(i)*(Td +sum(j, Tz(j)))/pq(i);

*[household consumption] --
eqXp(i)..      Xp(i)   =e= alpha(i)*(sum(h, pf(h)*FF(h))
                  +sum(j, FC(j)) -Td)/pq(i);

*[market clearing condition]
eqpqd(i)..     Q(i)    =e= Xp(i) +Xg(i) +sum(j, X(i,j));
eqpf(h)..      FF(h)   =e= sum(j, F(h,j));
*[fictitious objective function]
obj..          UU      =e= prod(i, Xp(i)**alpha(i));
* --------------------------------------------------------------------

* Initializing variables ----------------------------------------------
Y.l(j)  =Y0(j);
F.l(h,j)=F0(h,j);
X.l(i,j)=X0(i,j);
Z.l(j)  =Z0(j);
Xp.l(i) =Xp0(i);
Xg.l(i) =Xg0(i);
pf.l(h) =1;
py.l(j) =1;
pz.l(j) =1;
pq.l(i) =1;
Td.l    =Td0;
Tz.l(j) =Tz0(j);

* --------------------------------------------------------------------

* Setting lower bounds to avoid division by zero ----------------------
Y.lo(j) =0.00001;
F.lo(h,j)=0.00000;
X.lo(i,j)=0.00001;
Z.lo(j) =0.00001;
Xp.lo(i)=0.00001;
Xg.lo(i)=0.00001;
pf.lo(h) =0.00001;
```

```
py.lo(j)=0.00001;
pz.lo(j)=0.00001;
pq.lo(i)=0.00001;
Td.lo  =0.00001;
Tz.lo(j)=0.0000;

* ------------------------------------------------------------------
* numeraire ---
pf.fx("LAB")=1;
* ------------------------------------------------------------------
* Defining and solving the model ------------------------------------
Model nasia /all/;
Solve nasia maximizing UU using nlp;
* ------------------------------------------------------------------
* end of model ------------------------------------------------------
* ------------------------------------
```

Experiment Information and results of the model experiment

The detail results of the model experiment can be seen by displaying all after the SOLVE. To start with, we will look at the solution summary. It is shown below

Parameter:
Parameter tauz (production tax rate)
Food 0.060 Clothing 0.020
Parameter alpha (share parameter in utility function)
Food 0.286 Clothing 0.714
Parameter beta (share parameter in production function)

	Food	Clothing
Food	0.310	0.545
Clothing	0.690	0.455

Parameter b (scale parameter in production function)
Food 1.858 Clothing 1.992
Parameter ax (intermediate input requirement coefficient)

	Food	Clothing
Food	0.300	0.100
Clothing	0.100	0.200

Parameter ay (composite fact. input requirement coefficient)
Food 0.580 Clothing 0.660
Parameter mu government consumption
Food 0.229 Clothing 0.771
Parameter taud = 0.300 direct tax rate

Equations:

- Intermediate demand function
  eqX(food, food).. X(food, food) – 0.3*Z(food) =E=0
  eqX(food, clothing)... X(food, clothing) – 0.1*Z(clothing) =E=0

eqX(clothing, food).. X(clothing, food) – 0.1*Z(food) =E=0
eqX(clothing, clothing).. X(clothing, clothing) – 0.2*Z(clothing) =E=0

- Value added demand function
  eqY(food).. Y(food) – 0.58*Z(food) =E=0
  eqY(clothing).. Y(clothing) – 0.66*Z(clothing) =E=0
- Factor demand function
  eqF(capital, food).. – (0.310)*Y(food) + F(capital, food) + (9)*pf(capital) – (9)*py(food) =E=0
  eqF(capital, clothing).. – (0.545)*Y(clothing) + F(capital, clothing) + (36)*pf(capital) – (9)*py(clothing) =E=0
  eqF(labor, food).. – (0.689)*Y(food) + F(laborl, food) + (20)*pf(capital) – (20)*py(food) =E=0
- Unit cost function
  eqpzs(food)...(0.0004)*Z(food) – 0.58*py(food) + pz(food) – 0.3*pq(food) – 0.1*pq(clothing) =E=0
  eqpzs(clothing)...(0.0004)*Z(clothing) – 0.66*py(clothing) + pz(clothing) – 0.1*pq(food) – 0.2*pq(clothing) =E=0
- Direct tax revenue function eqTd... - 13.5*pf(capital) – 15*pf(labor) + Td =E= 1.5
- Production tax revenue function
  eqTz(food)... - (0.06)*Z(food) – (3)*pz(food) + Tz(food) =E=0
  eqTz(clothing)... - (0.02)*Z(clothing) – (2)*pz(clothing) + Tz(clothing) =E=0
- Government demand function
  eqXg(food)... Xg(food) + (8)*pq(food) – (0.228) *Td – (0.228) * Tz(food) – (0.228) * Tz(clothing) =E=0
  eqXg(clothing)... Xg(clothing) + (27)*pq(clothing) – (0.771) *Td – (0.771) * Tz(food) – (0.228) * Tz(clothing) =E=0
- Household demand function
  eqXp(food)... Xp(food) – (12.857)*pf(capital) – (14.285)*pf(labor) + (20)*pq(food) + (0.285)*Td =E=0
  eqXp(clothing)... Xp(clothing) – (32.142)*pf(capital) – (35.714)*pf(labor) + (50)*pq(clothing) + (0.714)*Td =E=0
- Market clearing condition, for good
  eqpqd(food).. – X(food. food) – X(food. clothing) – Xp(food) – Xg(food) + Q(food) =E=0
  eqpqd(clothing).. – X(clothing, food) – X(clothing, clothing) – Xp(clothing) – Xg(clothing) + Q(clothing) =E=0
- Factor market clearing condition
  eqpf(capital)... - F(capital, food) – F(capital, clothing) =E= -45
  eqpf(labor)... - F(labor, food) – F(labor, clothing) =E= -50

Utility function
obj... - (0.549) * Xp(food) – (0.549) * Xp(clothing) + UU =E=0

Appendix 4

```
  Set   u    SAM entry   /FOO, CLO, CAP, LAB, HOH,GOV,IDT,
                         INV, TRF, EXT/
    i(u)  goods          /FOO, CLO/
    h(u)  factor         /CAP, LAB/;
Alias (u,v), (i,j), (h,k);
* ----------------------------------------------------------------

* Loading data -----------------------------------------------------
Table  SAM(u,v)    social accounting matrix
       FOO   CLO   CAP   LAB   HOH   GOV   INV   IDT
 FOO    15    10                20     8     6
 CLO     5    20                45     7    10
 CAP    10    40
 LAB    20    30
 HOH                50    50
 GOV                            3 0                5
 INV                             5     3
 IDT    3      2
 TRF    1      2
 EXT    13     8
+
             TRF   EXT
 FOO                8
 CLO                5
 CAP
 LAB
 HOH
 GOV          3
 INV                8
 IDT
 TRF
 EXT
;
* ----------------------------------------------------------------
Parameter    nu(i)      share of fixed costs in capital costs;
nu(i)=0.1;

Parameter    Y0(j)      composite factor
             F0(h,j)    the h-th factor input by the j-th firm
             FC(j)      the fixed costs in the j-th firm
             X0(i,j)    intermediate input
             Z0(j)      output of the j-th good
             Xp0(i)     household consumption of the i-th good
             Xg0(i)     government consumption
             Xv0(i)     investment demand
             E0(i)      exports
             M0(i)      imports
             Q0(i)      Armington's composite good
```

```
           D0(i)       domestic good
           Sp0         private saving
           Sg0         government saving
           Td0         direct tax
           Tz0(j)      production tax
           Tm0(j)      import tariff

           FF(h)       factor endowment of the h-th factor
           Sf          foreign saving in US dollars
           pWe(i)      export price in US dollars
           pWm(i)      import price in US dollars
           tauz(i)     production tax rate
           taum(i)     import tariff rate
;
Td0    =SAM("GOV","HOH");
Tz0(j) =SAM("IDT",j);
Tm0(j) =SAM("TRF",J);

F0(h,j) =(1-nu(j))*SAM(h,j)$(ord(h) eq 1)
      +SAM(h,j)$(ord(h) ne 1);
FC(j)  =nu(j)*SAM("CAP",j);
Y0(j)  =sum(h, F0(h,j));
X0(i,j) =SAM(i,j);
Z0(j)  =Y0(j) +sum(i, X0(i,j))+FC(j);
M0(i)  =SAM("EXT",i);

tauz(j) =Tz0(j)/Z0(j);
taum(j) =Tm0(j)/M0(j);

Xp0(i) =SAM(i,"HOH");
FF(h)  =sum(j, F0(h,j));

Xg0(i) =SAM(i,"GOV");
Xv0(i) =SAM(i,"INV");
E0(i)  =SAM(i,"EXT");
Q0(i)  =(Xp0(i)+Xg0(i)+Xv0(i)+sum(j, X0(i,j)));
D0(i)  =(1+tauz(i))*Z0(i)-E0(i);
Sp0    =SAM("INV","HOH");
Sg0    =SAM("INV","GOV");
Sf     =SAM("INV","EXT");

pWe(i) =1;
pWm(i) =1;

Display Y0,F0,X0,Z0,Xp0,Xg0,Xv0,E0,M0,Q0,D0,Sp0,Sg0,Td0,Tz0,Tm0,FF,Sf,
      tauz,taum;
* Calibration --------------------------------------------------------
Parameter    sigma(i)     elasticity of substitution
             psi(i)       elasticity of transformation
```

```
           eta(i)       substitution elasticity parameter
           phi(i)       transformation elasticity parameter
;
sigma(i)=2;
psi(i) =2;
eta(i) =(sigma(i)-1)/sigma(i);
phi(i) =(psi(i)+1)/psi(i);

Parameter     alpha(i)      share parameter in utility func.
              beta(h,j)     share parameter in production func.
              b(j)          scale parameter in production func.
              ax(i,j)       intermediate input requirement coeff.
              ay(j)         composite fact. input req. coeff.
              mu(i)         government consumption share
              lambda(i)     investment demand share
              deltam(i)     share parameter in Armington func.
              deltad(i)     share parameter in Armington func.
              gamma(i)      scale parameter in Armington func.
              xid(i)        share parameter in transformation func.
              xie(i)        share parameter in transformation func.
              theta(i)      scale parameter in transformation func.
              ssp           average propensity for private saving
              ssg           average propensity for gov. saving
              taud          direct tax rate
;

alpha(i)=Xp0(i)/sum(j, Xp0(j));
beta(h,j)=F0(h,j)/sum(k, F0(k,j));
b(j)   =Y0(j)/prod(h, F0(h,j)**beta(h,j));

ax(i,j) =X0(i,j)/Z0(j);
ay(j)  =Y0(j)/Z0(j);
mu(i)  =Xg0(i)/sum(j, Xg0(j));
lambda(i)=Xv0(i)/(Sp0+Sg0+Sf);

deltam(i)=(1+taum(i))*M0(i)**(1-eta(i))
      /((1+taum(i))*M0(i)**(1-eta(i)) +D0(i)**(1-eta(i)));
deltad(i)=D0(i)**(1-eta(i))
      /((1+taum(i))*M0(i)**(1-eta(i)) +D0(i)**(1-eta(i)));
gamma(i)=Q0(i)/(deltam(i)*M0(i)**eta(i)+deltad(i)*D0(i)**eta(i))
      **(1/eta(i));

xie(i)=E0(i)**(1-phi(i))/(E0(i)**(1-phi(i))+D0(i)**(1-phi(i)));
xid(i)=D0(i)**(1-phi(i))/(E0(i)**(1-phi(i))+D0(i)**(1-phi(i)));
theta(i)=Z0(i)/(xie(i)*E0(i)**phi(i)+xid(i)*D0(i)**phi(i))**(1/phi(i));

ssp    =Sp0/(sum(h. FF(h))+sum(j, FC(j)));
ssg    =Sg0/(Td0+sum(j, Tz0(j))+sum(j, Tm0(j)));
taud    =Td0/(sum(h, FF(h))+sum(j. FC(j)));

```

```
Display alpha,beta,b,ax,ay,mu,lambda,deltam,deltad,gamma,xie,
     xid,theta,ssp,ssg,taud;
* ------------------------------------------------------------------

* Defining model system ---------------------------------------------
Variable       Y(j)         value added
               F(h,j)       the h-th factor input by the j-th firm
               X(i,j)       intermediate input
               Z(j)         output of the j-th good
               Xp(i)        household consumption of the i-th good
               Xg(i)        government consumption
               Xv(i)        investment demand
               E(i)         exports
               M(i)         imports
               Q(i)         Armington's composite good
               D(i)         domestic good

               pf(h)        the h-th factor price
               py(j)        value added price
               pz(j)        supply price of the i-th good
               pq(i)        Armington's composite good price
               pe(i)        export price in local currency
               pm(i)        import price in local currency
               pd(i)        the i-th domestic good price
               epsilon      exchange rate

               Sp           private saving
               Sg           government saving
               Td           direct tax
               Tz(j)        production tax
               Tm(i)        import tariff

               UU           utility [fictitious]
;

Equation       eqpy(j)      composite factor aggregation func.
               eqX(i,j)     intermediate demand function
               eqY(j)       value added demand function
               eqF(h,j)     factor demand function
               eqpzs(j)     unit cost function

               eqTd         direct tax revenue function
               eqTz(j)      production tax revenue function
               eqTm(i)      import tariff revenue function
               eqXg(i)      government demand function

               eqXv(i)      investment demand function
               eqSp         private saving function
               eqSg         government saving function

```

```
          eqXp(i)       household demand function

          eqpe(i)       world export price equation
          eqpm(i)       world import price equation
          eqepsilon     balance of payments

          eqpqs(i)      Armington function
          eqM(i)        import demand function
          eqD(i)        domestic good demand function

          eqpzd(i)      transformation function
          eqDs(i)       domestic good supply function
          eqE(i)        export supply function

          eqpqd(i)      market clearing cond. for comp. good
          eqpf(h)       factor market clearing condition

          obj           utility function [fictitious]
;
*[domestic production] ----
eqpy(j)..      Y(j)   =e= b(j)*prod(h, F(h,j)**beta(h,j));
eqX(i,j)..     X(i,j)  =e= ax(i,j)*Z(j);
eqY(j)..       Y(j)   =e= ay(j)*Z(j);
eqF(h,j)..     F(h,j)  =e= beta(h,j)*py(j)*Y(j)/pf(h);
eqpzs(j)..     pz(j)   =e= ay(j)*py(j) +sum(i, ax(i,j)*pq(i))
                    +FC(j)/Z(j);
*[government behavior] ----
eqTd..         Td      =e= taud*(sum(h, pf(h)*FF(h)) +sum(j, FC(j)));
eqTz(j)..      Tz(j)   =e= tauz(j)*pz(j)*Z(j);
eqTm(i)..      Tm(i)   =e= taum(i)*pm(i)*M(i);
eqXg(i)..      Xg(i)   =e= mu(i)*(Td +sum(j, Tz(j)) +sum(j, Tm(j))
                    -Sg)/pq(i);
*[investment behavior] ----
eqXv(i)..      Xv(i)   =e= lambda(i)*(Sp +Sg +epsilon*Sf)/pq(i);
*[savings] ----------------
eqSp..         Sp      =e= ssp*(sum(h, pf(h)*FF(h)) +sum(j, FC(j)));
eqSg..         Sg      =e= ssg*(Td +sum(j, Tz(j))+sum(j, Tm(j)));
*[household consumption] --
eqXp(i)..      Xp(i)   =e= alpha(i)*(sum(h, pf(h)*FF(h))
                    +sum(j, FC(j)) -Sp -Td)/pq(i);
*[international trade] ----
eqpe(i)..      pe(i)   =e= epsilon*pWe(i);
eqpm(i)..      pm(i)   =e= epsilon*pWm(i);
eqepsilon..    sum(i, pWe(i)*E(i)) +Sf
                   =e= sum(i, pWm(i)*M(i));
*[Armington function] -----
eqpqs(i)..     Q(i)    =e= gamma(i)*(deltam(i)*M(i)**eta(i)+deltad(i)
                    *D(i)**eta(i))**(1/eta(i));
eqM(i)..       M(i)    =e= (gamma(i)**eta(i)*deltam(i)*pq(i)
                   /((1+taum(i))*pm(i)))**(1/(1-eta(i)))*Q(i);
```

```
eqD(i)..      D(i)   =e= (gamma(i)**eta(i)*deltad(i)*pq(i)/pd(i))
                         **(1/(1-eta(i)))*Q(i);
*[transformation function] -----
eqpzd(i)..    Z(i)   =e= theta(i)*(xie(i)*E(i)**phi(i)+xid(i)
                         *D(i)**phi(i))**(1/phi(i));
eqE(i)..      E(i)   =e= (theta(i)**phi(i)*xie(i)*(1+tauz(i))*pz(i)
                         /pe(i))**(1/(1-phi(i)))*Z(i);
eqDs(i)..     D(i)   =e= (theta(i)**phi(i)*xid(i)*(1+tauz(i))*pz(i)
                         /pd(i))**(1/(1-phi(i)))*Z(i);
*[market clearing condition]
eqpqd(i)..    Q(i)   =e= Xp(i) +Xg(i) +Xv(i) +sum(j, X(i,j));
eqpf(h)..     FF(h)  =e= sum(j, F(h,j));
*[fictitious objective function]
obj..         UU     =e= prod(i, Xp(i)**alpha(i));
* -------------------------------------------------------------------

* Initializing variables ---------------------------------------------
Y.l(j)  =Y0(j);
F.l(h,j)=F0(h,j);
X.l(i,j)=X0(i,j);
Z.l(j)  =Z0(j);
Xp.l(i) =Xp0(i);
Xg.l(i) =Xg0(i);
Xv.l(i) =Xv0(i);
E.l(i)  =E0(i);
M.l(i)  =M0(i);
Q.l(i)  =Q0(i);
D.l(i)  =D0(i);
pf.l(h) =1;
py.l(j) =1;
pz.l(j) =1;
pq.l(i) =1;
pe.l(i) =1;
pm.l(i) =1;
pd.l(i) =1;
epsilon.l=1;
Sp.l    =Sp0;
Sg.l    =Sg0;
Td.l    =Td0;
Tz.l(j) =Tz0(j);
Tm.l(i) =Tm0(i);
* -------------------------------------------------------------------

* Setting lower bounds to avoid division by zero ----------------------
Y.lo(j) =0.00001;
F.lo(h,j)=0.00000;
X.lo(i,j)=0.00001;
Z.lo(j) =0.00001;
Xp.lo(i)=0.00001;
Xg.lo(i)=0.00001;
```

```
Xv.lo(i)=0.00001;
E.lo(i) =0.00001;
M.lo(i) =0.00001;
Q.lo(i) =0.00001;
D.lo(i) =0.00001;
pf.lo(h) =0.00001;
py.lo(j)=0.00001;
pz.lo(j)=0.00001;
pq.lo(i)=0.00001;
pe.lo(i)=0.00001;
pm.lo(i)=0.00001;
pd.lo(i)=0.00001;
epsilon.lo=0.00001;
Sp.lo  =0.00001;
Sg.lo  =0.00001;
Td.lo  =0.00001;
Tz.lo(j)=0.0000;
Tm.lo(i)=0.0000;
* -----------------------------------------------------------------
* numeraire ---
pf.fx("LAB")=1;
* -----------------------------------------------------------------
* Defining and solving the model -----------------------------------
Model nasia /all/;
Solve nasia maximizing UU using nlp;
```

Experiments and Results

It can be seen from the table 7.2.detail results of the model, many of the parameters are exactly as the ones we had in previous model, tauz (production tax rate), beta (share parameter in production function), b (scale parameter in production function), ax (intermediate input requirement coefficient), ay (composite fact, Input coefficient), and, mu (government consumption share). In addition, we have these new parameters

Parameter	Food	Clothing
Production tax rate (tauz)	0.060	0.020
Scale parameter in production function (b)	1.858	1.992
Composite , input coefficient (ay)	0.580	0.660
Government consumption share (mu)	0.229	0.771
Import tariff rate (taum)	0.077	0.250
Share parameter in utility function (alpha)	0.308	0.692
Investment demand share (lambda)	0.375	0.625
Share parameter in Armington function (deltam)	0.367	0.264
Share parameter in Armington function (deltad)	0.633	0.736
Scale parameter in Armington function (gamma)	1.901	1.674
Share parameter in transformation function (xie)	0.703	0.815
Share parameter in transformation function (xid)	0.297	0.185
Scale parameter in transformation function (theta)	2.240	3.070

Table 7.2. Detail results of the model

Share parameter in production function (beta):

	Food	Clothing
Food	0.310	0.545
Clothing	0.690	0.455

Parameter ax intermediate input requirement coefficient

	Food	Clothing
Food	0.300	0.100
Clothing	0.100	0.200

Equations:

- Composite factor aggregation function eqpy
  eqpy(food).. Y(food) – (1) * F(capital, food) – (1) * F(labor, food) =E=0
  eqpy(clothing).. Y(clothing) – (1) * F (capital, clothing) – (1) * F (labor, clothing) =E=
- Intermediate demand function eqX
  eqX(food, food)... X(food, food) – 0.3 * Z(food) =E=0
  eqX(food, clothing)... X(food, clothing) – 0.1 * Z(clothing) =E=0
  eqX(clothing, food)... X(cloting, food) – 0.1 * Z(food) =E=0
  eqX(clothing, clothing)... X(clothing, clothing) – 0.2 * Z(clothing =E=0
- Value added demand function eqY
  eqY(food).. Y(food) – 0.58 * Z(food) =E=0
  eqY(clothing).. Y(clothing) – 0.66 * Z(clothing) =E=0
- Factor demand function eqF
  eqF(capital, food).. – (0.310) * Y(food) + F (capital, food) + (9) * pf (capital) – (9) * py (food) =E=0
  eqF(capital, clothing).. – (0.545) * Y(clothing) + F (capital, clothing) + (36) * pf (capital) – (36) * py (clothing) =E=0
  eqF(labor, food).. – (0.689) * Y(food) + F (labor, food) + (20) * pf (labor) – (20) * py (food) =E=0
  eqF(labor, clothing).. – (0.455) * Y(clothing) + F (labor, clothing) + (30) * pf (labor) – (30) * py (clothing) =E=0
- Unit cost function eqpzs
  eqpzs(food).. (0.0004) * Z(food) – 0.58 * py(food) + pz(food) – 0.3 * pq(food) – 0.1 * pq(clothing) =E=0
  eqpzs(clothing).. (0.0004) * Z(clothing) – 0.66 * py(clothing) + pz(clothing) – 0.1 * pq(food) – 0.1 * pq(clothing) =E=0
- Direct tax revenue function eqTd
  eqTd.. – 13.5 * pf(capital) – 15 * pf(labor) + Td =E= 1.5
- Production tax revenue function eqTz
  eqTz(food).. – (0.06) * Z(food) – (3) * pz(food) + Tz(food) =E=0
  eqTz(clothing).. – (0.02) * Z(clothing) – (2) * pz(clothing) + Tz(clothing) =E=0
- Import tariff revenue function eqTm
  eqTm(food).. – (0.0769) * M(food) – (1) * pm(food) + Tm(food) =E=0

eqTm(clothing).. – (0.25) * M(clothing) – (1) * pm(clothing) + Tm(clothing) =E=0

- Government demand function eqXg
  eqXg(food).. Xg(food) + (8) * pq(food) + (0.2285) * Sg – (0.2285) * Td – (0.2285) * Tz(food) – (0.2285) * Tz(clothing) – (0.2285) * Tm(food) – (0.2285) * Tm(clothing) =E=0
  eqXg(clothing).. Xg(clothing) + (27) * pq(clothing) + (0.7714) * Sg – (0.7714) * Td – (0.7714) * Tz(food) – (0.7714) * Tz(clothing) – (0.7714) * Tm(food) – (0.7714) * Tm(clothing) =E=0
- Investment demand function eqXv
  eqXv(food).. Xv(food) + (6) * pq(food) – (3) * epsilon – (0.375) * Sp – (0.375) * Sg =E=0
  eqXv(clothing).. Xv(clothing) + (10) * pq(clothing) – (5) * epsilon – (0.625) * Sp – (0.625) * Sg =E=0
- Private saving function eqSp
  eqSp.. – 2.25 * pf(capital) – 2.5 * pf(labor) + Sp =E= 0.25
- Government saving function eqSg
  eqSg.. Sg – 0.0789 * Td – 0.0789 * Tz(food) – 0.0789 * Tz(clothing) – 0.0789 * Tm(food) – 0.0789 * Tm(clothing) =E=0
- Household demand function eqXp
  eqXp(food)..Xp(food) – (13.846) * pf(capital) – (15.3846) * pf(labor) + (20) * pq(food) + (0.3076) * Sp + (0.3076) * Td =E=0
  eqXp(clothing)..Xp(clothing) – (31.1538) * pf(capital) – (34.6153) * pf(labor) + (45) * pq(clothing) + (0.6923) * Sp + (0.6923) * Td =E=0
- World export price eqpe
  eqpe(food).. pe(food) – epsilon =E=0
  eqpe(clothing).. pe(clothing) – epsilon =E=0
- World import price equation eqpm
  eqpm(food).. pm(food) – epsilon =E=0
  eqpm(clothing).. pm(clothing) – epsilon =E=0
- Balance of payments eqepsilon eqepsilon.. E(food) + E(clothing) – M(food) – M(clothing) =E=-8
- Armington function eqpqs
  eqpqs(food).. – (1.0769) * M(food) + Q(food) – (1) * D(food) =E=0
  eqpqs(clothing).. – (1.25) * M(clothing) + Q(clothing) – (1) * D(clothing) =E=0
- Import demand function eqM
  eqM(food).. M(food) – (0.2203) * Q(food) – (26) * pq(food) + (26) * pm(food) =E=0
  eqM(clothing).. M(clothing) – (0.0747) * Q(clothing) – (16) * pq(clothing) + (16) * pm(clothing) =E=0
- Domestic good demand function eqD
  eqD(food).. –(0.7627) * Q(food) + D(food) – (90) * pq(food) + (90) * pd(food) =E=0
  eqD(clothing).. –(0.9065) * Q(clothing) + D(clothing) – (194) * pq(clothing) + (194) * pd(clothing) =E=0
- Transformation function eqpzd
  eqpzd(food).. Z(food) – (0.9433) * E(food) – (0.9433) * D(food) =E=0

eqpzd(clothing).. Z(clothing) – (0.9803) * E(clothing) – (0.9803) * D(clothing) =E=0

- Domestic good supply function eqDs
  eqDs(food).. – (0.899) * Z(food) + D(food) + (89.999) * pz(food) – (89.999) * pd(food) =E=0
  eqDs(clothing).. – (0.97) * Z(clothing) + D(clothing) + (194) * pz(clothing) – (194) * pd(clothing) =E=0
- Export supply function eqE
  eqE(food).. – (0.16) * Z(food) + E(food) + (16) * pz(food) – (16) * pe(food) =E=0 eqE(clothing).. – (0.05) * Z(clothing) + E(clothing) + (10) * pz(clothing) – (10) * pe(clothing) =E=0
- Market clearing condition, for comp, good eqpqd
  eqpqd(food).. – X(food, food) – X(food, clothing) – Xp(food) – Xg(food) – Xv(food) + Q(food) =E=0
  eqpqd(clothing).. – X(clothing, food) – X(clothing, clothing) – Xp(clothing) – Xg(clothing) – Xv(clothing) + Q(clothing) =E=0
- Factor market clearing condition eqpf
  eqpf(capital).. – F(capital, food) – F(capital, clothing) =E= -45
  eqpf(labor).. – F(labor, food) – F(labor, clothing) =E= -50

Utility function obj obj.. – (0.5394) * Xp(food) – (0.5394) * Xp(clothing) + UU =E=0

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