

A Planning Model Featuring Trade,
Intra-Sector Product Differentiation
and Income Distribution

by

Sherman Robinson
Princeton University

Jaime de Melo
Georgetown University

Research Program in Development Studies
Woodrow Wilson School
Princeton University
Princeton, New Jersey

Discussion Paper No. 69

November 1976

The work described in this paper has been supported by the Agency for International Development. We also wish to thank Kemal Dervis for his comments and helpful discussion. Neither he nor A.I.D. are responsible for any views expressed herein.

Note: Discussion papers of the Research Program in Development Studies are preliminary material circulated to stimulate discussion and critical comment. Please do not refer to discussion papers without the permission of the authors.

Table of Contents

	<u>Page</u>
I. Introduction	1
II. Foreign Trade in Multi-Sector Development Planning Models	3
III. A CGE Trade Model with Product Differentiation and Income Distribution	11
1. Introduction	
2. The Composite Good	
3. Factor Markets and Domestic Supply	
4. Income Distribution and Product Demand	
5. Trade and Material Balances	
6. Solving the Model	
IV. Trade Strategy, Growth and Income Distribution	36
1. Introduction	
2. Dynamic Linkages	
V. Conclusion	40

I. Introduction

Most developing countries engage in planning exercises because they wish to explore the implications for growth and structural change of alternative policies with respect to international trade and domestic resource allocation. In addition, there has recently been a growing concern about the impact of alternative development strategies on the distribution of income and especially on the alleviation of poverty. This paper presents a planning model whose primary focus is to simulate the impact of alternative trade strategies on industrialization and the distribution of income. The model is thus designed for the large number of relatively open developing economies for whom trade strategy and commercial policy are major issues in economic planning. It will be implemented with Colombian data to explore and quantify the effects of alternative trade and development strategies on the functional and size distributions of income. A static version will be used to examine the impact of trade strategies and commercial policy on the equilibrium structure of the economy while a dynamic version will explore the growth path of the economy under alternative trade strategies.

The model is in the tradition of wage and price endogenous computable general equilibrium (CGE) models. It incorporates both the factor and size distributions of income. In its treatment of income distribution, the model closely follows the work of Adelman and Robinson (1976). It also introduces a new specification of international trade that attempts to bridge the gap between standard

international trade theory and the usual treatment of foreign trade in multi-sector planning models. The approach is more general than the usual specification of trade in empirical general equilibrium models.¹ Indeed, the standard ways of incorporating trade may be viewed as special cases of the treatment offered here. By taking advantage of the great flexibility inherent in the CGE approach, the model directly incorporates the degree of substitutability in use between domestically produced and imported goods. The model thus explicitly incorporates product differentiation within sectors between imported and domestically produced goods.

The next section relates our specification of trade to that found in previous planning models and lays the groundwork for the subsequent presentation of the equation system. This presentation is followed by a discussion of the dynamic linkages to be incorporated in the growth model.

II. Foreign Trade in Multi-Sector Development Planning Models

The pure theory of international trade around which multi-sector trade-oriented planning models are built is based on a set of simplifying assumptions found in the Ricardian and Heckscher-Ohlin (H-O) models of trade. Among other assumptions, the H-O model assumes that factors of production are freely mobile within a country and that they are allocated in such a way that the value of a given factor's marginal product is the same in all industries. Thus the resulting concept of comparative advantage refers to the long-run under an optimal factor allocation pattern. Moreover, the H-O theory assumes constant returns to scale in production which implies that marginal cost is independent of output levels. If, in addition, the country does not affect the terms at which it trades internationally, specialization along lines suggested by comparative advantage will take place when relative prices are varied through commercial policy. Although the gains from specialization are an integral part of any discussion of the gains from trade, there is ample empirical evidence that the extent of specialization due to a change in relative prices is limited.² To the extent that one finds the fundamental assumptions underlying trade theory to be empirically reasonable, it is desirable in empirical work to formulate general equilibrium trade models in the spirit of that theory. However, a serious problem is to specify theoretically adequate models which do not display "excessive" degrees of specialization empirically.

The empirical formulation of trade models has proven to be a difficult task in a multi-sector framework for at least three reasons.

First, because the number of factors of production empirically observable is limited, a country model with fixed international terms of trade (often referred to as the small country assumption) will specialize and produce a limited number of goods. This difficulty in modelling a small country facing fixed terms of trade with more commodities than factors of production has often been discussed in the literature on the factor price equalization theorem.³

Second, the pure theory of trade upon which applied general equilibrium trade models are based does not take into account the fact that price differentials for the "same" product are commonly observed when products are distinguished by country of origin. The fact that price differentials are observed even for very fine commodity classifications suggests that product differentiation is accounting for the observed two-way trade. Thus, at one extreme, many traditional multi-sector trade models follow the pure theory of international trade and maintain the assumption that domestically produced and foreign goods have an infinite elasticity of substitution. In effect, they are the same good and two-way trade is ruled out.⁴ At the other extreme, development planning models in the structuralist and two-gap traditions emphasize the lack of substitution possibilities both among factors of production and between domestic and imported goods. They view the development process as a succession of structural disequilibria reflected in domestic bottlenecks arising from the limited ability of developing countries to substitute domestic for imported inputs. They assume that domestic and imported inputs are perfect complements in production and have to be

used in fixed proportions.

Third, multi-sector trade models in the programming tradition have generally not been very successful in examining the effects of tariff protection and price subsidies on resource allocation because of the well-known problems of including constraints on shadow prices in the primal of a programming model. Because of the widespread use of tariff policies to influence resource allocation and industrialization, it is of great practical interest to be able to analyze the implications of alternative tariff and subsidy policies in a trade-oriented planning model. The major problems associated with including such policies in programming models limit their usefulness in analyzing the effects of alternative development strategies.

At the risk of some oversimplification, one can attribute the relative scarcity of multi-sector trade-oriented models to the difficulty of successfully reconciling the basic assumptions underlying the pure theory of trade with available observations of the commodity composition of trade that one would like to capture in a model. A brief review of general equilibrium models of trade and development indicates how the various difficulties have been handled in multi-sector trade models.

Overcoming the problem of specialization under a constant returns to scale technology with few factors may be done in several ways. The most obvious approach is to attack the overdeterminacy problem at its root by adding more factors such as various types of capital and several labor skill classes. The data requirements for such a formulation considerably limit the possible extensions along these lines. Remaining on

the supply side, another approach is to assume that every sector has some fixed factor (such as entrepreneurs or fixed capital stocks) which results in diminishing returns to the other factors. This is the approach followed by Werin (1965), Lage (1970), Evans (1972), Taylor and Black (1974), de Melo (1975), Adelman and Robinson (1976), and others. Fixing sectoral capital stocks helps to overcome the specialization problem and is empirically justified in the short-run. However, the results derived under such assumptions cannot be used to indicate comparative advantage in the long run.

Ali (1976) has used a completely different approach to handling the specialization problem. In his study of comparative advantage in India, he argues that, due to the large degree of aggregation, a sectoral production function does not provide any information about the relative comparative advantage of industries within the sector. To handle this problem, Ali specifies a stepped supply function under the assumption that a sector's supply curve can be obtained by ranking industries within a sector according to their costs (defined as the domestic factor cost needed to save a unit of foreign exchange). The resulting form of the production function implies that as output is increased efficiency declines.⁵ This specification is helpful in overcoming the specialization problem and has some appeal for developing countries where the use of scarce foreign exchange is likely to have an effect on sectoral efficiency in production.

On the demand side, the usual approach is to drop the small country assumption. One can either make the world price a decreasing function of export volume or specify that import prices are an increasing function

of the volume of imports, or both. However, these assumptions are empirically reasonable for only a few countries and a few traded goods.⁶

Turning to the second issue, the assumption of perfect substitutability between domestic and foreign goods of the same category has been maintained in virtually all planning models which endogenously determine quantities traded.⁷ However, to avoid extreme behavior, most programming models impose upper and lower bounds on quantities traded. See for example Bruno (1966) and Evans (1972). Such constraints, however have little theoretical justification. Input-output models, on the other hand, sometimes assume both perfect substitutability and perfect complementarity at the same time. They use fixed coefficients to determine imports but also include them as a supply in the material balance equations. See for example Chenery and Clark (1957) and Adelman and Robinson (1976). Many input-output models also view imports as purely non-competitive, unable to be produced domestically, and which therefore only enter the trade balance equation. The inclusion of non-competitive imports is consistent with the two-gap literature which emphasizes the inherent structural rigidities in developing countries and the underlying behavioral assumptions are often valid. However, in terms of model behavior, non-competitive imports should not enter the material balance equations.

Finally, the study of trade strategies has not been adequately treated in planning models because of the difficulty of incorporating price distortions. With the exception of Evans' programming study of commercial policy in Australia, the only other studies of price policies in a multi-sector framework are those of Taylor and Black (1974) and

de Melo (1975). These two studies incorporate price distortions in a CGE model where prices and quantities traded are endogenously determined.

The thrust of our treatment of foreign trade is based on two related observations especially relevant for developing countries. The first concerns product differentiation. In an empirical application to a developing economy, it is unrealistic to assume that domestically produced manufactured goods and foreign produced manufactured goods under the same sectoral classification are essentially the "same," especially at the level of aggregation found in multi-sector economy-wide models. Differences in product quality reflect the imperfect transmission of technological knowledge and different labor skills in developed and developing countries. This view of imperfect substitutability between domestic and foreign manufactured goods amounts to introducing the possibility of two-way trade.⁸ It is therefore conceivable that a country will import machinery of a "high" quality and at the same time also export domestically produced machinery of a "lower" quality to other countries if the price of domestically produced machinery is equal to the exogenously given world price of machinery. Note that the pure small country assumption is maintained on the export side despite an alleged difference in quality. This assumption could be relaxed with the provision of additional data indicating the world elasticity of demand for the home country's exports of a particular commodity, or by specifying export supply functions.

Secondly, an essential feature of industrialization involves the substitution of domestically produced goods for foreign produced ones.

The successful accomplishment of this transition is a crucial element in the path towards industrialization. The extreme example of this lack of substitutability is exemplified in the literature on two-gap models developed by McKinnon (1964) and Chenery and Strout (1966). However, in a model which incorporates relative prices, it is natural to assume that domestically and foreign produced goods may be substituted for each other when commercial policy results in an alteration of their relative prices. In the case of capital goods, this possibility of substitution has been given empirical support by Michalopoulos (1975) in his case study of Argentina. He estimates the effect of changes in the relative price of domestic and foreign capital goods on the composition of the capital stock and finds that the elasticity of substitution between imported and domestic equipment is significantly different from zero.

In the algebraic presentation of the model below, the dichotomy between the two types of goods is maintained in all uses of the goods. Thus we define a single composite good in each sector which is made up of imports and domestically produced goods in that sector. This composite good defined for each sector is what is demanded by all users for consumption, intermediate use, and investment purposes.

The desired composition of the composite goods by users will be affected by changes in the relative prices of the foreign and domestic components of the good. Thus a policy of import substitution implemented by imposing high rates of effective protection will be captured by the model in the following way. First, low tariff rates on imported inputs will result in a higher desired share of these imported goods in the corresponding composite goods and so raise their demand. Second, high tariffs to protect a final good will lower the desired share of imports

of that good in the corresponding composite good.

The price system for the model is a hybrid in the following sense. The price of the imported component is tied to the world price through a tariff (and the exchange rate) and price follows the standard small country assumption. However the price of the domestic component behaves exactly like the price of a non-traded good and adjusts to clear domestic supply and demand. Indeed a change in commercial policy will affect the price of a composite good in two ways: (1) directly via the change in the tariff and (2) indirectly by the resulting change in the price of the domestically produced good as the domestic economy reaches a new equilibrium.

By specifying that imported and domestically produced goods are imperfect substitutes, the model captures an important feature of industries in less developed countries. By varying the parameters specifying the elasticity of substitution in use for different sectors, the model can incorporate assumptions ranging from complete insubstitutability (for example, two-gap models) to perfect substitutability (for example, neoclassical trade theory models). Indeed, some of our experiments will analyze the dynamic effects of trade strategy when the value of the elasticity of substitution in use between the domestically produced and imported goods increases smoothly over time (resulting, perhaps, from steadily improving quality of the manufacturing output in the developing country). In any case, it is important to explore the empirical importance of the elasticity parameter and its impact on the effectiveness of different trade strategies and patterns of commercial policy.⁹

III. A CGE Trade Model With Product Differentiation and Income Distribution

1. Introduction

This section presents the equations describing the static model. A summary discussion of applications and dynamic linkages is provided in the following section.

The endogenous variables are summarized in Tables 1 and 2.

We use a number of notation conventions which are listed below:

- Endogenous variables, and only endogenous variables are denoted by Roman letters without bars.
- Variables with different numbers of subscripts are different. For example, C_i and C_{ik} are different variables.
- Exogenous variables and parameters are denoted either by Greek letters or Roman letters with a bar over them.
- Quantities and prices of the composite goods have no superscript.
- The superscript "e" refers to export goods.
- The superscript "m" refers to imported goods.
- The superscript "d" refers to domestically produced goods.
- The superscript "p" refers to private (as opposed to government).
- The superscript "G" refers to government.
- The subscripts "i" and "j" always refer to output sectors.
- The subscript "q" refers to labor types.
- The subscript "g" refers to categories of income recipients.
- The subscript "k" refers to income classes
- The subscript "K" refers to capital (such as \tilde{Y}_K , capital income).
- Variables with a \sim over them are in units of money.

TABLE 1
 PRODUCT SUPPLY AND FACTOR MARKETS:
 ENDOGENOUS VARIABLES AND EQUATIONS

Name	Variable	Equation	Number
Net prices	P_i^*	(9)	n
Average wages	W_q	(15)	q
Capital rental	$W_{K,i}$	(11)	n
Domestic output	X_i^d	(7)	n
Labor aggregate	L_i	(8)	n
Labor by category	L_{iq}	(10)	n·q
Aggregate labor demand	L_q^D	(13)	q
Aggregate labor supply	L_q^S	(14)	q
Sectoral capital stocks	K_i	(12)	n
		Sum	<u>5n + 3q + nq</u>

TABLE 2
 PRODUCT MARKETS AND INCOME DISTRIBUTION:
 ENDOGENEOUS VARIABLES AND EQUATIONS

<u>Name</u>	<u>Variable</u>	<u>Equation</u>	<u>Number</u>
<u>Endogeneous Parameters</u>			
Domestic good ratio	S_i	(3)	n
Import ratio	m_i	(4)	n
Domestic price ratio	r_i	(5)	n
			Sum <u>3n</u>
<u>Income Distribution and Flow of Funds</u>			
Labor income	\tilde{Y}_q	(16)	q
Capital income	\tilde{Y}_K	(17)	1
Within group income dist.	\tilde{y}_g	(18)	q+1
Group mean income	\hat{y}_g	(19)	q+1
Overall income dist.	\tilde{y}	(20)	1
Income classes	\tilde{Y}_k^P	(21)	k
Population by income class	N_k	(22)	k
Private savings	\tilde{S}_k^P	(23)	k
Private consumption	\tilde{C}_k^P	(24)	k
Government revenue	\tilde{G}	(27)	1
Government saving	\tilde{S}^G	(28)	1
Total saving	\tilde{S}	(30)	1
Balance of trade	\tilde{T}^S	(33)	1
			Sum <u>4k + 3q + 8</u>

TABLE 2 cont.

<u>Name</u>	<u>Variables</u>	<u>Equation</u>	<u>Number</u>
<u>Quantities: Composite Goods and Imports</u>			
Total composite good	Q_i	(1)	n
Imports	M_i^m	(2)	n
Consumption by class and good	C_{ik}	(25)	n·k
Consumption by good	C_i	(26)	n
Government consumption	G_i	(29)	n
Aggregate investment	ΔK	(31)	1
Investment goods	Z_i	(32)	n
Intermediate goods	F_i	(39)	n
			Sum <u>$6n + n \cdot k + 1$</u>
<u>Quantities: Domestic Goods</u>			
Consumption	C_i^d	(36)	n
Investment	Z_i^d	(37)	n
Government consumption	G_i^d	(38)	n
Intermediate goods	F_i^d	(40)	n
Total domestic demand	D_i^d	(41)	n
Exports	E_i^d	(42)	n
			Sum <u>$6n$</u>

TABLE 2 cont.

<u>Name</u>	<u>Variables</u>	<u>Equation</u>	<u>Number</u>
<u>Prices and Exchange Rate</u>			
Exchange rate	R	(44)	1
Composite goods prices	P_i	(6)	n
Import prices	P_i^m	(34)	n
Export prices	P_i^e	(35)	n
Domestic goods prices	P_i^d	(43)	n
		Sum	<u>4n + 1</u>

2. The Composite Good

Aggregation Function

As discussed earlier, there are two different types of goods in the model economy: those which are produced domestically and those which are imported. These two types of goods are not considered to be perfect substitutes in use. Instead, domestically produced and imported goods of the same sectoral classification are combined together to make a single composite good for each sector which is what is demanded by all users. For example, consumers are assumed to have a two-level utility function. In the first level, the consumer combines, say, imported and domestic wine to make a composite "wine" which then enters the utility function. Domestic and imported wine substitute for one another through the aggregation function and the composite "wine" enters the utility function along with other composite goods.¹⁰

The composite good in each sector is defined as a C.E.S. aggregation of domestically produced (D_i^d) and imported (M_i^m) goods:

$$(1) \quad Q_i = \bar{B}_i [\beta_i (M_i^m)^{-\mu_i} + (1-\beta_i) (D_i^d)^{-\mu_i}]^{-1/\mu_i} \quad n \text{ equations}$$

Note that if for a given sector there is no substitutable import good, then $\beta_i = 0$, $\bar{B}_i = 1$ and $X_i = D_i^d$. Define the right hand side of (1) as $f_i(M_i^m, D_i^d)$. Since equation (1) is linearly homogeneous in M_i and D_i it can be rewritten as:

$$(1a) \quad Q_i = f_i(m_i, 1) D_i^d$$

where m_i is defined as the ratio of imported to domestic goods in sector i :

$$(2) \quad m_i = M_i^m / D_i^d \quad n \text{ equations}$$

It will be seen below that m_i is a function of the relative price of the domestically produced and the foreign good.

Equation (2) makes it clear that imported and domestic goods are considered to be substitutes in use by sectors.

It is important to keep the units of the various goods clearly in mind. Even though they may all have the same sector name, the composite good (Q_i), the imported good (M_i^m) and the domestic good (D_i^d) are all different goods. In contrast to the usual practice in planning models, they cannot appear together in the same material balance equations. They are related only through the aggregation function which can be used to define the ratio of the domestic good to the composite good for each sector:

$$(3) \quad S_i = D_i^d / Q_i = 1 / f_i(m_i, 1) \quad n \text{ equations}$$

The definition of the composite good in equation (1) is somewhat restrictive in that the same composite good is employed in all uses. For example, one might wish to specify a different aggregation of imported and domestic machinery to make composite machinery for use as investment than, say, for consumption or intermediate uses. Such a specification would not be difficult, although it would clutter up the algebra. We have not used the more general specification both because data are lacking to estimate the additional aggregation functions and because we suspect that the aggregation functions for different uses would not be very different for the fairly high level of aggregation in our model.

Import Demand

Buyers cannot directly purchase pre-mixed units of the composite good but must instead purchase imports and domestic goods and make up the

composite good by means of the aggregation function. We assume that in their purchasing, buyers seek to minimize the cost of obtaining the composite good. Given specified prices for the domestic and imported goods, the problem facing the buyer is mathematically equivalent to that facing the firm who wants to produce a specified level of output at minimum cost. The solution is to find a ratio of inputs (M_i^m to D_i^d) so that the marginal rate of substitution (the slope of the iso-output curve for the composite good) equals the ratio of price (P_i^d over P_i^m). Given that the aggregation function is homogeneous, the import ratio ($m_i = M_i^m/D_i^d$) is a function only of the price ratio and is independent of the level of output. For the C.E.S. aggregation function, the desired import ratio is given by:

$$(4) \quad m_i = [r_i \beta_i / (1 - \beta_i)]^{1/(1 + \mu_i)} \quad n \text{ equations}$$

where:

$$(5) \quad r_i = P_i^d / P_i^m \quad n \text{ equations}$$

is the ratio of the price of the domestically produced good P_i^d to the domestic price of the imported good P_i^m . Note that for goods for which there is no imported substitute, $\beta_i = 0$ and hence $m_i = 0$.

Equation (4) can be rewritten as:

$$\frac{M_i^m P_i^m}{D_i^d P_i^d} = \left[\frac{\beta_i}{1 - \beta_i} \right]^{\sigma_i} \left[\frac{P_i^d}{P_i^m} \right]^{(1 - \sigma_i)}$$

where $\sigma_i = 1/(1 + \mu_i)$ is the elasticity of substitution in use between imported and domestically produced goods. This formulation makes it clear that value shares are independent of the price ratio if and only if $\sigma_i = 1$.

Composite Good Price

Given the prices of imported and domestic goods (P_i^m and P_i^d), there is a corresponding price for the composite good. Since total expenditure on the composite good must equal expenditure on its imported and domestic components, it follows that:

$$P_i Q_i = P_i^d D_i^d + P_i^m M_i^m$$

Substitution from equation (1a), and (2) and (3) yields:

$$(6) \quad P_i = S_i (P_i^d + P_i^m m_i) \quad n \text{ equations}$$

Equation (6) defines the price of the composite good and does not depend on any behavioral assumptions.

3. Factor Markets and Domestic Supply

Production Functions

The technology for producing the domestic good is given by two-level C.E.S. production functions. Output is a C.E.S. function of aggregate labor and capital:

$$(7) \quad X_i^d = \bar{A}_i [\alpha_i K_i^{-\rho} + (1-\alpha_i) L_i^{-\rho}]^{-1/\rho} \quad n \text{ equations}$$

The capital good is assumed to be a composite of heterogeneous capital goods aggregated in fixed proportions. Labor is assumed to be a C.E.S. aggregation of different types of labor:

$$(8) \quad L_i = \sum_q [\gamma_{iq} L_{iq}^{-\lambda}]^{-1/\lambda} \quad n \text{ equations}$$

where the subscript q refers to different labor types. ¹¹

In addition, producers are assumed to require intermediate goods in fixed proportions to output as specified by the usual table of input-output coefficients.

Factor Demands

We assume that the producers of domestic output are profit maximizing perfect competitors. They will thus hire factors until the marginal revenue product equals the wage for each factor. Since intermediate goods must be used in fixed proportions, their cost can be deducted from the price of the output to give the net price to the firm from selling a unit of output. This net price equation is given by:

$$(9) \quad P_i^* = P_i^d - \sum_j \bar{a}_{ji} P_j - \theta_i P_i^d \quad n \text{ equations}$$

The \bar{a}_{ji} are the input-output coefficients and θ_i is the indirect tax rate. The input-output coefficients give the demand for the composite good as an intermediate input and hence, in the net price equation, they are multiplied by the prices of the composite goods. P_i^* gives the net receipts to the firm from selling a unit of output.

The first-order conditions for profit maximization require that wages equal marginal revenue products for all factors:

$$(10) \quad W_q = P_i^* \frac{\partial X_i^d}{\partial L_i} \frac{\partial L_i}{\partial L_{iq}} \quad q \cdot n \text{ equations}$$

$$(11) \quad W_{K,i} = P_i^* \frac{\partial X_i^d}{\partial K_i} \quad n \text{ equations}$$

In equation (10) it is assumed that the wage of a particular labor category (W_q) will be the same in all sectors. This implies that labor in each category is free to move across all sectors of production.

Equation (11), on the other hand, reflects the assumption that the capital stock in each sector is fixed and immobile during the period. The rental of capital will thus differ among sectors (and hence has an i subscript) since capital cannot move within the period so as to equate rentals across sectors. The sectoral immobility of capital is shown by specifying a fixed supply in each sector:

$$(12) \quad K_i = \bar{K}_i \quad n \text{ equations}$$

We intend to do a number of comparative statics experiments in which capital is assumed to be mobile among sectors. In this case, treat capital symmetrically with labor, replacing equations (11) and (12) with the following:

$$(11^*) \quad W_K = P_i^* \frac{\partial X_i^d}{\partial K_i}$$

$$(12^*) \quad \sum_i K_i = \bar{K}$$

Equation (11*) will be used to determine the demand for capital by sectors given the rental rate W_K and equation (12*) gives the market clearing equilibrium condition.

Given a wage, equation (10) will yield the labor demands in each sector, L_{iq} . These demands are aggregated across all sectors to give the total demand for labor in each category:

$$(13) \quad L_q^D = \sum_i L_{iq} \quad q \text{ equations}$$

The total labor supply in each category is assumed to be fixed exogenously:

$$(14) \quad L_q^S = \bar{L}_q^S \quad q \text{ equations}$$

Equilibrium in the labor markets requires that supply equal demand for labor in each category, or that the excess demands for labor equal zero.

$$(15) \quad L_q^D - L_q^S = 0 \quad q \text{ equations}$$

Table 1 summarizes the endogenous variables and their associated equations for equations (7) to (15). Note that if product prices are given, then there are just as many equations as there are endogenous variables. We can solve equations (7) to (15) for wages which clear all factor markets, employment, and domestic output in all sectors. The solution of these equations thus yields the supply of domestic goods to the product markets given specified prices.

The equations are, of course, highly non-linear in the endogenous variables. However, assuming that the first order conditions given by equation (10) can be solved for labor demands, then it is possible to substitute until the system is reduced to a set of q non-linear excess-demand-for-labor equations as a function of the q average wages, W_q . Once these equations are solved for market clearing wages, then all the other endogenous variables can be solved by simply evaluating the appropriate equations. The techniques used for solving this system are described below.

In the next section, we present the income and product demand equations and finally describe how the entire system is solved for wages, prices, income, production, and employment.

4. Income Distribution and Product Demand

Income Distribution and Private Consumption Demand

The income accruing to factors of production is given by:

$$(16) \quad \hat{Y}_q = \sum_i W_{q,i} L_{iq} \quad q \text{ equations}$$

$$(17) \quad \hat{Y}_K = \sum_i W_{K,i} K_i \quad 1 \text{ equation}$$

Equation (16) and (17) give the functional distribution of income among categories of labor and capital. The overall size distribution of income is generated by assuming that the distribution of income within each group can be described by a two parameter lognormal probability distribution function. Thus the distribution of income within each group is given by:

$$(18) \quad \hat{y}_g \stackrel{d}{=} f_g(\hat{y}_g | \mu_g, \sigma_g^2) \quad q+1 \text{ equations}$$

where f_g is the lognormal distribution with parameters μ_g and σ_g^2 . The subscript g refers to the number of distinct income earning groups. In this model $g = q + 1$. The logvariance for each within-group distribution is specified exogenously. The logmean, μ_g , however is a function of the group mean incomes.¹²

Aggregate group incomes are given by \hat{Y}_q and \hat{Y}_K . Assume that the first q groups are the different labor categories and that the last group is the capitalists. The number of people in each group is given by L_g where $L_g = \bar{L}^S$ for the different labor categories and L_{q+1} is the number of capitalists. The total population is assumed exogenous:

$$\bar{L} = \sum_g L_g = \sum_q \bar{L}_q^S + \bar{L}_{q+1}$$

The number of capitalists (\bar{L}_{q+1}) is assumed to be specified exogenously. Thus we have added a pure rentier class to the population of workers and have assumed that no workers receive capital income and that no capitalists receive wage income. It is easy to relax this rigid demarcation, but one must then specify which worker groups receive capital income and how much as well as how much labor income goes to capitalists. We will in fact distribute agricultural capital income to the category of rural labor under the assumption that they include landowners (and hence exclude landowners from the capitalist group).

Another problem is that capital income \hat{Y}_K includes the undistributed profits of corporations which are thus assumed to be part of the received income of capitalists. While this may be a reasonable procedure in a capitalist country, it is not the usual practice in studies of income distribution. We can adjust for undistributed profits by applying a retained earnings ratio to \hat{Y}_K to give the total income distributed to capitalists. The retained earnings must be added to savings in equation (23) below. It is easy and interesting to generate the income distribution both before and after correcting for retained earnings.

The mean income of each group is given by:

$$(19) \quad \hat{y}_g = (1 - \tau_g) \hat{Y}_g / L_g \quad q+1 \text{ equations}$$

where $\hat{Y}_g = \hat{Y}_q$ for the first q groups and equals \hat{Y}_K for the last group. The parameters τ_g are the average direct tax rates applied to factor incomes. Some progressivity is assumed by applying different average

tax rates to different categories of income. It would also be straightforward to apply a progressive rate structure to different levels of income in each category (or overall) since one can use the distribution functions (18) to generate the total amount of taxable income within any specified income ranges. Thus the model will generate the logmeans of the within-group distributions and only the logvariances need to be specified exogenously.

The distribution function describing the overall size distribution of income is a weighted average of the within-group distribution functions with the weights equaling population shares. Thus the overall distribution is given by:

$$(20) \quad \tilde{y} \stackrel{d}{=} (1/\bar{L}) \sum_g L_g f_g(\tilde{y} | \mu_g, \sigma_g^2) \quad \text{1 equation}$$

Note that the overall distribution function is a sum of distribution functions not the distribution of a sum of random variables. Thus central limit theorems do not apply and the function may, in principle, have any shape. Given specified within-group distribution functions, it is feasible to generate the overall distribution empirically even though it is analytically an intractable function. We use a computer algorithm described in Robinson (1976b) to generate empirically all the statistics of the overall distribution we require such as the Gini coefficient, decile distribution, and so forth.

In particular, we divide the overall population into a number of income classes which are each assumed to have a particular savings and consumption behavior. The algorithm is used to generate the total number of people (N_k) in each income class and the aggregate income

accruing to those people (\hat{Y}_k^P). To keep endogenous variables and equation counting straight, we list these variables below with associated equation numbers:

$$(21) \quad \hat{Y}_k^P \quad \text{k equations}$$

$$(22) \quad N_k \quad \text{k equations}$$

where the subscript k refers to the income class.

Aggregate private savings are calculated by applying a different savings function for each income class.

$$(23) \quad \hat{S}_k^P = f_k^P(\hat{Y}_k^P, N_k) \quad \text{k equations}$$

The demand for consumption goods is calculated by assuming that each income class has a distinct set of expenditure equations:

$$C_{ik} = f_i^k(\hat{C}_k^P, N_k, P_1, \dots, P_n)$$

where \hat{C}_k^P is per capita expenditure:

$$(24) \quad \hat{C}_k^P = (\hat{Y}_k^P - \hat{S}_k^P) / N_k \quad \text{k equations}$$

We have chosen to use Stone's linear expenditure system which yields the following expenditure equations:

$$(25) \quad P_i C_{ik} = [P_i \gamma_{ik} + \beta_{ik} (\hat{C}_k^P - \sum_i P_i \gamma_{jk})] N_k \quad \text{n.k equations}$$

The parameters γ_{ik} represent per capita committed expenditure and the β_{ik} are marginal budget shares. The equations satisfy the usual requirements for systems of demand equations such as Engle and Cournot aggregation.¹³

The expenditure equations are expressed in terms of the composite good because it is assumed that consumers aggregate imports and domestically produced goods according to equation (1) before using them. The composite good is what is assumed to be desired by all users for all uses. Aggregate demand for each consumer good is given by:

$$(26) \quad C_i = \sum_k C_{ik} \quad n \text{ equations}$$

Government Accounts

Government revenue is given by:

$$(27) \quad \begin{aligned} \tilde{G} = & \sum_q \tau_q \tilde{Y}_q + \tau_K \tilde{Y}_K + \sum_i \theta_i P_i^d X_i^d + \sum_i t_i P_i^{\$m} R M_i^m \\ & - \sum_i s_i^e P_i^{\$e} R E_i^d \end{aligned} \quad 1 \text{ equation}$$

The first three terms include direct and indirect taxes. The fourth term represents tariff collections on imports and the last term is an expenditure item reflecting government subsidies for exports. The variables in the last two terms will be discussed further below.

Government saving is assumed to be a function of government revenue and of the balance of international trade ($T^{\$}$).

$$(28) \quad S^G = f^G(\tilde{G}) + R T^{\$} \quad 1 \text{ equation}$$

where $R T^{\$}$ is value of the trade surplus in domestic currency. Including the balance of trade as part of government savings involves the implicit assumption that the government successfully neutralizes any monetary

repercussions of the balance of payments.¹⁴ The model in its present form does not permit monetary injections whether from domestic monetary expansion or from the balance of payments. It is possible to extend the model to include explicit money demand and supply equations and so include monetary and inflationary effects emanating from the balance of payments.¹⁵

The government is assumed to spend its net revenue (excluding government savings) in fixed shares. The government demand for goods is given by:

$$(29) \quad P_i G_i = \bar{g}_i (\bar{G} - \bar{S}^G) \quad n \text{ equations}$$

Note again that government demand is for units of the composite good.

Savings and Investment

Total savings is given by private and government saving:

$$(30) \quad \bar{S} = \bar{S}^G + \sum_k \bar{S}_k^p \quad 1 \text{ equation}$$

Savings are assumed to be spent on investment goods in order to purchase units of new capital stock. The composition of the capital good in different sectors is assumed to be the same, with the proportions given by the parameters \bar{b}_i . $\sum_i \bar{b}_i = 1$. The price of a unit of capital is thus given by $\sum_i \bar{b}_i P_i$ and the total amount of capital that can be purchased with the savings \bar{S} is:

$$(31) \quad \Delta K = \bar{S} / \sum_i \bar{b}_i P_i \quad 1 \text{ equation}$$

The demand for investment goods by sector of origin is given by:

$$(32) \quad Z_i = b_i \Delta K \quad n \text{ equations}$$

Note that the capital stock and investment demand is measured in units of the composite good.

In the model as presented above, investment is savings determined. The model determines incomes and savings by the different economic actors and then determines investment from equations (31) and (32). For some experiments with the model, it might be useful to be able to make aggregate investment (ΔK) exogenous.¹⁶ This can be accomplished by solving equation (31) for \tilde{S} instead of ΔK and then scaling the average savings rates of all savers so as to achieve the desired aggregate savings.

5. Trade and Material Balances

The balance of trade is calculated in dollars by valuing exports and imports in world prices (which are assumed to be exogenous). The equation is:

$$(33) \quad \tilde{T}^{\$} = \sum_i \bar{P}_i^{\$e} E_i^d - \sum_i \bar{P}_i^{\$m} M_i^m \quad 1 \text{ equation}$$

In general, we assume the level of the balance of trade to be specified exogenously and will let the model find the exchange rate that achieves the desired equilibrium.

Note that exports are assumed to be in units of the domestic good, not of the composite good. As mentioned earlier, we make the usual small country assumption so the price of exports does not depend on the volume. Because the domestic good and the import good are not perfect substitutes, one would generally assume that $\bar{P}_i^{\$e} \neq \bar{P}_i^{\$m}$.

The domestic prices of exports and imports depend on the exchange rate and on tariffs and subsidies. They are given by:

$$(34) \quad P_i^m = (1 + t_i^m) R \bar{P}_i^{\$m} \quad n \text{ equations}$$

$$(35) \quad P_i^e = (1 + s_i^e) R \bar{P}_i^{\$e} \quad n \text{ equations}$$

Given the exchange rate R , both P_i^m and P_i^e are determined since the other parameters are exogenous. Since the import good is not perfectly substitutable for the domestic good, there is no reason to assume that $P_i^d = P_i^m$. Indeed, they are not even strictly comparable since they really do not have the same units. They can only be used together through the aggregation function in equation (6) to define the price of composite good (P_i).

Since exports consist of domestically produced goods, P_i^e and P_i^d are in the same units and are comparable. Given the exchange rate and subsidy rate, we assume that the world price of exports determines a floor price for the domestic good: $P_i^d \geq P_i^e$. If the domestic price P_i^d were to fall below the export price P_i^e , then profit maximizing producers would export all their output, thus causing excess demand in the domestic market until the domestic price rises to the world price. However, it is perfectly possible for the export price to rise above the world price. In this case, there will be no exports and all production will go to satisfy domestic demand.

Equilibrium in the product markets requires that supply and demand be equated for each domestically produced good. With the exception of exports, the demands for goods have all been expressed in terms of the composite good. To determine the demands for domestic goods, we

use the domestic component ratio, S_i , defined in equation (3). Since the same aggregation function is used to make the composite good regardless of use, the ratio can be applied to all components of demand. For the components of final demand, the demands for domestic goods are given by:

$$(36) \quad C_i^d = S_i C_i \quad n \text{ equations}$$

$$(37) \quad Z_i^d = S_i Z_i \quad n \text{ equations}$$

$$(38) \quad G_i^d = S_i G_i \quad n \text{ equations}$$

The demand for intermediate goods is determined through the use of input-output coefficients and is expressed in units of the composite good.

$$(39) \quad F_i = \sum_j \bar{a}_{ij} X_j^d \quad n \text{ equations}$$

The demand for domestic goods for intermediate use is given by:

$$(40) \quad F_i^d = S_i F_i \quad n \text{ equations}$$

The demand for domestic uses of domestic goods is given by:

$$(41) \quad D_i^d = F_i^d + C_i^d + Z_i^d + G_i^d \quad n \text{ equations}$$

This is the demand which is combined with total import demand to give the aggregate demand for the composite good (Q_i). To get total demand for domestic production, one must add export demand, E_i^d .

The total supply of domestically produced goods is X_i^d from equation (7). Equilibrium in the product markets requires that supply

equal demand:

$$X_i^d = D_i^d + E_i^d$$

The solution problem reduces to that of finding a set of prices, P_i^d , such that supply equals demand in all product markets.

The treatment of exports and the existence of a floor price for export goods enables us to rewrite the equilibrium conditions. For those goods which are exported, the domestic price equals the export price and exports are determined residually after satisfying all domestic demands:

$$(42a) \quad E_i^d = X_i^d - D_i^d, \quad E_i^d > 0 \quad n_1 \text{ equations}$$

$$(43a) \quad P_i^d = P_i^e \quad n_1 \text{ equations}$$

where n_1 equals the number of export goods. There can, of course, be no negative exports. If the domestic price exceeds the export price, then exports are zero and the price is such that the domestic market clears:

$$(42b) \quad E_i^d = 0, \quad P_i^d > P_i^e \quad n_2 \text{ equations}$$

$$(43b) \quad X_i^d = D_i^d \quad n_2 \text{ equations}$$

where n_2 equals the number of goods for which there are no exports. Since $n_1 + n_2 = n$, there are n equations in each set. Equations (42a) and (42b) determine the level of exports and equations (43a) and (43b) determine the level of all domestic prices, P_i^d . Equations (42a) and (43b) reflect the equilibrium conditions that excess demands must equal zero in all product markets. When there are exports, equilibrium is achieved by exporting any residual supply at the export price. When there are no exports, equilibrium must be achieved by finding market clearing domestic prices such that equations (43b) are satisfied. This latter problem is essentially

that of computing "solution prices" for a general equilibrium system.

The exchange rate R is an endogenous variable in the model. It is allowed to vary so as to make the balance of trade, $T^{\$}$ in equation (33), equal to an exogenously specified value:

$$(44) \quad T^{\$} = \bar{T}^{\$} \quad 1 \text{ equation}$$

If the balance of trade were too low then there should be a devaluation, or an increase in R . A higher R raises the prices of both imports and exports, P_i^m and P_i^e . In the case of imports, this will lead to greater substitution of imported for domestic goods and so decrease the import ratio (m_i). Raising P_i^e should lead to an increased supply of export goods and may even induce sectors which have not exported to start doing so.

Table 2 summarizes the endogenous variables and associated equations for the composite good, income distribution and product demand parts of the model. There are exactly as many equations as endogenous variables. However, as usual for a general equilibrium system, the entire system is homogeneous of degree zero in all wages, prices, and the exchange rate. The general equilibrium can only determine relative prices, not the absolute level. We must thus add a price normalization equation:

$$(45) \quad \bar{P}^d = \sum_i \delta_i P_i^d \quad 1 \text{ equation}$$

which completes the presentation of the static model equations.

6. Solving the Model

From the discussion above, it should be clear that by substitution the model can be reduced to sets of excess demand equations in three markets:

those for labor, domestic products, and foreign exchange. The endogenous variables to be solved are wages, product prices, and the exchange rate. There are a number of different strategies and algorithms for solving such sets of market excess demand equations.¹⁷ Our solution strategy is based on the fact that the three markets can be segmented. Given the exchange rate and product prices, it is possible to solve the labor markets for equilibrium wages. Given the solution of the labor market equations -- yielding wages, employment, and product supply -- it is possible to solve the product market equations for a set of equilibrium product prices. Each solution of the labor and product markets yields a corresponding value for the balance of trade from equation (33).

Our strategy is first to set the exchange rate R and then solve the product and labor markets seriatim, repeating until they are both cleared. The resulting balance of trade is compared to the target balance and the exchange rate is adjusted. The product and labor markets are then solved with the new value of R . This iteration procedure is continued until all three markets are cleared.

In solving all three markets, a price adjustment approach is used. In the product and foreign exchange markets, a tatonnement procedure is used which generates new guesses at prices based on the calculated excess demands, sector by sector. In terms of computer algorithms, this approach is an adaptation of a Gauss-Seidel algorithm. In the factor markets, we also treat the excess demand equations directly but use a different algorithm that uses the derivatives of the excess demand equations with respect to the wages -- the Jacobian matrix.

Note that in deriving the excess demand for labor equations, it is necessary to solve the first order conditions to get labor demands

given wages. For Cobb-Douglas production functions, equation (10) can be easily solved analytically for labor demands. For two-level CES functions, the solution is not so straightforward. In this case, we solve the equations numerically using a variant of Newton's method.¹⁸

Since the model is highly non-linear, simply counting equations does not guarantee that a solution exists or that there is a unique solution. In terms of economic theory the model is a rather simple example of general equilibrium models which have been extensively studied. The model certainly satisfies all the assumptions necessary to guarantee that a solution exists.¹⁹ However, since the model ^{has} a number of consumers, we cannot guarantee that any solution we find is unique. This is probably not a serious problem but should be investigated empirically. Adelman and Robinson (1976) built a CGE model with many more consumers (fifteen in all) and found that their model displayed "strong local uniqueness." That is, when they shocked the model from an equilibrium and applied their solution algorithm it always returned to the same equilibrium.

IV. Trade Strategy, Growth, and Income Distribution

1. Introduction

The model described in the preceding section will be used to examine the implications of alternative trade policies for income distribution, economic structure and comparative advantage. The careful specification of income and government accounts will be important in tracing the impact of alternative trade regimes on the government budget, providing an additional channel through which trade policy affects the economy.

The static model, however, cannot handle two important issues. First, it cannot quantify the often cited merits of the "infant industry" argument which is the main justification provided for industrialization behind high tariff walls. Second, it does not provide any information about the economy's adjustment to structural disequilibria resulting from changes in economic policies.

Belief in the need for a development strategy based on protection of the manufacturing sector is powerful in developing countries. The argument for protection in this context is based on dynamic considerations. Those who argue for protection concede that trade distortions in the form of tariffs have static welfare costs, but argue that the dynamic benefits associated with a protectionist growth strategy are well worth the static costs. Under the infant industry argument, investment allocation and production in accordance with the static structure of comparative advantage is believed to prevent or delay the development of potentially

competitive industries. De Melo and Dervis (1976) have used a simple dynamic three-sector CGE model to indicate the quantitative importance of alternative assumptions concerning capital mobility, labor migration, and savings behavior in evaluating the dynamic effects of trade policy. Their results indicate that the dynamic effects of trade policy are quantitatively important and point towards the need for evaluating the impact of trade strategies on income distribution and resource allocation in a dynamic setting.

In the next section, we discuss our approach to modelling the intertemporal linkages in a fully dynamic model. As discussed in Robinson (1976a), we separate the market clearing equilibrium process from the dynamic adjustment process. The resulting dynamic model is recursive in time but simultaneous within periods.

2. Dynamic Linkages

The full dynamic model consists of two stages. The first stage is the static CGE model which is solved given values for all exogenous variables and parameters. The second stage consists of a set of submodels providing all the intertemporal linkages. The stage 2 submodels treat the solution values of the endogenous variables in stage 1 as exogenous and endogenously solve for the variables and parameters that are exogenous to the stage 1 model in the next period.

Our stage 2 model will consist of three submodels. The first will determine the sectoral allocation of investment, the second will determine the growth and allocation of the labor force by type of labor,

and the third will update a number of technological parameters.

Capital Allocation

Within the static model, there are two alternative views of investment that can be specified. In the first, the rate of growth of the aggregate capital stock is specified exogenously. In the second, investment expenditure is determined by aggregate savings and thus depends on the entire solution of the static model. In the second approach -- which is the one included in the equations presented above -- trade strategy and commercial policy will have an effect on aggregate investment and hence on growth.

In the static model, capital was assumed to be immobile between sectors and hence the solution will in general yield different profit rates among sectors. In the stage 2 model, investment will be allocated among sectors as a function of profit rate differentials.²⁰

Labor Force

Each category of labor has a specified "natural" rate of growth. In addition, there is movement among labor categories according to two different mechanisms. The first is rural-urban migration. We plan to experiment with variants of a Harris-Todaro migration model using an exogenously specified urban wage in the stage 1 model. For the version of stage 1 where aggregate employment is specified exogenously, migration will simply be a function of the rural-urban wage differential.

The second mechanism underlying inter-category labor movement is education or human capital formation. In our model, the extent of

such skill upgrading will be specified exogenously.

Parameter Updating

Technical change in production can be specified by assuming that the productivity parameters (\bar{A}_i) in the sectoral production functions grow at specified rates. Such exogenous technical change is neutral and disembodied.

As a country develops, another dimension of technical change that we can include in the model is that domestically produced goods improve in quality and become more substitutable for imported goods. We can capture this effect by specifying time trends for the elasticity of substitution in use between imported and domestically produced goods.

Depending on how ambitious one is, there are a number of other parameters one might change dynamically. For example, one might specify time trends in the margin/^{a1}budget shares in the expenditure functions or in the savings rates. Such changes might make the model more "realistic" in that it can better track actual historical data. However, there is a cost in terms of added complexity.

V. Conclusion

Recent developments in the field of trade policy have been dominated by the elaboration of the theory of domestic distortions in open economies. Essentially the modern approach focuses on the choice between alternative policies and provides a greatly improved method of analyzing the effects of trade policies. However, as discussed in de Melo (1977), the analytical rigor and intellectual effort which has gone into this theoretical work has not been matched on the empirical side where the measurement of the welfare costs of domestic distortions has concentrated on trade distortions and has most often been carried out in a static, partial equilibrium framework. This paper offers a methodology to simulate and measure the effects of trade policies within the framework of an empirically implementable computable general equilibrium planning model that captures many of the interesting features of recent models of international trade.

The model described in this paper will be used as a simulation laboratory for examining the effects of different trade strategies on growth and distribution. Our treatment of trade, especially the specification of imperfect substitutability between imported and domestically produced goods, should make the basic model structure applicable to a wide range of relatively open developing countries for whom trade strategy and commercial policy are important issues in planning. With the explicit inclusion of the size distribution of income and the concomitant complete specification of the income accounts, the model also traces the effects of trade strategies on the distribution of income. In addition, the endogenous solution of wages and prices

enables us to experiment with policy instruments such as direct and indirect taxes, tariffs, and price subsidies which are not included in the more traditional quantity oriented planning models. The approach used here in specifying a computable general equilibrium (CGE) model provides a general methodological framework that is quite flexible and especially well-suited to simulate market behavior. As illustrated by the model presented here, it is relatively easy to introduce a number of alternative behavioral assumptions within this framework.

Footnotes

Part I

¹See for example Evans (1972), de Melo (1975), Adelman and Robinson (1976).

Part II

²For example, the reduction of tariff barriers among members of the EEC has led to substantial intra-industry specialization but little inter-industry specialization.

³In the context of a small country assumption with linear homogeneous production functions, Samuelson (1953) has shown that in a perfectly competitive model with n final goods traded and s primary factors of production, where $n > s$, the overdetermination resulting from more fixed prices through trade than variable factor prices resolves itself through the country specializing in the production of s commodities. Note that this result is closely linked with a linear programming theorem which states that the number of activities in the optimal solution will at most equal the number of constraints.

⁴Exceptions are Ali (1976) and Deardorf, Stern and Baum (1976).

⁵See Ali (1976) chapter 2 for the derivation of the efficiency parameter in terms of domestic resource cost.

⁶If primary products are excluded, there are indeed few manufactured goods for which developing countries may exercise monopoly power, especially when viewed from the level of aggregation typical in multisector models. See Weisskopf (1971) and Chenery and Raduchel (1971) for a justification of this approach.

⁷ See Bruno (1966), Evans (1972), Taylor and Black (1974), and de Melo (1975). In Ali's model the consumption bundle of a commodity is made up of a Cobb-Douglas combination of domestically produced and foreign goods of the same sectoral classification.

⁸ See Armington (1969) for the presentation of a theory of demand for products distinguished by place of production. This approach focuses on the consequences of introducing imperfect substitution in demand.

⁹ Armington (1969b) indicates the quantitative importance of the elasticity of substitution in computing the effects of price changes on the pattern of trade.

Part III

¹⁰ See Armington (1969a) for a detailed discussion of these assumptions.

¹¹ Other production functions such as Cobb-Douglas or generalized C.E.S. functions might be used. The Cobb-Douglas is just a special case using both a Cobb-Douglas aggregation function and a Cobb-Douglas production function.

¹² Given that the within-group distribution functions are lognormal, the log mean is related to the arithmetic mean by the following equation:

$$\mu_g = \log(\hat{y}_g) - 1/2 \sigma_g^2$$

See Aitchison and Brown (1957).

¹³ For a survey of systems of expenditure equation, see Brown and Deaton (1972).

¹⁴ Taylor and Black (1974) also make this assumption.

¹⁵ See Adelman and Robinson (1976) for ^a /CGE model with endogenous money supply and inflationary effects.

¹⁶ de Melo and Dervis (1976) have experimented with different savings and investment functions in a three sector dynamic CGE model with trade. Their dynamic results are quite sensitive to different assumptions about savings behavior.

¹⁷ For a survey of solution strategies and computer algorithms, see Adelman and Robinson (1976).

¹⁸ For a survey of such techniques, see Jaratt (1970).

¹⁹ See Arrow and Hahn (1971).

²⁰ Capital is assumed to flow to sectors with higher than average expected profit rates. There are a number of issues involved, both theoretical and empirical, that are beyond the scope of this paper.

References

- Adelman, I. and S. Robinson, (1976). Income Distribution Policy in Developing Countries: A Case Study of Korea, Stanford University Press, forthcoming.
- Aitchison, J. and J.A.C. Brown, (1957). The Lognormal Distribution, Cambridge: Cambridge University Press.
- Ali, I., (1976). "Comparative Advantage and Trade Policy in a General Equilibrium Framework: A Case Study of India," unpublished Ph.D. Thesis, The Johns Hopkins University.
- Armington P., (1969a). "A Theory of Demand for Products Distinguished by Place of Production," IMF Staff Papers, Vol. 16, pp. 159-178.
- Armington, P., (1969b). "The Geographic Pattern of Trade and the Effects of Price Changes," IMF Staff Papers, Vol. 16, pp. 179-201.
- Arrow, K. and F. H. Hahn, (1971). General Competitive Analysis, San Francisco: Holden-Day.
- Blitzer, C., P. Clark and L. Taylor, ed., (1975). Economy Wide Models and Development Planning, Oxford University Press.
- Brown, A. and A. Deaton, (1972). "Models of Consumer Behaviour," Economic Journal, December.

- Bruno, M., (1971). "Optimal Patterns of Trade and Development," in Chenery, Ed., Studies in Development Planning, Harvard University Press.
- Chenery, H.B. and A.M. Strout, (1966). "Foreign Assistance and Economic Development," American Economic Review, September.
- Chenery, H.B. and W. Raduchel, (1971). "Substitution in Planning Models," in H. Chenery ed., Studies in Development Planning, Harvard University Press.
- Corden, W., (1971). The Theory of Protection, Oxford University Press.
- Corden, W., (1974). Trade Policy and Economic Welfare, Oxford University Press.
- Deardorf, A., R. Stern and C. Baun, (1976). "A Simulation Model of World Trade and Production," paper presented to International Finance Seminar, Princeton University, November.
- de Melo, J., (1975). "A Multi-Sector Price Endogenous Trade Model Applied to Colombia," unpublished Ph.D Dissertation, Johns Hopkins University.
- de Melo, J., (1977). "A General Equilibrium Approach to Estimating the Costs of Domestic Distortions," American Economic Review, forthcoming.
- de Melo, J. and K. Dervis, (1976). "Modelling the Effects of Protection in a Dynamic Framework," RPDS Discussion Paper No. 66, Princeton University.

- Dervis, K., (1975). "Substitution, Employment and Intertemporal Equilibrium in a Non-Linear Multi-Sector Planning Model for Turkey," European Economic Review, Vol. 6, pp. 77-96.
- Evans, D., (1972). A General Equilibrium Analysis of Protection, North Holland Press.
- Jaratt, P., (1970). "A Review of Methods for Solving Nonlinear Algebraic Equations in One Variable," in P. Rabinowitz, ed., Numerical Methods For Nonlinear Algebraic Equations, London: Gordon and Breach.
- Johansen, L., (1974). A Multi-Sectoral Study of Economic Growth, North Holland Press. Second edition.
- Lage, G., (1970). "A Linear Programming Analysis of Tariff Protection," Western Economic Journal, Vol. 8, No. 2, pp. 167-185.
- McKinnon, R., (1964). "Foreign Exchange Constraints in Economic Development and Efficient Aid Allocations," Economic Journal, Vol. 74, pp. 388-409.
- Michalopoulos, C., (1975). "Production and Substitution in Two-Gap Models," Journal of Development Studies, Vol. 11, No. 4, pp. 343-356, July.

- Robinson, S., (1976a). "Towards an Adequate Long-Run Model of Income Distribution and Economic Development," American Economic Review, Vol. 66, No. 2, pp. 122-128.
- Robinson, S., (1976b). "Income Distribution Within Groups, Among Groups and Overall: A Technique of Analysis," RPDS Discussion Paper No. 65, Princeton University.
- Samuelson, P., (1953). "Prices of Factors and Goods in General Equilibrium," Review of Economic Studies, Vol. 34, pp. 1-20.
- Taylor, L. and S. Black, (1974). "Practical General Equilibrium Estimation of Resource Pulls Under Trade Liberalization," Journal of International Economics, Vol. 4, No. 1, pp. 37-58.
- Weisskopf, T., (1971). "Alternative Patterns of Import Substitution in India," in H. Chenery, ed., Studies in Development Planning, Harvard University Press.
- Werin, L., (1965). A Study of Production, Trade and Allocation of Resources, Stockholm: Högskolan, Acta.