ARAB REPUBLIC OF EGYPT

THE INSTITUTE OF NATIONAL PLANNING

Memo No.1502

The Use General Equilibrium Models In Medium Term Planning

Theoretical Background

By

Dr.Fathia Zaghloul & Dr. Afaf Nakhla

May 1989

CAIRO
SALAH SALEM St-NASR CITY

Contents

Introduction :

Currently developed countries required a century to industrialize. This transformation involves large and systematic shifts in the structure of production, demand, employment, investement, and trade. Developing countries aim at achieving a similar transformation in a shorter period in an adverse world cirumstances.

The heart of the development problem is the relation among resource allocation decisions in different sectors of the economy. Early formulation of this problem were based on simple extensions of the leontief input-output system. These led to the accumulation of data on the relation among economic sectors, which has made possible the formulation of more complex analytical systems. Input-output and linear programming planning models pioneered in the 1950's and 1960's by Leontief, Chenery and others describe the problem from the point of view of a planner able to determine economic quantities as part of a centrally determined optimal plan. Recently a great deal of efforts are devoted to building applied general equilibrium models to support the formulation and conduct of economic policy in developing countries. This work focuses explicitly on the mixed market nature of most developing economies. The emphasis has thus shifted to modelling the market mechanism, including special institutional features and distortions, as it operates in actual, always partially decentralized economies.

In this paper we discuss the use of general equilibrium models in macro economic analysis that is now becoming an important part of meduim term planning efforts in mixed economies. We present a multisector, general equilibrium, policy model that can be used in the preparation of a five year plan, in exploring the direct and indirect effects of different economic policies. It can also be used to explore the effects of external events.

In a later stage we aim at applying this model to the Egyptian economy .

The Use of Models in Policy Analysis :

The analysis of development policy has evolved through the interaction between development theories and their application to varied countries and problems. In policy analysis, there is a gap between the erea of activity of pure theory, trade and growth theory in particular, and the real world that faces the policy maker and planner. Policy formulations needs more than the qualitative insights that pure theory can yield. Theoretical reasoning always provides the starting point, but models are always needed to provide quantitative significance of the various mechanisms analysed by theory. Further more, indirect effects of policies may escape intuition and thus the attention of theorists, whereas emperical modeling can reveal their presence and importance. Also senstivity tests are needed to clarify the role of key behavioural assumptions or important parameter values .

Emperical general equilibrium models that can be solved numerically are useful to provide a bridge between the theorist, the planner, and the policy maker. Theorists will be able to relate the functioning of the applied models to known theorems and analytical results. Policy makers,on the other hand, will be able to recognize in the questions adressed by the model some of the real-world policy difficult choices they face. Constructive debate can facus on particular behavioral assumption, a particular sector, or a particular set of parameter values. Disagreements and differences in policy recomendations can be traced back to specific behavioral assumptions, emperical estimates, or fundamental differences in normative goals. Models should be flexible and detailed enough to accomodate various aspects of the reality of developing countries but should also remain close to pure economic theory. Important aspects of reality still defy formal economic analysis, however, and development problems in particular do not always fit into the established neoclassical frame work. A multisector, general equilibrium model need not always conform to walrasian theory.(1) It can accept rationing of foreign exchange and persistent excess demands in some important markets. Although the equilibrium described may not be Walrasian , neoclassical resource allocation theory remains the fundamental framework of the analysis. Different general equilibrium models may focus on different kinds of economy-wide consistency. They are designed for policy analysis and cannot be used to make unconditional projections or forcasts. In contrast to the large, temporally disagregated, macro economic forcasting models whose econometric specification relies heavily on lagged endogenous variables. The mechanisms driving general equilibrium models should be clear and easy to grasp, the model has to be as transparent and simple as possible.

If a country facing a foreign exchange shortage is thinking in a devaluation of its currency, and if export demand elasticities and substitution elasticities between domestic and imported goods are low,

---

(1) Dervis, K. and Others (1982), [3]

then the country will gain nothing by devaluation, instead it will suffer from an adverse terms-of-trade effect. Extensive studies are needed befor taking such a step. Are supply elasticities thought to be very low ? If so, in which sectors and for what reasons? Is it a macro economic problem, with the price level seen tied to the exchange rate by strong cost-push factors that make a real devaluation impossible ? Or, is the whole problem is based on income distribution considerations ? If so, who stands to gain or lose from a devaluation? A general equilibrium model can provide an economy wide framework that permits an explicit specification and evaluation of each of these operations.[(1)]

---

(1) Dervis K., and Others , [3]

Multisector Models and Development Policy:

Today, some fast-growing developing countries are achieving a large and systematic transformation in a relatively short time. Both the speed and systematic nature of this transformation implies that sectors cannot be considered in isolation from one another. Bottlenecks arise and it is necessary to view the economy at a sufficiently disaggregated level to reflect important differences in production and trade structures.
Furthermore, this complex transformation process depends jointly on both domestic policies and external events, including changes in international prices and access to markets in developed countries. Structural adjustements to external events is an important feature of development policy.

Multisector models provide a very sueful framework to understand and manage structural changes. Such models in corporate production at a level of aggregation that permits the analysis of structural change and also captures the essential interdependent nature of production, demand, and trade within a general equilibrium system. Whereas input-output models can capture only simple general equilibrium relationships, more recent models are able to incorporate market mechanisms and policy instruments that work through price incentives. Application of multisector general equilibrium models contributes to a better understanding of how different policies affect economic performance. Different general equilibrium models may focus on different kinds of economy-wide consistency.

In development strategy i.e. medium to long term policies, focus is on real variables such as the growth and structure of production, employment and investement. Factors as capital accumulation, laborforce growth, productivity change, trade structure, investement allocation, real resource transfers through the foreign sector, and broad changes in the structure of demands as a result of income growth reflect the important forces at work. These factors largely determine the nature of the development process in a country and must provide the central focus of an analysis of different development strategies. Historically planners in socialist as well as in some developing countries worked within environment of a command economy. They were thus able to ignore the market system and to rely largely on command instruments. Production targets, investment allocation, intermediate inputs, and even labor were allocated directly in physical terms without much concern with the underlying value flows and market incentives. Most countries today, however, including eastern European countries, work within the environment of a mixed economy in which the market plays a central role. The exchange rate, taxes, tariffs, subsidies, and other policy variables that affect relative prices and incentives through the market mechanism have become more important than command policies in modern mixed economies, developed and underdeveloped. Given the prevalence of the market mechanism, a major focus of policy analysis is to study carefully the relation between different policies and policy packages on the one hand and, on the other, the market responses to them. It is important to understand how incentive policies affect the allocation of resources and the structure of growth.

The analytic framework on which policy analysis is based, is explicitly or implicitly, that of an economy wide, multisector model. The core around which all such applied models are built is the input-output model. The essence of input-output analysis is that it captures the important element of the inter relatedness of production arising through the flow of intermediate goods among sectors. Even with its assumptions of linearity and cost-determined prices independent of demand, the simplest input-output model nonetheless represents a powerful tool for applied general equilibrium analysis . Multisector planning models are now extanded to include in a realistic manner the feadbacks through the price mechanism that achieve equilibrium between the independent optimising behaviours of suppliers and demanders of products, the essence of multisector policy analysis is to capture this interdependence .

The accounting framework that underlies multisector analysis is that of the input-output accounts. Through the more complete "System of National Accounts" the input-output and national income and product accounts have been integrated into a single general framework. The more recent interest in income distribution and the flow of funds among "institutions" defined more broadly than in the system of national accounts has led to the development of a more general social accounting framework. All these systems provide a complete and consistant picture of the "circular flow" in an economy. Even without the apparatus of a fully specified formal model, such accounting systems provide a powerful tool of analysis because they focus on the interrelationships among the different "actors" in the economy and impose the requirement that all real and nominal flows must be consistant. Such a "consistency check" can often reveal problems both with the data and with the economic assumptions underlying policy analysis . As a matter of fact the major usefulness of applied general equiblibrium models is not in their particular emperical results, which may quickly becomes outdated, but in the fact that they force policy makers to analyze the implications of policy choices within a consistent analytic and information framework.

Prices play a crucial role in computable general equilibrium models and are solved so as to "clear markets" in the economy model. They are thus determined endogenously so as to equilibrate the results of individual optimizing behaviour of a number of actors, for example, producers, owners of factors of production, households, and governement.

Given their theoretical structure, input-output and linear programming models seem best suited to a situation in which a central authority fully in control of the various quantity variables in the system, but subject to various technological and physical constraints has to make consistant or optimal decisions. Input-output analysis has often been used to solve the famous problems of material balancing in the productive sphere of a centrally planned economy. Kantrovich observed in a programming approach a clear link between centralized planning and the scarcity price concept of neoclassical economic theory, while Dantrig developed linear programming as a tool for optimal central decision making. Formulation of these models does not appear well suited to situations where many agents independently maximize their own welfare functions and jointly but unintentionaly determine an outcome that can be affected only indirectly by the planner or policy maker. In mixed economic systems a great deal of economic activity is not under the direct control of policy makers. Autonomous decision making by various economic "actors" and market mechanisms have an important impact on resource allocation. Linear programming and input-output models usually do not contain variables that can be considered to be instruments controlled by policy makers. They can benefit from the consistent economy wide picture provided by the models, but they cannot easily relate the computed variables to any actual policy decisions .

In practice, applications of linear models (Input-output & linear programming) to developing countries have always involved a number of compromises and extensions to the basic model in order to make the models more realistic and useful in an applied setting.(1) Some modifications were made to capture indirectly the supposed effects that policy changes would have on endogenous variables. For example, the impact of import coefficients of the rise in the relative price of imports due to a tariff can be specified exogenously and so be fed back into the model. Other modifications represent attempts to capture non-linearities by imposing various constraints and/ or piecewise linear functions. None of these modifications, however, addresses the essential problem that the models do not directly include the sorts of price-incentive variables that represent the essential tools of planners and policy makers in mixed economies.

In order to achieve greater policy relevance, the model should not try to represent a central command economy, it should, instead, try to present a framework in which endogenous price and quantity variables are allowed to interact so as to simulate the working of at least partely decentralized markets and autonomous economic decesion makers. Such price endogeneity and general equilibrium interaction cannot be achieved using the standard linear programming formulation. Since economic behaviour and relations such as budget constraints, consumption functions and saving functions must

---

(1) For example see Chenery (1971), [2]

be expressed in current endogenous factor and commodity prices. But the standard primal constraint equations of a linear program cannot include the "shadow" prices that result as a by-product of the maximization or, to put it differently, one cannot in general expect that the resource allocation and production structure determined by the solution of a linear program is consistent with the incomes and budgets that result from its dual solution. Indeed, if factor prices have any impact on the structure of demand, the quantities supplied that are the outcome of the primal solution will in general not equal the quantities demanded that are implied by the dual solution. On the contrary, computable general equilibrium models include the fundamental general equilibrium links among production structure, incomes of various groups and the pattern of demand .

A General Equilibrium Model for Medium Term Economic Policy:

The most important feature of this model is that imported goods are not treated as rigid complements to domestic goods more as perfect substitutes, that rules out twoway trade. We consider foreign and domestic goods as not indentical, and may have different prices, and may be characterised by a degree of substitutability that varies across sectors. We shall define for each tradable commodity category an aggregate or composite commodity Q_i which is a constant elasticity substitution (CES) function of commodities produced abroad (imports M_i) and commodities produced domestically D_i . The aggregation is given by:

$$Q_i = \bar{B}_i \left[\delta_i M_i^{-\rho_i} + (1-\delta_i) D_i^{-\rho_i} \right]^{-1/\rho_i} = f(M_i, D_i)$$

where B_i , δ_i , and ρ_i are parameters and M_i and D_i are like inputs "producing" the aggregate output. The demands for imports and domestically produced commodities become derived demands, in the same way as the demand for factor inputs is a derived demand in a traditional production model. Given the specified prices for the imported and domestic goods, the problem facing the user or buyer is mathematically equivalent to that facing the firm wishing to produce a specified level of output at minimum cost. The solution is to find ratio of inputs (M_i to D_i) so that the marginal rate of substitution (the slope of the iso-output curve for the composite good) equals the ratio of the price of the domestically produced commodity to price of the imported commodity. The familiar first-order condition for cost minimization yield

$$m_i = \frac{M_i}{D_i} = \left(\frac{PD_i}{PM_i}\right)^{\sigma_i} \left(\frac{\delta_i}{1-\delta_i}\right)^{\sigma_i}$$

where PD_i = domestic good price,

PM_i = the domestic currency price of imports

$\sigma_i = \frac{1}{1+P_i}$ = the trade-substitution elasticity

If θ_{im} and θ_{id} are the value "shares" of imports and domestically produced goods in total domestic expenditure:

We have $$\frac{\theta_{im}}{\theta_{id}} = \frac{PM_i}{PD_i} \cdot \frac{M_i}{D_i} = \left(\frac{\delta_i}{1-\delta_i}\right)^{\sigma_i} \left(\frac{PD_i}{PM_i}\right)^{\sigma_i -1}$$

If the trade substitution elasticities σ_i equal unity, then the last term disappears and the value shares remain constant irrespective of relative prices. In this case the CES aggregation function reduces to a Cobb-Douglas function. The magnitude of σ_i determine the responsiveness of domestic demand to changes in the relative price of imported goods brought about by trade and exchange-rate policy or exogenous events.

Rather than working with the import-to-domestic ratio, it is often convenient to work with the ratio of domestic goods in total composite commodity use. We shall call it the "domestic use ratio", and denote it by d_i . Then the aggregate function (1) can be written as :

$$Q_i = f_i\ (m_i\ ,\ 1)\ \ D_i$$

where $m_i = \frac{M_i}{D_i}$

then we have

$$d_i = \frac{Di}{Q_i} = f_i^{-1}\ (m_i\ ,\ 1\ )$$

By using d_i, we can go from composite commodity demand to the derived demand for the domestically produced commodity. If V_i, C_i and Z_i denote the intermediate demand, consumption demand and investement demand for composite commodity i respectively then the demand function for the domestically produced components will be :

$$V_i^d = d_i\ V_i$$

$$C_i^d = d_i\ C_i$$

$$Z_i^d = d_i\ Z_i$$

These domestically produced goods combine with imports to produce the aggregate good Q_i .

In this way we can expect a more realistic behaviour of quantities and prices, with the tendency to specialization much diminished and the domestic price system more autonomous than in neoclassical theory but less isolated from world prices than in fixed coefficient models.

On the export side we assume moderate export demand elasticities and thus have the country face downward-sloping demand curve for its exports. We assume the world demand function for our exports to be of the following simple constant elasticity form :

$$E_i = \bar{E}_i \left(\frac{\pi_i}{PWE_i} \right)^{\eta_i}$$

where E_i = exports of the i^{th} sector

and π_i is an "aggregate" world price for products in category i and reffects a weighted average of production costs and trade policies in all countries. The fact that our country is small allows us to treat π_i as exogenously fixed. But PWE_i, which is the dollar price of our exports, is endogenously determined by our domestic production costs, export incentives, and exchange rate policy :

$$PWE_i = \frac{PD_i}{(1+te_i)ER}$$

where ER is the exchange rate,

te_i is the rate of export subsidy,

η_i is the price elasticity of export demand, and ,

$\overline{E}_i$ is a constant term reflecting total world demand for commodity category i and the countries market share when $\pi_i = PWE_i$.

In the following we are going to present the model in a complete equation form. Endogenous variables are denoted by capital letters. Lowercase letters, Greek letters, and letters with bars (‾) are exogenous variables or parameters (with the exception of d_i) .

We consider the economy to be devided into 5 sectors (i =1,2,3,4,5) (1) Agriculture. (2) Industry. (3) Petrole and petrolium products. (4) Construction, transporation and inventory (productive services). (5) other services. Labor is devided into 2 categories (k =1,2) : skilled and nonskilled labor. The economy is composed of 3 groups: wage earners, capitalists and the government.

Defenision of Variables and Parameters: (1)

Endogenous Variables :

PM_i , i = 1,2,3,5 = import price of sector i in local currency (Pounds)

PWE_i , i = 1,2,3,5 = export price of sector i in dollars (supply (price of domestic exports)

ER = the exchange rate

PD_i , i = 1,2,3,4,5 = donestic price of sector i in pounds.

P_i = 1= 1,2,3,4,5 = composite commodity price of sector i in Pounds.

PN_i = i = 1,2,3,4,5 = net or value added price of sector i in Pounds.

X_i^S , i = 1,2,3,4,5 = domestic production (supply) of sector i

L_i , i = 1,...,5 = Agregate labor in sector i

L_{ik} , (i = 1,...,5 , k = 1,2) = labor in category k and sector i .

W_k , K = 1,2, = Wages of labor category K .

L_k^D , K = 1,2 = total employment of labor category K

E_i , i = 1,2,3,5 = Exports of sector i .

M_i , i = 1,2,3,5 = Imports of sector i .

---

(1) The model is taken from the appendix of ch. 7 of [3] we consider n = 5 , m = 2

R_L = labor income

R_K = capital income

R_G = Government income .

TINV = total investment

Y_i , $i = 1,2,3,4,5$ = investment by sector of destination (investement used in sector i)

Z_i , $i = 2,4,5$ = investment by sector of origin (campital formation of commodity category i)

C_i , $i = 1,2,3,4,5$ = total consumption of sector i .

C_{ij} , $i = 1,...5$, $j = L,K,G$ = consumption of commodity category i by category of consumer (laborers, capitalists and government)

V_i , $i = 1,2,3,4,5$ = Intermediate demand for sector i .

D_i , $i = 1,..,5$ = total demand for domestic use for sector i

d_i , $i = 1,2,3,4,5$, = Domestic use ratio for composite commodity i .

X_i^D , $i = 1, ... 5$ = total demand for domestically produced goods of sector i .

Total number of endogenous variables = 108 .

Exogenous variables :

$\overline{PW}_i$, i = 1,2,3,5 = world price of imports of sector i in dollars

$\overline{P}$ = price level

$\overline{K}_i$, i = 1,...,5 = capital in sector i .

$\overline{F}$ = net foreign capital inflow.

π_i = average world price for commodity category i .

$\overline{L}^s_k$, K = 1,2 = Supply of labor in category K .

Parameters :

tm_i , i = 1,2,3,5 = tariff rate on imports of sector i .

te_i , i = 1,2,3,5 = export subsidy rate for sector i .

td_i , i = 1,2,3,4,5 = indirect tax rate .

$\overline{A}_i$, i = 1,2,3,4,5 = Productivity parameter for sector i .

σ_i , i = 1,....,5 = trade substitution elasticity in the CES trade aggregation function

δ_i , i = 1,....,5 = share parameter in the CES trade aggregation function .

t_k , k = 1,2, = direct tax rate on labor income category k .

tk_i , i = 1, ... 5 = direct tax rate on nonlabor income in sector i .

$\overline{S}_L$ = saving rate out of labor income .

$\overline{\zeta}_i$, i = 1,..., 5 = wage ratio in net price .

$\overline{S}_k$ = saving rate out of capital income .

$\overline{S}_G$ = saving rate out of government income .

θ_i , i = 1,2,3,4,5, = investment share of sector i .

q_{ij} , i = 1,....5 , j = L,K,G = expenditure share of consumer category j on products of sector i .

η_i = price elasticity of export demand of sector i .

<u>Coefficients :</u>

a_{ij} = fixed input output coefficients

S_{ij} = capital composition coefficients

Ω_i , i = 1,....5 = weights for the price index ($\sum_i \Omega_i = 1$)

<u>The equations of the model :</u>

<u>Price equations :</u>

Import price equations

1) $PM_i = PW_i \ (1 + tm_i) \ ER$ i = 1,2,3,5

Export price equations

2) $PWE_i = \frac{PD_i}{(1+te_i)ER}$ i = 1,2,3,5

Composite price equations

3) $P_i = d_i \ (PD_i + PM_i \frac{M_i}{D_i})$ i = 1,2,3,4,5

Net price equations

4) $PN_i = PD_i - \sum_{j=1}^{5} P_j \; a_{ji} - td_i \; PD_i$, $i = 1,2,3,4,5$

Price level equation

5) $\sum_{i=1}^{5} \Omega_i \; P_i = \overline{P}$

Production functions

We consider production functions to be of the type: constant elasticity of substitution

6) $X_i^S = \overline{A}_i \; [\; \alpha_i \overline{K}_i^{-\beta_i} + (\; 1- \alpha_i) \; L_i^{-\beta_i} \;]^{-1/\beta_i}$, $i=1,\ldots,5$

where α_i and β_i are parameters .

Labor aggregation functions

Also the two categories of labors is considered to be aggregated by a CES function .

7) $L_i = \overline{L} \; [\; \lambda_i \; L_{1i}^{-\gamma_i} + (\; 1 - \lambda_i) \; L_{2i}^{-\gamma_i} \;]^{-1/\gamma_i}$, $i = 1,\ldots,5$

Labor market equilibrium

$PN_i \dfrac{\partial X_i}{\partial L_{Ki}} = W_{ki}$, $i = 1,2,\ldots,5$, $i = 1,2,$

where $\dfrac{\partial X_i^S}{\partial L_{ki}} = \dfrac{\partial X_i}{\partial L_i} \cdot \dfrac{\partial L_i}{\partial L_{ki}} = \overline{A}_i (1- \alpha_i) \; \overline{L} \; \lambda_i$ (from 7)

L_L = constant = ξ_i and can be considered as a wage ratio in net price. i.e.

8) $$W_{ki} = \xi_i \; PN_i \qquad i = 1,2,\dots 5 \;, K = 1,2$$

9) $$L_k^D = \sum_{i=1}^{5} L_{ki} \qquad K = 1,2$$

10) $$L_k^D - \bar{L}_k^S = 0 \qquad K = 1,2$$

Foreign trade relations :

Export demand functions

11) $$E_i = \bar{E}_i \left(\frac{\Pi i}{PWE_i} \right)^{\eta_i} \qquad , i = 1,2,3,5$$

$\bar{E}_i$ = a constant term reflecting total world demand for sector i .

Import demand function

12) $$M_i = \left(\frac{\delta_i}{1-\delta_i} \right)^{\sigma_i} \left(\frac{PD_i}{PM_i} \right)^{\sigma_i} D_i \qquad , i = 1,2,3,5$$

Balance of payment equilibrium

13) $$\sum_i \overline{PW}_i \cdot M_i - \sum_i PWE \cdot E_i - \bar{F} = 0$$

Income relations

Net labor income is given by

14) $$R_L = \sum_{i=1}^{5} \sum_{k=1}^{2} W_k \cdot L_{ki} \quad (1-t_k)$$

Net nonlabor factor income is given by

15) $$R_k = \sum_{i=1}^{5} (PN_i X_i - \sum_{k=1}^{2} W_k L_{ki}) \quad (1-tk_i)$$

Government income is composed of the direct tax on labor income+ direct tax on nonlabor income + tariffs -export subsidies + indirect taxes + net foreign capital inflow

$$16)\quad R_G = \sum_{i=1}^{5} \sum_{k=1}^{2} t_k W_k L_{ki} + \sum_{i=1}^{5} tk_i \left(PN_i X_i^D - \sum_{k=1}^{2} W_k L_{ik}\right)$$

$$+ \sum_{i=1}^{5} t_{mi} PW_i ER. M_i - \sum_{i=1}^{5} te_i PWE_i ER. E_i$$

$$+ \sum_{i=1}^{5} td_i X_i^S PD_i + \overline{F} . ER .$$

Investment equations

$$17)\quad TINV = \overline{S}_L R_L + \overline{S}_k R_k + \overline{S}_G R_G$$

$$18)\quad Y_i = \theta_i \; TINV \qquad i = 1,\ldots,5$$

$$19)\quad Z_i = \sum_i S_{ij} Y_i \qquad i=2,4,5$$

Consumption demand equations

Total consumer demand for composite commodity i, equal to the sum of the demands coming from wage earners, capitalists and government

$$20)\quad C_i = C_{iL} + C_{ik} + C_{iG}$$

$$21) \quad C_{ij} = \bar{q}_{ij} \; (1-\bar{S}_j) \; \frac{R_j}{P_i} \quad , \quad j = L,K,G$$

i.e. C_i is the total consumer demand for composite commodity i . equal the sum of the demands coming from wage earners, capitalists and the government .

Intermediate demand equations

$$22) \quad V_i = \sum_{j=1}^{5} a_{ij} \; X_j$$

Product market equilibrium

$$23) \quad D_i = d_i \cdot (Y_i + C_i + V_i)$$

The domestic use ratio d_i is given by

$$24) \quad d_i = \frac{D_i}{Q_i} = \bar{B}_i^{-1} \; [\; \delta_i \left(\frac{M_i}{D_i}\right)^{-\rho_i} + (1- \delta_i) \quad ^{1/\rho_i}$$

Total demand for domestically produced goods is :

$$25) \quad X_i^D = D_i + E_i$$

Product market equilibrium is defined by :

$$26) \quad X_i^D - X_i^S = 0$$

Total number of equations = 108

Solution Methods :

Up till now there exist no "canned program that can be used to solve all general equilibrium models-no simple equivalent to the simplex method in linear programming. We must therefore exploit the mathematical and economic properties of the system in order to reduce the number of nonlinear equations that must eventually be solved. Then we must choose among existing algorithms of varying complexity and applicability, no one of which dominates for all models. Adelman and Robinson[1] distinguish between a "solution strategy" and a "solution algorithm" the purpose of a solution strategy is to establish numerically a set of simultaneous nonlinear functions (generally excess demand equations) whose solution will provide the equilibrium values of all the endogenous variables in the model. A solution algorithm is a computational technique for solving the set of simultaneous nonlinear equations numerically.

First the equations of the model are reduced by substitution to a set of nonlinear excess demand equations. In the model there are three sets of markets that must cleared: factor markets, product markets, and the foreign exchange market. Principally it is possible to attack all three sets of markets simultaneously, but it is usually more efficient computationally to separate them .

Figure 1 presents the flow chart for an example of a product market solution strategy for a model with fixed sectoral capital stock, we also assume that the exchange rate varies to clear the market for foreign exchange Assuming an initial guess at product prices and the exchange rate, the strategy then works on the labor market. Given sectoral production functions, the assumption of profit maximization behavior on the part of producers, and an initial guess at wages of different skill categories of labor, one solves for the demand for labor in each sector, given labor supplies (or labor supply functions), one computes excess demands for labor different skill categories. If they are found to be zero, the labor market is solved. If not, the solution algorithm generates a new guess at wages and start a new iteration.

When the labor market is solved, the model generates wages, capital rentals, employment, production, and exports (based on some specifications of export market). One then have enough information to generate the functional, institutional, and household income distributions-the entire flow of funds in the SAM. Then, given the parameters of the household expenditure functions, one can generate the demand for products and imports, Given the product supplies solved earlier, one generates the excess demands for products. If they are zero, the model is solved. If not the solution algorithm generates a new guess at prices and exchanges rate and starts a new iteration.

Johansen [5] presented the simplest solution strategy that can be used. That is to reduce the model to a set of log-linear equations (linear in growth rates) in all the endogenous. The system of linear equations can then be solved by inverting the resulting matrix of coefficient, which is the simplest possible solution algorithm. The

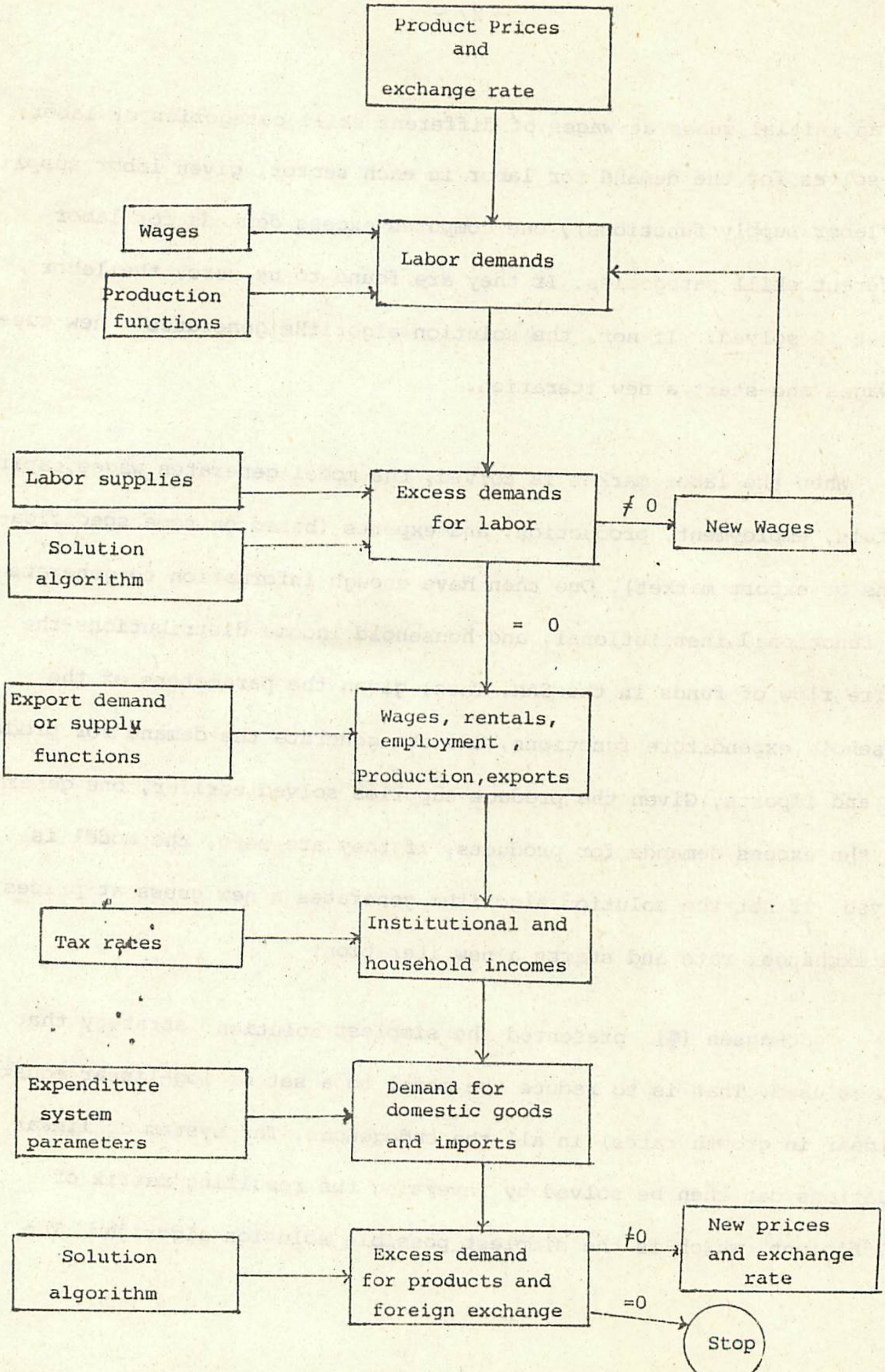

Figure 1. Product market solution strategy

gain in using a simple solution algorithm must be weighted against the limitation in flexibility of model specification in herent in being required to reduce the equations to a log-linear system .

There exist other algorithms that work directly with the various excess demand equations using a solution stategy of the kind described. One type is to simply adjust the price in each sector in response to that sector's excess demand. If sectoral excess demand is positive, raise the price, if negative, lower the price. This technique is a special version of the Gauss-Seidel iteration procedure and does not require any evaluation of derivatives of the excess demand equations. It is thus easy to implement and has been used in a number of models (1) . A disadvantage of such method is that it becomes inefficient in models in which there are significant interactions among markets. For example the flexible- exchange-rate models. In such cases other type of algorithms can be used, it is called "Jacobian algorithms", because their performance is sensetive to the determinant of the matrix of numerical derivatives-the Jacobian. In this algorithms Newton-Raphson iteration method can be used, generally it has quadratic convergence properties provided that the initial guess is sufficiently close to the solution. If the initial guess of prices is far from the

---

(1) Adelman and Robinson (1978) [1] used this technique to solve their twenty-nine sector model .

solution, the method of steepest descent is preferred but it is slower to converge. A number of algorithms have been developed that interpolate between Newton-Raphson and steepest directions. These algorithms differ in how they do the interpolation, how they choose the step size, and how they compute the derivatives. A major disadvantage of a technique that require the numerical approximation of derivatives is that such method require n+1 function evaluations before they even start. While a simple adjustement method (the previous type) can easily converge in ten or twenty iterations add would thus clearly dominate any technique that requires n+1 iterations just to get start. Even for a model in which such method is in_sufficient, the trade-off in moving to a Jacobian technique appears to be quite serious.

Use of the Newton-Raphson technique requires the inversion of the Jacobian matrix, and thus the method fails if the Jacobian is zero. It becomes very sensetive and may fail if the Jacobian is small. Such algorithms usually incorporate some test of singularity of the Jacobian and change direction if it becomes too small. The above discussion indicate that there exist serious trade-offs among model specification, solution strategy and solution algorithm.

Application to the Egyptian Economy :

In order to apply the model to the Egyptian economy a big amount of data and information is needed. We will be in need of a valid estimation of exogenous variables, parameters and coefficients of the model . We have to start with values for the exogenous variables of the model (listed in page 20). Prices can be taken equal to 1, i.e. they are considered to be normalized. This can always be done in general equilibrium models, since prices refere to big sectors and we are interested in how they will change in the near future, i.e. in the rates of increase (or decrease) in the coming years.

$\bar{F}$ which is the net foreign capital inflow can be taken from Plan estimates. It was planned to become equal to 1300 million pounds in the year 1987-1988 . However some studies[1] on the Egyptian economy estimate it at a higher values goes up to 35 .00 million pounds for the year 86 - 1987[2] .

CAPMAS is now preparing a new social accounting matrix (SAM) for the year 1983-1984, we can take from it a lot of coefficients as a_{ij}, input - output coefficients, S_{ij} the capitial composition coefficients, Θ_i the investment shares of different sectors and q_{ij} the expenditure share of different consumer categories on products of different sectors.

١ ــ معهد التخطيط القومى " تطور التجاره الخارجية وميزان المدفوعات ومشكلة تفاقم العجز
وسياسات مواجهته " قضايا التخطيط والتنمية فى مصر ، رقم ٧، ١٩٧٨.

٢ ــ مرجع (٨).

Other parameters such as elastisity of substitution between domestic and imported goods and price elastisity of exports need a lot of econometric work and may raise a lot of problems that can be solved partly by senstivity studies of the results to parameter values or it can be estimated on the base of Expert's openion or taken from studies on other countries with similar conditions. For example price elastisity of exports η_i can be taken equal zero for industry and service[1]. This implies that the volume of Egyptian exports of industrial goods and of services are independent of prices. This can be justified as Egypt is a small exporter in these fields and hence the quantity of exports can be fairly considered as independent of the relation of international to domestic prices of exports and Egypt can in principle export what is available depending on its exports promotion efforts. This is not the case in the agriculture sector as Egypt is a large exporter of cotton, so we must assume that prices may affect the quantity exported, as reflected by the elasticity Export elasticity of agricultural sector η_1 can be estimated as 3[2]. Trade substitution elasticities in the CES trade agrigation function σ_i can be taken from the same reference [4] as $\sigma_1 = 0.4$, $\sigma_2=0.8$, $\sigma_4 = 0.2$ and $\sigma_5 = 0.8$.

We will also be in need of specified policy packages that are required to be tested using the model. We may exclude some relations or substitute it by other simpler ones either because of lack of data or

---

1- This has been done in the study [4]

2- The same reference [4]

being more suitable to the egyptian circumstances . But this will need a careful study and to take into consideration the number of equations and the endogenous variables and keep them equal.

Finally, we will also be in need of a computer program for any iteration procedure, for solving a system of equations numerically, e.g. Newton-Raphson or Gauss-Seidel Procedures .

References

1- Adelman, I. and S. Robinson, "Income distribution policies in developing countries", Stanford, Calif. Stanford University Press 1978 .

2- Chenery, H. B. (1971): " Studies in Development Planning ", Cambridge, Mass, Harvard University Press,

3- Dervis K., J. de Melo and S. Robinson, "General equilibrium models for development policy". A world Bank Research publication, 1982 .

4- Hallouda, A. and others "social Accounting Matrices and economic modelling for Egypt", CAPMAS, June 1984 .

5- Johansen, L. "A multi-sectoral study of Economic Growth", Amesterdam North-Holland, 1960 .

6- Manne, A. (1974): "Multi-sectoral models for development planning: A survey, Journal of Development Economic, Vol. 1, PP. 574 - 595 .

٧ ــ فتحيه زغلول " نموذج البنك الدولى للاقتصاد المصرى " مسلسل رقم (٤٩) دورة الاساليب الحديثة فى التخطيط ــ معهد التخطيط القومى ــ القاهره ــ الصندوق العربى للانماء الاقتصادى والاجتماعى الكويت ١٩٧٨.

٨ ــ د. فتحيه زغلول" تطور نموذج برمجة خطية للمساهمة فى اعداد خطة خمسية للاقتصاد المصرى " مذكرة خارجية رقم (١٤٧٩) ١٩٨٨.

٩ ــ معهد التخطيط القومى " تطور التجاره الخارجية وميزان المدفوعات ومشكلة تفاقم العجز وسياسات مواجهة " قضايا التخطيط والتنمية فى مصر . رقم (٧) ، ١٩٧٨.