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EXPLORATION OF OPTIMAL STRATEGIES FOR THE DEVELOPMENT OF AN OIL-BASED ECONOMY: THE CASE OF SAUDI ARABIA

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Exploration of optimal strategies for the development of an oil-based economy: The case of Saudi Arabia

by

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DEDICATION

To the greatest human being

in my life

to my mother with love

I. INTRODUCTION

This study is concerned with development planning in the oil-based economy of Saudi Arabia. The oil-based economies of the Middle East share common characteristics. They have two distinctive sectors: the oil sector and the nonoil sector. They depend on the production and exportation of oil as the main source of revenue and foreign exchange. There is a great dependence on oil on those economies and oil by its nature is a nonrenewable resource which is going to be depleted. Moreover, any event that would adversely affect the price or production of oil could undermine the efforts of economic development in these countries. The nonoil sector in the oil-based economies of the Middle East is in a state of underdevelopment which makes any effort designed to reduce the dependence on oil concentrated on developing the nonoil sector and diversifying the structure of the economy. Like most of the developing countries, the oil-based economies have engaged in development planning. One characteristic which makes those countries different than other less developed countries is the availability of capital for investment which comes directly from oil revenue and frees those countries from the need to attract foreign capital. The oil in those oil exporting countries is publicly owned which makes the governments play a very important role in the process of economic development through the practice of economic development planning. With the special position of the oil-based economies of the Middle East, long-term prospective planning will be of a substantial help in giving indications as to how fast the oil resource should be exhausted and how the oil revenue should be spent in order to achieve the development goals of those countries.

Saudi Arabia is the largest producer and has the largest oil reserves in the Middle East. Its dependence on oil is very clear from the high share of the oil sector in the Gross Domestic Product (GDP). Besides representing more than 60% of the GDP in 1982, the oil sector provided almost all the country's foreign exchange. Saudi Arabia is a capital-surplus country and, accordingly, has a high degree of financial independence. While the country's economy during the 1970s, which was a period of high oil production and high oil revenues, was considered one of the fastest growing economies in the world, its growth was limited by many factors. The most important of which are shortages of labor and a limited absorptive capacity. To satisfy the growing demand for both skilled and unskilled laborers, the country increased its dependence on non-Saudi workers. Realizing that the economy of Saudi Arabia is dependent on oil which is an exhaustible resource, the main question facing the country is how to use the flow of oil income to create a nonoil sector capable of generating a flow of nonoil income before the oil reserve is depleted.

To take advantage of the massive resources which resulted from the increased prices of oil during the 1970s, development planning was initiated by the Saudi government and development plans have been prepared. Because the oil is the major source of income and since it is a nonrenewable resource, the national utilization of this resource for the ultimate goal of creating a self-sustained economy which can replace this dependence on oil in the future becomes eminent and development planning is considered the best way to do that.

A. Objective of the Study

Realizing the importance of development planning and its role in coordinating economic decision making over the long-run in order to direct and accelerate a country's development and considering the special case of the oil-based economy of Saudi Arabia, this study's main objective is to explore optimal strategies for the development of the Saudi economy. That will be done through the development of a two-sector planning model for the Saudi Arabian economy. The model is going to be an optimal model which when solved will give the optimal time path of the major economic variables. The model is a long-run optimal planning model using the technique of dynamic linear programming. The development of such a planning model for the Saudi economy will provide a helpful tool to examine different possible strategies for the economic development of Saudi Arabia. The structure of the model will be the same as the formal structure of a linear programming model with its components of an objective function and a set of constraints. The constraints will be specified through a two-sector macroeconomic model which specifies the variables based on the country's system of national income accounts. The objective function reflects the main goal of the development planning of Saudi Arabia, which emphasizes the development of the nonoil sector.

B. Organization of the Study

This study is divided into three main parts. The first part is a review of economic planning models in general where the key elements of the planning process, particularly the objective, and the tools used in developing a development plan in the less developed economies will be addressed. A survey of the major planning models will be provided which includes macroeconomic models, input-output models, and the linear programming models. Since the model which will be developed in this study is a linear programming model, special attention is given to the linear programming models and their applications in development planning. A review of development planning in oil-based economies is given in this part of the study which includes a discussion of the major characteristics of the oil-based economies and a review of some empirical studies dealing with the subject of development planning in some oil-based economies.

Because the model will be developed for the Saudi economy, it is important to have some idea about the country and its economy. This will be given in the second part of the study, which will provide a profile of the Saudi Arabian economy. It will give an idea about the structure and characteristics of Saudi economy with its distinctive sectors: the oil sector and the nonoil sector. This review of the Saudi economy will provide a background for developing the macroeconomic model and explain some economic relationships which will be quantified while developing our planning model.

In the last part of this study, the empirical model will be developed that includes the development of the objective function and a macroeconomic model which will determine the different relationships between different macroeconomic variables. The estimation of different parameters and coefficients of the model will be given with some exogenous variables as the data needed to run the model and provide an optimal solution. The numerical results of the different variables of the model will be given at the end of this part where different sensitivity analyses will be carried out to see how changes in some parameters or exogenous variables affect the numerical results of the model.

Finally, the conclusion and some recommendations will be presented.

II. REVIEW OF ECONOMIC PLANNING MODELS

A. Elements of the Planning Process: An Introduction

After the Second World War, the practice of economic planning has spread throughout the world. While the socialist economies are considered as planned economies by definition, some developed market economies are experimenting with planning--or planning ideas--of various sorts. Virtually all developing nations today accept planning as an essential means of guiding and accelerating their development. This acceptance of planning by the developing countries of the third world stemmed from the belief that centralized national planning is the best organized way to ensure a sustained high rate of economic growth and to overcome the major obstacles to development.

Certainly, development planning requires the direct intervention of the government in managing the national economy, and a country is considered to be engated in development planning if its government makes a deliberate and continuing attempt to accelerate the rate of economic and social progress and to alter institutional arrangements which are considered to block the attainment of this goal (Waterston, 1979, p. 21). The intervention of the government is required in each step of the development planning process. The government first chooses social objectives, then sets various targets and finally organizes a framework for implementing, coordinating, and monitoring a development plan.

There are four fundamental economic and institutional arguments used to rationalize the use of development planning in the developing countries (Todaro, 1981, p. 432). The first and most used argument is the market failure argument. It states that the markets in developing economies are permeated by imperfection of structure and operation. The existence of distorted prices in those economies makes both consumers and producers respond to signals and incentives which are not a reflection of real cost of goods and services. Also, distorted prices will lead to gross disparities between social and private valuations of alternative investment projects. In the absence of governmental interference, therefore, the market is said to lead to a misallocation of present and future resources, or, at least, to one that may not be in the best long-run social interest. The second argument is resource mobilization and allocation argument. Because of the very limited resources available to the developing countries, investment projects must be chosen within a context of an overall development program that takes account of external economies, indirect repercussions, and long-term objectives. Economic planning will help in channeling the scarce resources to its most productive uses. Some also argue that a detailed statement of national economic and social objectives in the form of specific development plan can have an important psychological impact on the population, and it may succeed in rallying the people behind the government in its effort to raise the standard of living of the people and to overcome the country's inherited economic and social problems. The fourth argument is the foreign aid argument. Many less developed countries feel that the best way to attract foreign aid is to formulate a detailed development plan with specific sectoral output targets and carefully designed investment projects.

Given these as a rationale, this chapter addresses the key elements of the planning process, particularly the objective and the tools used in developing a development plan in the less developed economies.

The most general formal objective of planning is to subject the economic and social process to a systematic and sustained influence regarding the achievement of prescribed objectives (Kenessey, 1978). The choice of a plan which will influence the economic and social variables involves solving a constrained maximization problem with its requirements of specifying an objective function and constraints.

This problem can be stated formally as to choose X so to maximize $\mu(X)$ subject to the condition that $g(X) = 0$ (Heal, 1979). The maximand $\mu(X)$ will be referred to as the objective function; the equation $g(X) = 0$ specifies some set of values from within which X must be chosen. The problem, then, is to choose, of all permissible values of X (those satisfying $g(X) = 0$), that gives the highest values of $\mu(X)$.

Dealing with the planning problem as a constrained maximization problem involves the following steps. The first step is to identify the "choice variables" which represent the "state of the economy". The central planning authority can in principle choose a value for every economically important variable, and can therefore determine the state of the economy in detail. The state of the economy will be denoted by a vector s. There are certain limitations on the values that the components of s may assume. Those limitations are represented by the resource constraints and the technological constraints. A value of s which satisfied all of these constraints will be described as feasible, and the set of all feasible states of the economy will be denoted by S. The problem facing the planning authority is to choose $s \in S$ and the assumption is that it seeks to choose that $s \in S$ which gives the highest possible value of an objective function $\mu(s)$. This objective function associates with any state of the economy s a number $\mu(s)$ which serves to indicate how desirable that state of the economy seems to the planning authority.

A different approach to the development planning problem is the one which has objectives stated in the form of fixed targets. In such a case, the planning procedure would require the planners to choose target values for the variables felt to be important, and then to attempt to find the feasible plan which, in some sense, conforms best to these targets. Heal considers this approach inferior to the first one (Heal, 1979, p. 23) stating that, if feasible targets are chosen, then either they may be inefficient or a constrained maximization problem must be solved to find them. If, on the other hand, infeasible targets are chosen, then finding the feasible state of the economy nearest to them is itself a constrained maximization problem. Heal also recognizes frequent use of this approach in development planning practices despite its intellectual shortcomings. Besides the main reason for choosing this approach which is the difficulties involved in constructing an objective function, others were mentioned in the literature (Kenessey, 1978, p. 255). One of them is that the basis for selecting certain targets are not purely economic and welfare considerations, which make their consideration in optimization procedures extremely difficult. Also, in many cases, the specification of overall targets may not be the result of choice but the outcome of unavoidable socioeconomic pressures and constraints.

As we saw earlier dealing with the development planning problem as a constrained maximization, one requires the specification of an objective function. The task of choosing the appropriate one is not easy. The objective function of the planning problem serves to represent preferences between alternative states of the economy. There are two steps which exist in constructing an objective function. The first is to discover the arguments of the objective function which means to identify the variables (for example, the level of employment, the distribution of income, an index of the output of consumption goods, or the rate of growth) whose magnitudes affect the planner's assessment of the state of the economy. Suppose that the variables about which planners are concerned are S_1, S_2, ..., S_n. Then, the objective function can be written as $\mu(S_1, S_2, \ldots, S_n)$ (Heal, 1979, p. 10).

The second step is to determine the form of the function. Heal (1979) mentioned two approaches to deal with this problem. One approach is to let the planning office construct a number of alternative objective functions, present these to the planners, and spell out their implications in detail. The planners then choose a preferred one of these objective functions; possibly they also suggest modifications that need to be made in order to bring the preferences implicit in it more closely into correspondence with their own. The second approach involves attempting to plot out planner's preferences directly; the most obvious way of doing it would simply be to ask them to rank a wide range of alternative states--a wide enough range to give an indication of the form of their preference map over the alternatives likely to be in question. In practice, such an approach has never been tried.

In comprehensive development planning, the choice of an objective function is very important and always the subject of discussion about the appropriate objective function for the given country. Certainly, the specific form of the objective function depends on the purpose for which it is formulated, the type of planning to be undertaken, the techniques to be used, and the availability of information and data (Ballool, 1981, p. 158).

Specifying the planning problem as a constrained maximization requires, besides an objective function, constraints which limit the values that the economic variables can take. There are two main classes of constraints that restrict the set of possible states of the economy--resource constraints and production constraints.

Resource constraints represented by the limited amount of resources, either raw materials--land, coal, oil, etc.--or a limited amount of skilled labor, all of which are essential to the operation of the economy. The limitation of the availability of resources is of importance because they may clearly limit the range of possible economic activity. Heal argues that most of those resources are limited in the short run but, over a long period of time, their values could be affected (Heal, 1979, p. 18). For example, if we consider the case of the constraint imposed by the limited amount of labor, in the short run, the maximum amount of labor of all kinds available to the economy would normally be determined by exogenous factors beyond the control of planners, except in the case of a country with substantial immigration or emigration which can be influenced by government policy. Over a long period, planners could influence the rate of population growth by altering the pattern of family allowances, changing official policy toward birth control, etc. But there are the biological factors which determine limits to the natural rate of change of population. As Heal puts it:

> When we consider the factors affecting the supply of labor carefully, that the maximum labor force need not always be seen as exogenously given; there may be exogenously-determined limits, but within these there is scope for variation (Heal, 1979, p. 18).

As a general conclusion, resource constraints are not always inflexible except in the very short run; for the long run, their availability depends to a large extent on the economic programs adopted now and in the future.

The second class of constraints is the production constraints which are represented by production function. Then the production constraints are technological conditions governing and limiting the production process. They specify the relationships that must exist between the inputs to a process and the output of that process. Given those relationships, the maximum amount of output which can be generated from a certain amount of inputs is given. The technical conditions governing production are certainly not given; they have altered dramatically over time as a result of technical progress (Heal, 1979, p. 19), and technical progress in turn occurs as a result of research and development activities.

B. Development Planning Models: A Survey

In practice, development planning is a very complex process. It involves many different organization and individual agents interacting in the formulation and execution of a country's economic and social policies and the process of development planning will involve, in general, the following five steps (Spulber and Horwitz, 1976, p. 162). The first step is concerned with the objective function. It involves a careful inspection and determination of the major problems confronting the economy, and essential issues with which the planners must be concerned, as well as the related need to define the society's goals. The second step is to define the data needed like saving and import propensities, capital-output ratios, and input-output coefficients. Also, the defining of the constraints and formulating particular hypotheses concerning the future are part of this step. The choice and specifying a model that defines the key interrelations among the main variables is the third step in this process. There is a great interdependence between the second and the third step; while available data suggest the model should be selected, the model also suggests the date requirements. The data and model specification process, therefore, involves feedback from one to the other so as to assure that the demands of the latter are compatible with the capabilities of the former. The fourth step is the establishment of both the proper projections for those variables that can either be accurately forecasted, or are to be directly or indirectly controlled by the planner, and the sectoral adjustments that will have to be made or will be taking place within the chosen plan period. As we see, this step involves the estimation of an exogenous variable. The final step in this process is to define the policies and instruments to carry out the plan implied by the projections and the required sectoral adjustment.

The importance of the model in the process of development planning is very clear. The model plays very important role in describing the system and thus defining the problem. Everything else--data requirement, speculations about the future, and sectoral implications--emanate from it. This importance of the economic planning model makes the task of building a model for a certain country a very important part of the planning process. Any formal development plan has to be formulated with some reliance upon a planning model and certainly that model should be designed to fit the development strategy of that certain country as well as its principal concerns. The strategy, which in this context refers to a chosen development path, for example, an export promotion or import substitution orientation, varies greatly among countries according to size, relations with the world-wide economy, natural resources, level of development, social objectives, and outlook (Biltzer, 1975). Because of this variation in strategy and the data availability, there is no one model appropriate for all countries.

Models, in general, are abstractions of the real world where they do not perfectly reflect reality. Economic planning models, where they are intended to be practical tools to analyze certain development planning problems, leave out relationships and details which could be included or cannot be formalized. But the results we obtain from such models provide some information necessary for formulating plans and making economic decisions. By using models, the planner is able to study systematically certain economic interrelationships which otherwise might not be easily understood. As the models relate policies to economic reaction, they provide the planners with the opportunity to check possible trade-offs and their magnitudes besides the internal consistency of a set of plans.

There are different kinds of models used in development planning. Some of them are on the aggregate level where they consider the economy as a whole, and some on the sectoral level where they are concerned with a specific sector in the economy. Also, models are different, among other things, in their scope and whether they are dynamic or static. In any case, building a planning model requires first the specification of functional form and utilizing accounting and statistical procedure for the estimation of relevant parameters and then they could be used to explore the specific implications of alternative plans.

1. Aggregate models

The simplest and most used models in the developing countries are the aggregate growth models. They deal with the entire economy and make macroeconomic estimates of planned or required changes in principal economic variables. These are aggregate variables (for example, saving, investment, capital stock, exports, imports) which are considered to be critical to the determination of levels and growth rates of the country's output. Because of their simplicity, the aggregate growth models are very commonly used and they provide a convenient method for forecasting GNP growth in the medium-term and long-term. The aggregate models possess several characteristics (Taylor, 1975, p. 34). The first one is that those models are always expressed in real terms which means that both relative price changes are largely ignored and the interactions of inflation, finance, and flows of funds are omitted from the formulation. The second is that the specification of those models includes a limited set of policy instruments. The models are used to sketch out future growth paths for the economy which seem feasible in terms of estimates of future savings levels, availability of foreign exchange, and so on. Shifts in interest rates, forced development of financial markets, trade subsidies and all the other policies to mobilize these resources do not appear in the formulation. Third, all aspects of uncertainty--ranging from the price of the major export to the standard error of estimate of the capital-output ratio--are usually left out of the formal model, being dealt with (if at all) by sensitivity analysis. The fourth characteristic is that institutional limitations on policy appear in rudimentary form and many political limitations which deeply affect plan formulation are left out. Those four characteristics are very important since, as Taylor asserted, they hold not only for aggregate models but also for multisector models as well.

Most aggregate growth models are based on the well-known Harrol-Domar growth model which views limited savings as the major constraint on aggregate economic growth. Given capital-output ratios and the desired rate of growth, the model can be solved for the required saving to generate that growth. Usually, in developing countries, domestic saving is short of providing the desired amount needed and a policy measure has to be taken to raise domestic savings or to attract foreign assistance. The specification of Harrod-Domar model for development planning (Taylor, 1975, p. 37) starts with formulating the production function where output is related to capital stock through the capital-output ratio. The main assumption here is that capital-output ratio is constant:

$$K(t) = K\ Y(t) \tag{1}$$

where:

$K(t)$ = capital stock at time t

$Y(t)$ = output (GNP) at time t

K = average and marginal capital-output ratio.

The second assumption is that there is a constant ratio of output(s) saved and the equality between saving and investment holds:

$$I(t) = sY(t) = K(t+1) - K(t) + \delta K(t) \tag{2}$$

where:

$I(t)$ = gross investment at period t

δ = the fraction of the capital stock depreciated in each period.

Now, if g is the rate of growth of output:

$$g = [Y(t+1) - y(t)]/Y(t) = \Delta Y(t)/Y(t) \tag{3}$$

where Δ is the forward difference operator, then capital stock must be growing the same rate since from equation 1 we know that:

$$\frac{\Delta K}{K} = k\,\frac{\Delta Y}{K} = \frac{k\Delta Y/Y}{K/Y} = \frac{\Delta Y}{Y} \qquad (4)$$

Using equation 2, we have, therefore, the basic Harrod-Domar growth equation:

$$g = \frac{sY - \delta K}{K} = \frac{s}{k} - \delta \qquad (5)$$

In the planning application of this model, the basic equation 5 is written in a different form:

$$n + p = \frac{s}{k} - \delta \qquad (6)$$

where:

n = the expected rate of growth of the labor force

p = the rate of growth of productivity

Given the saving and depreciation rates, and given the capital-output ratio, equation 6 is usually used to investigate whether domestic saving will be sufficient to provide an adequate number of new employment opportunities to a growing labor force.

Since the Harrod-Domar model emphasizes the saving behavior, even though it is not stable in the developing countries, an extension of the basic formula is possible which will disaggregate the source of saving. If we assume income could be divided into wage income W and profit income π, and there are different marginal propensities to save from wage income (sw) and profit income ($s\pi$), then:

$$W + \pi = Y \qquad (7)$$

and

$$s_W W + S_\pi \pi = I \qquad (8)$$

By manipulating equation 5 and substituting 8 into it, we arrive at a modified Harrod-Domar equation which can be used to check on the saving behavior of each group of income recipients.

Many variants of the aggregate growth models were employed in development planning. They were designed to deal with specific development problems. For example, when foreign exchange is considered the main constraint to economic growth, the so-called two-gap model is employed which is a generalization of the Harrod-Domar model, which takes the problem of foreign trade into account. Another example is the Mahalanobls model where the focus is on the bottleneck which may be created by a shortage of capital goods. The model divides the productive sector into one which produces capital goods and another which produces consumption goods, and the main question addressed here is whether to assign newly produced capital to the capital-producing sector or to the consumption goods producing sector. This model was applied to India and it assumes certain proportion of capital good goes to the capital producing sector and investigates the growth sequences of changing this proportion.

The aggregate growth models as we noticed are very simple and they can provide only a rough first approximation of the general directions an economy might take. One of the limitations of those models is the concentration on saving and the assumption that saving rate is stable which is not true in the developing countries, and also the difficulties implicit in estimating the capital-output ratios.

2. Input-output models

A more disaggregated multisectoral model, which has become quite common and has been used in many developing countries, is the input-output model. It is considered one of the most powerful tools of analysis and planning.

Input-output model divides the economy into many sectors and the activities of those sectors are interrelated with one another by means of a set of simultaneous equations. Each sector is considered an output producer and, for the production of that output, it needs both primary inputs and intermediate inputs which are outputs of other sectors. In each sector, the balance between demand and supply is maintained and for sector i demand equals supply as follows (Taylor, 1975, p. 42):

$$X_i + M_i^c = \sum_j X_{ij} + C_i + G_i + J_i + E_i + S_i \qquad (9)$$

where:

X_i = the volume of gross output from sector i

M_i^c = competitive imports into sector i

X_{ij} = intermediate sales from sector i to sector j

C_i = consumer demand for products of sector i

G_i = government expenditures for products from sector i

J_i = capital formation and replacement demand for sector i products

E_i = exports from sector i

S_i = changes in stocks of sector i products.

Equation 9 above can be written as follows:

$$X_i + M_i^C = \sum_j X_{ij} + F_i \tag{10}$$

where:

F_i = total final demands from sector i.

One of the most important assumptions of the input-output technique is the constant production coefficient assumption and estimating those coefficients is central to this work. If we assume the coefficients are simply inputs per unit of output for a given sector, then:

$$a_{ij} = \frac{X_{ij}}{X_j} \tag{11}$$

where:

a_{ij} = input from sector i per one unit of output of sector j.

By using equation 11 above, equation 10 can be written as follows:

$$X_i + M_i^C = \sum_j a_{ij} X_j + F_i \tag{12}$$

For all sectors using matrix notation and dropping subscripts:

$$X = AX + (F - M^c) \qquad (13)$$

where:

A = technical coefficient matrix.

From 13, we can get the final solution, where X which is the vector of sectoral outputs is a function of final demand, technical coefficients, and competitive imports:

$$X = (I - A)^{-1}(F - M^c) \qquad (14)$$

Therefore, the output of each sector goes either for intermediate use by other sectors or for final use. Assuming final demand is given for each sector, then the model can forecast the industrial output levels and their requirements of both intermediate inputs and primary inputs. In input-output models, the following assumptions are usually adopted to avoid the many complications arising from having a large number of industries in the model:

1. Each industry produces only one homogeneous good.
2. Each industry uses a fixed input ratio for the production of its output.
3. Production in every industry is subject to constant return to scale.

There are many uses for the input-output system in development planning. It could be used as a systematic framework for developing the plan, for checking the consistency of various goals, and for elucidating the implication of alternative possibilities.

If we assume for the period covered by our plan that the final demand is given with its component of different goods needed to be produced by the different sectors of the economy, then from the input-output tables we can deduce the requirements of each sector of both intermediate and primary input and see if those requirements are compatible with the limited resources available to that economy. A plan constructed by the help of the input-output tables will have two basic advantages. The first is its incorporation of direct and indirect requirements and its internal consistency and it is very difficult to attain consistency on a plan without reliance on interindustry tables (Kenessey, 1978). The input-output tables are an important framework for the compilation of every kind of economic statistics and serve as a check on the consistency of data independently estimated in different branches of the economy.

The planning application of input-output system can be demonstrated as follows (Taylor, 1975, p. 46):

$$X = (I - A)^{-1}(F - M^{c}) \tag{14}$$

From equation 14 above, we can get gross output requirements contingent on a forecast of final demand and competitive imports. If we assume that capital, labor, and noncompetitive intermediate imports are tied to output by proportionality relationships, then 14 also provides the basis for finding out what quantities of these inputs are required by some vector of final demand. That can be demonstrated by the following equations:

$$L = \lambda X = \lambda(I - A)^{-1}(F - M^{C}) \tag{15}$$

$$K = kX = k(I - A)^{-1}(F - M^{C}) \tag{16}$$

$$M^{NC} = a_0X = a_0(I - A)^{-1}(F - M^{C}) \tag{17}$$

where:

L, K, M^{NC} are vectors of labor use, capital, and non-competitive imports required by the net final demand vector $(F - M^{C})$.

λ, k, and a_0 are vectors of sectoral labor-output, capital-output, and intermediate import-output ratios.

These equations for predicting factor uses are widely used and provide partial answers for a number of questions which often arise during the planning process. For example, if F and M^{C} equations are aggregate forecasts of final demand, then K, L, etc. are predictions of total resources required to meet final demand forecasts. If those requirements are compatible with what is available of foreign exchange, skilled labor, capital, etc. during the planning period or the final demand forecasts must be revised to be more realistic.

So far, we discussed the static input-output models where we considered the forecast of one period and the demand-creating effects of investment. The input-output models can be dynamic where more than one period is considered and investment in each period depends on the future rate of growth of output. As investment in one period translated to capital stock in the next period in each sector, this will set a capacity limit on production in each sector which will be taken into account in these dynamic input-output models.

Input-output tables incorporate many forms of economic statistics and, in many less developed countries, there are not enough data to meet the requirements of an input-output table. The input-output system depends on two things: the projection of the coefficient matrix and the projection of final demand; and without accurate and sufficient information, it is very difficult to make these two projections.

As we noticed, the input-output models depend on the assumption of constant technical coefficients which imply no technical change in sectoral production process which is not compatible with the objective of development planning, which is to transform the economy's industrial structure and to improve the production process in some industries. That requires the continuous revision of those coefficients.

3. Linear programming model

Input-output models ensure the consistency aspects of the plan. Given certain goals, the industrial output and input requirements will be forecast for each sector which will provide the ability to check whether the planned output targets will satisfy overall limitations on available capital, labor, and foreign exchange. The choice of a given value for the target variables represented by the expected demand is essential to the input-output technique, but if we are dealing with an open-ended objective where no specific values are given to the target variables and goals are represented by an objective function, the use of mathematical programming will ensure, in this case, getting efficient and consistent values of economic variables.

Mathematical programming refers to the process by which the best value is chosen among other possible values through seeking the maximum or minimum of an objective function with given constraints. So it is a systematic examination of a number of feasible alternatives in order to find the optimum (Griffin and Enos, 1970, p. 90). In development planning, the mathematical programming procedure is utilized to create an optimal plan which will be chosen from among a set of possible plans that satisfy the constraints imposed by the availability of economic resources and the economic structure. In any mathematical programming, the objective function and the constraints are the main components and the result of the program depends on the specification of those two components. When both the objective function and constraints take linear form, this is called linear programming, which is the method most commonly used in development planning. Since the input-output models are usually in linear form, the use of linear programming can complement input-output models by choosing among alternatives the optimal values of demand patterns and resource allocation through maximization of a welfare function, taking into consideration the production limitation imposed by input-output and other constraints.

The major components and the specifications of the linear programming model can be explained by the help of the following example. The objective is to maximize a given objective function which, in the planning context, the ultimate measure of welfare, with all the implicit difficulties in choosing such an objective function, the form of the function is a linear one.

$$\text{Maximize } 0 = a_1X_1 + a_2X_2 + \ldots + a_nX_n \qquad (18)$$

subject to:

$$b_{11}X_1 + b_{12}X_2 + \ldots + b_{1n}X_n \leq C_1 \qquad (19)$$

$$b_{21}X_1 + b_{22}X_2 + \ldots + b_{2n}X_n \leq C_2 \qquad (20)$$

$$\vdots$$

$$b_{m1}X_1 + b_{m2}X_2 + \ldots + b_{mn}X_n \leq C_m \qquad (m+1) \qquad (21)$$

and

$$X_1, X_2, \ldots X_n \geq 0 \qquad (m+2) \qquad (22)$$

where:

The X's are the variable subjects of this optimization and a combination of them will yield a maximum value for the objective function. They are called the target variables.

The a's are the weights attached to each target variable.

The C's are the amount of resources available, and each one of them will constrain the solution and will be met either exactly (=) or with a surplus left over (<).

The b's are the input coefficients, which are the amount of the given resource required per one unit of the target variable. For example, b_{12} is the amount of the 1st (C_1) resource needed per one unit of the 2nd target variable (X_2).

The last constraint is called the nonnegativity constraint which specifies that the target variables should be positive.

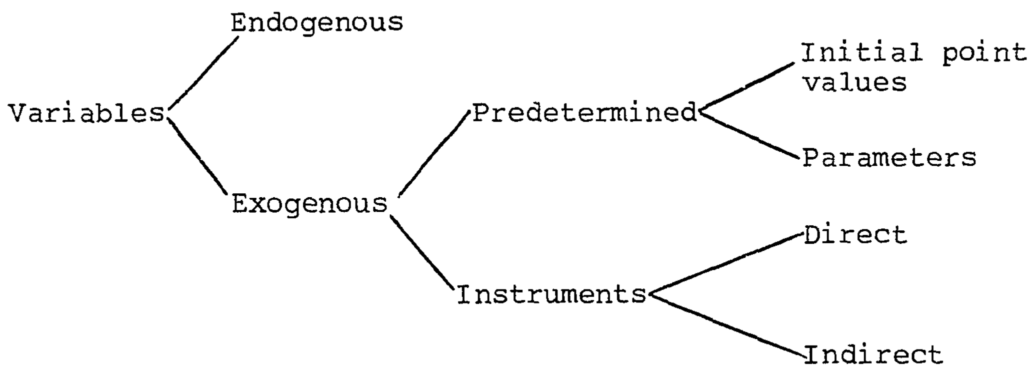
From the formal structure of the linear programming problem as applied to development planning, we notice the most difficult problem is to specify the objective function which should be a reflection of the objectives of the policy makers which is assumed to reflect the preferences of the society as a whole. The objective function should be specified a priori and to get an optimal value of certain economic variables involved in the objective function, preferences are expressed as objectives not targets with given values, and the task of the planner is to seek optimal solutions given the available resources. In most applied studies, where the social welfare function, which is the ideal objective function, is difficult to be specified, the use of the aggregate private consumption function as an approximate to the social welfare function is common. Eckaus and Parikh (1968, p. 22) justify that choice because they consider aggregate private consumption as the most important determinant of welfare. Others consider the aggregate private consumption as the unique determinant of the level of welfare (Bowles and Whynes, 1979, p. 118), arguing that consumption offers the only benefits to the consumer in the final analysis, while investment is only of concern insofar as it affects the stream of consumption possibilities, offering no intrinsic satisfaction itself.

Linear programming could be static where only one time period is considered or dynamic where the model works within the framework of many time periods dealing with dynamic investment planning. In dynamic linear programming models, the usual specific form of the objective function is the present discount value of aggregate private consumption over the planning periods. Implicit in this specification is the choice of the appropriate discount rate which represents the value given to consumption at each period.

It should be clear that having consumption as the only variable in the objective function does not rule out other goals from being included in the model. They can be enforced via the model constraints, and any goal imposed via a constraint is equivalent to one that has an infinite weight in the objective function until it is satisfied, after which, the weight is zero. When the goals are formulated as inequalities, it is most convenient to have them appear as constraints (Eckaus and Parikh, 1968, p. 22).

The other component of the linear programming model is the constraints. They work to restrict the set of possible values that the economic variables can take. In such models, a macroeconomic model representing the different relations existing between the different economic variables will involve the constraints imposed on the target variables. In general, there are two types of constraints: the resource constraint and the production constraint. The resource constraint represents the limited amount of resources available for that economy. Such resources as raw materials, skilled labor, domestic saving, and foreign exchange are essential to the operation of the economy and their limited amount certainly will restrict the ability of the economy to expand. The production constraints are represented by production functions which are technical relationships governing and limiting the production process. When a production function is specified for a certain sector, or for the economy as a whole, as in the case of an aggregate production function, it will give the maximum amount of output which can be generated from a given amount of inputs.

In planning models in general and in linear programming model in particular, as it is applied in development planning, the variables included in the model can be divided into two main categories: endogenous variables and exogenous variables (see below).



The first category is the endogenous variables which constitute the the target variables like national income, aggregate consumption and expected to change over time as a consequence of technological progress and government policies. The exogenous variables can be divided into predetermined variables and instruments. Instruments are variables under the control of the policy makers and by changing their levels they affect endogenous variables. The instruments can be divided into direct and indirect. The direct are those which are fixed by government policy, for example, the income tax rate or the size of the government expenditures; the indirect are those which can only be influenced by government policy through other instruments such as the marginal saving rates.

The predetermined variables or environmental conditions, as they are called sometimes, are expressed in two forms, as initial points and as parameter values. The initial points are statistical estimates of the variables at the beginning instant, the parameters are the numerical values of the constants linking the variables at that and, by assumption, all successive times (Griffin and Enos, 1970). The coefficient of the production functions are assumed to be given and implicit in this assumption that the currently or historically prevailing technical coefficients of production are the optimum ones given the prices of factors of production and outputs.

For any linear programming problem, there is a dual problem. In using linear programming for development planning, the problem is to determine the optimal allocation of resources which is called the primal. For this primal, there is a dual which is solved simultaneously while solving the primal. When the dual is solved, the optimal values we get are those of the optimum valuation of the resources or what is known as "shadow prices". The shadow prices are equilibrium prices compatible with the optimal utilization of resources and could be used in evaluating different projects in the developing countries.

One of the most important assumptions of a linear programming model is the one dealing with the parameters of the model which assumes those parameters are constant. Sensitivity analysis is used to explore how any change in those parameters can affect the optimal values of the program, and it is useful in planning in the sense that it will show which parameter has the greatest impact on the optimal values of the program. If, for example, an increase in the value of one parameter will yield a great increase in the target variables, then an effort to increase this parameter should be considered in the process of development planning.

C. Development Planning in Oil-Based Economies: A Review

1. Introduction

The increase in oil prices in 1973-74 and the subsequent large amount of foreign exchange acquired by the members of the Organization of Petroleum Exporting Countries (OPEC) attracted some attention to those countries and their evolving economies. The 13 countries which are members of OPEC have a common element bringing them together, namely, oil wealth. They now possess more than 60% proven reserves of the world's oil. The OPEC countries, while oil is a common factor, differ from one another in many respects--in area, size and population, natural resources endowment (including oil reserves), ethnic and religious origins, stage of economic development, standard of living, type of government, international association, and a host of other social and cultural values (Amuzegar, 1982).

With the large amount of foreign exchange available to OPEC countries, many questions were raised about the recycling of oil surpluses through the international financial system, and the development of the OPEC type economies and their absorption capacities. In the literature concerning economic development in the third world, there is an emphasis on investment and its role in capital formation. Limited domestic saving and/or limited foreign exchange that restricted real capital formation have been considered the major constraints to economic development. While concepts of absorptive capacity and noneconomic constraints have often been given some mention, the problems of financial constraints to investments have been emphasized (Wassink, 1978). As a result of the price increase of oil, the financial constraints for the OPEC countries were eased for some and eliminated for others.

The new wealth available to the OPEC countries enables them to expand their development spending. A noticeable increase in public expenditure to finance the investment in infrastructure, social services, and productive capacity expansion is a dominant feature in those countries. But this expansion in development expenditure is faced by new set of problems. One of these problems is the limited absorptive capacity, where some countries have a limited ability to make a productive capital investment. Other problems are limited skilled labor, inflation, and the social conflict created by the large number of foreign workers and the conflict between traditional groups who look at the rapid change as a distortion to the traditional values of the society and the elite modernizing group.

2. Characteristics of the oil-based economies

An OPEC type economy can be characterized by having two distinctive sectors: the oil sector and the nonoil sector. The main source of revenue and foreign exchange is the production and exportation of oil to the rest of the world. There is a great dependence on oil in those economies. Oil in its nature is a nonrenewable resource which is going to be depleted sooner or later, and any event that would adversely affect the price or production of oil could undermine the efforts of economic development in these countries. In order to reduce the dependence on oil as the major source of income, one of the most urgent goals of economic development in most OPEC countries is to diversify the structure of the economy. Since all OPEC countries are part of the third world where people have a low standard of living, it is necessary to use the oil income to raise the standard of living for the present generation taking into consideration that any strategy designed to do so should ensure the welfare of future generations and reduce dependence on oil through domestic diversification.

The nonoil sector in most of the OPEC countries is in a state of underdevelopment and any strategy of diversification implies the creation of a viable modern economy outside the oil sector that would sustain a relatively high income level after the end of the oil era. It requires maintaining extremely high levels of investment compared with production in the nonoil sectors for a long time, while at the same time sustaining large expenditures in training and education (Hablutzel, 1981).

Oil in oil-exporting countries is publicly owned which makes governments play a very important role in the process of economic development through the practice of economic development planning. The proceeds from oil provide the necessary capital for investment which frees the country from the need to attract foreign capital and give the national authorities a flexible option to put together a set of economically rational, socially unifying, and politically acceptable policies for the use of oil proceeds (Amuzegar, 1982).

The development planning in OPEC countries should consider two sets of decisions. The first one is to decide whether to produce oil and use its revenue to finance current development or use its revenues for investment abroad where its income could be used to finance future investment or keep oil in the ground for future sale. The second one is to evaluate different domestic programs and projects and choose the ones that use the available resources as efficiently as possible.

3. A review of empirical studies

Attempts have been made in the literature to deal with the subject of development planning in the OPEC type economies where the uniqueness of these economies as capital surplus economies were considered. What follows is a review of some empirical studies.

Homa Motamen (1979) was concerned with planning in an oil-based economy. She examined the possible investment strategies open to an oil-producing country that desires to maintain its overall economic position in the post-resource era. The question raised in the book was the following: Given the resource's lifetime, how can this wealth be transformed so that when the resource is depleted it is replaced by an alternative source of revenue?

Since OPEC countries' foremost concern is with their ability to generate real economic development in their domestic nonoil sectors before the stock of oil is exhausted, the objective function as stated in the study is to maximize the stock of domestic nonoil capital that can be accumulated before the depletion of oil, taking into account the constraints operating for the conversion of the oil wealth into other forms of wealth. She treats oil and oil revenue as an exogenous variable, claiming that the decisions to produce and export oil in OPEC countries at any given time are not determined by their internal economic planning but rather by political considerations. The focus of the book is on the determination of the optimal expenditure of the revenue from a nonreplenishable resource, where this revenue is estimated in advance. With this objective in mind, an intertemporal planning model was formulated using optimal control theory. By applying this method, it is illustrated how the economy can be guided towards a given target. After reaching analytical solutions, the model is subsequently tested by means of computing algorithm known as the "method of feasible directions" (Motamen, 1979, p. 5).

The model that Motamen formulated to analyze the intertemporal planning problem facing an oil-based economy is advanced in two stages. The first stage is to develop a macroeconomic model to explain the basic structure and characteristics of the economy. And the second stage is to apply a dynamic programming technique using the specification of the model. The problem is treated as one with finite horizon, and the system is studied as discrete time intervals.

The macroeconomic model[1] is highly aggregated and developed within a Keynsian framework. The national income was divided into three components: oil sector, nonoil sector, and the returns from the portfolio of assets held outside the country.

The internal nonoil income is generated by means of the existing stock of domestic capital and labor is assumed to be in abundant supply where the sources of skilled labor could be imported in the case of shortage in the domestic supply. The only variable in the production function of the nonoil sector is capital stock where it is related to nonoil income through capital-output ratio.

Private consumption is linked to nonoil income generated domestically and the only export is oil. There are two important constraints in the model. The first one is that the post-oil generation should not face any debt which means that no foreign debt faces the economy when the oil resource is exhausted. The second constraint is concerned with the minimum import requirement of the economy. The macro model is very simple and very aggregated. There are eight equations and eleven variables and four parameters. She treated the time path of the oil revenue as exogenous, but she investigated the extent to which the solutions reached in this model are sensitive to change in time path of oil receipts.

This planning model was applied to Iran where the model parameters and coefficients were quantified to explain the behavior of the Iranian economy. The last part of the study comprised some sensitivity analyses where a large number of simulations were conducted against changes in certain model parameters as well as variations in the time path of the oil revenue. The effect of those simulations on the planning strategy were discussed. The time period used for the study covers the period 1970-95.

The most important conclusion of the study is that the optimal solution for investing the oil revenue is to ask for a lower rate of return on foreign (than on domestic) investment in the earlier stages of the life of the resource, and vice versa in the later stages. This means to accumulate reserves outside the economy during the early years of the resource's life and to invest internally only if the rate of return is higher than abroad. Conversely, to invest more domestically during the later years of the resource's life and accept a lower rate of return than abroad. Since the base year of the study was 1970, there was a chance to compare the optimal solutions reached by the model with the actual policies adopted by Iran. She found that the actual policies adopted are different than the optimal ones and led to waste, economic chaos and they are the main reasons for the Iranian revolution in 1978-79.

Another study dealing with development planning in an oil-based economy is by Al-Sabah (1983). It was an attempt to propose a framework strategy for development planning in

Kuwait up to the year 2000. The study specified two objectives for development planning. The first one is to build up a capable nonoil domestic sector and the second is to reduce dependence on foreign labor, while attempting to encourage Kuwaiti female participation in the labor force. The second part of the study was dealing with the actual determinants of the Kuwaiti female participation rate by means of field work using a survey technique.

A macroeconomic model[2] for Kuwait was developed including three income generating sectors: oil, nonoil, and the overseas sector. The study treats the income generated from the nonoil and the overseas sectors as endogenous and seeks to identify their determinants. The treatment of the income generated from the oil sector is different. First, it assumes a plausible scenario for the price of Kuwait exports of crude oil and solves for an optimal crude output rate. The second way to treat the oil income is to assume a given government-specified desirable scenario for output of crude oil and to solve for the optimal trajectory for the price of oil.

The model is an economy-wide model dealing with the entire economy and it is a dynamic long-term perspective model. It is dynamic in that it seeks to derive "trajectories" for the endogenous and instrument variables between an initial and a terminal time. Thus, the aim is to provide the planner with information on how to get from now to some target year.

It is a perspective model aiming to assist in the design of a framework for develop planning.

The objective function included two variables: the nonoil output and the number of foreign labor. The first objective is to maximize nonoil output and the second objective is to minimize the number of foreign labor in the country. The objective function used is a quadratic form and is the weighted sum of squares of the deviations of each variable from the desired path.

Domestic nonoil income is assumed to be determined by a Cobb-Douglas production function in capital and labor and with disembodied neutral technical change. Income from the portfolio of assets held overseas is assumed to be a nonlinear function of the stock of external assets with one period lag.

Al-Sabah (1983) applied three different optimization models. All three adopt the same objective function, attempting to maximize nonoil income and to minimize the stock of foreign labor by the end of the planning horizon. They differ in the number of instruments. The first one has only two instruments: investment in the domestic nonoil sector and the change in foreign labor. The second model has a third instrument which operates on the labor variable: Kuwaiti female participation rate. The third introduces a fourth instrument operating on oil income which is either the price of crude or the output of crude oil.

The results of the optimization indicate a higher level in total income, nonoil domestic income, investment in nonoil domestic sector, as well in Kuwaiti female participation rate up to the year 1990. However, these results indicate clearly the adverse effects of a policy that pursues an abrupt and sharp reduction in foreign labor. The reduction in foreign labor would reduce the nonoil domestic output which means the dependence on foreign labor will continue if the country wants to reduce independence on oil income and income from overseas portfolio. The implication here is that policy makers have to be extremely cautious in the policies they pursue with respect to the foreign segment of the labor force.

Another attempt, which concerned the long-run intertemporal planning strategy problems of an oil economy, was made by Ballool (1981), where he investigated the optimal choice of investment of oil revenue in Saudi Arabia. He followed the same path taken by Motamen in her study about Iran (Motamen, 1979), which was discussed earlier. The question the study was trying to answer was the following: With exogenous determination of the production and value profile for the oil resource, how can the resulting stock of wealth be transformed into domestic nonoil capital stock in Saudi Arabia so that, when the oil resource is depleted, it will have been replaced by the best flow of alternative income production capability in Saudi Arabia? To try to answer this question, Ballool presented a planning model which was advanced in two stages. First, a macroeconomic model[3] is developed to explain the basic structure and characteristics of the economy. Then, a dynamic programming technique is applied using specifications of the model within the framework of optimal control theory. The oil sector was taken as exogenous and the study did not deal with the production process of oil. The nonoil output is a function of capital stock at the nonoil sector and income from foreign investment is related to the stock of investment overseas. The objective function is to maximize the nonoil sector capital stock subject to two constraints. The first one is that the post-oil generation should not face a debt raised by its predecessors and the second is the minimum import requirement where, in any time period, over the planning horizon, the total payments for essential imports of raw materials and investment goods must not exceed the net surplus of foreign exchange earnings.

The study considered labor in abundant supply assuming that any extra demand over the domestic supply could be satisfied by foreign labor. The consumption function was a function of nonoil income which is a common characteristic of the oil-based economies in the Middle East.

The optimization process used was optimal control theory which led to the following results. The first important result is that, if the minimum import constraint is not binding, the rule is to invest internally or externally wherever the higher rate of return is offered. This means that at the margin external and internal rates of return should be equal. When the minimum import constraint becomes binding, the conclusion of the study was similar to that of Motamen (1979) where, to insure a flow of foreign exchange in the future, especially of the late life of the oil resources, the country should invest overseas in the early period and invest more domestically during the later years of the resource life. This study advocates an accumulation of foreign assets up to the year 1990 and found that the actual investment by the government of Saudi Arabia for the period from 1971 to 1979 was following very closely the oil income and far below the optimal values produced by he algorithm.

The three studies cited above have one thing in common. They all deal with strategies for development planning for an oil-based economy in the Middle East. They all follow an optimization approach based on discrete dynamic optimization technique. The aim of each one of them is to determine the optimal trajectory of investment in the nonoil sector which maximizes the stock of domestic nonoil capital formation before the ultimate depletion of the oil resource. To get to that goal, Motamen (1979) and Ballool (1981) follow the same approach and have very similar models. They only differ in the application. Motamen's application is Iran, Ballool's is Saudi Arabia. They both have very simple macroeconomic models describing the economy and they both ignore the constraint imposed by lack of skilled labor and unskilled labor in the case of Saudi Arabia. Their concern was to find an optimal strategy to invest oil surplus which was taken as given. They concentrated on the choice between investing domestically or abroad and that was reflected in their conclusions.

The treatment of the oil sector was different in those studies. While both Ballool and Motamen treat the oil output and oil income as exogenous determined by circumstances outside the control of each country, Al-Sabah (1983) considered a scenario of expected oil price or output and solved optimally for output or price. None of the three studies dealt with the oil production process and its inputs requirements.

Lack of skilled and sometimes unskilled workers is one of the obstacles of economic development in the oil countries of the Middle East. Only Al-Sabah's study deals with that problem. Her concern with the female participation in the work force in Kuwait led to the treatment of foreign workers and their effect on economic development in Kuwait. She assumed that the government can control the flow of foreign labor. One of the goals of development in Kuwait is to limit the presence of foreign labor in the country in order to avoid any adverse socioeconomical effects of their presence. It is important to notice that these three recent applied studies established the basis for more investigation of the development strategies open for the Middle East oil-based economies.

Cleron (1978) used another approach to deal with the problem of development strategy for an oil-based economy. In his discussion of the long-term planning aspects of Saudi Arabia, he developed a dynamic simulation model based on system dynamics. There was no objective function explicitly specified and the purpose of the simulation was not to present an optimal program of economic development but to clarify the way the economy works and how problems are generated and interrelated. The method of analysis was based upon both the identification and the analysis of the feedback loops that control the long-term dynamics of the economy. The assemblage of all relevant feedback loops constituted the postulated structure of the economy that was the dynamic simulation model. This simulation model which represents the structure of the economy includes both the mechanism which generates the economic development and the constraints which retard the development process. While the model does not set the direction for economic development through exploring an optimal strategy, it assesses long-term strategies of development on the basis of assumptions referring to policy decisions, structural changes and behavioral patterns. It is clear with the many development problems faced by the oil-based economies, this assessment required many assumptions and many simulations.

Optimal depletion of exhaustible resources has been a widely discussed subject in the economic literature where many alternative objectives in the choice of an optimal depletion rate have been considered. Most of the literature in this area has been concerned to analyze depletion policies for closed economies or for an economic system taken to be the world as a whole. For example, Heal was concerned with the problem of exhaustion of natural resources in a global sense (Heal, 1974). While Weinstein and Zeckhauser (1975) approached the problem from a market behavior aspect and drew the conclusion that under a perfectly competitive commodity and capital market, the optimal price of resources rises with the rate of interest. Approaching the problem from a different direction, Solow (1974) concentrated on the problem of achieving an equitable balance between present and future generations where he concluded that earlier generations are entitled to draw down the pool in an optimal way so long as they add to the stack of reproducible capital.

One of the main concerns of the oil-rich countries is the rate of which their oil resources should be depleted.

In trying to address this concern, Moussavian (1980) developed a model for the Iranian economy. The model is designed to analyze how fast the large oil reserves of a country be extracted and exported, and what sectoral investment and employment program, financed partly by these resource exports, would improve the distribution of income in the country. These two aims of the model are to be a long-term (perspective) model with some degree of disaggregation of the production sphere as well as the consumption sectors in the economy. So, the model is an optimal inter-industry, long-term dynamic model. With many changes in the parameters of the model, many plans were developed and those runs ranked by a certain criteria hypothesized in the study.

As we noticed in the last applied study, it discussed the question of optimal depletion of exhaustible resources in oil-rich country that required the analysis of the production process of the extraction sector, namely oil. The first four studies we discussed did not consider the process of extracting oil and concentrated mainly on the best way to spend the given oil revenue.

There is no doubt in my mind that, with the special position the oil-based economies of the Middle East find themselves in, long-term perspective planning will be of a substantial help in giving indications as to how fast the oil resource should be exhausted and how the oil revenue should be spent. Saudi Arabia is the largest producer and has the largest amount of oil reserves in the Middle East, but the growth of the economy is limited by many factors, the most important of which are shortages of labor and a limited absorptive capacity. The economy of Saudi Arabia is dependent on oil which is an exhaustible, nonrenewable resource and certainly the main question facing the country is how to use the flow of oil income to create a nonoil sector capable of generating a flow of nonoil income before the oil reserve is depleted. The subject of this study will be in the same line as those reviewed earlier. It deals with a long-run optimal planning model for Saudi Arabia, using the linear programming technique.

There are two main sectors in the economy, oil and nonoil, and the production process in both sectors will be considered with all its implications for the future requirement of both inputs: capital and labor. This is very important in the base of Saudi Arabia with its relatively scarce labor resources and its increasing dependence on foreign labor. Unlike some of the studies reviewed, the model will give an indication of the rate of depletion of oil which is consistent with the development requirements of the country by treating the oil prices as exogenous and solve for the quantity of oil produced.

The structure of the model will be the same as the formal structure of a linear programming model as discussed earlier, with its component of an objective function and a set of constraints. The constraints will be specified through a two-sector macro model which specifies the variables based on the country's system of national income accounts. The structure of the national income accounts of Saudi Arabia with its components is found in the Appendix. The objective function reflects the main goal of the development planning of Saudi Arabia, which emphasizes the development of the non-oil sector. The multiple goals of development in Saudi Arabia are too complex to be captured in a highly consolidated model such as we are developing. The data base necessary to build a detailed multisectoral planning model for Saudi Arabia is not available at this time.

D. Notes

[1]The relations of Motamen's macro model are:

$$Y_t = O_t + R_t + P_t$$

$$R_t = f_t(K_{t-1})$$
$$P_t = g_t(E_{t-1})$$
$$K_t = K_{t-1} + I_t$$
$$E_t = E_{t-1} + B_t$$
$$C_t = \gamma R_t$$
$$0 < \gamma < 1$$
$$M_t = O_t + P_t - B_t$$
$$B_t = Y_t - C_t - I_t - G_t$$

where $t = 1, \ldots, T$

where:

Variables

Y_t = net national income

O_t = net income from the oil sector

R_t = net income from the nonoil sector generated domestically

P_t = income from the portfolio of foreign assets (held externally)

K_t = stock of capital in the domestic nonoil sector

E_t = portfolio of assets held outside the country including government lendings abroad

I_t = net domestic investment in the nonoil sector

B_t = balance of payments surplus (+) or deficit (-)

C_t = private consumption

G_t = government expenditure

M_t = imports

Parameters

γ = average propensity to consume out of nonoil income

β = minimum percentage of nonoil income required for imports of raw materials

ϕ = minimum percentage of investment goods required to be imported from abroad - implying $(I - \phi)$ of the total investment goods used in the economy are produced domestically

$\mu = \dfrac{1 + \beta - \gamma}{1 - \phi}$. This parameter is defined as the com- combination of the parameters, γ, β, and ϕ to facilitate exposition of the analysis.

[2] The structure of El-Sabah model is as follows:

The objective function:

Optimize = $f(Y(2)_t, Y(9)_t) \qquad t = 1, \ldots, T$

The constraints:

(i) $Y(1) = Y(2) + Y(3) + E(1)$

(ii) $Y(2) = a_1 Y(4)^{a2}_{-1}\, Y(8)^{a3}_{-1} \qquad a2 + a3 = 1$

(iii) $Y(3) = a_4 (C5)^{a5}_{-1} \qquad a < a_4 < 1$

$\qquad a < a_5 < 1$

(iv) $Y(4) = Y(4)_{-1} + U(1)$

(v) $Y(5) = Y(5)_{-1} + Y(6)$

(vi) $Y(6) = Y(1) - U(1) - Y(7) - E(2)$

(vii) $Y(7) = a_6 Y(2)$

(viii) $Y(8) = E(3) + Y(9)$

(ix) $Y(9) = Y(9)_{-1} - (E(6) - E(5)_{-1}) + U(2)$

(x) $E(3) = E(4) + E(5)$

(xi) $E(5) = E(6) + E(7)$

where:

Endogenous target variables

Y(1) Total income
Y(2) Income from nonoil domestic sector
Y(3) Income from financial assets held overseas
Y(4) Stock of capital, nonoil domestic sector
Y(5) Stock of overseas financial assets
Y(6) Balance of payment deficit or surplus
Y(7) Private consumption expenditure
Y(8) Total labor force
Y(9) Non-Kuwaiti labor force
Y(10) Stock variable to check constraint

Exogenous variables

E(1) Income from oil sector
E(2) Government consumption expenditure
E(3) Kuwaiti labor force
E(4) Male Kuwaiti labor force
E(5) Female Kuwaiti labor force
E(6) Female Kuwaiti participation rate
E(7) Female Kuwaiti population

Instruments

U(1) Total (private and government) net investment in nonoil sector
U(2) Change in non-Kuwaiti labor

[3]Equations and structural relations of Ballol's model:

$$Y_t = L_t + S_t + R_t$$
$$S_t = f_t(K_{t-1})$$
R $$R_t = g_t(P_{t-1})$$
$$K_t = K_{t-t} + I_t$$
$$P_t = P_{t-1} + B_t$$
$$C_t = \beta S_t$$
$$0 < \beta < 1$$
$$M_t = L_t + R_t - B_t$$
$$B_t = Y_t - (C_t + I_t + G_t)$$
where $t = 1,2,\ldots, T$

Variables

Y_t = net national income

L_t = net income from the oil sector

S_t = net income from the nonoil sector domestically

R_t = income from the portfolio of foreign assets (held externally)

K_t = stock of capital in the domestic nonoil sector

P_t = portfolio of assets held outside the country (including government lending abroad)

I_t = net domestic investment in the nonoil sector

C_t = private consumption

G_t = government expenditure

M_t = imports

B_t = balance of payments surplus (+) or deficit (-)

Parameters

β = APC, average propensity to consume out of nonoil income

$1-\beta$ = APS, average propensity to save out of nonoil income

δ = minimum percentage of nonoil income required for imports of raw materials

$1-\delta$ = the percentage of the total nonoil income required for raw materials which are used in the economy and which are produced domestically

μ = minimum percentage of investment goods required to be imported from abroad--where $(1-\mu)$ of the total investment goods used in the economy are produced domestically

$\phi = \frac{1+\delta-\beta}{1-\mu}$ = the combinations of the parameters β, δ, μ are defined to facilitate exposition of the analysis.

III. A PROFILE OF THE SAUDI ARABIAN ECONOMY

A. Introduction

The Kingdom of Saudi Arabia occupies about four-fifths of the Arabian Peninsula in the extreme southwest of Asia. The country's size is 2.3 million square kilometers (about 865,000 square miles) which is approximately the size of the United States east of the Mississippi River. The population is about 8 million and the population density is less than 4 people per square kilometer. Because a large part of the country is desert, there are no rivers and rainfall is generally very sparse; water is a scarce resource. Besides its important strategic location and being the site of Islam's holiest places in Makkah and Medinah, the country possesses about one-quarter of the world's proven oil reserves.

After a long period of a low standard of living, the discovery and rapid expansion of production and exportation of oil made the country one of the world's wealthier nations in terms of per capita income. The per capita income in 1981 was $12,600 and the country's holdings of international reserves (predominantly in foreign currencies) is currently more than $27 billion.

The Saudi economy is an oil-based economy. While the oil sector is not an important source of employment, it is certainly the dominant source of foreign exchange earnings, government revenues, and a source of growth of the national income (El Mallakh, 1982). The share of oil sector in GNP is more than 60% in 1982 (see Table 1). The dependence on one source of income--specifically if it is a nonrenewable source, namely oil--invites a long-term risk. The obvious danger in the Kingdom's dependence on oil revenues is the incongruity that may emerge in the long run between the mounting requirements for future development and the risk that, if anything should reduce oil revenues, the country may not be able to generate sufficient alternative sources of income (Looney, 1982, p. 1).

Unlike many developing countries, Saudi Arabia, as a capital-surplus country, has a high degree of financial independence and the challenge facing development there is how to use the oil revenues to create a self-sustaining growth in the nonoil sector. The relationship between the two distinctive sectors in the economy--the oil sector and the nonoil sector--is fundamentally financial in nature with the oil sector providing the revenues for the funding of the extensive development in the nonoil economy.

During the 1970s, which is a period of high oil production and high oil revenues, the Saudi Arabian economy was considered one of the fastest growing economies in the world. The GDP had shown a very high rate of growth in both current and constant prices. The average annual rate of growth from

Table 1. GDP and contribution of nonoil and oil sectors to GDP at current prices (millions of Saudi Riyals)[a]

Year	GDP	Nonoil GDP	% of total GDP	Oil GDP	% of total GDP
1969	15,975	7,721	48	8,255	52
1970	17,399	8,051	46	9,347	54
1971	22,921	8,866	39	14,056	61
1972	28,258	9,884	34	18,373	66
1973	40,551	12,456	31	28,095	69
1974	99,315	16,825	17	82,692	83
1975	139,599	29,137	21	110,462	79
1976	164,526	49,004	30	115,522	70
1977	205,401	70,369	34	134,687	66
1978	225,401	93,337	41	132,064	59
1979	249,539	110,999	44	138,540	56
1980	385,807	135,761	35	250,046	65
1981	520,589	161,565	31	359,024	69
1982	524,710	188,130	36	336,588	64

[a]Source: Saudi Arabian Monetary Agency, annual report, different issues.

1970 to 1979 is 35.38% in current prices and 11.15% in constant 1970 prices.

The Saudi Arabian economy is driven by both free and command-economy philosophies. While the government advocates a free economy, where the private sector should have a great role in the development of the country, most economic activities are controlled by the government, especially since the oil sector is owned by the government. The private non-oil sector is small and dependent on the opportunities provided by the government. The private activity is concentrated in the service sector where it has a long tradition of commercial activities. The free trade policies adopted by the government encourage the private sector trade activities and help in expanding the service sector.

The role of the government has been enhanced by the introduction of development planning and the implementation of both the first and the second development plans. In describing the nature of development planning in Saudi Arabia, Looney wrote:

> Because of the mixed nature of the Saudi Arabian economy where both public and private sectors have separate but significant roles to play, development planning in the Kingdom has been what is often referred to in the planning literature as "perspective" for the public sector, but only "indicative" for the private sector. Accordingly, state planning has attempted to encourage the growth of both public and private sectors in a pragmatic fashion by: (1) earmarking a large proportion of oil revenues for direct public domestic investment, and (2) pointing the way for private investment in other fields through conductive information, projection and incentives (Looney, 1982, p. 97).

B. The Oil Sector

It is difficult to imagine Saudi Arabia without oil because oil represents, with its direct and indirect contributions, the essence of economic life. The discovery of oil in 1938 is certainly a turning point in the history of Saudi Arabia. It brought with it a new wealth which was much needed to alleviate the low standard of living which resulted from a very primitive economy and a harsh climate. With the help of the oil income, the country went through a period of transformation of both the economic and social structures and a high rate of growth in income was achieved.

The oil sector in Saudi Arabia has natural and institutional features (Aldoasary, 1983, p. 9) which made it possible to satisfy a growing demand for the Saudi oil at a very low cost. The natural features are the huge oil reserves, the free-flowing oil wells, and the proximity of the oil fields to the ports. The institutional features are the public ownership of the oil resource, the large size of the concession area, the long duration of the oil concession, and the small number of oil operators. All those features resulted in a low average cost of extraction of oil in Saudi Arabia. It was estimated that the production cost per barrel in 1960 ranged from $0.086 to $0.105 in the gulf area (Adelman, 1972). In 1981, the average cost of producing one barrel of oil is approximately 30¢ (Looney, 1982).

The country has a huge oil reserve. It is now estimated at 165 billion barrels of crude oil which represents about 25% of the whole world's proven reserves. In the past, the discoveries of oil reserves was more than what was produced (Table 2) which makes Saudi Arabia the only major oil producer in which the growth of proven reserves remains almost constantly higher than the growth in extraction rate (Cleron, 1978, p. 19). There is a wide belief that there are potentials for more oil proven reserves in the country, especially in the Rub al Khali (Empty Quarter) where exploration activities continue.

With the continuing demand for the Saudi oil by the rest of the world, the rate of production had showed a major increase during the seventies and reached a daily average of 9.93 million barrels per day during 1980. Domestic oil consumption also increased as a result of economic growth. The high rate of daily production during the seventies, which was considered more than what the country needed to support economic development, was the subject of an intensive debate inside Saudi Arabia. Many argued that stable or even decreased level of production was in the best interests of Saudi Arabia, but the government continued to produce at a high level arguing that it is in the best interest of the country to maintain a production policy that will produce stability in the world market.

Table 2. Selected data for the oil sector (billions of barrels)[a]

Year	Total oil reserve	Total production	Total export	Total oil revenue (million US $)	Average daily production (million bb/d)
1960	45.6[b]	.481	.469	333.7	1.32
1965	65.7[b]	.805	.789	664.1	2.21
1970	138.7	1.387	1.382	1,214.0	3.80
1971	138.26	1.741	1.722	1,884.9	4.77
1972	137.07	2.202	2.196	2,744.6	6.03
1973	136.83	2.773	2.769	4,340.1	7.60
1974	141.04	3.095	3.099	22,573.5	8.48
1975	144.58	2.583	2.581	25,576.2	7.08
1976	151.41	3.124	3.140	30,754.9	8.60
1977	169.48	3.358	3.325	36,540.1	9.19
1978	167.06	3.038	2.986	32,233.8	8.30
1979	168.39	3.479	3.393	48.435.2	9.53
1980	167.46	3.624	3.555	84,466.4	9.93
1981	164.82	3.586	3,486	101,813.0	9.80
1982	165.00	2.367	2.255	70,478.8	6.50

[a]Source: Saudi Arabian Monetary Agency, annual reports, different issues.

[b]Aramco proven reserves.

There are many factors which will influence future production of the Saudi oil. Besides being an influential OPEC member and expected to follow the production policies of this organization, production must be maintained to provide sufficient revenue to finance the economic development, with its main goal of lessening dependence on the oil sector. The assurance of economic prosperity of future generations and maintaining a stable world oil market are important factors which should be considered when establishing a long-run future oil production policy.

Because the government is the sole owner of oil in Saudi Arabia, increased oil production and the large jump in oil prices in the seventies resulted in a high government oil revenue. While oil revenues in 1970 were little more than a billion dollars, it jumped to 22.5 billion dollars in 1974 and reached a peak of 101.8 billion dollars in 1981. The government revenues from oil consist of royalties and income taxes paid by the oil companies besides income to the government from its share in the ownership of Aramco. There is a source of oil income to the government which is very small compared to the previous ones, that is the oil product tax which is levied on consumption of locally produced or imported oil products.

Oil revenues are important for the country since, in addition to being the main source of financing the development plans in general, they have a great effect on investment, balance of payments, foreign exchange earnings, currency and price stabilization, and regional development and cooperation (El Mallakh, 1982).

The oil industry, in general, is capital intensive and in Saudi Arabia, besides being capital intensive, it uses the most advanced technology. It employs a small portion of the labor force which is not more than 3% of the country's labor force while it generates more than 50% of GNP. Almost 100% of the country's exports are oil and oil products which makes the oil sector provide a direct contribution to the country's foreign exchange earnings and the balance of payments. The oil sector in Saudi Arabia, as in all major oil-exporting countries, is isolated from the rest of the economy, employing few people and using little of domestically produced goods. Its relations with the nonoil sector is mostly financial since the most important contribution ofoil to the economic development of Saudi Arabia is its ability to generate funds which could be used to create a self-sustaining growth in the nonoil sector as stated by El Mallakh (1982).

> When a single commodity such as oil plays so vital a role in the economy and when the commodity is a wasting asset, it is then crucial that not only the asset itself be exploited by a very sound and rational production utilization programming policy, but also the actual and potential proceeds from it must be utilized in a way that contributes most to the objective of achieving a stage of self-sustaining economic growth (p. 73).

C. The Nonoil Sector

The Saudi economy, besides having a capital intensive oil sector, has a fast growing nonoil sector. Exploring the potential of the nonoil sector is extremely important since the future of Saudi Arabia lies in developing this sector and lessening the dependence on oil. The nonoil sector employs about 97% of the labor force and generated less than 40% of GNP in 1982.

During the 1970s, the nonoil sector had shown a relatively high rate of growth. The annual rate of growth in this sector from 1970 to 1975 was 9% in real terms, and 14% from 1975 to 1980. From 1980 to 1982, the annual rate of growth in the nonoil GDP measured in constant prices was 11.8%. Nevertheless, the share of nonoil GDP in total GDP did not increase because of the continuing high output and high prices of oil.

Nonoil sector activities are shared by the private sector and the government. The nonoil private sector consists of agriculture, manufacturing, electric and public utility sector, construction, wholesale and retail trade, transport and communications, private dwellings, finance, insurance and other services, and social services. The government sector consists of public administration, education, health, and defense.

Trade is a very important part of the private sector activities because most of the domestic commodity supply is imported. The free trade policy followed by the government and the dominance of the private enterprise system are major factors for making the trade, services, and construction sector dominate the private sector economy.

1. Agriculture

Because of Saudi Arabia's geography and climate, the opportunities for agricultural development are limited. Most of the land in Saudi Arabia is arid or semi-arid and no more than .3% of the total land area is cultivated. Saudi Arabia is a net importer of food and approximately two-thirds of all foodstuffs are supplied by external resources.

The contribution of the agricultural sector to the Gross Domestic Product (GDP) measured in 1970 prices has been falling. It was 5.7% in 1970, 3.7% in 1975, 3.3% in 1980, and 3.4% in 1982 (Table 3). While the share of agricultural output to GDP was declining, the agricultural output was increasing with moderate rates compared to the rates of growth of the other sectors.

Besides the harsh climate, scarcity of water is the most limiting factor in the agricultural development of Saudi Arabia and the future of agriculture depends mainly on how this scarce resource is going to be used and on how the irrigation facilities are going to be extended. There are about 4.5 million hectares of arable land which can become

Table 3. Agricultural output and its share in GDP (millions of Saudi Riyals)[a]

Year	Agricultural output (1970 prices)	Share in GDP (%)	Rate of growth (%)
1o70	984.1	5.7	
1971	1,017.8	5.1	3.4
1972	1,050.1	4.6	3.1
1973	1,088.7	4.0	3.7
1974	1,129.6	3.6	3.8
1975	1,174.1	3.7	3.9
1976	1,221.0	3.5	4.0
1977	1,282.0	3.2	4.9
1978	1,483.0	3.5	15.6
1979	1,550.0	3.5	4.5
1980	1,639.0	3.3	5.7
1981	1,735.0	3.3	5.8
1982	1,835.0	3.4	5.7

[a]Source: Saudi Arabian Monetary Agency, annual report, different issues.

cultivatible if there is enough water available. The country has no lakes, rivers or streams and rain is sparse in most of the country. Agriculture depends on groundwater which is a depletable resource, although it is estimated that fossil water aquifers exist under as much as two-thirds of Saudi Arabia territory (El Mallakh, 1982). Other factors limiting the agricultural production are:

1. The small land holdings in some parts of the country which make the use of agricultural machinery difficult and the continuous dependence on primitive techniques of irrigation and production.
2. The inadequate infrastructure especially roads which makes it difficult for the farmers to get access to markets.
3. The high income and rapid recovery of investment in other sectors compared to the agricultural sector discourages private investors to invest in agriculture.

Even though many analysts believe that Saudi Arabia will continue to be a net food importer and the goal of self-sufficiency in food is not a realistic one, the government considers agricultural development as an integral part of economic diversification and lessening the dependence on oil. The importance of agriculture in Saudi Arabia may be understood considering that about 25% of the labor force is in agriculture. In the past decade, the number of people working in the agricultural sector has been declining since the great influx of wealth from oil revenues attracted people to urban centers. Agricultural development is important considering the labor shortages in the country and the increase in agriculture productivity will release manpower from this sector to the industrial sector. Also, the increase in agricultural production will achieve an acceptable level of self-sufficiency in food and will provide raw material for agricultural-based industry.

With the help of oil revenues, the government encouraged agriculture and set many policies and programs in order to increase agriculture production. To provide more land for agriculture, the government granted potentially productive land to Saudi citizens who are willing and able to farm it. Also, the government provided free interest loans through the Saudi Agricultural Development Bank (SADB) which was established in 1965. The Bank extended three types of loans: short-term loans for inputs on seasonal basis, medium-term credits for equipment, and longer loans for the purchase and improvement of land. The continuous increase in the credits given by the bank to farmers (Table 4) reflects the continuing attention given to the agricultural sector. Besides the free interest loans provided by SADB, subsidies for farm machinery are available for up to 50% of the machinery's

Table 4. Loans granted by the Saudi Agricultural Development Bank[a]

Year	No. of loans	Value of loans (thousands of Riyals)
1970	4,356	16,134
1971	4,381	16,627
1972	3,865	16,558
1973	4,477	19,593
1974	5,414	36,304
1975	16,251	145.505
1976	19,702	269,433
1977	21,377	489.838
1978	20,298	585,668
1979	23,758	709,072
1980	19,782	1,128,686
1981	45,128	2,530,866
1982	37,446	2,932,902

[a]Source: Saudi Arabian Monetary Agency, annual reports, different issues.

price. Other types of incentives including guaranteed prices and regular supplies of agricultural inputs at subsidized prices are provided by the government.

The significant increase in the field of wheat production was used by the government as a testimonial for the success of its agricultural policies. The government buys all wheat production from farmers and pays 3.5 Riyals per kilo which is almost six times the world price. This policy resulted in the large increase in wheat production of 150,000 tonnes in 1979. In 1982, the Grain Silos and Flour Mills Organization (GSFMO) bought 239,690 tonnes of home-produced wheat. In 1983, GSFMO bought 692,000 tonnes of wheat from 12,000 Saudi farmers. This represented 71% of that year's total domestic consumption.

2. Industry

Saudi Arabia is not known as an industrial country and the industrial sector is small indeed. But within the context of the economic development process in this country, industrialization is looked upon as a way to increase output as a means to introduce new technology and to lessen the dependence of the economy upon the export of crude oil. The main goal of Saudi industrialization is to foster the diversification of the economic base to achieve greater economic self-sufficiency and protection from external supply disruption, and to gain the cost advantages from domestic manufacturing activity (Akhdar, 1982).

The contribution of the industrial sector other than oil refining in GDP is small--it was 2.5% in 1970, 2.3% in 1975, and 3.6% in 1982 (Table 5). While the industrial sector experienced modest rates of growth before 1973, the new area of great oil wealth acquired after 1973 had a positive effect on the industrial sector. In 1973, the industrial sector was dominated by small firms engaging in light manufacturing. About 96% of all industrial establishments employed less than ten people. While 62% of the labor force employed in industry was engaged in light manufacturing, 38% was employed in heavy industries such as petrochemicals, minerals and metal products (El Mallakh and El Mallakh, 1982). After 1973, the industrial sector grew rapidly and from 1975 to 1978 a total of 1,035 private industrial establishments were licensed with a total capital of SR 16,780 million (Johany, 1982). By the end of 1982, the number of industrial licenses reached 2,689 with a total capital of SR 112.3 billion. Heavy industry is dominated by petroleum refining and steel production. While the largest manufacturing operations consist of hydrocarbon and cement plants, other manufacturing plants produce fertilizer, copper wires and cable, and some light manufacturing and processing of foodstuffs, textiles, wood and paper in the private sector.

The industrial sector in Saudi Arabia suffers like the

Table 5. Industrial sector share in GDP in constant price of 1970 (million Riyals)[a]

Year	Petroleum refining		Other manufacturing	
	Value added	Share in GDP (%)	Value added	Share in GDP (%)
1970	1,241	7.1	431	2.5
1971	1,355	6.8	484	2.4
1972	1,304	5.7	543	2.4
1973	1,378	5.0	599	2.2
1974	1,417	4.5	665	2.1
1975	1,300	4.1	721	2.3
1976	1,359	3.9	828	2.4
1977	1,523	3.8	956	2.4
1978	1,591	3.8	1,103	2.6
1979	1,689	3.8	1,276	2.8
1980	1,749	3.5	1,477	3.0
1981	1,745	3.3	1,711	3.2
1982	1,716	3.2	1,982	3.6

[a]Source: Saudi Arabian Monetary Agency, annual reports, different issues.

rest of the economy, from the lack of skilled manpower in both the technical and management fields. Also, the lack of enthusiasm on the part of the private sector to invest in industrial projects, preferring the fast profit generated from real estate and commerce, undermined the government determination to let the private sector bear the responsibility of implementing most of the industrial projects. Other constraints to achieving a rapid industrial development are the inefficient infrastructural facilities and the lack of well-organized capital market.

To achieve its industrial objective, Saudi Arabia is following a strategy that will encourage the private sector to invest in manufacturing industry. The government provides a wide range of financial, tariff and other incentives to private investors. The government will supplement the efforts of the private sector by assuming responsibility of the large-scale industries which required a large amount of capital and technical experience which is beyond the ability of the private sector.

To help finance the new industrial projects taken by the private sector, the government established the Industrial Development Fund (SIDF) in 1974. The SIDF provides interest-free medium- and long-term loans to private investors which covers up to 50% of a project's capital requirements. The loans given by SIDF to electric companies in the country allow those companies to expand and upgrade their facilities (Table 6).

Because of the availability of oil and natural gas in the country, the Saudi Arabian government has started the development of hydrocarbon-based industries which will exploit the comparative advantage the country has in terms of cheap energy and feedstock needed for this type of industry. The capital-intensive energy-intensive industries have been initiated by the government in the form of joint ventures with foreign firms who have been providing managerial, technical, and marketing know-how. There are several petrochemical, fertilizer, and iron and steel plants being built in two industrial complexes, namely, Jubail and Yanbu, and as of 1985, those plants have started production. This large-scale industrial base will give Saudi Arabia the capacity to produce as much as 8% of the world demand for certain base chemicals by 1990 and yield an annual income of $2.5 billion a year and will provide the raw material needed for secondary manufacturing in the future.

Clearly, the petrochemical industries are not alternatives to the oil sector when it is depleted since they depend themselves on oil and natural gas. But they will generate additional value added from the use of oil and natural-gas resources while they last and will contribute to the creation of a new class of trained domestic labor force

Table 6. Loans disbursed by SIDF (million Riyals)[a]

Year	Industry	Electricity, gas and water	Total
1976	292.0	1,409.0	1,701.0
1977	704.3	1,569.0	2,273.3
1978	1,268.1	3,883.1	5,151.2
1979	1,117.2	5,728.6	6,845.8
1980	1,306.5	5.183.7	6,490.2
1981	1,171.8	5,489.4	6,661.2
1982	796.7	4,550.5	5,347.2

[a]Source: SAMA annual report, 1982.

which can be transferred to other expanding economic sectors as the oil sector declines in relative importance (Akhdar, 1982).

3. <u>Services</u>

The service sector is the fastest growing sector in the Saudi nonoil economy. It averaged a real rate of growth of 8.3% annually between 1970 and 1975. During the second development plan which covered the period from 1975 to 1980, the service sector had enjoyed the highest rate of growth. The average rate of growth was more than 14% annually, exceeding the planned rate of growth of 13.3% annually.

The contribution of the service sector to the GDP (see Table 7) was about 30% in 1970 and decreased to 24.3% in 1974. But with the new wealth coming from oil after the high increase in oil prices, the share of the service sector in the GDP was increased to 28% in 1976 and continued its upward trend until it reached its peak of 38% in 1982, which makes it the highest contributor to the GDP after the oil sector. This confirms the idea that most of the growth in the nonoil sector in the first and second development plans was not in the strictly productive sectors of agriculture and industry but rather in services which could correctly be termed a secondary or transfer sector (Barker, 1982).

The service sector includes the following subsectors:

1. Wholesale and retail trade, restaurants and hotels
2. Transports, storage and communication
3. Finance, insurance, real estate, and business services
4. Community, social and personal services
5. Producers of government services.

The main reasons for the high rate of growth of the service sector is the large increase in government services, which include education and health services, and the free trade policies followed by the government. Since the private sector has a long tradition of commerce and trade practices, and since most of the domestic commodity supply is imported,

Table 7. Service sector contribution to GDP in 1970 prices (million Riyals)[a]

Year	Service sector value added	Share in GDP (%)	Rate of growth (%)
1970	5,182	29.8	
1971	5,547	27.9	7.0
1972	5,906	25.7	6.5
1973	6,699	24.4	13.4
1974	7,672	24.3	14.5
1975	8,201	25.9	6.9
1976	9,637	28.0	17.5
1977	11,111	28.0	15.3
1978	12,807	30.5	15.3
1979	14,541	32.4	13.5
1980	16,718	33.8	15.0
1981	18.922	35.5	13.2
1982	20,614	38.0	8.9

[a]Source: Saudi Arabian Monetary Agency, annual reports, different issues.

trade is a very important part of the private sector activities.

The private sector depends mainly on foreign workers in running the large number of small firms controlling most of all commerce and services. That is especially clear in the wholesale and retail trade, hotels, restaurants, storage and communication, which have been enjoying the highest rates of growth.

D. Population and Labor Force

The country with its large geographic size and comparatively small population faces a unique problem. While many less developed countries face shortages in foreign exchange and large population, Saudi Arabia is financially secure, but there is a lack of both skilled and unskilled labor. That constrains economic development and makes the task of developing the domestic labor force a priority in the government's program.

There are no reliable estimates for the Saudi population and many sources present different figures. The latest official census was taken in 1974. The estimate of the total population was 7,012,642 which is considered by some to be on the high side. According to the World Bank statistics, the population of Saudi Arabia was 9.3 million in 1981. The population consists of people living in urban or rural areas, and bedouin tribes who are still basically nomadic. The nomads constituted 27% of the population in 1974 and certainly this percentage has been decreasing over time. Considering the size of the country and its population, we find that the population density is low and it is about four persons per square kilometer.

It is estimated by the United Nations that 44% of the population are under 15 years of age and the economic participation rate of Saudi males 12 years and older was about 65% in 1980, down from 69% in 1975. In large part, this is attributable to the longer span of formal education for those 12 years of age and older (El Mallakh, 1982). Because of the traditional role of the women in the society, their participation in the work force is still low and not more than 6% of the total labor force. Adult literacy rate is low relative to the industrialized and some developing countries. Even though the exact figure of adult literacy rate is not available, it is probably a little more than 20%.

Like the total population, the natural rate of growth is not known for certain, because of the inadequate report of births and deaths throughout the nation, especially in rural areas. It is estimated between 2.8 to 3% and with net immigration, the population growth estimate is 4% annually (El Mallakh, 1982). This high rate of growth of the Saudi population is expected to remain high as an improved infant and child mortality rate compensates for lower fertility rates among the more educated strata of society (Barker, 1982).

Given the above facts, and considering the massive development program the country is engaged in, we find the real need for managers, technicians, and skilled workers remains particularly acute. The problem is the continuing imbalance between the economy's growing manpower needs and the number of new Saudi entrants into the labor force.

As an employer, the government has contributed to the problem by making great demands for Saudi labor, thereby reducing the supply of manpower available to other sectors. Like many developing countries, employees of the government are less efficient and you find many government offices crowded with employees who do little work. But working for the government provides more job security to the employee because a sound system of social security has not been developed yet. One important manpower related problem emerges from the traditional cultural values of the society. Many people in Saudi Arabia still look down upon working in manufacturing because they believe it is not prestigious to be a worker in a factory and prefer a less paying job in a different sector which is, according to those values, more prestigious.

As a result of the accelerated economic growth and its requirements of labor in the 1970s, and the inability of the

Saudi labor supply to satisfy these requirements, an in-flow of non-Saudi labor has occurred. The massive in-flow of non-Saudi workers created an increasing expatriate labor force in the country. While in 1970 the percentage of expatriate work force was 27% of the total work force, it rose to more than 50% in 1980 (see Table 8).

Table 8. Expatriates in the work force in Saudi Arabia (in percent)[a]

Year	% of total labor force
1960	10
1965	17
1970	27
1975	40
1980	53

[a]Adapted from Sherbiny (1984).

There is no exact estimate of the expatriate labor force in Saudi Arabia, but in 1980, it was estimated to be around 2 million workers. This high figure and the increasing dependence on non-Saudi workers with the potential of social problems related to their presence, especially in a conservative society like the Saudi Arabians, has worried the policy makers and pushed them to find ways to lessen the dependence on non-Saudi workers. In some sectors of the economy, there is greater dependence on non-Saudi workers. That is clear in manufacturing, construction and community services subsections of the private sector.

Many policy measures were adopted by the government to reduce dependence on non-Saudis in the labor force. Some of these measures work in the supply side were progressive educational programs, and efforts to change attitudes toward labor were part of both the second and third development plans. But the dependence on non-Saudi labor has continued and likely will continue through the 1980s despite the slow down in economic activities as a result of the reduction in oil revenues which started in 1983 (Sherbiny, 1984).

E. The Role of the Government

The oil in Saudi Arabia is owned by the government and, subsequently, all oil revenues accrue to the government. This enables the government to play an important role in the development process considering the high share of the oil sector in GDP and the high level of oil revenues. The essential goal of the government is to use the proceeds from oil to influence the local economy in order to reach some degree of diversification and raise the standard of living of the Saudi population. To do that, the government uses many measures as fiscal and monetary policies, participation in capital accumulation, and direct assistance and incentives to the private sector through several governmental financial institutions.

The channel through which the oil revenues are transmitted into the local economy is the annual budget as observed by El Mallakh (1982):

> It is indeed through government expenditure appropriations that one sees the greatest influence of the government on the levels of economic activities. The annual budget serves both as a means to appropriate government expenditures and as platforms on which to outline the government's tax, trade, financial and other policies. Budgets also serve as the medium through which development plans are executed (El Mallakh, 1982, p. 36).

As a result of the jump in oil prices in the 1970s, the government's actual revenues have increased substantially. While in the 1960s, the total government revenue was not more than SR 1,638 million, it was SR 5,965 million in 1970 and SR 84,618 million in 1975. The government revenues kept growing very rapidly during the second half of the 1970s until it reached SR 191,105 million in 1980 and rose to SR 324,790 million in 1982.

The dominance of the oil revenues in government revenues is clear (Table 9) since it was about 90% in 1970 and rose to 97.3% in 1974 following the increase in oil prices. The relative share of other sources of government income has been low for several reasons. Certainly, the main reason is the rapid growth in the oil income. Other

Table 9. Actual government revenues and expenditures (millions of SR)[a]

	Revenues					
Year	Oil	Nonoil	Total	Share of oil revenue (%)	Total expenditure	Revenue minus expenditure
1970	4,936	805	5,741	89.2	6.028	-287
1971	6,944	1,010	7,954	89.5	5,293	1,661
1972	9,945	1,171	11,116	87.1	8.130	2,986
1973	13,669	1,650	15,326	89.9	10,158	5,168
1974	37,493	3,104	40,597	97.3	18,595	22,002
1975	84,618	15,485	100,103	94.1	35.039	65,064
1976	93.873	9,511	103,384	90.4	81.784	21,600
1977	121,902	14,055	135,957	89.1	106,737	29,220
1978	115,412	16,829	132,241	86.2	137.110	-4,869
1979	116,876	14,629	131,505	87.5	146,255	-14,750
1980	191,105	20,091	211,196	89.6	185,724	25,472
1981	312,819	35,300	348,119	89.9	230,416	117,703
1982	324,790	43,216	368,006	88.3	283,258	84,748

[a]Source: Saudi Arabia, Achievements of the Development Plans (1390-1402/1970-1982): Facts and Figures. Ministry of Planning (1983).

reasons are:

1. The liberal trade policy followed by the government where custom duties were very low.
2. No sales tax in the country.
3. There is no income tax on individuals and only foreign companies and foreign interests in joint Saudi foreign companies pay income tax. The Saudi companies and Saudi interests in joint Saudi-foreign companies pay 2.5% tax on current net assets which is called Zakat.

The large amount of oil revenues which accrue to the government makes the need of other sources of revenue not urgent and produce such a tax system.

From 1970 to 1982, a rapid growth in the government expenditures can be seen in Table 9. In most of the 13 years covered in Table 9, the actual government revenues exceed the actual government expenditures which represents the limited ability of the economy to absorb all the oil revenues. The excess of revenues over expenditures has become part of the general reserves.

Development planning was initiated by the government and development plans have been prepared in order to take advantage of the new and massive resources and to finance economic and social progress. Because the oil is the major source of income and since it is a nonrenewable resource, the national utilization of this resource for the ultimate goal of creating a self-sustained economy which can replace this dependence on oil in the future becomes very eminent and development planning is considered the best way to do that.

The history of development planning in Saudi Arabia started when the government invited the International Bank of Reconstruction and Development (IBRD) to send a mission to investigate the possibilities of economic development. One of the recommendations of the IBRD's mission, which visited the country in 1960, was the creation of a central planning body. In 1961, the central planning council was established and was entrusted with the technical and financial responsibility for planning and implementation of the project. In 1965, the Central Planning Organization (CPO) was established to replace the central planning council. The first serious planning effort by the government was the production of the first five-year development plan in 1970 to cover the period from 1970 to 1975. Following the replacement of the CPO by the Ministry of Planning in 1975, the second five-year plan was announced.

The government of Saudi Arabia has adopted central planning and all government agencies play a role in both planning and execution of the Kingdom's development plans. Key roles, however, are played by the ministries of Planning and of the Finance and National Economy, the former in the coordination of development plans and the latter in the provision of statistical information. The structure of the national planning process starts with the submission of planning guidelines to the king. Sectoral planning is subsequently undertaken by the respective agencies in consultation with the Ministry of Planning. Following the sector planning phase, the Ministry of Planning, under the policy direction of the ministerial planning committee, is responsible for plan coordination and follow up (Second Development Plan, 1975-1980).

The first development plan which covered the period from 1970 to 1975 was prepared under a financial constraint, but the increase in the oil revenue during the plan period made the government revenue more than expected and eased that financial constraint. The plan projected an outlay of SR 41.3 billion and an average annual growth of the GDP of 9.8%. The plan concentrated on building the much-needed infrastructure and expected the agricultural sector to grow by 4.6% annually and industry to grow by 14% annually. The actual expenditures during the plan period were SR 78.2 billion and annual rate of growth of GDP was 13.2%, but the rate of growth in both agriculture and industry was less than expected. The actual rates of growth were 11% and 3% for industry and agriculture. Even though the first plan was the first experience, it succeeded in establishing some needed infrastructure in the country.

The second development plan started in 1975 during a period of high oil income which eliminated any financial constraints. The problem during that period was the ability of the country to absorb all the surplus funds.

The principal goals of this plan were:

1. Maintain the religious and moral values of Islam,
2. Assure the defense and internal security of the Kingdom,
3. Maintain a high rate of economic growth by developing economic resources, maximizing earnings from oil over the long term, and conserving depletable resources,
4. Reduce economic dependence on export of crude oil,
5. Develop human resources by education, training, and raising standards of health,
6. Increase the well-being of all groups within the society and foster social stability under circumstances of rapid social changes,
7. Develop physical infrastructure to support achievement of the above goals.

The second plan was considered an ambitious one, and it proposed to spend SR 498 billion. The GDP was projected to grow in real terms at 10% annually and the nonoil sector at 13.3% annually. Because the country did not have the organizational and technical resources needed to proceed with the plan, the targets of the plan had to be scaled down at the end of 1976. While the annual rate of growth of the GDP during the second plan was 8% which is less than projected, both agriculture and industry annual rate of growth were more than expected as seen in Table 10.

As the second plan, the third development plan also started in a period of high oil income, but the major physical constraints to development, while not completely eliminated, had been reduced and the infrastructure is adequate. The country also faced the high influx of foreign labor from abroad.

In order to curb what was considered a large number of foreign workers coming into the country, a new strategy was established which emphasized high growth in certain sectors with proven potential. The third plan will more efficiently utilize domestic and foreign skilled manpower in capital-intensive hydrocarbon and other manufacturing industries, in agriculture and mining with the objective of furthering diversification of the economy (El Mallakh, 1982). The total expenditure for the third plan was estimated at SR 782.7 billion with annual rate of growth of the real GDP at 3.9%. The nonoil economy is expected to grow at 6.19% annually.

Table 10. Second plan rate of growth (at constant price)[a]

Sectors	Planned	Actual
Agriculture	4.0	5.4
Industry	14.0	15.4
Services	13.3	14.1
Oil	9.7	4.8

[a]Source: Third Development Plan (1975-1980), Kingdom of Saudi Arabia (Ministry of Planning, 1980).

F. The Balance of Payments

Since the early seventies, the current account of the balance of payments of Saudi Arabia has shown a surplus which indicates more receipts than payments (see Table 11). The main reason for this surplus is the sharp increase in oil prices during the seventies. While the surplus was SR 320 million in 1970, it jumped to SR 81,993 million in 1974, providing the country with a large amount of foreign exchange. After 1974, the current account surplus started to decrease until 1978 where it showed a deficit of SR 7,525 million. But with the second increase in oil prices in 1979, the surplus showed up again and grew to SR 137,726 million in 1980 and SR 129,729 in 1981. Because of the dependence of the Saudi economy and Saudi exports on oil and oil products, any change in the oil markets will have a great effect on the economy. This is clear in the case of the balance of payment since the decrease in demand for oil in 1982 resulted in a deficit in the balance of payment current account.

Since Saudi Arabia is the leading oil exporting country, international trade has a very important role in the country's development. Almost the entire exports consist of oil and oil products which change from one year to another depending on the state of the oil market. It is clear from Table 11 that, while the exports depend on the state of the oil market, imports continue to increase. In 1970, the value of imports were SR 3,730 million. It continued to increase during the decade until it reached SR 93,946 million in 1980 and SR 118,080 million in 1982.

The continuous increase in imports reflects the dependence of the country on international trade. The country depends on imports to satisfy its needs of both capital and consumer goods which are not produced domestically. The capacity of both heavy industry and manufacturing is limited and to satisfy the growing demand for capital and consumer goods as well as for foodstuffs, the country has to depend heavily on imports. The increase in imports was enhanced by the government policies of free trade, low tariffs, and subsidies for imported foodstuffs.

During the 1970s, the country's major imports suppliers

Table 11. Summary of the balance of payments (million Saudi Riyals)[a]

	1970	1971	1972	1973	1974	1975
			A. Current Account			
Merchandise exports fob	9,400	15,728	17.937	21,683	115,966	96,010
Merchandise imports fob	-3,730	-3,883	-5,283	-6,870	-12,672	-21,120
Trade balance fob	5,670	11,845	12,654	14,813	103,294	78,890
Other goods, services & income; credit	1,274	1,530	1,922	2,868	9,239	11,258
Other goods, services & income; debit	-5,436	-8,055	-6.710	-5,070	-25,101	-22,858
Other goods, services & income; net	-4,162	-6,525	-4,788	-2,202	-15,862	-11,600
Balance of goods, services & income	1,508	5,320	7,866	12,611	87,432	63,290
Private unrequited transfers	-824	-932	-1,107	-1,452	-1,840	-1,952
Official unrequited transfers	-364	-306	-652	-1,840	-3,599	-11,002
Total unrequited transfers	-1,188	-1,238	-1,759	-3,292	-5,439	-12,954
Current acct. bal.	320	4,082	6,107	9,319	81,993	50,336
			B. Capital Account			
Direct investment & other long-term capital[b]	419	-639	252	-3,380	-31,505	-32,143
Other short-term cap.[b]	-365	104	-1,413	-2,542	-13,603	13,701
Counterpart items	-140	-558	-545	600	-803	3,331
Total change in reserves[c]	-252	-3,015	-4,374	-3,997	-36,082	-35,225

[a]Source: Saudi Arabia, Achievements of the development plans (1390-1420/1970-1982): Facts and figures (Ministry of Planning, 1983).

[b]Minus indicates net outflow.

[c]Minus indicates increase.

1976	1977	1978	1979	1980	1981	1982
125,782	142,239	125,758	189,958	335,065	375,862	250,559
-36,659	-51,811	-68,061	-79,080	-93,946	-114,860	-118,080
89,123	90,428	57,697	110,878	241,119	261,002	132,479
16,119	21,191	21,987	25,945	37,480	54,919	64,870
-39,606	-50,589	-64,281	-81,512	-114,050	-153,003	-183,360
-23,487	-29,398	-42,294	-55,567	-76,570	-98,084	-118,390
65,636	61,030	15,403	55,311	164,549	162,918	14,089
-3,489	-5,309	-9,670	-11,311	-13,522	-13,868	-17,860
-11,729	-13,750	-13,258	-11,772	-13,301	-19,321	-
-15,218	-19,059	-22,928	-23,083	-26,823	-33,189	-17,860
50,418	41,971	-7,525	32,228	137,726	129,729	-3,771
-39,382	-26,451	6,048	-12,462	-91,110	-80,761	-5,169
2,087	-6,013	-39,570	-18,980	-33,487	-16,513	1,018
497	-3,457	-775	-1,225	3,057	4,711	4,484
-13,620	-6,050	41,822	439	-16,185	-37,166	3,438

were the United States, Japan, and West Germany. Most imports were handled by the private sector, reflecting the very active role played by the private sector in the Saudi trade.

As a result of the current account surpluses during the 1970s, Saudi Arabia has acquired a substantial amount of foreign assets. Since there is no one estimate for the net foreign assets accumulated by the Saudi government, the figure in 1980 ranged from $75 billion to $125 billion (Barker, 1982, p. 19). The international reserves which are part of the net foreign assets consist mainly of foreign exchange and is estimated to be more than $29 billion in 1982 as estimated by the International Monetary Fund (IMF).

Another result of the high increase in oil prices is the expansion of economic assistance by the Saudi government to the developing countries. According to Zubair Iqbal (1983), Saudi Arabia alone provided over 56% of all Arab concessional assistance during 1975-81. The amount of concessional assistance by the Saudi Government during the period of 1975-81 is estimated as $5,712 million which corresponds to about 6% of the GNP. To contribute to development projects in developing countries through extended loans, the Saudi government established the Saudi Development Fund (SDF) in 1974. The authorized capital for SDF was increased from $2,843 million in 1975 to $7,400 million in 1981.

The increasing foreign labor force in the Kingdom has contributed to the transfer of resources from Saudi Arabia to the rest of the world. The increasing number of foreign workers from the developing countries in Saudi Arabia explains the expansion in workers' remittances which was increased from SR 877 million in 1974 to SR 5,427.9 million in 1982 (National Accounts of Saudi Arabia, 1982).

IV. EMPIRICAL MODEL

A. Introduction

Saudi Arabia is an oil dependent country where oil represents the major source of income and, since oil is a depletable resource with finite quantity, it finds itself in a critical position. It is trying to channel the income created by oil through a program of investment in the nonoil sector in order to create a nonoil producing sector which can complement the oil income during the resource's lifetime and to substitute for oil income when this resource is exhausted. This will ensure a high standard of living not only for the present generation but for future generations as well. To achieve this goal, it is necessary to exploit the oil resource in a rational way and use the proceeds generated by the oil sector, during its lifetime, in such a way that will contribute most to achieving this goal.

For this study, which is concerned with the question of development planning in Saudi Arabia, we will develop a model that characterizes the Saudi economy as an oil-based economy by determining the relationships between different macroeconomic variables and try to find the optimal time path of major macroeconomic variables which are compatible with the long-term goal of economic development of Saudi Arabia.

The model, which is a two-sector macroeconomic model, will help by indicating the time path of the oil depletion rate which is consistent with the needs of economic development and will assist in economic evaluation of intertemporal investment strategies in Saudi Arabia. In the context of development planning in Saudi Arabia, the long-term aspects of the investment program of the oil surplus in the nonoil sector will be of a great concern, especially when we realize the fact that the oil sector is publicly owned and the government acquires the oil surplus which can be invested. Since both oil production decisions and investment of the oil surplus are under the government's control, that makes the government play a major role in the direction of the process of capital formation. That does not imply that the government is the only investment decision maker in the country and a look at the consolidated saving and investment account, which is account #6 in the structure of Saudi Arabia's National income accounts (Appendix), reveals that the nonoil sector which is mainly private has a role in those decisions but the government has the power to affect investment decisions since it controls the main source of income and certainly the main source of investable surplus.

Because of the distinctive feature of the Saudi economy with its sectors: oil and nonoil, the model will be a two-sector model. While the oil sector activities consist of the production of crude oil and oil products, the nonoil sector consists of different subsectors. The nonoil activities are shared by the private sector and the government. The nonoil private sector consists of agriculture, manufacturing, electric and retail trade, transport and communications, private dwellings, finance, insurance and other services, and social services. The government sector consists of public administration, education, health, and defense. It is important to indicate that the development of the nonoil sector depends on the oil sector since it provides most of the investable surplus which could be used to develop the nonoil sector. For the model to serve the purpose of this study, it should be a long-term dynamic model. It assumes a lifetime for the oil resource and investigates the intertemporal pattern of resource extraction which is compatible with the long-time strategy of developing the nonoil sector. That is to say, the oil extraction will not be considered as exogenous determined by outside forces, but instead, it is endogenous, determined within the system where its depletion is determined according to the needs of the optimal plan and the level of investment as stated by the plan. At the same time, the pattern of investment over time in the optimal plan is determined by the rate of extraction which means there is an interaction between the two where they are determined simultaneously by the optimal model.

The model which will be used in this study is the multiperiod linear programming model. The use of linear programming is common in planning models (Manne, 1974). Linear programming is a general mathematical optimization technique. When used in planning models, it involves the maximization of an explicit social welfare function over the period of the plan subject to the production and other constraints faced by the nation (Salvatore, 1977). The main advantage of using linear programming is that it provides an optimum solution for the problem and, in development planning, it provides a means for efficient systematic exploration of the economy's choice set. In the case of our model, one of the most significant motives for using linear programming is that the data for using this model were available. There are certain disadvantages of using linear programming. The first is the problem of developing a social welfare function to be maximized where a conflict may exist between different alternatives. The second is the assumption of linear economic relations, while in the real world, nonlinear relationships prevail.

The model when solves will give optimal values of the endogenous variables at the beginning of different discrete intervals. Each interval is five years and the base year of the model is 1980. The terminal year is 2014.

The model is a macroeconomic model and it is common in this kind of planning model to assume constant prices throughout the plan's duration (Biltzer, 1975). That involves an assumption of constant domestic prices and because of the Saudi economy's high degree of openness, domestic prices will be assumed equal to international prices which means a constant exchange rate over the planning period. One exception is oil prices which are not expected to remain constant over time. The experience of the last decade shows how difficult it is to predict oil prices. Where the expectations by the end of the 1970s were that the oil prices will continue to rise in the future (Moussavian, 1980), the events of the early 1980s, during which oil prices decreased, proved otherwise. It should be clear that it is not the purpose of this study to predict the movement of oil prices in the future and a reasonable assumption about the future course of oil prices is encough for the purpose of this study. The change in future oil prices will be eligible for sensitivity analysis where some different courses of future oil prices could be considered.

In this model, appropriate value quantities will be used in place of physical quantities (i.e., values of the variables are going to be expressed in terms of Saudi Riyals unless specified otherwise).

As in all linear programming models, we will have an objective function and a set of linear constraints. The constraints will be part of the two-sector macro model which will describe the relationships between the different economic variables in the oil-based economy of Saudi Arabia.

B. Objective Function

The objective function should be stated to represent as accurately as possible the objectives of the policy makers. The long-term objectives of the oil exporting countries of the Middle East including Saudi Arabia is to generate real economic development in their nonoil sectors before the stock of oil is exhausted and any objective function should be chosen so that it portrays these long-term objectives (Motaman, 1979).

In standard linear programming models, the use of aggregate private consumption as the main component of the objective function is common (see Chenery and McEwan, 1976; Eckaus and Parikh, 1968). This choice is justified by considering that the long-term objective of policy makers is to enhance the welfare of the population and aggregate private consumption is the main determinant of welfare. But in the case of Saudi Arabia, where the government owns the oil resource which is the main source of income and where the traditional system requires that the government share with the whole populace the wealth of the country and, therefore, subsidies, provision of social services, and increased employment become mechanisms through which wealth is redistributed, private consumption alone is not a sufficient measure of the economic welfare of the population (El Mallakh, 1982).

One of the very important characteristics of the aggregate private consumption in the oil exporting countries in general and in Saudi Arabia in particular is its close association with the nonoil sector. Private consumption has no relation to the oil sector. Even though the latter provides most of the income, it does not employ more than 3% of the labor force. Private consumption is related to the nonoil sector value added only (as will be seen later).

Final private consumption expenditure is defined in the National Income Accounts of Saudi Arabia (NIA) as the outlays of resident households on new durable and nondurable goods and services less their net sales of second-hand goods, scraps and wastes. It also defines resident households and individuals as all individuals living within the domestic territory of the country except foreign visitors in the country for less than one year. It is clear from these definitions that private consumption expenditure is by both Saudi nationals and guest workers and it is not possible to separate guest-worker consumption expenditure from Saudi national consumption expenditure since there is no data vailable. It is also worth mentioning here that, given the structure of NIA (Appendix), the largest portion of private household income comes from wage income from both oil and nonoil sectors and no data are available for the government transfer to individuals or the interest earnings on private wealth held abroad.

Since the long-term objective is to develop the nonoil sector, the objective function should include nonoil sector value added. But because of the dependence of the aggregate private consumption on the nonoil value added, the objective function can be stated so as to include the aggregate private consumption in the planning period. The use of aggregate private consumption in the objective function is justified not because it is the main component of welfare but because of its close relation with the nonoil value added and the maximization of the aggregate private consumption means the maximization of the nonoil value added. It is important to remember that any objective which is not included in the objective function could be introduced as a constraint.

The objective function which will be maximized is the sum of discounted aggregate private consumption in each period of the planning horizon:

$$OB = \sum_{t=1}^{T} \frac{CH_{(t)}}{(1+w)^{t-1}}$$

where:

OB = sum of present value of CH

$CH_{(t)}$ = aggregate private consumption at time t w = social discount rate.

The social discount rate is mainly a price of time which means the rate planners use to calculate the net present value of time stream of values which in our case is the aggregate private consumption. It may differ from the market rate of interest depending on the subjective evaluation of the planners. The higher future consumption is valued in the government planning scheme, the lower will be the social discount rate. The choice of social discount rate is ultimately arbitrary and depends on the subjective choice of the planners. In our model, the choice of w, which is applied to future private consumption, is arbitrary, but it is hoped to be a good proxy of the real world's social discount rate.

C. The Macro Model

The relations between different variables of the Saudi economy will be specified by a macroeconomic model which will provide the constraints for our planning model. Each variable will be either an annual flow or stock; for example, GDP_t will be annual flow of the gross domestic product during interval t, where $t = 1,2,...,T$, and T is the terminal period.

The first equality in the model is the one equating aggregate supply of goods and services to aggregate demands:

$$GDP_t + M_t = CH_t + I_t + CG_t + E_t \qquad (23)$$

The total supply consists of gross domestic product (GDP) and total imports (M), while the total demand is the sum of private consumption expenditure (CH), gross investment (I), government consumption expenditure (CG), and total exports (E).

Since there are two producing sectors (oil and nonoil sectors), gross domestic product equals the sum of the value added in each sector.

$$GDP_t = QO_t + QN_t \tag{24}$$

where:

QO = value added by the oil sector

QN = value added by the nonoil sector.

Gross investment expenditure (I) is divided between the two sectors:

$$I_t = IO_t + IN_t \tag{25}$$

where:

IO = investment by oil sector

IN = investment by nonoil sector.

Equality between gross investment and saving is maintained where saving is the sum of total domestic saving and foreign saving:

$$I_t = S_t + SF_t \tag{26}$$

where:

S = total domestic saving

SF = foreign saving.

Assuming a constant marginal saving rate, domestic saving can be expressed as a function of gross domestic product:

$$S_t = sGDP_t \tag{27}$$

where we have a constant marginal saving rate (s) which is equal to the average saving rate.

Government revenues (GR) comes from two sources: the oil revenue and the nonoil revenue. Since the oil sector is owned by the government and there are no income taxes on individuals, most government revenues come from the oil sector in the form of royalties and taxes on oil company income. Government oil revenue is a linear function of the oil sector's value added and government nonoil revenue is a function of nonoil sector's value added.

$$GR = GRO_t + GRN_t \tag{28}$$

$$GRO_t = r_1 + r_2\ QO_t \tag{29}$$

$$GRN_t = n_1 + n_2\ QN_2 \tag{30}$$

where:

GRO = government revenue from oil sector

GRN = government revenue from nonoil sector.

Foreign saving depends on the condition of the balance of payments. The current account of the balance of payments of Saudi Arabia has shown a surplus most of the time cince the increase in oil prices at the end of 1973.

$$SF_t = M_t + LPF_t + RF_t + PIN_t - E_t \qquad (31)$$

where:

LPF = repatriated compensation of foreign labor

RF = net foreign transfers

PIN = net property and entrepreneurial income.

As is clear from equation 31 above, foreign saving is not only determined by the difference between imports and exports but also by net foreign transfers, net property, and entrepreneurial income, and payment to foreign labor inside the country which is transferred abroad.

Compensation of foreign labor, which is repatriated, is related to the number of foreign workers in the country and to their wage rate. But since no data on wage rates are available at the present time, I will consider the number of foreign workers and the total wage income as the only independent variables in the function determining LPF.

$$LPF_t = \ell_o + \ell_1 LF_t + \ell_2 WI_t \qquad (32)$$

where:

LF = total non-Saudi labor force

WI = total wage income.

The transfers received from abroad is a negligible amount compared to what the country paid to foreign countries. Since the amount paid, especially by the government, is related to political rather than economic factors, RF will be considered as an exogenous variable.

$$RF_t = \overline{RF}_t \tag{33}$$

Net property and entrepreneurial income (PIN) is the difference between operating surplus paid to foreigners and property and entrepreneurial income from abroad.

$$PIN_t = OSF_t - PIF_t \tag{34}$$

where:

OSF = operating surplus paid to foreigners

PIF = property and entrepreneurial income from abroad.

As a result of the large amount of balance of payments current account's surplus, the country has acquired a large amount of foreign assets which are expected to yield a flow of income over the planning period.

$$PIF_t = iIF_{(t-1)} \tag{35}$$

Income from investment abroad, as stated by function 35, at period t is equal to a certain percentage of the total investment abroad (IF) with one period lag. The constant (i) is approximated by the prevailing international interest rate which will be treated as a predicted exogenous variable over the planning period.

The change in the stock of accumulated foreign assets is related to the state of the balance of payments current account.

$$IF_{(t)} = IF_{(t-1)} - SF_{(t)} \tag{36}$$

SF represents surplus or deficit in the current account of the balance of payments (- surplus, + deficit). If we have a deficit, $IF_{(t)}$ will be less than $IF_{(t-1)}$ and, if we have surplus, $IF_{(t)}$ will be more than $IF_{(t-1)}$.

According to the Saudi Arabian National Income Statistics, income is divided into wage income and operating surplus which includes profits. Part of that operating surplus is paid to foreigners who have investment in the country.

$$OSF_t = a_1 + a_2 \, OS_t \tag{37}$$

where:

a_1, a_2 are constants to be estimated

OS = total operating surplus.

Both total wage income and total operating surplus are functions of gross domestic product (GDP) and the sum of WI and OS represents the domestic factor income in the National Income Accounting. It should be noticed that the two variables are not independent and, if we estimate WI, then OS could be estimated as a residual.

$$WI_t = b_1 + b_2 \, GDP_t \tag{38}$$

$$OS_t = C_1 + C_2 \, GDP_t \tag{39}$$

Exports could be divided into exports from oil sector and exports from nonoil sector. At the present time, Saudi exports are almost totally consisting of crude oil and oil products which make total exports equal to exports from the oil sector only, which implies also that, in the foreseeable future, Saudi Arabia will only have a comparative advantage in petrochemicals which depends mainly on oil and oil products.

$$E_t = EO_t \tag{40}$$

where:

EO = export from oil sector.

Government consumption expenditure (CG) at any period of time will be treated as an exogenous variable. The government consumption expenditure which includes expenditure on welfare and social infrastructure is a tool in the hands of the government, used to raise the standard of living of the Saudi population. One of the main components of the government expenditure is expenditure on military and internal security which is given a first priority by the government and this kind of expenditure will not depend mostly on economic factors. In this model, the government expenditure will be exogenous determined by the government outside the system.

$$CG_t = \overline{CG}_t \tag{41}$$

Saudi Arabia depends on imports to meet its needs for goods and services. Most consumer goods, foodstuffs, and all capital goods are imported. That makes the demand for imports depend on the components of total demand, namely, private consumption expenditure (CH), total investment (I), and government consumption expenditure (CG).

$$M_t = m_c CH_t + m_i I_t + m_g CG_t \quad (42)$$

where m_c, m_i, and m_g are constants representing the imported components of private consumption, total investment, and government consumption, respectively.

One of the characteristics of the oil-based economies is the dependence of the private consumption expenditure on the nonoil income generated domestically. It bears little relation to the receipts from oil exports and examination of the living standards of the inhabitants of the Middle East would support this presumption (Motamen, 1979, p. 15). In the case of Saudi Arabia, Ballool asserted that the private consumption bears little relation to receipts from oil wealth (Ballool, 1981, p. 208). Saudi Arabia oil industry is capital intensive and employs a very small percentage of the labor force (not more than 3%) even though it generated most of the GDP. All oil income is received by the government and there are no income taxes on individuals. That makes the private consumption expenditure related to the nonoil value added (QN).

$$CH_t = cQN_t \quad (43)$$

This specification of the private consumption function assumes a constant marginal propensity to consume (c) which is at the same time the average propensity to consume.

1. The nonoil sector

As an important part of the macroeconomic model, the production process of the nonoil sector will be considered through the specification of a production function. The production function is a technical constraint representing the maximum amount of output which could be produced from certain amounts of inputs. Any production function for the Saudi nonoil sector should consider the manpower constraints facing the country.

Assuming we have only two inputs--capital and labor--and there is no short-run substitution between capital and labor in the production process, the production function could be written as:

$$QN_t = \min\left(\frac{KN_t}{\alpha N}, \frac{LN_t}{\beta N}\right) \tag{44}$$

where:

KN = capital stock in the nonoil sector

LN = labor in the nonoil sector

αN = capital output ratio in the nonoil sector

βN = labor output ratio in the nonoil sector

Both αN and βN are going to be estimated.

Implicit in the above formulation of the production function is that the lesser amount either of labor or capital will dictate production. That is to say, that, if there is a shortage in one factor of production, the level of production will be fixed by this factorwhile the other factor is underemployed.

The supply of capitaldepends on investment in this sector and depreciation of the stock of capital:

$$KN_{(t)} = KN_{(0)} + \sum_{\tau=0}^{t-1} \left[IN_{(\tau)} - \delta KN_{(\tau)}\right] \tag{45}$$

where δ is the rate of depreciation which takes a constant value and $KN_{(0)}$ is the capital stock at the base year.

2. The oil sector

The importance of the oil sector in the Saudi economy necessitates the rational exploitation of this resource which involved connecting the oil production to the need for the economic development of the country. The main question is whether to treat the oil sector variables as exogenous or endogenous variables. Treating them as exogenous variables means that oil production and oil revenues are not under the control of the Saudi government and depend mainly on the world demand for oil. The world demand facing the oil producing countries is not under their control but depends on the economic conditions in the oil consuming countries. During the 1970s and early 1980s, the changes in the world oil market proved how difficult it is to forecast the world oil demand. But even though one can produce a fairly convincing argument about the exogeneity of the oil sector production and revenues, it is important to investigate to what extent should oil be produced and exported in such a way that is consistent with the needs of economic development of the country. That implies treating the oil sector variables as endogenous variables which we will do in this model with the exception of the oil price, which will be assumed given. Endogeneity of the oil production means that they are determined within the planning system according to the need of the plan and its associated level of investment. That is consistent with the objective of development planning and it will abandon the idea of divorcing the two main sectors from each other or at best assuming a one-way link (from the oil sector to nonoil sector) (Al-Sabah, 1983).

While it is extremely difficult to relate the current production level of oil in Saudi Arabia to strictly economic variables, the mechanism of production has to be considered through a production function. Therefore, the potential output of oil is related to capital and labor by the following production function:

$$QO_t = \min\left(\frac{KO_t}{\alpha O}, \frac{LO_t}{\beta O}\right) \tag{46}$$

where:

KO = capital stock at oil sector

LO = labor at oil sector

αO, βO = capital and labor output ratios in the oil sector.

This production function has the same characteristics as the nonoil production function, that is, the lesser amount either of labor or capital will dictate production and both capital and labor output ratios will be estimated.

Capital supply is determined by investment in the oil sector and the constant rate of depreciation (δ).

$$KO_{(t)} = KO_{(0)} + \sum_{\tau=0}^{t-1} \left[IO_{(\tau)} - \delta KO_{(\tau)}\right] \qquad (47)$$

where:

$KO_{(0)}$ = capital stock at the base year which is one of the inputs of the model.

In order to relate the value added of the oil sector to the production rate of oil, we will take an intermediate step where the value added of the oil sector is related to the gross value of oil.

$$QO_{(t)} = d_2\ GVO_{(t)} \qquad (48)$$

where:

GVO = gross value of oil.

Gross value of oil (GVO) is equal to the quantity of oil produced in terms of barrels multiplied by the price of oil which will be considered as given (i.e., determined outside the model).

$$GVO_{(t)} = qO_{(t)} \cdot \overline{PO} \qquad (49)$$

where:

qO = quantity of oil produced

$\overline{PO}$ = world oil price.

Implicit in this specification is the assumption that the demand for the Saudi oil exports is perfectly elastic. The model then will solve for the optimal output of oil. This output of oil is produced for domestic consumption and exports.

$$qO_{(t)} = qE_{(t)} + qD_{(t)} \tag{50}$$

where:

qE = the quantity of oil exported

qD = the quantity of oil consumed domestically.

The value of oil exports at any period of time equals the quantity of oil exported multiplied by the world price of oil.

$$EO_{(t)} = qE_{(t)} \cdot \overline{PO} \tag{51}$$

The quantity of oil consumed domestically is related to the value added of the nonoil sector by the energy output ratio, which indicates the quantity of crude oil that the economy consumes for each Riyals of nonoil production (Cleron, 1978, p. 24).

$$qD_{(t)} = e\ QN_{(t)} \tag{52}$$

where:

e = energy output ratio.

One of the most important variables of the oil sector is the quantity of oil proven reserves. It puts a limit on the maximum amount of oil produced during the planning period. This constraint can be introduced here by making the sum of the planned outputs for future intervals less than or equal to the proven reserves in the base year.

$$\sum_{t=0}^{T} qO_{(t)} \leq PR_{(0)} \qquad (53)$$

where:

$PR_{(0)}$ = oil proven reserves at the base year.

3. <u>The labor market</u>

One of the main characteristics of the Saudi economy is its lack of skilled and unskilled labor force which resulted in an increasing dependence on non-Saudi laborers. The variables for labor demand and supply in this model will be aggregated over skills and occupations but the distinction between Saudi and non-Saudi laborers is very important within the context of development planning in Saudi Arabia. The model will provide the future requirement of labor and its component of non-Saudi labor, which has to be imported, and investigates whether the dependence on non-Saudi labor has to continue or not.

Assuming full employment where total labor demand is equal to total labor supply at any period of time:

$$TLD_t = TLS_t \qquad (54)$$

where:

TLD = total labor demand

TLS = total labor supply

and total demand is the sum of labor demand by the oil sector and the labor demand by the nonoil sector:

$$TLD_t = LN_t + LO_t \tag{55}$$

where:

LN_t = labor demand by the nonoil sector

LO_t = labor demand by the oil sector.

Total labor supply consists of the supply of Saudi's labor and non-Saudi's labor:

$$TLS_t = LS_t + LF_t \tag{56}$$

where:

LS = Saudi labor force

LF = non-Saudi labor force.

Assuming full employment for the Saudi labor force and assuming that the rate of growth of Saudi labor is equivalent to the rate of growth of the Saudi population, the supply of the Saudi labor at any period of time will be equal to the supply of labor last period plus the new number of people entering the labor market:

$$LS_t = LS_{t-1} + rLS_{t-1} \tag{57}$$

where:

r = rate of growth of the Saudi population which is constant.

Since the government has a tight control over the non-

Saudi labor coming to Saudi Arabia, the number of non-Saudi laborers will be a policy variable used by the government. The supply of non-Saudi labor at any period of time is the sum of non-Saudi laborers during the past period plus the new permits issued for non-Saudi laborers to come to the country:

$$LF_t = LF_{t-1} + PL_t \tag{58}$$

where:

PL = number of permits issued for non-Saudi laborers by the Saudi government.

4. Other constraints

The absorptive capacity as a constraint which limits the ability of the economy to absorb increases in the supply of capital can be introduced through imposing an upper limit on the rate of growth of investment:

$$I_t \leq (1 + f)\ I_{t-1} \tag{59}$$

To avoid any decrease in the amount of investment which may result in this model, another constraint is added which puts a lower bound on the growth of investment:

$$I_t \geq I_{t-1} \tag{60}$$

One of the most important goals of the policy makers in Saudi Arabia is to increase the standard of living of the country's population, and this goal could be incorporated in the model through a constraint which will not only stop any decline in the private consumption expenditure but also will ensure that the private consumption expenditure will grow by at least the rate of growth of the population:

$$CH_t \geq (1 + r)\ CH_{t-1} \qquad (61)$$

In a model such as the one we are dealing with, the problem of the terminal year investment always has to be considered. Models of this type usually do not allocate investment at the terminal year since there is no output after that point, or as it has been described, the terminal year is the end of the world for the model. One way to solve this problem, which will be adopted in this model, is to make investment at the terminal year related to the desired rate of growth of output in the post-terminal year (Porter, 1970) Since our goal is to ensure continuous high standards of living, the terminal conditions will set the desired growth rate for oil and nonoil sectors and by ensuring a continuous growth in the nonoil sector will ensure continuous growth in aggregate consumption.

In this model, we have two sectors, oil and nonoil, and gross investment in the terminal year is the sum of investment by each sector:

$$I_T = IN_T + IO_T \qquad (62)$$

For the nonoil sector, investment will be used to replace depreciated capital stock or to increase capital stock:

$$IN_T = \delta KN_T + (KN_{T+1} - KN_T) \quad (63)$$

and from the production function 44:

$$KN_T = \alpha nQN_T \quad (64)$$

$$KN_{T+1} = \alpha nQN_{T+1} \quad (65)$$

subtracting 64 from 65:

$$\therefore kN_{T+1} - KN_T = \alpha n(QN_{T+1} - QN_T) \quad (66)$$

If we assume that the desired rate of growth of the nonoil output for the post-terminal year period is gn:

$$\therefore QN_{T+1} - QN_T = gn\ QN_T \quad (67)$$

Substituting 64, 66, and 67 in 63, we get the following function:

$$IN_T = \delta\alpha n\ QN_T + \alpha n\ gn\ QN_T \quad (68)$$

$$IN_T = QN_T\ (\delta\alpha n + \alpha n\ gn) \quad (69)$$

The last function (69) can be added as an extra constraint in the last period of the model.

We follow the same procedure for the oil sector, where we get the constraint (70) which could be added to the last period to accommodate for the oil sector investment in that period.

$$IO_T = QO_T\ (\delta\alpha O + \alpha O\ gO) \quad (70)$$

where:

gO = desired rate of growth of oil output in the post-terminal year period.

A list of the variables for the model follows.

List of variables:

GDP = gross domestic product
M = total imports
CH = private consumption expenditure
I = gross investment
CG = government consumption expenditure
E = total exports
QO = value added by the oil sector
QN = value added by the nonoil sector
IO = investment by oil sector
IN = investment by nonoil sector
S = total domestic saving
SF = foreign saving
GR = government revenues
GRO = government revenues from oil
GRN = government revenues from nonoil sector
LPF = repatriated compensation of foreign labor
RF = net foreign transfers
PIN = net property and entrepreneurial income
LF = total non-Saudi labor force
WI = total wage income
OSF = operating surplus paid to foreigners
PIF = property and entrepreneurial income from abroad
IF = investment abroad
OS = total operating surplus
EO = exports from oil sector
KN = capital stock at the nonoil sector
LN = labor at the nonoil sector
KO = capital stock at the oil sector
LP = labor at oil sector
GVO = gross value of oil
qO = quantity of oil produced
PO = world oil price
qE = the quantity of oil exported
qD = the quantity of oil consumed domestically
TLD = total labor demand
TLS = total labor supply
LS = Saudi labor force
LF = non-Saudi labor force
PL = number of permits issued for foreign labor by the government
PR = oil proven reserves

D. Data Set

This model includes 40 variables. From those variables, there are only four exogenous variables, CG, RF, PO, and PR. While the values of these exogenous variables have to be supplied to the model at each period, which implies certain assumptions about their changes over time, the values of the endogenous variables will be output of this model. The naming and specification of the variables of this model follow closely the official government classification as published in the National Accounts of Saudi Arabia. The gross domestic product (GDP) will be the gross output of the resident producers less the purchasers' values of their intermediate consumption which is, in other words, the producers' values of the value added of the resident producers plus import duties. The value added in both the oil sector (QO) and the nonoil sector (QN) are the gross domestic product originated in these two sectors and they added up to the gross domestic product.

The variables in the model represent aggregate macroeconomic variables and the only disaggregation is distinction between the oil sector and nonoil sector sets of variables.

From the 24 parameters included in the model, there are 7 which will be assigned specific values. These seven are ω, i, r, g_n, g_o, f, and δ. The rest of the parameters will be estimated statistically including the capital output ratios and the labor output ratios of both the oil and the nonoil sectors.

1. Data sources

One of the major factors affecting the choice of a certain model is the availability of the data. Data availability determines to what extent the model builder should expand his model, since the more data available the more freedom the model builder has in constructing the structure of the model.

The data available for Saudi Arabia plays a major factor for building the model in its present form. There are three major sources for Saudi Arabia economic data which are published yearly:

1. National Account of Saudi Arabia which is published by the Central Department of Statistics, Ministry of Finance and National Economy, Riyadh, Saudi Arabia.
2. Saudi Arabian Monetary Agency (SAMA) Annual Report and the Statistical Summary both published by SAMA each year.
3. The Statistical Year Book published by the Central Department of Statistics, Ministry of Finance and National Economy, Riyadh, Saudi Arabia.

Data from the above sources, from the United Nations Income Accounts, and International Monetary Fund Financial Statistics will be utilized to estimate the functions of the model, get the value of the parameters, and get the other predetermined variables needed to run the model.

2. Estimation

To apply the model and get the optimal trajectories for the endogenous variables, we need to supply it with initial data. These initial data consist of the values of the stock variables in the base year, the values of the exogenous variables, and an estimation of the coefficients and parameters of the different functions of the model.

a. Stock variables These variables are the independent variables measured at the base year. These variables include the capital stock in both the oil sector ($KO_{(0)}$ and the nonoil sector ($KN_{(0)}$), the stock of assets held outside the country ($IF_{(0)}$), and the quantity of oil proven reserves at the base year ($PR_{(0)}$). Another variable which has to be estimated in the base year is work force variable with its component of Saudi and non-Saudi workers.

Nonoil capital stock ($KN_{(0)}$): This variable represents the amount of physical capital existing in the nonoil sector at the base year. There is no figure available for this variable and it has to be estimated. This variable is not only difficult to estimate but also its measurement has been the subject of an intense debate which makes any estimate open to the question of whether it reflects the true value of the capital stock (Motamen, 1979). There are, in general, two methods to estimate this variable. The first is to add up the value of investment over a long period of time, where the choice of the starting point is arbitrary. The second method is to assume a capital output ratio and estimate the capital stock using the available value added in the non-oil sector and the capital output ratio.

Using the first method, Ballool (1981) estimated the capital stock in the nonoil sector in 1970 to be SR 17,055 million. Using this figure as our base for estimating the capital stock in the nonoil sector, we got a time series of this variable from 1970 to 1982 by applying the following formula:

$$KN_{(t)} = KN_{(t-1)} + (IN_{(t-1)} - \delta KN_{(t-1)})$$

where the capital stock in any period is equal to the capital stock of the previous period plus net investment. The coefficient δ represents the depreciation rate which is assumed to be 10%. The results are presented in Table 12 where the estimate of the capital stock in the nonoil sector in 1982 is SR 201,221 million.

Capital stock in oil sector ($KO_{(O)}$): What is said about the capital stock in the nonoil sector in terms of availability of data and difficulty of estimation is applied to the capital stock in the oil sector. According to the Industrial Statistics (see Aldoasary, 1983), the capital stock in the oil sector is estimated to be about SR 24,751 million in 1978. This figure represents the fixed capital assets in the

Table 12. Investment and capital stock in the nonoil sector from 1970 to 1982 (million Saudi Riyals)[a]

Year	Investment (IN)	Capital stock (KN)
1970	2,270	17,055
1971	2,354	17,620
1972	2,733	18,212
1973	3,654	19,123
1974	5,767	20.864
1975	14,182	24,546
1976	28,118	36,274
1977	43,876	60.764
1978	58,838	98,562
1979	68,432	147,544
1980[b]	84,805	201,221
1981	95,565	265,905
1982	109,711	334,879

[a]Source: Saudi Arabia Monetary Agency, different issues (Ballool, 1981).

[b]KN_{1980} used in the model is not KN_{1980} as used in this table because I am using a five year-period and the value used in the model is an average of five-year period.

$$KN_{1980} = \frac{KN78 + 79 + 80 + 81 + 82}{5} = 209.$$

oil sector, including the petroleum refinery sector in Saudi Arabia. To get the value of KO in our base year 1980, we apply the same formula as the one for the nonoil capital stock:

$$KO_{(t)} = KO_{(t-1)} + (IO_{(t-1)} - \delta KO_{(t-1)})$$

and we assumed δ to be 10%. The results are presented in Table 13 where the capital in the oil sector in 1980 is SR 35,518 million.

Foreign assets: The International Monetary Fund estimated the net foreign assets accumulated by the year 1980 to be SR 313,830 million (Financial Statistics; International Monetary Fund, 1983).

Labor Force: While there is no unique figure for the estimate of the labor force in Saudi Arabia, the most accepted estimate is 3,870,000 workers in the country in 1980. The non-Saudi labor force is estimated to be 2,400,000 workers in the same year.

Oil proven reserves (PR): The country is estimated to possess 158 billion barrels of crude oil in 1980.

b. Exogenous variables We have three exogenous variables which will be determined outside the model and their values will be supplied to the model at each time period. These variables are government expenditure (CG), net foreign transfers (RF), and the oil price (PO).

Government expenditure, which includes a large proportion

Table 13. Investment and capital stock in the oil sector from 1970 to 1982 (millions of Saudi Riyals)[a]

Year	Investment (IO)	Capital stock (KO)
1970	327	12,719
1971	577	11,744
1972	670	11,173
1973	2,040	10,726
1974	2,633	11,693
1975	3,659	13,157
1976	5,422	15,500
1977	7,316	19,372
1978	8,053	24,751
1979	8,222	30,329
1980	12,763	35,518
1981	10,811	44,229
1982	12,604	50,617

[a]Source: Saudi Arabian Monetary Agency, annual reports, different issues (Aldoasary, 1983).

devoted to arms purchases and military expenditure, is not a function of the performance and behavior of the economy, and the determinant of its level is purely a political decision (Ballool, 1981, p. 303). To supply CG to the model at each time interval, we assume a rate of annual increase of 5%.

Most of the foreign transfers are government transfers to foreign countries and international agencies. Since the oil price increase of 1973, Saudi Arabia has emerged as the largest OPEC aid donor and given its oil reserves and financial assets, it is most likely to maintain a large-scale foreign aid over a long period of time. These foreign aids are determined purely by political variables and the security needs of the country have the greatest impact on aid policies (Hunter, 1984). The net foreign transfers variable (RF) will be considered as an exogenous variable assuming a 5% rate of growth annually. Table 14 represents the values of CG and RF which will be used in this model.

Because of the fluctuations of the oil market in the 1970s and the early 1980s, it is very difficult to project the oil prices in the future. This study is certainly not undertaken to determine the future course of the oil price, rather, its main concern is to explore a strategy for development planning in an oil based economy. The introduction of future oil prices to the model will set future oil income and future oil production which has a very important implica-

Table 14. Projection of government expenditure (CG) and net foreign transfers (RF) (billions of Saudi Riyals)

Year	CG	RF
1980	76.10	34.27
1985	97.10	43.73
1990	123.90	55.79
1995	158.10	71.19
2000	201.74	90.85
2005	257.40	115.92
2010	324.40	147.91

tion in terms of future economic development. But a model of this type, which concentrates mainly on the expenditure side of this income in a way consistent with the long-run economic goals of an oil-based economy, is expected to yield different results for the endogenous variables with different expectations of the future oil prices. This can be explored by using sensitivity analysis where there are different scenarios of the future course of oil prices. For the time being, for the first run of the model, the real price of oil will be assumed constant at the 1980 level.

c. Estimation of parameters The equations of the model are divided into three types: identities, behavior, and technical relationships. We need to estimate both the behavior and technical relationships. The ordinary least squares estimation procedure will be used to estimate the parameters of both the behavior and technical equations, using different tests applied to such procedures. The following results are the best estimations of those procedures.

Estimates of the behavior function:

1. Saving function (5)

$$S = .4796\ GDP$$
$$(24.497)^{1}$$

2. Government revenue from oil (7)

$$GRO = .877\ QO$$
$$(32.3696)$$

3. Government revenue from nonoil (8)

$$GRN = .1839\ QN$$
$$(28.2079)$$

4. Compensation of foreign labor (10)

$$LPF = .000641\ LF + .0225\ WI$$
$$(7.1057) \qquad (6.9548)$$

5. Operating surplus paid to foreigners (15)

$$OSF = .0814\ OS$$
$$(6.9406)$$

---

[1]Value of the t-ratio.

6. Wage income (16)

$$WI = .19098\ GDP$$
$$(24.951)$$

7. Operating surplus (17)

$$OS = .8087\ GDP$$
$$(83.2313$$

8. Import function (20)

$$M = .5277\ CH + 4298\ I + .5705\ CG$$
$$(9.947) \quad (7.541) \quad (4.383)$$

9. Consumption function (21)

$$CH = .6593\ QN$$
$$(28.1669)$$

10. Relation between GVO and QO (26)

$$QO = .823\ GVO$$
$$(26.7908)$$

11. Relation between qD and QN (30)

$$qD = .001456\ QN$$
$$(23.9)$$

Estimation of the production functions:

For the oil sector, the following estimates are obtained by OLS:

$$QO = 6.4098\ KO$$
$$(10.6826)$$

$$AO = 4.7964\ LO$$
$$(11.1910)$$

In estimating the production function for the nonoil sector by OLS, the intercepts are significant in the relation between labor and output.

$$QN = .6911\ KN$$
$$(16.82)$$

$$QN = -99.976 + .06136\ LN$$
$$(-18.6783)\ (31.2285)$$

Using the values of the stock variables, the exogenous variables, and the parameters estimated as represand earlier, the model will be run to yield a numerical solution to the model. The dynamics from one period to the other will be carried, as specified by the model, through investment and growth of labor. Investment in any period will result in an expansion in the productive capacity in the next period since it will increase capital stock. As labor grows from one period to the other, the ability to produce will increase.

E. Numerical Results

Before presenting the numerical solution of our planning problem, it is very important to stress that the goals of development in Saudi Arabia are too complex to be captured in a simple model like the one we are dealing with. The main purpose of the simple two-sector model we have developed is to assist in exploring the long-run perspective of inter-temporal investment strategies of the Saudi economy given the lifetime of the oil resource. The numerical results of the model should be interpreted very carefully and our attention should be focused on the direction of the values of the variables over time rather than on their absolute values. Also, it is very important to have a great deal of refinement and more reliable data to improve upon this model and its use in the context of policy application.

The model when solved will produce an optimal trajectory for the endogenous variables and, in order to get a numerical solution, certain initial data have to be supplied. Those initial data include the values of the stock variables in the base year, the values of the exogenous variables, and numerical values for the set of coefficients and parameters. In the previous chapter, we provided an estimation of all the initial data needed, and it is necessary before presenting the numerical solution of the model to summarize those initial data. This has been done in Tables 15 and 16. The first table provides the values of the stock variables in the base year, namely 1980, measured in billions of Saudi Riyals. The stock variable here represents an average of five-year values since, in our model, we are dealing with time intervals, each consisting of five years. The second table is a summary of the parameters of the model which were estimated in the previous chapter.

The model includes seven discrete time intervals, each one consisting of five years. The optimal values produced by the model of the endogenous variables will be given at the

Table 15. Values of the stock variables at 1980 (billions of Saudi Riyals)

Variable	Values
KN	209
KO	37
CG	76
RF	34
IF	313
PR[a]	158

[a]Billion barrels.

beginning of each time interval. The base year of the model is 1980 and the terminal year is the year 2014.

The results of the model are reported in Table 17, which is a summary of the values of all the model variables at each time period. To compare the results of the model to the actual numbers of 1980 as reported by the Saudi Arabian government statistics, the first column in Table 17 contains the actual 1980 figures.

Looking at the model results for 1980 and comparing them to the actual figures as reported in the first column, we notice that they are very close. But, while the actual production of oil (QO) in 1980 was 3.6238 billion barrels, the model produced a lower level of production. The optimal

Table 16. Summary of the parameters of the model

Parameter	Values
w	.08
s	.4796
r_2	.8774
n_2	.1839
ℓ_1	.000641
ℓ_2	.0225
i	.08
a_2	.0814
b_2	.19098
c_2	.8087
mc	.5277
mi	.4298
mg	.5705
c	.6593
αn	.6911
βn	.06136
δ	.10
α_0	6.4098
β_0	4.7965
d_2	.823
e	.001456
r	.03
g_n	.05
g_o	.05
f	.13

Table 17. Summary of the model's results: First run (billions of Saudi Riyals)

Variable	Actual 1980 values	Model values						
		1980	1985	1990	1995	2000	2005	2010
GDP	385.81	330.29	383.13	444.45	638.86	761.87	967.25	1122.01
M	132.35	135.98	195.55	234.38	282.51	341.34	403.57	475.86
CH	102.39	95.00	115.59	160.14	194.84	237.06	288.43	350.94
I	79.72	98.54	183.90	183.90	207.81	234.83	242.57	244.97
CG	76.10	76.10	97.10	123.91	158.10	201.74	257.40	324.40
E	258.49	233.65	242.55	210.87	375.78	438.46	582.42	677.57
QO	250.05	206.50	218.51	201.43	343.20	402.14	529.56	589.48
QN	135.76	123.79	164.62	243.00	295.66	359.73	437.68	532.53
IN	67.46	93.57	175.68	175.68	200.62	227.01	228.31	231.17
IO	12.26	4.96	8.23	8.23	7.19	7.82	14.26	13.79
S	166.84	158.53	183.90	213.33	306.65	365.69	464.28	538.56
SF	87.12	60.00	0	0	0	0	76.25	44.79
GR	211.20	203.88	221.93	221.36	355.39	418.87	544.96	614.96
GRO	189.30	181.10	191.64	176.66	300.99	352.68	464.43	516.97
GRN	21.90	22.78	30.29	44.71	54.40	66.19	80.53	97.99
LPF	3.2118	2.78	3.269	4.14	5.32	6.27	7.69	9.00
RF	34.27	34.82	43.73	55.79	71.19	90.85	115.92	147.91
PIN	1.54	.07	0	4.02	16.76	0	7.78	0
WI	75.30	63.09	73.18	84.89	122.02	145.52	184.74	214.30
OSF	20.64	21.64	25.12	29.12	41.86	50.14	63.38	73.52
PIF	19.10	21.57	25.12	25.11	25.11	25.11	55.60	73.52
IF	313.83	313.83	313.83	313.83	313.83	313.83	695.09	919.05
LF[a]	2447	2262	2703	3713	4295	4997	5884	6996

[a]Values in thousands of workers.

Table 17. (Continued)

Variable	Actual 1980 values	Model values						
		1980	1985	1990	1995	2000	2005	2010
OS	311.90	267.20	309.96	359.55	516.84	616.35	782.50	907.71
EO	258.49	233.65	242.55	210.87	375.78	438.46	582.42	641.99
KN	209.62	209.62	520.28	1008.45	1130.51	1161.03	1425.29	1497.85
LN[a]	3818	3644	4309	5585	6443	7487	8756	10301
KO	37.1	37.09	34.09	49.65	53.54	62.73	82.61	91.96
LO[a]	53	43	45	42	71	84	110	123
GVO	347.07	250.91	265.51	244.75	417.01	488.83	643.46	716.25
qO[b]	3.6238	2.620	2.772	2.556	4.354	5.102	6.718	7.478
qE[b]	3.5099	2.440	2.553	2.202	3.924	4.578	6.081	6.703
qD[b]	.1139	.180	.239	.354	.430	.524	.637	.775
L[a]	3871	3687	4355	5628	6515	7571	8867	10424
LS[a]	1424	1424	1651	1914	2219	2573	2983	3458

[b]Values in billion barrels.

level of production in 1980 was 2.620 billion barrels. This result confirms the idea that Saudi Arabia was producing, during that period, more oil than what was actually needed for economic development. The lower level of oil production was reflected in a lower level of Gross National Product in that year. Another point of interest arises when comparing the actual 1980 figures with the optimal values, as produced by the model, which is the lower level of investment in the actual 1980 figures. The optimal value of I is 98.54 billion Riyals compared to the lower level of 76.10. In terms of investment in each sector, we notice the lower level of investment in the nonoil sector coupled with higher than optimal levels of investment in the oil sector.

While Table 17 includes the values of the exogenous variables as they were estimated in the previous chapter, it also includes the values of the endogenous variables which are the products of solving our linear programming dynamic model. Table 17 shows the time path of the endogenous variables over the planning period.

The model is set to maximize the objective function which contains the aggregate private consumption in each time period and, because of close relations between this variable and the nonoil sector value added, the model will solve for the optimal trajectory of the nonoil value added and the rest of the endogenous variables will be determined in relation to this variable.

Our attention will be focused on the time path of the most important variables of the model. Since the main goal of the model is to develop the nonoil sector, it is very important to look at the time path of the nonoil investment (IN). The model set itself to finding the optimal path of this variable over time.

The time path of the nonoil investment is shown in Figure 1 where we notice the continuous growth over time of IN which will provide the capital needed for the growth of production in the nonoil sector. The increase over time of IN is the reason and a direct result of the expanding absorptive capacity of the economy. It should be noticed that in Saudi Arabia most of the domestic investment during the 1970s was devoted to building the infrastructure of the country which resulted in an expanded absorptive capacity and enabled the country to make higher levels of investment.

Certainly, the growth of the nonoil value added, as can be seen in Figure 2, comes as the investment in that sector grows over time.

Comparing the value added of the oil sector with the value added of the nonoil sector, we notice the continuous dominance of the oil sector in the early periods and in the last periods, since the model tends to exhaust the country's oil reserves which resulted in a high production of oil in

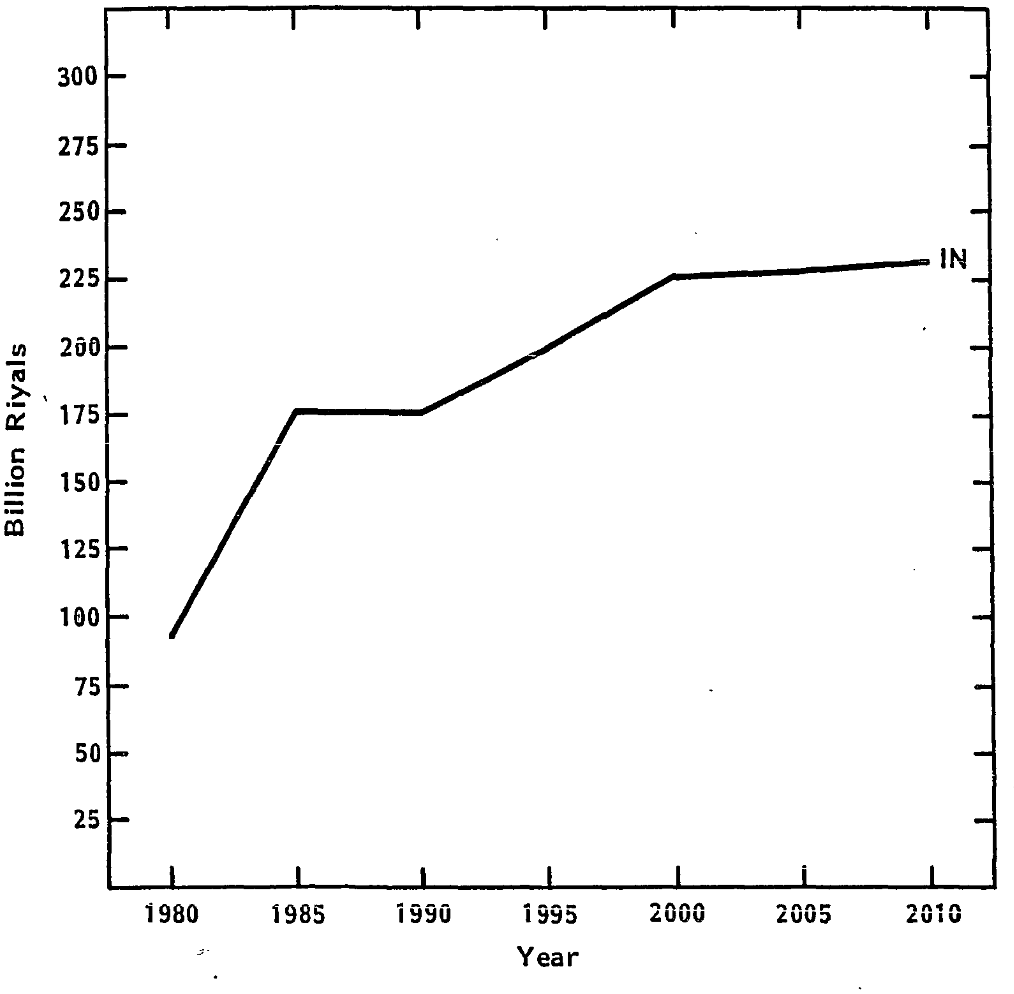


Figure 1. The time path of the nonoil sector investment (IN) (1980-2010)

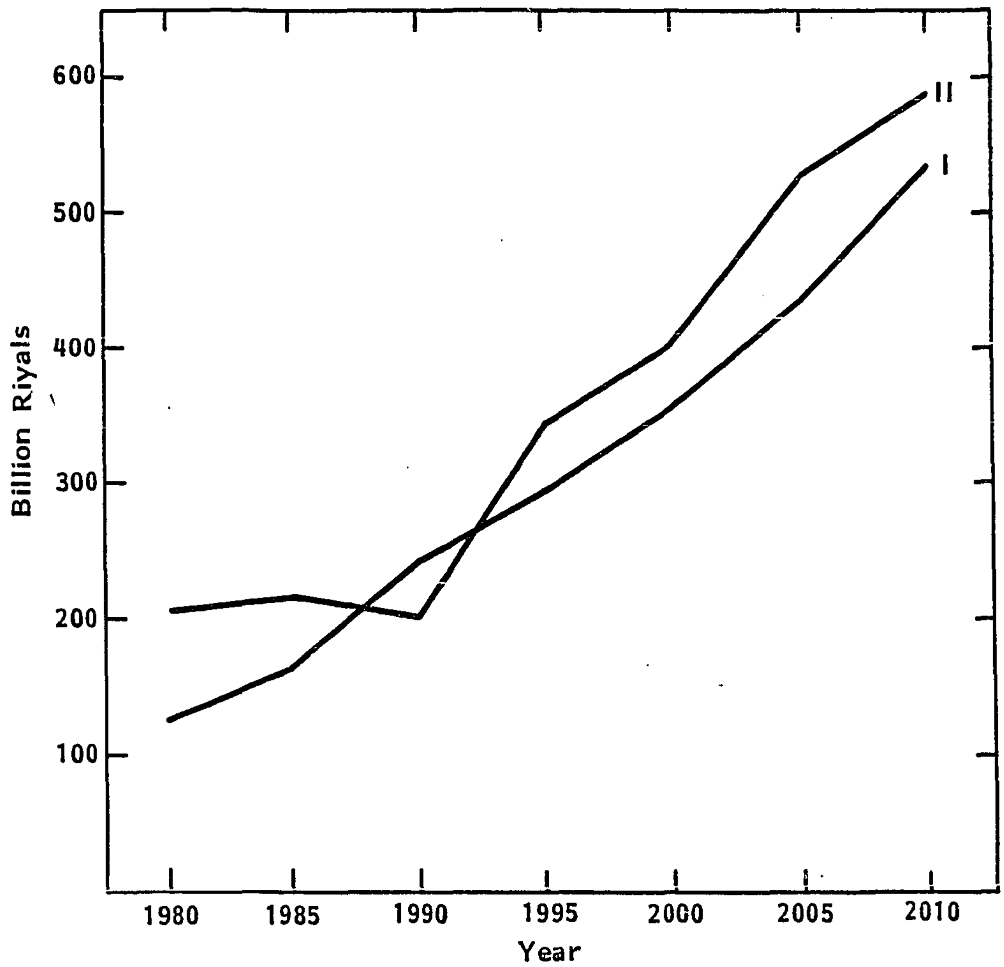


Figure 2. The path of the oil and nonoil value added (1980-2010); I = nonoil value added, II = oil value added

the last three periods.

One of the most interesting results of the model is the situation of the balance of payments over time, with the exception of the first and the last two periods, the model produced a balanced current account which shows that the country would not need to borrow or use its international reserves to finance its expanding investment policy over the lifetime of the oil resource. On the contrary, with the level of oil production envisioned by the model results, the country will be able to maintain its international reserves over the planning period and add more to them in the last two periods. That will ensure their utilization for the welfare of the future generations and the enjoyment of the continuous income from the investment of those international reserves abroad. One note concerning the foreign trade is that the exports of crude oil and oil products will dominate the export sector until the depletion of oil which makes the oil sector still yet the main source of foreign exchange needed for the growing demand of imports during the planning period.

The expansion of the nonoil sector demands an increasing number of laborers. The ability of the country to supply a domestic labor force to satisfy the increasing demand of the nonoil sector is very limited. That necessitates the increasing demand for expatriate laborers which has happened in the recent past in Saudi Arabia and is expected to happen in the future.

The first run of this model, as represented in Table 17, confirms this fact. It should be noticed that, in the first run of this model, a liberal policy concerning foreign labor was adopted. It allows as many foreign laborers as needed to come to the country. In this case, labor was not a binding constraint. This is to assume that labor is in a perfectly elastic supply and in the absence of domestic labor, the services of such laborers can be imported from abroad. The results in Table 17 indicate a continuous increase in both the foreign labor number and the percentage in the total labor force. While the number of foreign workers in the country was more than two million in 1980, which represented about 60% of the labor force, it will increase to more than four million 1995 and that represents 65% of the total labor force in the country. By the last period, the number of foreign laborers will reach 6.9 million and that is 66% of the total labor force.

The kind of policy adopted in the first run of this model will increase the number of foreign laborers and increase the country's dependence on foreign labor. Since the presence of a large number of foreign workers in the country could represent a potential threat to the country's social stability, one of the goals of economic development is to limit dependence on expatriate workers and increase the participation of the Saudis in the labor force.

To examine how the labor constraint will affect the future economic development of Saudi Arabia, we will run the model again with a binding labor constraint. One plausible scenario is to keep the percentage of foreign labor to Saudi labor constant over the planning period. The percentage share of the foreign labor in the total labor force in Saudi Arabia will be kept constant at the 1980 level which was about 60%.

The results of running our model using the above constraint are presented in Table 18. The introduction of this labor constraint will affect mostly the nonoil sector since it is a labor intensive sector and little can be said about the effect of this new constraint on the level of the output or value added in the oil sector. The level of both the value added and investment in the nonoil sector is less over time than what it was in the first run (see Figure 3). This result indicates the importance of a very carefully designed foreign labor policy. Any drastic reduction in the foreign labor force in the country may undermine the effort of economic development and its main goal of economic diversification. It is important to stress that any policy designed to limit the foreign labor in the country should be coupled with a serious effort to increase the participation of Saudi citizens in the labor force. That could be accomplished by extensive education, training and an increase of participation

Table 18. Summary of the model's results: Second run (billions of Saudi Riyals)

	Model values						
Variable	1980	1985	1990	1995	2000	2005	2010
GDP	319.78	338.56	415.63	514.54	620.28	830.61	963.50
M	127.64	150.49	183.45	224.07	274.21	336.19	410.65
CH	95.00	115.58	140.63	171.11	208.19	253.30	308.19
I	79.13	79.13	89.41	101.04	114.18	129.01	145.79
CG	76.10	97.10	123.90	158.10	201.74	257.40	324.40
E	225.06	197.24	245.13	308.36	370.38	527.08	595.77
QO	195.99	180.46	223.76	280.63	304.36	474.64	539.03
QN	123.79	158.08	191.87	233.92	315.92	355.96	424.47
IN	73.91	73.91	82.41	93.73	104.12	119.17	184.26
IO	5.21	5.21	7.01	7.31	10.01	9.84	12.61
S	139.13	162.51	199.50	246.98	297.73	398.69	462.48
SF	60.00	0	0	0	0	65.58	29.49
GR	189.16	187.36	231.54	289.15	325.05	481.76	550.83
GRO	171.88	158.27	196.24	246.11	266.92	416.26	472.73
GRN	17.27	29.09	35.30	43.04	58.13	65.41	78.10
LPF	2.60	3.01	3.76	4.49	5.32	6.29	7.70
RF	34.82	43.73	55.79	71.19	90.85	115.92	147.91
PIN	0	0	2.13	8.61	0	3.09	0
WI	55.36	64.66	79.39	98.28	118.47	158.64	184.03
OSF	21.57	22.19	27.24	33.72	3.69	54.43	63.14
PIF	21.57	25.12	25.11	25.11	25.11	51.34	63.14
IF	313.83	313.83	313.83	313.83	313.83	641.72	798.83
LF[a]	2262	2589	3292	3805	4426	4541	5948

[a]Values in thousands of workers.

Table 18. (Continued)

Variable	Model values 1980	1985	1990	1995	2000	2005	2010
OS	234.49	273.89	336.25	416.26	501.80	671.96	779.47
EO	225.06	197.24	245.13	308.36	325.76	527.08	595.77
KN	209.62	421.98	475.07	530.79	601.36	821.26	1006.48
LN[a]	3645	4202	5160	5966	6935	7425	9293
KO	37.09	35.34	34.91	43.78	47.48	74.06	84.08
LO[a]	41	37	46	58	63	99	112.66
GVO	238.15	219.28	271.89	340.98	369.82	576.72	654.96
qO[b]	2.486	2.289	2.839	3.560	3.861	6.022	6.838
qE[b]	2.349	2.059	2.559	3.219	3.401	5.503	6.220
qD[b]	.137	.230	.279	.341	.460	.519	.618
L[a]	3686	4240	5206	6024	6999	7524	9406
LS[a]	1424	1651	1914	2219	2573	2983	3458

[b]Values in billion barrels.

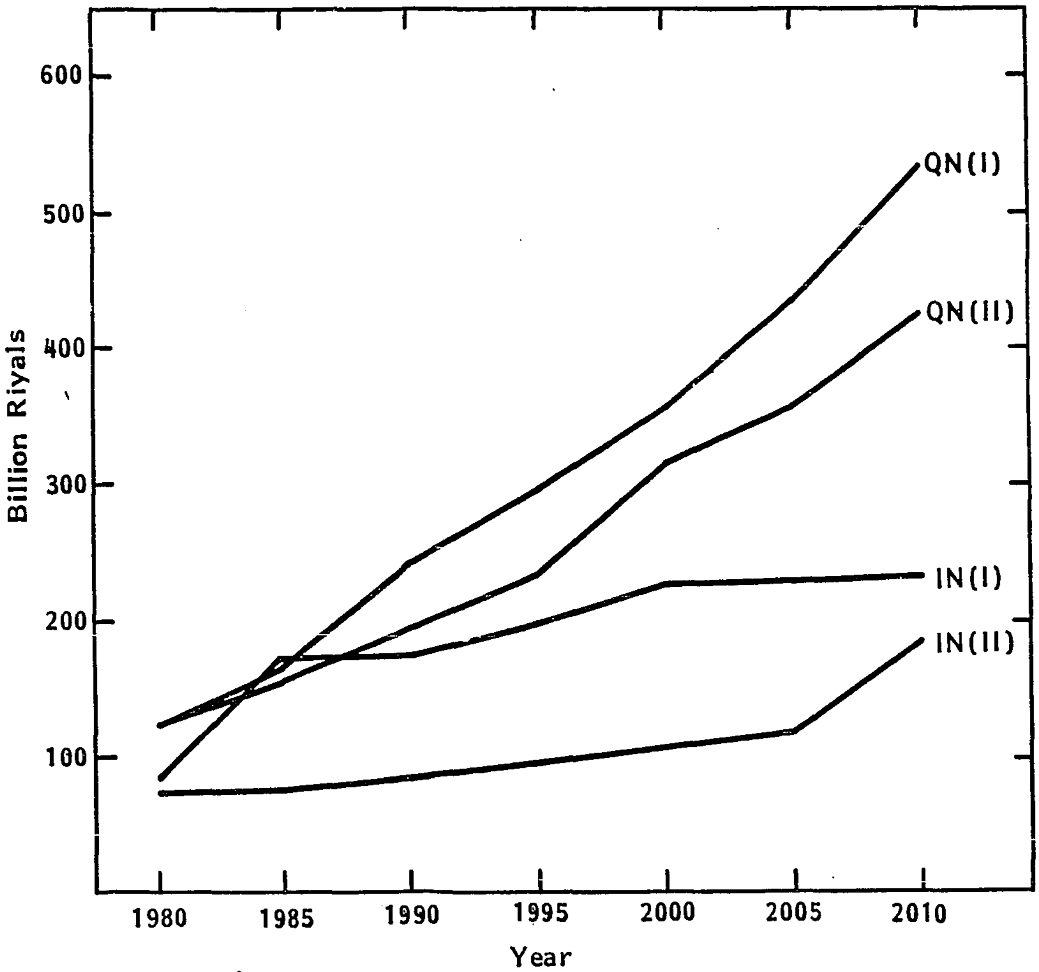


Figure 3. The time path of the nonoil value added (QN) and the nonoil investment (IN); I = first run, II = second run

of women in the labor force.

The application of this model to Saudi Arabia and the results obtained provided evidence of the ability of Saudi Arabia, in the future, to use its oil resources to develop its domestic economy. The optimal results of the model presented in Table 18 provide a smooth oil production over time which is consistent with the needs of economic development of the country. The level of oil production envisioned by the model which will satisfy this goal is only 2.486 billion barrels in 1980. This amounts to 6.8 million barrels per day during the five-year period from 1980 to 1985. It will not exceed the 8 million barrels per day level until 1995 when it will reach less than 10 million barrels per day. This model envisioned an exhaustion date of the oil resources in the country in 2014, which is the terminal year of the model. As a result, a noticeable increase in the oil production is seen during the last two periods of the model. The oil resources may not in reality be exhausted by the terminal year of the model, considering the potential of more oil discoveries in the country, which is not taken into account in this model.

The amount of oil production during the planning period will be the main source of foreign exchange needed for an increasing import demand and will provide the surplus needed for investment in the nonoil sector. It is also worth noting that the country will not accumulate more foreign assets during the early intervals of the planning period and the level of foreign assets will stay as it was in 1980. During the last two periods of the model, the high oil output provides a surplus in the country's current account which could be added to the country's foreign assets which will generate income in the future periods.

Finally, while the model is mainly intended to provide a demonstration of the methodology for planning an oil-based economy, it shows the possibility of transferring the oil income into a productive capital in the oil-rich countries and that requires a policy of extensive investment in the nonoil sector which cannot be done without a direct intervention by the government since it controls the main source of investable income.

V. CONCLUSION

The main objective of this study was to develop a planning model for the oil-based economy of Saudi Arabia. The model when applied will be a good tool which provides some assistance in evaluating different long-term strategies open to the country while pursuing its aim of diversifying its economy and reducing its dependence on one depletable source of income, namely oil.

Development planning in the less developed countries (LDC) has gained popularity after the Second World War and virtually all LDC now are engaged in development planning in one way or another. The oil-based economies of the Middle East are part of the underdeveloped world. They share most of the major characteristics with the underdeveloped countries. They are different in that the increase of oil prices during the 1970s provided these countries with a substantial amount of foreign exchange. As a result, the financial constraints which are considered the major constraints to development in LDC were eased for some oil-based economies and eliminated for others.

The oil-based economies of the Middle East depend on production and exportation of oil to the rest of the worls as the main source of revenues and foreign exchange. This dependency has increased over time, especially during the 1970s. The danger of increasing dependence on oil comes from the nature of the oil resource itself. It is a nonrenewable resource that is going to be depleted sooner or later, and any event that would adversely affect the price or the quantity produced of oil could have undersirable consequences on the economy. Realizing this fact, the most urgent goal of economic development is to diversify the structure of the economy and use the oil income to build a nonoil sector which can replace the income generated from the oil sector when the oil resources are depleted.

The governments of the oil-based countries play a very important role in the process of economic development through the practice of development planning. Long-term prospective planning will be of a substantial help in giving indications as to how fast the oil resources should be exhausted and how the oil revenues should be spent. The development planning in the oil-based economies should consider two sets of decisions. The first one is to decide whether to produce oil and use its revenues to finance current development or use its revenues for investment abroad where its income could be used to finance future investment or keep oil in the ground for future sale. The second one is to evaluate different domestic programs and projects and choose the ones that use the available resources as efficiently as possible.

Saudi Arabia is the largest oil producer and has the largest amount of oil reserves in the Middle East. The economy of Saudi Arabia is an oil-based economy where the oil sector is the main source of foreign exchange earnings, government revenues, and a source of growth of the national income. The growth of the economy is limited by shortages of labor and a limited absorptive capacity. The country has enjoyed a period of high income and high growth during the 1970s as a result of the increase in oil prices and oil production. But the basic fact about this economy is that it is still dependent on oil which is an exhaustible resource.

Development planning was initiated by the Saudi government and development plans have been prepared in order to take advantage of the new resources and to finance economic and social progress. Because the oil is the major source of income and since it is a nonrenewable resource, the national utilization of this resource for the ultimate goal of creating a self-sustained economy which can replace this dependence on oil in the future becomes very eminent, and development planning is considered the best way to do that.

In this study, an optimal two-sector macroeconomic planning model was developed for the Saudi economy. Using the technique of linear programming, the model was solved to obtain optimal time paths of major macroeconomic variables which are compatible with the long-term goal of economic development of Saudi Arabia. It provides the optimal trajectories of investment in the nonoil sector over the planning period. As far as the oil sector is concerned, the model assumes a lifetime for the oil resource and investigates the intertemporal pattern of resource extraction which is compatible with the long-term strategy of developing the nonoil sector.

The model, as with any linear programming model, has an objective function and a set of linear constraints. The objective function reflects the main goal of the development planning of Saudi Arabia, which emphasizes the development of the nonoil sector. Because of the close association between the aggregate private consumption and the nonoil sector, the aggregate private consumption constitutes the main component of the objective function. The constraints are part of the two-sector macro-model which describes the relationships between the different economic variables in the oil-based economy of Saudi Arabia. To solve the model, it has to be provided with initial values which are stock variables in the base year and different parameters. The process of optimization led to a set of optimal values of the endogenous variables at the beginning of different discrete time intervals. Each interval is five years and the base year of the model is 1980 and the terminal year is 2014.

The results of the optimization indicated the possibility of developing a nonoil sector in the oil-based economy, but that requires a high level of investment compared with production in the nonoil sector for a long time. When the optimal figures were compared with the actual figures of 1980, they were very close, with the exception of the rate of production of oil. While the actual production of oil in 1980 was 3.623 billion barrels, the model produced a lower level of production which confirms the idea that Saudi Arabia during that time was producing more oil than what was actually needed for economic development. The optimal results of the model provided an oil production over time which is consistent with the needs of economic development of the country. The level of oil production envisioned by the model is only 2.486 billion barrels in 1980. This equals to 6.8 million barrels per day during the five-year period from 1980 to 1985. The level of oil production will not exceed 8 million barrels per day until 1995 when it will reach around 10 million barrels per day.

The optimal results indicated that the country will enjoy a balanced current account over the planning period except the first and the last two periods when it will enjoy a surplus. That shows that the country would not need to borrow or use its international reserves to finance its expanding investment during the lifetime of the oil resource. The country will be able to maintain its international resources over the planning period and add more to them in the last two periods. That will ensure their utilization for the welfare of the future generations. The dominance of oil and oil products as the main components of exports will continue over the planning period which makes the oil sector the main source of foreign exchange needed for the growing demand for import.

Since the country has shortages in both skilled and unskilled labor, it depends on expatriate laborers to satisfy increasing demand. The presence of large numbers of non-Saudi workers in the country could represent a potential threat to the country's social stability.

The optimal results of the model revealed the increasing dependence on expatriate labor in the future. That was when the first run of the model assumed no binding labor constraint. This is to assume that labor is in a perfectly elastic supply and, in the absence of domestic labor, the services of such laborers can be imported from abroad. That will lead to a continuous increase in both the number of foreign laborers and their percentage of the total labor force. But such policy is not desirable because of its potential threat to social stability. One of the goals of economic development should be to limit the dependence on expatriate workers and increase the participation of the Saudis in the labor force.

To examine how the labor constraint affects the future development of Saudi Arabia, we ran the model again, introducing labor as a binding constraint. We introduced a maximum limit to the number of expatriate workers in the country. This is done by keeping the percentage of expatriate workers in the labor force constant at the 1980 level. The result was a reduction in the nonoil sector output over the planning period compared to the first result. That indicates that any reduction in foreign labor would reduce the nonoil domestic output which means the dependence on foreign labor will continue over the planning period if the country wants to develop its nonoil sector and reduce its dependence on the oil sector. This conclusion indicates how careful the country should be when designing any policy to limit foreign labor. Any policy of this kind should include a serious effort to increase the participation of Saudi citizens in the labor force. One obvious way to achieve that is to increase the participation of the largely underutilized segment of the population, namely women. For the future of Saudi Arabia, it seems imperative and in the best interests of the society to provide more opportunities for women to participate in the economic development of the country.

Finally, it should be clear that the goals of development in Saudi Arabia are too complex to be captured in a simple model like the one we are dealing with. But the two-sector model we developed could be helpful in exploring the long-run perspective of intertemporal investment strategies of the Saudi economy given the lifetime of the oil resource. To improve upon this model, a great deal of refinement and more reliable data are needed.

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VIII. APPENDIX: THE STRUCTURE OF SAUDI ARABIAN NATIONAL INCOME ACCOUNT

Account #1. "Nonoil sector"

A. Operations on Current Account

Debit	Expenditure	Revenue	Credit
1.1 - Compensation of Employees		1.9 - Sales of Final Consumption Goods	
1.1a - to domestic households	3.6a	1.9a - to households	3.1a
1.1b - to abroad	5.5a	1.9b - to government	4.3a
1.2 - Operating Surplus		1.10 - Sales of Intermediate Goods	
1.2a - factor income to domestic household	3.8	1.10a - nonoil sector	1.6a
		1.10b - to government	4.2a
1.2b - factor income to gov.	4.9a	1.11 - Sales of Capital Goods	
1.2c - factor income to abroad	5.6a	1.11a - to nonoil sector	1.16
1.2d - nonoil sector saving	1.19	1.11b - to oil sector	2.11
1.3 - Indirect Taxes	4.6a	1.11c - to government	4.11
1.4 - Direct Taxes	4.7a	1.12 - Subsidies	4.4b
1.5 - Zekat and Jehad	4.8a	1.13 - Property and Entrepreneurial Income from Abroad	5.2b
1.6 - Purchase of Intermediate Goods			
1.6a - from nonoil sector	1.10a		
1.6b - from oil sector	2.8a	1.14 - Export	5.1a
1.7 - Transferred Abroad	5.7c	1.15 - Inventory Variation	1.17
1.8 - Imports	5.4a		

B. Operations on Capital Account

1.16 - Purchase of Capital Goods	1.11a	1.19 - Nonoil Sector Saving	1.2d
1.17 - Inventory Variation	1.15	1.20 - Capital Movements	
1.18 - Capital Movements		1.20a - from households	3.10a
1.18a - to households	3.12a	1.20b - from government	4.12b
1.18b - to government	4.14b	1.20c - from abroad	5.9a
1.18c - to abroad	5.11a		

Account #2. "Oil Sector"

A. Operation on Current Account

Debit	Expenditure	Revenue	Credit
2.1 - Compensation of Employees		2.7 - Sales of Final Consumption Goods	
2.1a - to domestic households	3.6b	2.7a - to households	3.1b
2.1b - to abroad	5.5b	2.7b - to government	4.3b
2.2 - Operating Surplus		2.8 - Sales of Intermediate Goods	
2.2a - factor income to gov.	2.2a	2.8a - to nonoil sector	1.6b
2.2b - factor income to abroad	5.6b	2.8b - to government	4.2b
2.2c - oil sector saving	2.14	2.9 - Inventory Variation	2.12
2.3 Indirect Taxes	4.6b	2.10 - Export	5.1b
2.4 - Direct Taxes	4.7b		
2.5 - Transferred Abroad	5.7d		
2.6 - Imports	5.4b		

B. Operations on Capital Accounts

Debit	Expenditure	Revenue	Credit
2.11 - Purchase of Capital Goods	1.11b	2.14 - Oil Sector Saving	2.2c
2.12 - Inventory Variation	2.9	2.15 - Capital Movements	
2.13 - Capital Movements		2.15a - from government	4.12a
2.13a - to government	4.14a	2.15b - from abroad	5.9b
2.13b - to abroad	5.11b		

Account #3. "Households

A. Operation on Current Account

Debit	Expenditure	Revenue	Credit
3.1 - Private Final Consumption		3.6 - Compensation of Employees	
3.1a - from nonoil sector	1.9a	3.6a - paid by nonoil sector	1.1a
3.1b - from oil sector	2.7a	3.6b - paid by oil sector	2.1a
		3.6c - paid by government	4.1a
3.2 Direct Taxes	4.7c	3.7 - Government Transfers	4.4a
3.3 - Zakat and Jehad	4.8b	3.8 - Factor Income from Nonoil	1.2a
3.4 - Transferred Abroad	5.7b	3.9 - Factor Income from Abroad	5.2a
3.5 - Personal Saving	3.11		

B. Operations on Capital Account

3.10 - Capital Movements		3.11 - Personal Saving	3.5
3.10a - to nonoil sector	1.20a	3.12 - Capital Movements	
3.10b - to government	4.14c	3.12a - from nonoil sector	1.18a
3.10c - abroad	5.11c	3.12b - from government	4.2c
		3.12c - from abroad	5.9c

Account #4. "Government"

A. Operations on Current Account

Debit	Expenditure	Revenue	Credit
4.1 - Compensation of Employees		4.6 - Indirect Taxes	
4.1a - to domestic households	3.6c	4.6a - from nonoil sector	1.3
4.1b - to abroad	5.5c	4.6b - from oil sector	2.3
4.2 - Intermediate Consumption		4.7 - Direct Taxes	
4.2a - from nonoil sector	1.10b	4.7a - from nonoil sector	1.4
4.2b - from oil sector	2.8b	4.7b - from oil sector	2.4
		4.7c - from households	3.2
4.3 - Final Consumption		4.8 - Zakat and Jehad	
4.3a - from nonoil sector	1.9b	4.8a - from nonoil sector	1.5
4.3b - from oil sector	2.7b	4.8b - from households	3.3
4.4 - Transfers & Subsidies		4.9 - Income from Property and Entrepreneurship	
4.4a - to households	3.7	4.9a - from nonoil sector	1.2b
4.4b - to nonoil sector	1.12	4.9b - from oil sector	2.2a
4.4c - to abroad	5.7a	4.9c - from abroad	5.2c
4.5 - Government Saving	4.13	4.10 - Transferred Payment from Abroad	5.3

B. Operations on Capital Account

Debit	Expenditure	Revenue	Credit
4.11 - Purchase of Capital Goods	1.11c	4.13 - Government Saving	4.5
4.12 - Capital Movements		4.14 - Capital Movements	
4.12a - to oil sector	2.15a	4.14a - from oil sector	2.13a
4.12b - to nonoil sector	1.20b	4.14b - from nonoil sector	1.18b
4.12c - to households	3.12b	4.14c - from households	3.10b
4.12d - to abroad	5.11d	4.14d - from abroad	5.9d

Account #5. "External Sector"

A. Operations on Current Account

Debit	Expenditure	Revenue	Credit
5.1 - Exports		5.4 - Imports	
5.1a - nonoil sector	1.14	5.4a - nonoil sector	1.8
5.1b - oil sector	2.10	5.4b - oil sector	2.6
5.2 - Property & Entrepreneurial Income		5.5 - Compensation of Employees	
		5.5a - from nonoil sector	1.1b
5.2a - to individuals	3.9	5.5b - from oil sector	2.1b
5.2b - to nonoil sector	1.13	5.5c - from government	4.1b
5.2c - to government	4.9c		
		5.6 - Property & Entrepreneurial Income	
5.3 - Transfer Payments to Gov.	4.10		
		5.6a - from nonoil sector	1.2c
5.4 - External Surplus	5.10	5.6b - from oil sector	2.2b
		5.7 - Other Current Transfers	
		5.7a - from government	4.4c
		5.7b - from households	3.4
		5.7c - from nonoil sector	7.7
		5.7d - from oil sector	2.5

B. Operations on Capital Account

Debit	Expenditure	Revenue	Credit
5.9 - Capital Movements		5.10 - External Surplus	5.8
5.9a - to nonoil sector	1.20c		
5.9b - to oil sector	2.15b	5.11 - Capital Movements	
5.9c - to households	3.12c	5.11a - from nonoil sector	1.18c
5.9d - to government	4.14d	5.11b - from oil sector	2.13b
		5.11c - from households	3.10c
		5.11d - from government	4.12d

National Product & National Income

Compensation of employees	
a - by nonoil sector	1.1
b - by oil sector	2.1
c - by government	4.1
+ Operating Surplus	
a - nonoil sector	1.2
b - oil sector	2.2
= Domestic Factors Income	
- Compensation of Employees from the rest of the world	5.5
+ Net property & entrepreneurial income from rest of the world	(5.2-5.6)
+ Indirect Taxes	4.6
- Subsidies	4.4

Consumption Expenditure
- by households
- by government

Investment Expenditure
- by nonoil sector
- by oil sector
- by government

Inventory Variations

Surplus of Exports over Imports

= National Income at Market Prices = Gross National Product at Market Prices

- Net Factor Payment Abroad (5.2 - 5.5 - 5.6)

= Gross Domestic Product

= Value Added by the Oil Sector + Value Added by the Nonoil Sector