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## Multisectoral economic models for developing countries

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# Kiel Working Papers

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Working Paper No. 117

Multisectoral Economic Models for Developing Countries:  
A Theoretical Framework and an Illustration of their  
Usefulness for Determining some Implications of UNCTAD  
Proposals for Commodity Market Reforms.

by  
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Multisectoral Economic Models for Developing Countries:  
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Proposals for Commodity Market Reforms.

1. Introduction

A feature of the economies of many less developed countries (LDC's) is their heavy reliance for foreign exchange earnings on a few export commodities whose markets are characterised by low income elasticities on the demand side and whose supply is continually expanding under the influence of improved production technologies while remaining highly sensitive to year to year weather conditions. Given these commodity market characteristics, such economies, unless they reduce their high export concentration in these commodities, are faced with both an unstable export earnings pattern and a long run deterioration in their terms of trade. It is not surprising therefore that these countries have in recent years under the guidance of the UNCTAD Secretariat, shown increasing interest in proposals to conclude international commodity agreements or producer cartels in selected commodity markets with the aim of both raising the prices of the commodities concerned and reducing their year to year variability.<sup>1</sup> Implicit in such proposals is an attempt to at least halt if not reverse the flow of resources from the less wealthy producing countries to the more wealthy consuming countries which is taking place through the decline in many low energy content raw materials prices relative to world commodity prices in general.

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<sup>1</sup> Such proposals to 'reform' selected international commodity markets are being negotiated under the UNCTAD Secretariat's so called Integrated Programme for Commodities. (See UNCTAD (1975)). In essence this programme calls for the stabilisation of and increase in the secular trend of commodity prices and export earnings of the developing countries by way of a variety of means including buffer stocks and export and production constraints. These commodity market intervention measures are to be linked in their financing by a Common Fund arrangement.



There have been a number of recent economic appraisals of the UNCTAD plans for commodity market reform. These studies have to date concentrated mainly on assessing the likelihood of success of various price fixing and stabilisation measures in selected commodity markets and with the financing implications associated with the achievement of certain market intervention measures.<sup>1</sup> Such issues, while crucial to the likely success of the Integrated Programme for Commodities, are not the concern of the present study. Rather, the starting point in this study is to take as given the ability of UNCTAD programmes to influence the terms of trade and price variance in selected world commodity markets. That is, we treat as exogenous, alternative proposals for commodity market reforms. Given these proposals, our aim is to determine their consequences for resource allocation and economic welfare in a sample of less developed countries. Since such commodity market reforms form the basis of the so called International Economic Order, an associated aim is to examine the implications for various LDC's of alternative methods (to commodity market intervention) of achieving resource transfers from rich to poor countries.

At the outset we would expect that developing countries would have divergent economic interests in UNCTAD plans for commodity market reform. Country-specific factors such as (i) the concentration of exports and imports in commodities comprising the UNCTAD programme, (ii) the relative price responsiveness of export supplies and import demands and (iii) input-output (I-O) structure (especially the intensity of use of domestically produced and imported commodities together with primary factor inputs in various industries and the disposition of imported and domestically produced commodity sales to intermediate usage and final demands) can be expected to yield different economic implications of any commodity relative price changes. The essential aim of our applied analysis is to identify the extent and nature of these differences.

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<sup>1</sup> See for example the studies by Behrman (1977) and Murray and Atkinson (1978).

Some brief comments on the scope of the empirical work planned for the present study are in order. The study focuses in detail on a selection of 10 LDC's of diverse levels of economic development and economic structure.<sup>1</sup> For each country the important linkages in production, consumption, exporting and importing of a selection of 10 commodities (the so called core commodities of the UNCTAD Integrated Commodity Programme<sup>2</sup>) are modelled. In addition, given the dramatic change in the world relative price of crude oil over the last decade and the important foreign exchange implications for many LDC's of a continued upward trend in real oil prices the commodities crude oil and oil products are also distinguished in the sectoral disaggregation of sample countries.<sup>3</sup> The study investigates the effects of specified commodity market regulations and related plans on a selection of economic variables for each country. The selection includes: (i) indicators of economic welfare such as real incomes per capita and real wage levels, (ii) the industrial composition of the gross domestic product and where of interest the occupational composition of the workforce, (iii) the pattern of imports and exports at a commodity level, (iv) the distribution of returns to factors of production and (v) the composition of the macroeconomic aggregates.

The central task of this paper is to specify a model system capable of addressing the above issues. In outline the entire system consists of a set of individual country models each linked to a single entity (interpreted as the rest of the world) via a set of rest of the world demand and supply equations for the

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<sup>1</sup> The countries are: Ivory Coast, Kenya, India, South Korea, Malaysia, Turkey, Brazil, Chile, Colombia and Mexico.

<sup>2</sup> These commodities are: coffee, cocoa, tea, sugar, cotton, sisal, jute, rubber, copper and tin.

<sup>3</sup> Hence the resource allocative and real income effects of higher real world oil prices on sample countries can be readily investigated within the modelling framework.

commodities produced by each country. The framework makes no provision however for formal linkages between specific country models.<sup>1</sup> Only one system of country model equations is specified. This system has however sufficient flexibility to accommodate the relevant country specific structural and institutional features. Since the central aim of the project is to quantify and explain the economic implications across countries of a given exogenous shock, the choice of a unique model design ensures that variations in response across countries can be attributed solely to specific features of each economy and not to differences in model specification. Furthermore, by working with a single framework computing requirements are greatly simplified.

The design of the paper is as follows: Section 2 presents in detail the theoretical structure of the country model. Section 3 gives examples of how the model might be closed to address both short run and long run policy issues. Section 4 outlines the procedure for simulating the resource allocative effects in each country of world commodity price changes and a reduction in commodity price variability while section 5 suggests a procedure for using results from the sample countries to generate results for many additional countries not modelled. Concluding remarks are contained in section 6.

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<sup>1</sup> This is a justifiable omission given the largely inconsequential trade flows between the countries comprising the sample of 10.

## 2. The Basic Country Model

The design of any economic model must of course be tailored towards the purposes for which the model is to be produced. In the context of the project aims outlined in the introduction we therefore specify a model which focuses heavily on determining endogenously trade flows between each country and the rest of the world given exogenous changes in world commodity prices.

The model presented in this section can be placed in the rapidly growing set of neoclassical price responsive general equilibrium models. These models are constructed around an input-output matrix and endogenously determine both commodity and industry quantities in an equilibrium process. Within this set of models two types of approaches are apparent. The first, as characterised by the work of Adelman and Robinson (1978), Whalley (1978) and Dervis de Milo and Robinson (1981), involves specifying and solving the model in its complete non-linear structural form. The second approach, which is that followed in this study, is essentially that pioneered by Johansen (1960) and developed further by Dixon (1980). This approach employs the technique of logarithmic differentiation to the underlying system of non linear equations to produce a set of structural equations linear in all growth rates. Simple matrix methods can then be used to solve the equation system. Thus instead of writing

$$(1) \quad Z = f(X_1, X_2)$$

where  $Z$  is output and  $X_1$  and  $X_2$  are inputs, we use the linear percentage change from

$$(2) \quad z - \epsilon_1 x_1 - \epsilon_2 x_2 = 0$$

where  $\epsilon_i$  is the elasticity of output with respect to inputs of factor  $i$  and  $z$ ,  $x_1$  and  $x_2$  are the percentage changes in  $Z$ ,  $X_1$  and  $X_2$  respectively. In matrix notation, a Johansen-type model can be represented by

$$(3) \quad Az = 0$$

where A is an  $m \times n$  matrix of elasticities and z is the  $n \times 1$  vector of percentage changes in model variables. To solve the model  $n-m$  variables must be declared exogenous. Once the choice of exogenous variables has been made (3) is rewritten as

$$(4) \quad A_1 z_1 + A_2 z_2 = 0$$

where  $A_1$  is the  $m \times m$  matrix formed by the  $m$  columns of A corresponding to the endogenous variables and  $A_2$  is the  $m \times (n-m)$  matrix formed by the  $n-m$  columns of A corresponding to the exogenous variables.  $z_1$  and  $z_2$  are, respectively the  $m \times 1$  and  $(n-m) \times 1$  vectors of endogenous and exogenous variables. Assuming that  $A_1$  is invertible, we proceed from (4) to the solution

$$(4A) \quad z_1 = Bz_2$$

where B is the  $m \times (n-m)$  matrix defined by

$$(4B) \quad B = -A_1^{-1} A_2$$

Equation (4A) expresses the percentage change in each endogenous variable as a linear function of the percentage changes in the  $n-m$  exogenous variables. We note that  $B_{ij}$  is the elasticity of the  $i$ th endogenous variable with respect to changes in the  $j$ th exogenous variable. For example,  $B_{ij}$  could represent the percentage change in the demand for labour of skill type  $q$  in industry  $j$  arising from a one per cent increase in the foreign currency price of imported commodity  $i$ . The great advantage of the linear computational framework is that the  $n-m$  exogenous variables may be chosen in many different ways. Thus the model can be applied to a wide range of policy issues without changing its basic structure or its computing algorithm.

This flexibility is greatly reduced in models which employ non-linear solution algorithms. With such models the exchange of even one endogenous variable with another previously exogenous variable constitutes a major model revision.

The Johansen approach however is not without its disadvantages. Because the A matrix is assumed fixed, equation (3) provides only a local representation of the structural equation system. That is (2) is valid only for 'small' changes in  $X_1$  and  $X_2$ . Fortunately, recent work by Dixon et al (1981) indicates that these linearisation errors introduced by the Johansen approximation are small.

An excellent example of the Johansen approach to general equilibrium model building is provided by Dixon (1980). The following specification of the system of equations for our typical country model draws heavily on Dixon's work.

## 2.1 Building Blocks of the Typical Country Model

The equations of our typical country model can be classified into 6 groups. These are,

- (a) demands for commodities (domestically produced, competitive imports and non competing imports),
- (b) demands for primary factors (labour by occupation, capital and land),
- (c) commodity supply equations,
- (d) pricing equations which impose the condition of zero pure profits in all activities (production, exporting and importing),
- (e) market clearing equations for domestic commodities and for primary factors,
- (f) miscellaneous equations to specify the behaviour of macroeconomic aggregates and to define useful summary variables.

The model recognizes five commodity demand categories, (i) intermediate input demands for current production, (ii) demands for inputs into capital creation, (iii) household demands, (iv) export demands and (v) other demands (which includes government consumption demands and inventory demands). Similarly, five industry input categories are distinguished (i) domestic commodities, (ii) competing import commodities, (iii) non-competing import commodities, (iv) primary factors (occupational specific labour inputs, fixed capital, agricultural land) and (v) a residual category termed other costs which includes working capital costs and miscellaneous production taxes net of subsidies. Given this disaggregation, our basic input-output (I-O) data requirements for each country model's base year are as depicted in Figure 1.

In Figure 1 we distinguish  $g$  domestic commodities,  $g$  import competing commodities,  $n$  non-competing import commodities,  $r$  labour occupations and  $h$  domestic industries. The column sums of the  $\tilde{A} + \tilde{F} + \tilde{J} + \tilde{K} + \tilde{L} + \tilde{M} + \tilde{N}$  matrices represent the domestic outputs of each industry in base year value units. Similarly, the row sums of  $\tilde{A} + \tilde{B} + \tilde{C} + \tilde{D} + \tilde{E}$  represent the outputs of domestic commodities. Alternatively, domestic industry outputs can be obtained as the column sums of  $\tilde{O}$  and domestic commodity outputs as the row sums of  $\tilde{O}$ . The row sums of  $\tilde{F} + \tilde{G} + \tilde{H} + \tilde{I} + (-\tilde{Z})$  represent the c.i.f. value of imports of competing import commodities while the row sums of  $\tilde{J} + (-\tilde{Y})$  represent the c.i.f. value of non-competitive imports.

Note that Figure 1 provides no explicit recognition of the demands for margins services to facilitate the flows of goods and services in the domestic economy. Neither does it distinguish the taxes levied on such flows.<sup>1</sup> Secondly, note

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<sup>1</sup> Given the particular policy orientation of the project, the modelling of margins and taxes would seem to be of secondary importance. Furthermore, such an exercise would considerably overtax the I-O data for most developing countries as well as dramatically increase the size of the model.

Figure 1: Schematic Input-Output Data Base for a typical Country Model

		Industries (producing current goods)	Industries (capital formation)	House- hold con- sumption	Exports	Other (govern- ment and stock)	- Duty
Domestic Commodities	g	h $\tilde{A}$	h $\tilde{B}$	1 $\tilde{C}$	1 $\tilde{D}$	1 $\tilde{E}$	
Competing Import Commodities	g	$\tilde{F}$	$\tilde{G}$	$\tilde{H}$		$\tilde{I}$	- $\tilde{Z}$
Non-competing Imports	n	$\tilde{J}$					- $\tilde{Y}$
Labour Occupations	r	$\tilde{K}$					
Fixed capital	1	$\tilde{L}$					
Land	1	$\tilde{M}$					
Other costs	1	$\tilde{N}$					
Commodity Supplies	g	$\tilde{O}$					



that Figure 1 allows for non-competing imports to be used only as an input into the production of current goods. This treatment accords with the empirical evidence at the level of commodity disaggregation distinguished for each of our sample of countries. Finally, note that the process of capital creation is shown as not directly using primary inputs. These enter capital creation via their content of the commodities used in capital creation.

In what follows we develop a theory to explain all the flows distinguished in figure 1. This theory is simple and orthodox. It places particular emphasis on price responsiveness and substitution. Sets of structural equations are derived under the standard neoclassical assumption of cost minimisation subject to a production function constraint in the case of producers and utility maximisation subject to a budget constraint in the case of consumers.

## 2.2 Notation

A few words on the notational conventions followed are in order at this point. In the development of the model equations we use lower case letters to indicate the percentage change in the corresponding upper case variables. That is, the percentage change in any variable  $V$  is represented by  $v$  where  $v = \frac{dV}{V} 100$ . Also used is an extensive system of superscripts and subscripts to distinguish different variables. For example,  $X_{(is)j}^{(k)}$  is used to denote the demand by using industry  $j$  for input  $i$  of type  $s$  for purpose  $k$ . The letter  $i$  refers to those commodities classed as competing. Possible values for  $k$  are 1 (current production), 2 (capital creation), 3 (household consumption), 4 (exports) and 5 (other demands). Possible values for  $s$  are 1 (domestically produced) and 2 (imported). Thus  $X_{(i2)j}^{(2)}$  would denote the demand for imported good  $i$  into industry  $j$  for capital creation. Note from Figure 1 that not all combinations of  $i, s, j, k$  are possible. Thus for example,  $X_{(i1)}^{(4)}$  would signify the demand for domestic good  $i$  for export. In this case the  $j$  subscript is redundant while  $s$  would always

be 1. (Reexports of imports are not permitted). Similarly,  $X_{\ell j}^N$  would denote the demand for non-competing import  $\ell$  in industry  $j$ . Since in each country, non-competing imports are sold only into the production of current goods there is no need for the usual superscript. Further examples are  $X_{vj}^P$  which denotes the input of primary factor  $X^P$  of type  $v$  into industry  $j$  ( $v = 1$  denotes aggregate labour,  $v = 2$  denotes fixed capital and  $v = 3$  denotes agricultural land)<sup>1</sup> and  $X_{1,q,j}^P$  which denotes the input of labour of occupation type  $q$  into industry  $j$ .

### 2.3 Production Technology for Current Goods

We describe the production technology available to each of our  $h$  industries in two parts, (i) the relationship between the industry's inputs and its activity level and (ii) the relationship between its activity level and its commodity outputs.

On the input side we assume that industry production functions exhibit constant returns to scale (CRTS) and are of a three level or nested form. At the first level we have the Leontief assumption. That is, there is no substitution between the I-O commodity groups or between them and an aggregate of the primary factors, the non-competing imports and the input category other costs.<sup>2</sup> At the second level we have CES functions describing substitution possibilities between imported and domestic goods of the same type. At this level

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<sup>1</sup> Only the agricultural and mining industries 'use' land in the sense that land as a factor earns a rental. In the case of mining industries the return on 'land' represents a return to the orebody in the ground, that is, the mine itself.

<sup>2</sup> This assumption is considered reasonable in view of the failure of previous studies (see for example Sevaldson (1976)) to satisfactorily explain changes in I-O coefficients over time by changes in their relative prices.

we also have CRESH<sup>1)</sup> functions describing substitution possibilities between the three groups of primary factors labour, fixed capital and agricultural land. At the third level we have CRESH functions describing substitution prospects between the r labour occupations within the aggregate labour input category.

On the output side we allow producers in each industry to produce a combination of commodities where the aggregation of commodities to the industry activity level is described by CRETH<sup>2)</sup> functions. These allow us to capture the idea of imperfect transformation between commodities that constitute an industry's output according to changes in relative commodity prices and the transformation elasticities between commodities.

<sup>1</sup> CRESH (Constant Ratio Elasticities of Substitution Homothetic) functions were introduced by Hanoch (1971). Under CRESH, the aggregation of primary factors  $X_1, X_2, X_3$  to a composite  $X$  is written  $\sum_{v=1}^3 (X_v/X)^{h_v} Q_v/h_v = \kappa_1$  (5A) where  $h_v \leq 1$  (but not equal to zero),  $Q_v \geq 0$  and the  $Q_v$ 's and  $\kappa_1$  are normalised so that  $\sum_v Q_v = 1$ . The partial elasticity of substitution between factors 1 and 2 ( $\sigma_{12}$ ) is given by  $\sigma_{12} = (1/1-h_1) (1/1-h_2) (1/\sum_{v=1}^3 \hat{S}_v)$  where  $\hat{S}_v = S_v/1-h_v$  with  $h_v$  being the CRESH parameter for factor  $v$  and  $S_v$  the share of total primary factor costs accounted for by factor  $v$ . The advantage of CRESH over CES is that it allows  $\sigma_{12}, \sigma_{13}$  and  $\sigma_{23}$  to differ. Thus CRESH provides additional flexibility when more than two factors are involved. Note that if all  $h_v$  share a common value CRESH collapses to CES with substitution elasticities  $\sigma = 1/1-h$ .

<sup>2</sup> CRETH (Constant Ratio Elasticity of Transformation Homothetic) functions were first proposed by Dixon (1976). A summary of their properties and an illustration of their use in commodity supply analysis is given in Vincent, Dixon and Powell (1980). Under CRETH, the aggregation of the  $i$  industry products  $Y_i$  to an index of industry activity  $Z$  is given by  $\sum_i (Y_i/Z)^{k_i} Q_i/k_i = \kappa_2$  (5B) where  $k_i > 1$  and the  $Q_i$ 's and  $\kappa_2$  are normalised so that  $\sum_i Q_i = 1$ . Thus apart from the restrictions on the parameters (which in CRETH ensure product-product transformation surfaces that are convex to the origin) CRESH and CRETH are analogous. The partial elasticity of transformation between commodities 1 and 2 ( $\tau_{12}$ ) in the set of  $i$  competing commodities is given by  $\tau_{12} = -(1/k_1-1)(1/k_2-1)(1/\sum_i \hat{S}_i)$  where  $k_i$  is the CRETH transformation parameter for commodity  $i$  and  $\hat{S}_i = S_i/k_i-1$  with  $S_i$  being the share of the total output of the industry represented by the output of commodity  $i$ . Note that CRETH allows the partial elasticities of transformation to differ between pairs of products.

## 2.4 Demands for Inputs into Current Production

Demand functions for the various types of inputs into current production are derived under the assumption that producers minimise their costs of producing a given output level subject to the constraints imposed by the nested production functions described above. That is, the typical producer in industry  $j$  must choose the input levels

$x_{ij}^{(1)}$  :  $i = 1, \dots, g$  'effective'<sup>1</sup> intermediate inputs,

$x_j^P$  : 'effective'<sup>2</sup> primary input,

$x_{(is)j}^{(1)}$  :  $i = 1, \dots, g$  intermediate inputs from domestic  
 $s = 1, 2$  and imported sources,

$x_{v,j}^P$  :  $v = 1, 2, 3$  aggregate labour,<sup>3</sup> fixed capital and land inputs,

$x_{1,q,j}^P$  :  $q = 1, \dots, r$  input of labour of occupation type  $q$ ,

$x_{\ell j}^N$  :  $\ell = 1, \dots, n$  non-competing imports,

$x_j^O$  : inputs of other costs.

to minimise

$$(5) \quad \sum_{i=1}^g \sum_{s=1}^2 P_{(is)} \cdot x_{(is)j}^{(1)} + \sum_{v=2}^3 p_{vj} x_{v,j}^P + \sum_{q=1}^r x_{1,q,j}^P p_{1,q} + \sum_{\ell=1}^n p_{\ell}^N \cdot x_{\ell j}^N + p_j^O x_j^O$$

---

<sup>1</sup> The concept of 'effective' intermediate inputs is defined by (7).

<sup>2</sup> The concept of 'effective' primary inputs is defined by (8).

<sup>3</sup> The concept of aggregate labour inputs is defined by (9).

subject to Leontief<sup>1</sup>

$$(6) \quad \left\{ \frac{X_{ij}^{(1)}}{A_{ij}^{(1)}}, \frac{X_j^P}{A_j^P}, \frac{X_{lj}^N}{A_{lj}^N}, \frac{X_j^O}{A_j^O} \right\} = z_j \quad \begin{array}{l} i = 1, \dots, g \\ l = 1, \dots, n \end{array}$$

and

$$(7)^2 \quad X_{ij}^{(1)} = \text{CES}_{s=1,2} X_{(is)j}^{(1)}$$

and

$$(8)^3 \quad X_j^P = \text{CRESH}_{v=1,2,3} X_{vj}^P$$

and

$$(9)^3 \quad X_{ij}^P = \text{CRESH}_{q=1, \dots, r} X_{1,q,j}^P$$

where  $x_j$  denotes industry  $j$ 's activity level and the  $P$ 's denote the respective prices of the  $X$ 's. (From the point of view of the producer the  $Z$  and  $P$ 's are treated as being exogenous). Thus  $P_{(is)}$  is the price of good  $i$  from source  $s$  to industry  $j$  for current production. In the absence of taxes and margins on commodity flows the price of a given commodity will be the same to all end users. Hence the omission of the (1) superscript and the replacement of the  $j$  subscript with a dot to indicate the same price for each  $j$ . Similarly  $P_{1,q}$  is the price to industry  $j$  of a unit of labour of skill type  $q$ . It is sufficient for our purposes to treat occupational labour as being homogeneous across industries, as indicated by the use of the dot in place of the  $j$ .

<sup>1</sup> In (6) Leontief{ $f_i$ } = minimum { $f_1, f_2, \dots, f_r$ }.  
 $i = 1, r$

<sup>2</sup> Equation (7) assumes that in order to capture the idea of imperfect substitutability between domestic and imported commodities of the same category, these commodities are combined to provide a unit of effective input according to the well known CES function.

<sup>3</sup> Equations (8) and (9) indicate that  $X_{vj}^P$  and  $X_{1,q,j}^P$  are aggregated according to the CRESH functional form given in footnote 1 on page 12.

The  $P_{vj}$   $v = 2, 3$  are the rental costs to industry  $j$  of capital and agricultural land. By retaining the  $j$  subscripts we can, if required, model these factors as being industry specific.  $P_{\ell}^N$  are the prices of each of the  $\ell$  non-competing inputs to each of the  $j$  industries.  $P_j^O$  is the price of units of other costs in industry  $j$ . Finally, the  $A$ 's are a set of Leontief I-O coefficients.  $A_{ij}^{(1)}$  for example represents the minimum amount of 'effective' input to support a unit of activity in industry  $j$ .

The solution to the above cost minimising problem<sup>1</sup> yields input demand equations of the form

$$(10) \quad x_{(i,s)j}^{(1)} = z_j - \sigma_{ij}^{(1)} \left( p_{(is).} - \sum_s S_{(is)j}^{(1)} p_{(is).} \right)$$

$$i = 1, \dots, g$$

$$s = 1, 2$$

$$j = 1, \dots, h$$

$$(11) \quad x_{\ell j}^N = z_j$$

$$\ell = 1, \dots, n$$

$$j = 1, \dots, h$$

$$(12) \quad x_{vj}^P = z_j - \sigma_{vj} (p_{vj} - \sum_{v=2}^3 S_{vj}^* p_{vj} - S_{1j}^* p_{1.})$$

$$v = 2, 3$$

$$j = 1, \dots, h$$

$$(12A) \quad x_{1,j}^P = z_j - \sigma_{1j} (p_{1.} - \sum_{v=2}^3 S_{vj}^* p_{vj} - S_{1j}^* p_{1.})$$

$$j = 1, \dots, h$$

$$(13) \quad x_{1,q,j}^P = x_{1j}^P - \sigma_{1,q,j} (p_{1,q,.} - \sum_q S_{1,q,j}^* p_{1,q,.})$$

$$q = 1, \dots, r$$

$$j = 1, \dots, h$$

$$(13A) \quad x_j^O = z_j$$

where

$$(14) \quad p_{1.} = \sum_{q=1}^r p_{1,q,.} S_{1,q,.}$$

---

<sup>1</sup> See Dixon (1980) for a complete algebraic derivation of the solution to this type of problem.

In equation (10)  $\sigma_{ij}^{(1)}$  is the CES substitution elasticity (between domestic and imported sources) for commodity  $i$  used as a current input into industry  $j$  and  $S_{(is)j}^{(1)}$  denotes the share of good  $i$  from source  $s$  in the total costs of input  $i$  into industry  $j$  for current production. If there are no changes in the relative prices of good  $i$  from alternative sources then a 1 per cent increase in  $Z_j$  leads to a 1 per cent increase in each of  $X_{(i1)j}^{(1)}$  and  $X_{(i2)j}^{(1)}$  (CRTS). If however the price of domestic good  $i$  rises relative to the price of imported good  $i$  then there will be substitution against the domestic source of good  $i$  in favour of imports. The strength of this substitution effect is governed by the size of the substitution parameter  $\sigma_{ij}^{(1)}$ .

Equation (11) indicates that the demand for non-competing imports will move in proportion to the output of the industry into which they are used. Equations (12), (12A) and (13) have a similar interpretation to (10). In (12) and (12A) which specify the demand functions for primary factors,  $\sigma_{vj}$  ( $v=1,2,3$ ) are the CRESH substitution parameters for each of the primary factors and  $S_{vj}^*$  is the 'modified' primary factor cost share.<sup>1</sup> In (13),  $\sigma_{1,q,j}$ ,  $q = 1, \dots, r$ , are the CRESH substitution parameters for each labour occupation in industry  $j$  and  $S_{1,q,j}^*$  is the CRESH 'modified' cost share of labour of occupation type  $q$  in total labour costs in industry  $j$ .<sup>2</sup> In interpreting (12)

---

<sup>1</sup> In terms of the equation defining the CRESH function (equation (5A))  $\sigma_{vj} = (1/1-h_{vj})$  and  $S_{vj}^* = \sigma_{vj} S_{vj} / \sum_{v=1}^3 \sigma_{vj} S_{vj}$  where  $S_{vj}$  is the share of primary factor  $v$  in the total primary factor costs of industry  $j$ .

<sup>2</sup>  $\sigma_{1,q,j} = (1/1-h_{1,q,j})$  where  $h_{1,q,j}$  is the 'h' parameter from the CRESH function aggregating occupational labour inputs and  $S_{1,q,j}^* = \sigma_{1,q,j} S_{1,q,j} / \sum_{q=1}^r \sigma_{1,q,j} S_{1,q,j}$  where  $S_{1,q,j}$  is the cost share of labour of occupation type  $q$  in total labour costs in industry  $j$ .

we regard  $p_{1,j}$  as the percentage change in the cost of a unit of labour to each of the  $j$  industries. Then (12) implies that in the absence of factor price changes, a one per cent increase in  $j$ 's activity level requires a one per cent increase in  $j$ 's requirements for labour in general, capital and land. However, increases in the cost to industry  $j$  of any particular factor relative to a weighted average of the costs of the three factors leads to substitution away from that factor towards the other two. Similarly (13) indicates that if there is no change in the relative prices of the different types of labour then the occupational composition of industry  $j$ 's workforce is unchanged. However, if  $P_{1,q,j}$  increases relative to a weighted average of all the occupational wage rates payable by industry  $j$  then  $j$ 's use of labour of type  $q$  will increase more slowly than  $j$ 's use of labour in general.<sup>1</sup> Equation (13A) reflects the Leontief assumption between other costs and industry activity level. Equation (14) simply expresses the price of labour in general as a share weighted average of the prices of each of the labour occupations.

## 2.5. Commodity Supplies

Commodity supply equations are derived assuming that at any given activity level,  $Z_j$ , producers in industry  $j$  choose the commodity output combination to maximise their revenue. That is, we assume that for each industry  $j$

$$X_{(i1)j} \quad i = 1, \dots, g \text{ (outputs of commodities)}$$

are chosen to maximise

$$\sum_{i=1}^g P_{(i1)} \cdot X_{(i1)j}$$

subject to

$$(15)^2 \quad \text{CRETH } X_{(i1)j} = Z_j \quad i = 1, \dots, g$$

---

<sup>1</sup> From footnote 2 on page 16 and footnote 1 on page 12 we note that  $\bullet_{1,q,j}^{(1)}$  will be positive.

<sup>2</sup> See equation (5B) in footnote 2 on page 12.



where the P's and Z are treated as exogenous. (Note that  $P_{i1}$  which represents the basic price received by producers of good  $i$  in industry  $j$  is, in the absence of margins and taxes equivalent to the price paid by the users of good  $i$  (see equation (5)). The solution to the above revenue maximising problem yields supply equations of the form;

$$(16) \quad x_{(i1)j} = z_j + \sigma_{(i1)j}^T \left( P_{(i1)}. - \sum_{i=1}^g C_{(i1)j}^* P_{(i1)}. \right)$$

$$i = 1, \dots, g$$

$$j = 1, \dots, h$$

Equation (16) relates each industry's supplies of commodities to the industry's overall activity level and to the relative prices of the various commodities produced by that industry. If there are no relative commodity price changes then a one per cent increase in industry  $j$ 's activity level generates a one per cent increase in the supplies of the commodities it produces. If however the price of domestic commodity  $i$  increases relative to a weighted average of the prices of all the commodities produced by industry  $j$  then  $j$  transforms the commodity composition of its output in favour of commodity  $i$  and away from the other commodities. The strength of this transformation effect is governed by the transformation parameter  $\sigma_{(i1)j}^T$ .<sup>1</sup> The  $C_{(i1)j}^*$  are the 'modified' revenue shares of commodity  $i$  in the total commodity revenue of industry  $j$ .<sup>2</sup>

In our generalised derivation of equation (16) each of the  $j$  industries is allowed to produce each of the  $g$  commodities. In actual fact however only a few industries in our sample of LDC's will be modelled as producing a multiple of products and in such cases the number of products produced will be very low. Thus  $C_{(i1)j}$  for most  $i$  and  $j$  will be zero.

---

<sup>1</sup> In terms of footnote 2 on page 12,  $\sigma_{(i1)j}^T = (1/k_{(i1)j} - 1)$ . Note that the restrictions placed on the  $k_{(i1)j}$  ensure that  $\sigma_{(i1)j}$  is positive.

<sup>2</sup>  $C_{(i1)j}^* = C_{(i1)j} \sigma_{(i1)j}^T / \sum_{i'=1}^g C_{(i'1)j} \sigma_{(i'1)j}^T$  where  $C_{(i1)j}$  is the revenue share of commodity  $i$  in industry  $j$ 's output.

## 2.6 Demands for Inputs for the Production of Fixed Capital

We assume that a unit of capital for use in industry  $j$  can be created according to the production function

$$(17) \quad Y_j = \text{Leontief} \left\{ \frac{X_{ij}^{(2)}}{A_{ij}^{(2)}} \right\} \quad i = 1, \dots, g$$

where

$$(18) \quad X_{ij}^{(2)} = \text{CES } X_{(i,s)j}^{(2)} \quad s = 1, 2$$

$Y_j$  is the number of units of capital created for industry  $j$ ,  $X_{(i,s)j}^{(2)}$  represent the inputs of good  $i$  from domestic and imported sources to the production of capital for industry  $j$  and the  $A$ 's are a set of Leontief I-O coefficients. Note from (18) that just as we allowed imports and domestic goods to be imperfect substitutes in current production we also allow them to be imperfect substitutes when they are used for the purpose of capital creation.

We assume that producers of capital for industry  $j$  treat input prices as beyond their control and for any given level of capital creation  $Y_j$  they choose  $X_{(is)j}^{(2)}$  to minimise

$$\sum_{s=1}^2 \sum_{i=1}^g P_{(is)} \cdot X_{(is)j}^{(2)}$$

subject to (17) and (18). The solution<sup>1</sup> to this problem yields a set of demand functions for goods for capital creation of the form

$$(19) \quad x_{(is)j}^{(2)} = Y_j \cdot \sigma_{ij}^{(2)} \left( P_{(is)} \cdot - \sum_{s=1}^3 S_{(is)j}^{(2)} P_{(is)} \right)$$

$$\begin{aligned} i &= 1, \dots, g \\ s &= 1, 2 \\ j &= 1, \dots, h \end{aligned}$$

---

<sup>1</sup> For an algebraic derivation of the solution of this type of problem see Dixon (1980).

where  $S_{(is)j}^{(2)}$  is the share of good  $i$  from source  $s$  in the total cost of good  $i$  used for creation of capital in industry  $j$  and  $\sigma_{ij}^{(2)}$  is the elasticity of substitution between imported and domestic good  $i$  as inputs for creation of capital of type  $j$ .

Note that while the above specification does not explain how the investment level,  $Y_j$ , in each industry is determined, it does allow for the commodity composition of capital to vary across industries. Hence we can recognize that, for example, a given unit increase in investment in agriculture brings forth a greater increase in demand for tractors than say a similar unit increase in investment in the textile processing industry. To implement (19) requires that the matrices  $\tilde{B}$  and  $\tilde{G}$  of Figure 1 can be constructed. These matrices do not form part of a conventional I-O table. Their construction requires the availability of a capital coefficients matrix (a matrix showing capital inputs of type  $i$  to produce a unit of investment in industry  $j$ ). Thus the extent to which in practice we can recognize separate capital goods production functions for each industry will depend on the country availability of industry specific capital coefficients.<sup>1</sup>

## 2.7 Household Demands

These are explained by the conventional utility maximising framework. Letting  $Q$  be the number of households we assume that the consumption bundle of effective inputs  $(X_i^{(3)}/Q)$  for the average household<sup>2</sup> is chosen to maximise the household utility

$$(20) \quad \left( U \quad X_i^{(3)}/Q \right)$$

---

<sup>1</sup> If for example just one capital goods production function for the economy is assumed then the I-O data requirements are considerably less - vectors of domestic and imported commodity flows to investment replace the matrices  $\tilde{B}$  and  $\tilde{G}$ .

<sup>2</sup> We specify only one type of household. That is, we assume that little is lost by aggregation over different types of consumers.

subject to

$$(21) \quad x_i^{(3)} = \text{CES}_{s=1,2} x_{is}^{(3)} \quad \text{and}$$

$$(22) \quad \sum_{s=1}^2 \sum_{i=1}^g p_{is}^{(3)} x_{is}^{(3)} = C$$

where  $p_{is}^{(3)}$  is the price of good  $i$  from source  $s$  to consumers,  $x_{is}^{(3)}$  is the corresponding demand and  $C$  is the aggregate consumer budget. The solution<sup>1</sup> to the above utility maximising problem yields consumer demand functions of the form

$$(23) \quad x_{is}^{(3)} = x_i^{(3)} - \sigma_i^{(3)} \left( p_{(is)} - \sum_{s=1}^2 S_{is}^{(3)} p_{(is)} \right)$$

$i = 1, \dots, g$   
 $s = 1, 2$

$$(24) \quad x_i^{(3)} - q = \epsilon_i (c-q) + \sum_{k=1}^g \eta_{ik} p_k^{(3)} \quad i = 1, \dots, g$$

where

$$(25) \quad p_k^{(3)} = \sum_{s=1}^2 S_{ks}^{(3)} p_{(ks)} \quad k = 1, \dots, g$$

Note that in consumption, as well as in production, we allow for imperfect substitution between imported and domestic goods according to CES functions.  $\sigma_i^{(3)}$  is the elasticity of substitution between domestic and imported sources of good  $i$  in consumption,  $S_{is}^{(3)}$  is the share of total consumer spending on good  $i$  which is devoted to good  $i$  from source  $s$ ,  $p_k^{(3)}$  is the percentage change in the price of composite good  $k$  in consumption and the  $\epsilon_i$  and  $\eta_{ik}$  are expenditure elasticities and own cross price elasticities of consumption respectively.

---

<sup>1</sup> A complete algebraic solution to this type of consumer maximisation problem is given in Dixon (1980).

## 2.8 Export Demands

We write the export demand functions for a country's goods by the rest of the world as

$$(26) \quad P_{i1}^e = X_i^{(4)}^{-\gamma_i} F_i^{(4)}$$

where  $P_i^e$  is the foreign currency price of domestic good  $i$ ,  $\gamma_i$  is a positive parameter (the reciprocal of the foreign elasticity of demand for good  $i$ ) and  $F_i^{(4)}$  is a shift variable which will increase if there is an increase in foreign demand for good  $i$ . In percentage change form (26) becomes

$$(27) \quad \Delta P_i^e = -\gamma_i \Delta X_i^{(4)} + \Delta f_i^{(4)}$$

Equation (27) has been written to cover all  $i$  commodities. For commodities that are not exported both  $\gamma_i$  and  $f_i^{(4)}$  would be set to zero. The parameter  $\gamma_i$  governs the slope of the foreign demand curve for a particular country's exports of good  $i$ . For world commodity markets in which a country is a major supplier, e.g. Ivory Coast with coffee and Malaysia with tin, the relevant  $\gamma_i$  would be set to a non-zero number.<sup>1</sup> As will be seen more clearly from Appendix B, equation (27) provides a link between a particular country's exports and the rest of the world.

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<sup>1</sup> Some guidance on the appropriate setting for  $\gamma_i$  is given in Appendix B.

## 2.9 Other Demands

These consist of government purchases (plus changes in inventories).<sup>1</sup> Governments are viewed as buying domestic and imported goods and services. No formal theory is presented. We simply write that

$$(28) \quad x_{is}^{(5)} = c_R h_{is}^{(5)} + f_{is}^{(5)} \quad \begin{array}{l} i = 1, \dots, g \\ s = 1, 2 \end{array}$$

where  $c_R$  is the percentage change in aggregate real consumption expenditure,  $h_{is}^{(5)}$  is a parameter and  $f_{is}^{(5)}$  is a shift variable. If for example  $h_{is}^{(5)}$  were set to one and the  $f_{is}^{(5)}$  to zero then the vector of other demands would remain a constant share of aggregate real consumption. We define  $c_R$  as

$$(29) \quad c_R = c - \epsilon^{(3)}$$

where  $c$  is the percentage change in aggregate consumption expenditure in money terms and  $\epsilon^{(3)}$  is an appropriately constructed index of consumer goods prices in the domestic economy.  $\epsilon^{(3)}$  is in turn defined by

$$(30) \quad \epsilon^{(3)} = \sum_i \sum_s W_{is}^{(3)} P_{(is)}$$

where  $W_{is}^{(3)}$  represents the share of aggregate consumer spending devoted to good  $i$  from source  $s$ .

---

<sup>1</sup> For simplicity, changes in inventories are lumped with government purchases. It is difficult to incorporate such changes into a model framework which stresses equilibrium conditions. For accounting purposes we have included them as part of other demands. The alternative would have been to simply delete them and proceed with a slightly unbalanced I-O table.

## 2.10 The Price System

Because of the absence of a treatment of margins and taxes on commodity flows each country model uses only one set of prices. Commodity prices are assumed to be the same to each end user in each industry. We assume that there are no pure profits in the production of current goods, the production of capital goods and in importing and exporting. Hence we write that.

Domestic production

$$(31) \quad \sum_{i=1}^g P_{(i1)} \cdot X_{(i1)j} = \sum_{i=1}^g \sum_{s=1}^2 X_{(is)j}^{(1)} P_{(is)} + \sum_{\ell=1}^n P_{\ell}^N X_{\ell j}^N + \sum_{q=1}^r p_{1,q} \cdot X_{1,q,j}^P + \sum_{v=2}^3 p_{vj} X_{vj}^P + p_j^O X_j^O$$

$$j = 1, \dots, h$$

The left hand side of (31) is the value of the output of industry  $j$  and the right hand side is the total payment for inputs (intermediate input costs, non-competing import input costs, labour costs, capital plus land costs, other costs). The equality is implied by the assumption of no pure profits. In percentage change form (31) becomes;

$$(32) \quad \sum_{i=1}^g P_{(i1)} \cdot C_{(i1)j} = \sum_{i=1}^g \sum_{s=1}^2 P_{(is)} \cdot H_{(is)j}^{(1)} + \sum_{\ell=1}^n p_{\ell}^N H_{\ell j}^N + \sum_{q=1}^r p_{1,q} \cdot L_{1,q,j} + \sum_{v=2}^3 p_{vj} H_{vj}^P + p_j^O H_j^O$$

$$j = 1, \dots, h$$

where the  $C$ 's are revenue shares and the  $H$ 's are cost shares. Thus  $C_{(i1)j}$  is the revenue share of commodity  $i$  in the output of industry  $j$  while  $H_{(is)j}^{(1)}$  for example is the share of industry  $j$ 's current production costs accounted for by the cost of its inputs of good  $i$  from source  $s$ .

Capital creation

$$(33) \quad \Pi_j Y_j = \sum_{i=1}^g \sum_{s=1}^2 P_{(is)} \cdot X_{(is)j}^{(2)} \quad j = 1, \dots, h$$

where  $\Pi_j^1$  is the price of a unit of capital in industry j. Equation (33) imposes the condition that the value of new capital in industry j equals the cost of its production. In percentage change form (33) becomes;

$$(34) \quad \pi_j = \sum_{i=1}^g \sum_{s=1}^2 p_{(is)} \cdot H_{(is)j}^{(2)} \quad j = 1, \dots, h$$

where  $H_{(is)j}^{(2)}$  represents the cost share of good i from source s in the total cost of constructing a unit of capital for industry j.

Importing

$$(35) \quad P_{i2} = P_{i2}^m T_i \phi \quad i = 1, \dots, g$$

where  $P_{i2}$  is the basic price of imported good i (the price received by importers),  $P_{i2}^m$  is its foreign currency c.i.f. price,  $\phi$  is the exchange rate (domestic currency units per unit of foreign exchange) and  $T_i$  is one plus the ad valorem tariff (or tariff equivalent) on imports of good i. Equation (35) equates the domestic selling prices of imported commodities ( $p_{i2}$ ) to the costs of importing. In percentage change terms (35) becomes

$$(36) \quad p_{i2} = p_{i2}^m + t_i + \phi \quad i = 1, \dots, g$$

Similarly, for non-competing imports we write that

$$(37) \quad p_{\ell}^N = p_{\ell}^{Nm} + t_{\ell}^N + \phi \quad \ell = 1, \dots, n$$

where  $p_{\ell}^{Nm}$  is the percentage change in the foreign price of non-competing import good  $\ell$  and  $t_{\ell}^N$  is the percentage change in one plus the ad valorem tariff on non-competing good  $\ell$ .

---

<sup>1</sup> Note that  $\Pi_j$  represents the cost of producing a unit of capital for industry j whereas  $P_{2j}$  is the cost of using or renting a unit of capital for industry j.



Exporting.

Our final set of zero pure profits conditions equates the revenue from exporting to the relevant costs. That is,

$$(38) \quad P_{i1}^e V_i \phi = P_{i1} \quad i = 1, \dots, g$$

where  $P_{i1}^e$  is the foreign currency price of domestic good  $i$  f.o.b. and  $V_i$  is one plus the ad valorem rate of export subsidy. Thus on the left of (38) we have the value in domestic currency units of exporting a unit of commodity  $i$  and on the right we have the cost of doing so, that is, the domestic price of a unit of  $i$ .<sup>1</sup> In percentage change form (38) becomes

$$(39) \quad p_{i1}^e + v_i + \phi = p_{i1} \quad i = 1, \dots, g$$

## 2.11 Determining the Allocation of Investment Across Industries

In section 2.4 we specified demand functions for inputs to capital creation in each industry. With industry specific capital creation functions we need a theory to describe how many units of capital will be created in each industry (the  $y_j$ ). The least ambitious procedure would be to set the  $y_j$  exogenously. One would expect however that changes in the terms of trade facing a particular country would cause **changes** in the pattern of investment across industries. This may have important consequences for the balance of trade. For example if investment is shifted as a result of changes in world commodity prices towards industries whose capital structure is relatively import intensive then this will lead to a deterioration in the balance of trade and may in addition have adverse consequences for the domestic suppliers of investment goods.

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<sup>1</sup> Note that for algebraic convenience the  $i$  subscript in (38) is allowed to run over all products. As will be explained in section 3, for a non export commodity such as say services, the model would determine the  $v_i$  endogenously. The  $p_{i1}$  would be determined by domestic cost conditions.

Given our concentration on trade flows it would seem desirable to endogenise the allocation of investment across industries. This is achieved using the same procedure outlined in Dixon (1980). Five steps are involved.

(i) We define the current rate of return on capital in industry  $j$ ,  $R_j$ , as

$$(39) \quad R_j = \frac{P_{2j}}{\pi_j} - d_j \quad j = 1, \dots, h$$

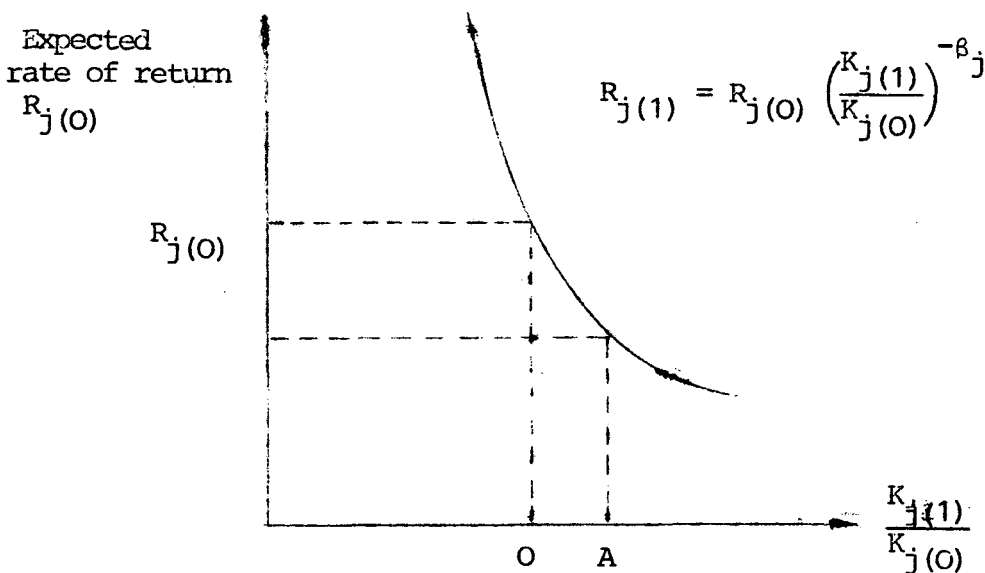
where  $d_j$  is the rate of depreciation in industry  $j$  (assumed constant) and  $P_{2j}$  and  $\pi_j$  were previously defined as the rental rate on capital in industry  $j$  and the cost of producing a unit of capital in industry  $j$  respectively.

(ii) We assume capital takes one period to install.

(iii) We assume that investors are cautious in assessing the effects of expanding the capital stock in industry  $j$ . They behave as if they expect that industry  $j$ 's rate of return schedule in one period's time will have the form

$$(40) \quad R_j(1) = R_j(0) \left( \frac{K_j(1)}{K_j(0)} \right)^{-\beta_j}$$

where  $\beta_j$  is a positive parameter,  $K_j(0)$  is the current level of capital stock in industry  $j$  and  $K_j(1)$  is the level at the end of one period. The situation described in (40) may be illustrated as



where the horizontal axis measures the ratio of next period's capital stock to current capital stock and the vertical axis measures the expected rate of return. If the capital stock were maintained at the existing level  $O$ , then the expected rate of return is the current rate  $R_j(O)$ . However if investment plans were set so that  $K_{j(1)}/K_{j(0)}$  would reach  $A$  then businessmen would behave as if they expected the rate of return to fall to  $B$ .

(iv) We assume that total investment,  $I$ , is allocated across industries so as to equate expected rates of return. This implies that there exists some rate of return  $\lambda$  such that

$$(41) \quad \left( \frac{K_{j(1)}}{K_{j(0)}} \right)^{-\beta_j} R_j(O) = \lambda$$

(v) We define equations for  $K_{j(1)}$  and  $I$ . We assume that

$$(42) \quad K_{j(1)} = K_{j(0)} (1-d_j) + Y_j \quad j = 1, \dots, h$$

$$(43) \quad I = \sum_j \pi_j Y_j$$

Equation (42) assumes that the effects of past investment decisions are fully incorporated into the current capital stock, with the only variables influencing capital stock at the end of one period being current capital stock and current investment. Equation (43) simply defines aggregate investment spending. Expressing (39), (41)-(43) in percentage change form gives

$$(44) \quad r_j(O) = \Omega_j (p_{2j} - \pi_j) \quad j = 1, \dots, h$$

$$(45) \quad -\beta_j \left( k_{j(1)} - k_{j(0)} \right) + r_j(O) = \lambda \quad j = 1, \dots, h$$

$$(46) \quad k_{j(1)} = k_{j(0)} (1-G_j) + Y_j G_j \quad j = 1, \dots, h$$

$$(47) \quad \sum_j (\pi_j + Y_j) T_j = i$$

where  $\Omega_j = (R_j(O) + d_j) / R_j(O)$  i.e., the ratio of the gross rate of return in industry  $j$  to the net rate of return,  $G_j = Y_j/K_{j(1)}$  i.e., the ratio of gross investment in industry  $j$

to its future capital stock and  $T_j$  is the share of total aggregate fixed investment accounted for by industry  $j$  i.e.,

$$T_j = Y_j \Pi_j / \sum_{j=1}^h Y_j \Pi_j$$

Equations (44)-(47) effectively endogenise investment allocation across industries. Suppose for example that the world price for cotton fabrics were to increase relative to other world commodity prices. This would tend to increase the demand for capital required by the cotton fabrics industry leading initially to an increase in the rental rate on capital and hence the rate of return in the cotton fabrics industry relative to other rates. Equations (44)-(47) will ensure that industries for which the upward movements in their rate of return schedules are most pronounced will receive an increased share of the investment budget. The 'cost' of this theory is the introduction of a number of additional parameters required for its implementation.

## 2.12 Market Clearing Equations

We next specify equations that equate demand and supply for domestically produced commodities and for the primary factors of production, labour capital and land. We write

$$(43) \quad X_{i1} = \sum_{j=1}^h X_{(i1)j}^{(1)} + \sum_{j=1}^h X_{(i1)j}^{(2)} + X_{i1}^{(3)} + X_{i1}^{(4)} + X_{i1}^{(5)}$$

$$i = 1, \dots, g$$

where

$$(49) \quad X_{i1} = \sum_j X_{(i1)j} \quad i = 1, \dots, g$$

$$(50) \quad L_q = \sum_{j=1}^h X_{1,q,j}^P \quad q = 1, \dots, r$$

$$(51) \quad K_j(0) = X_{2j}^P \quad j = 1, \dots, h$$

$$(52) \quad N_j = X_{3j}^P \quad j = 1, \dots, h$$

Equation (48) equates supply and demand for each of the domestically produced goods. Total supply is the sum over the outputs of  $i1$  by each of the industries (see (16)). Total demand is composed of intermediate input demand, demand for inputs into the production of capital equipment, household consumption demand, export demand and other demand.

Equation (50) equates labour supply in each occupation to the demand for it. It implies that labour is shiftable between industries. It does not however necessarily imply a situation of full employment. Equations (51) and (52) equate supply and demands for capital and land respectively in each industry.

As will be demonstrated later however the model can allow for capital mobility between industries, that is, the  $k_j(0)$  can be determined endogenously. Expressing (48) to (52) in percentage change terms gives

$$(53) \quad x_{i1} = \sum_{j=1}^h x_{(i1)j}^{(1)} B_{(i1)j}^{(1)} + \sum_{j=1}^h x_{(i1)j}^{(2)} B_{(i1)j}^{(2)} + x_{i1}^{(3)} B_{i1}^{(3)} \\ + x_{i1}^{(4)} B_{i1}^{(4)} + x_{i1}^{(5)} B_{i1}^{(5)} \quad i = 1, \dots, g$$

$$(54) \quad x_{i1} = \sum_{j=1}^h x_{(i1)j} D_{(i1)j} \quad i = 1, \dots, g$$

$$(55) \quad l_q = \sum_{j=1}^h x_{1,q,j}^P B_{1,q,j} \quad q = 1, \dots, r$$

$$(56) \quad k_j(0) = x_{2j}^P \quad j = 1, \dots, h$$

$$(56A) \quad n_j = x_{3j}^P \quad j = 1, \dots, h$$

The B's in (53) refer to the shares of the sales of domestically produced goods which are absorbed by the various types of demands identified on the right hand side. For example  $B_{(i1)j}^{(2)}$  refers to the share of total sales of good  $i1$  absorbed by sales to industry  $j$  for capital creation. In (54) the D's are production shares.  $D_{(i1)j}$  is the share of industry  $j$  in the

economy's output of good  $i$ . In (55)  $E_{1,q,j}$  is the share of the total employment of labour of type  $q$  which is accounted for by industry  $j$ .

### 2.13 Aggregate Imports, Exports and the Balance of Trade

Aggregate demand for competing import good  $i$  ( $X_{i2}$ ) represents the sum of its demands over all end uses. That is,

$$(57) \quad X_{i2} = \sum_{j=1}^h x_{(i2)j}^{(1)} + \sum_{j=1}^h x_{(i2)j}^{(2)} + x_{i2}^{(3)} + x_{i2}^{(5)} \quad i = 1, \dots, g$$

In percentage change form (57) becomes

$$(58) \quad x_{i2} = \sum_{j=1}^h x_{(i2)j}^{(1)} B_{(i2)j}^{(1)} + \sum_{j=1}^h x_{(i2)j}^{(2)} B_{(i2)j}^{(2)} + x_{i2}^{(3)} B_{i2}^{(3)} + x_{i2}^{(5)} B_{i2}^{(5)} \quad i = 1, \dots, g$$

where the  $B$ 's are shares of total import flows. For example,  $B_{(i2)j}^{(1)}$  denotes the share of total imports of good  $i$  which is absorbed by industry  $j$  for current production.

Similarly, aggregate demand for non-competing import good  $\ell$  may be written in percentage change form as

$$(59) \quad x_{\ell}^N = \sum_{j=1}^h x_{\ell j}^N B_{\ell j}^N \quad \ell = 1, \dots, r$$

where  $B_{\ell j}^N$  represents the share of the flow of non-competing import good  $\ell$  absorbed by industry  $j$ .

In terms of foreign currency cost, the aggregate value of imports ( $M$ ) is given by

$$(60) \quad M = \sum_{i=1}^g P_{i2}^m X_{i2} + \sum_{\ell=1}^n P_{\ell}^{Nm} X_{\ell}^N$$

which in percentage change form gives

$$(61) \quad m = \sum_{i=1}^g (p_{i2}^m + x_{i2}) M_{i2} + \sum_{\ell=1}^n (p_{\ell}^{Nm} + x_{\ell}^N) M_{\ell}^N$$

where  $M_{i2}$  and  $M_{\ell}^N$  are the shares of the aggregate foreign currency cost of commodity imports which are accounted for by each of the  $g$  and  $n$  competitive and non-competitive imports respectively.

Next we define the economy's aggregate foreign currency export receipts,  $E$ , as

$$(62) \quad E = \sum_{i=1}^g p_{i1}^e X_i^{(4)}$$

which in percentage change form becomes

$$(63) \quad e = \sum_{i=1}^g (p_{i1}^e + x_i^{(4)}) E_i$$

where  $E_i$  is commodity  $i$ 's share of export receipts in aggregate foreign currency export receipts.

Finally we define the balance of trade,  $B$ , as

$$(64) \quad B = E - M$$

From (64) we can write that

$$(65) \quad 100 \Delta B = Ee - Mm$$

where  $\Delta B$  is the change (not the percentage change) in  $B$ . Because  $B$  can change sign we avoid the percentage change form of (64). Thus  $\Delta B$  is the only variable in the model which requires units. These will depend on the units used for  $E$  and  $M$ . An example might be say billions of domestic currency units at the base year exchange rate with the US dollar.

## 2.14 Macro and Miscellaneous Equations

Our standard model system contains a very simple treatment of the behaviour of the macroeconomic aggregates. First we define the percentage change in real aggregate investment  $i_R$  as

$$(66) \quad i_R = i - \epsilon^{(2)}$$

where  $i$  is the percentage change in aggregate nominal investment and

$$(67) \quad \epsilon^{(2)} = \sum_{j=1}^n T_j \pi_j$$

$\epsilon^{(2)}$  is an investment goods price index made up of a weighted average of the percentage changes in capital goods prices where the weights  $T_j$  reflect the shares of total investment spending accounted for by investment spending in each industry. Next we add the equation

$$(68) \quad i_R = c_R + f_R$$

where  $f_R$  is an exogenous shift variable whose role is to fix the relationship between movements in real aggregate consumption and investment. If for example we were interested in a long run experiment in which the balance of trade was held constant then an exogenous setting of  $f_R$  to zero would imply that aggregate consumption and investment shares of the gross domestic product are invariant to the shock under study.

That is, marginal propensities to consume and to save are constant.

Equation (68) would seem adequate for experiments in which we could safely assume that the exogenous shock under study had no necessary implications for the long run net capital inflow position of the economy. That is,  $\Delta B$  could be set to zero.



However we might envisage experiments for which we would expect that as a result of the exogenous shock the long run net capital inflow position would change. Under such circumstances the basic framework presented above would be inadequate. Changes in net capital inflow would imply a change in the share of the aggregate capital stock owned by domestic residents and foreigners which in turn would require a change in foreign debt servicing requirements. For such experiments it would seem desirable to broaden the specification to allow for the endogenising of the net capital inflow position of the economy ( $\Delta B$ ). The ingredients missing from the above specification to achieve this ~~area~~ are a domestic savings function and an aggregate investment function. With the addition of these equations the change in the net capital inflow position of the economy can be computed as the difference between aggregate investment and domestic savings. The additional equations required to endogenise  $\Delta B$  are set out in Appendix A.

We also need to add equations to define aggregate employment and the aggregate capital stock. We write

$$(69) \quad \ell = \sum_{q=1}^r \ell_q \psi_{1q}$$

and

$$(70) \quad k_{(0)} = \sum_{j=1}^h k_{j(0)} \psi_{2j}$$

where  $\ell$  is the percentage change in aggregate employment,  $k_{(0)}$  is the percentage change in the aggregate current capital stock,  $\psi_{1q}$  is the share of employment of occupation  $q$  in total employment and  $\psi_{2j}$  the share of capital of type  $j$  in the total value of fixed capital in the base year economy.

Next we define several indexing equations to increase the flexibility of operation of the model. These are

$$(71) \quad p_j^0 = h_j^0 \epsilon^{(3)} + f_j^0 \quad j = 1, \dots, h$$

$$(72) \quad p_{1,q,.} = h_{1,q,.} \epsilon^{(3)} + f_{1,q,.} + f_1$$

In (71) and (72) the  $h_j^0$  and  $h_{1,q}$  are indexing parameters and the  $f_j^0$  and  $f_{1,q}$  and  $f_1$  are shift variables. Equation (71) allows us to fix the price of other costs in each of the  $j$  industries exogenously. As will become apparent in section 4 the exogenous setting of the relevant  $p_j^0$ 's provides an important part of our modelling of risk response in the relevant commodity producing and importing industries. Equation (72) allows us to exogenously set real and nominal occupational wage rates and the economy wide wage. For example we might wish to model the labour market for say informal labour as responding differently to the labour market for formal labour, under the influence of say an increase in the world prices of agricultural commodities relative to those of non agricultural commodities. We might consider informal wages to be endogenous (determined by labour supply and demand) while those in the formal sector to be exogenous. In such a scenario we would set  $f_{1,q}$  and  $h_{1,q}$  (where  $q$  refers to formal) to zero and one respectively thus ensuring that the real formal wage for  $q = \text{formal}$  was held constant. In the case of the non formal labour market we would allow the relevant  $f_{1,q}$  to be determined endogenously by the model. Alternatively we might wish to endogenise the economy wide real wage rate given an exogenously specified set of occupational wage relativities. In such an experiment  $h_{1,q}$  would be set to one for all  $q$  and  $f_{1,q}$  would be set exogenously. The endogenous value of  $f_1$  would represent the shift in the economy's real wage level under the influence of the shock.

Finally we define the percentage change in the economy's gross domestic product (gdp) as

$$(73) \quad \text{gdp} = S_c c_R + S_i i_R + S_g x_G + S_e e + S_m m$$

i.e., as a share weighted sum of the percentage changes in each of the final demand categories. In (73),  $x_G$  refers to a weighted average of other demands from domestic and imported sources. That is

$$(74) \quad x_G = \sum_s \sum_i x_{is}^{(5)} s_{is}^{(5)}$$

where  $S_{is}^{(5)}$  is the share of other demands for good  $i$  from source  $s$  in total other demands.  $S_g$  represents the share of total other demands in the gross domestic product.<sup>1</sup>

## 2.15 The Complete Country Model

The complete set of structural equations of the standard country model (with exogenous net capital inflow) are shown in Table 1. All model variables are listed and defined in Table 2 and all parameters in Table 3.

### 2.15.1 Equations and Variables

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From Tables 1 and 2 we see that there are  $5gh + nh + 12h + rh + 12g + 2n + 2r + 14$  equations in  $5gh + nh + 15h + rh + 18g + 4n + 3r + 19$  variables. Hence to close the model requires exogenously setting the values for  $3h + 6g + 2n + r + 5$  variables. As noted earlier and taken up further in Section 3, it is the ability of the model user to close the model in numerous ways by switching variables between endogenous and exogenous sets that makes the model a flexible tool for policy analysis. Typical dimensions for  $g$ ,  $h$ ,  $n$  and  $r$  in individual country models are 10, 8, 4 and 2 respectively. This yields a very large system of equations, too large for easy inversion of  $A_1$  in (4). For each country model the number of equations and variables which enter the computation in (4) is substantially reduced by some simple algebraic substitutions. Firstly, the  $2gh$  equations and variables describing the intermediate

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<sup>1</sup> Note that gdp can also be measured as a weighted average of the percentage changes in the employment of primary factors i.e.,

$$gdp = S_L \ell + S_K k(0) + S_N n$$

where  $\ell$ ,  $k(0)$  and  $n$  are the percentage changes in the employment of aggregate labour, capital and land respectively,  $S_L$ ,  $S_K$  and  $S_N$  are the relevant shares of payments to these factors in value added and  $n = \sum_j S_j^n n_j$  where  $S_j^n$  is the share of industry  $j$ 's land in the economy's total land employment.

Table 1

## STANDARD COUNTRY MODEL: EQUATION SYSTEM

Identification	Equation	Subscript Range	Number of Equations	Description
(10)	$x_{(is)j}^{(1)} = z_j - \sigma_{ij}^{(1)} \left[ p_{(is).} - \sum_s S_{(is)j}^{(1)} p_{(is).} \right]$	$i = 1, \dots, g$ $s = 1, 2$ $j = 1, \dots, h$	2gh	Demands for intermediate inputs, domestic and imported
(11)	$x_{lj}^N = z_j$	$l = 1, \dots, n$ $j = 1, \dots, h$	nh	Demands for non-competing imports
(12)	$x_{vj}^P = z_j - \sigma_{vj} \left[ p_{vj} - \sum_{v=2}^3 S_{vj}^* p_{vj} - S_{1j}^* p_{1.} \right]$	$v = 2, 3$ $j = 1, \dots, h$	2h	Demands for fixed capital and land
(12A)	$x_{1j}^P = z_j - \sigma_{1j} \left[ p_{1.} - \sum_{v=2} S_{vj}^* p_{vj} - S_{1j}^* p_{1.} \right]$	$j = 1, \dots, h$	h	Demands for labour in general
(13)	$x_{1,q,j}^P = x_{1j}^P - \sigma_{1,q,j} \left[ p_{1,q,.} - \sum_q S_{1,q,j}^* p_{1,q,.} \right]$	$q = 1, \dots, r$ $j = 1, \dots, h$	rh	Demands for labour of each occupation
(13A)	$x_j^O = z_j$	$j = 1, \dots, h$	h	Demands for other costs
(14)	$p_{1.} = \sum_{q=1}^r p_{1,q,.} S_{1,q,.}$		1	Price of labour in general
(16)	$x_{(il)j} = z_j + \sigma_{(il)j}^T \left[ p_{(il).} - \sum_{i=1}^g C_{(il)j}^* p_{(il).} \right]$	$i = 1, \dots, g$ $j = 1, \dots, h$	gh	Commodity supplies by industry

Identification	Equation	Subscript Range	Number of Equations	Description
(19)	$x_{(is)j}^{(2)} = y_j - \sigma_{ij}^{(2)} \left( p_{(is)} - \sum_{s=1}^2 S_{(is)j}^{(2)} p_{(is)} \right)$	$i = 1, \dots, g$ $s = 1, 2$ $j = 1, \dots, h$	2gh	Demands for inputs to capital creation
(23)	$x_{is}^{(3)} = x_i^{(3)} - \sigma_i^{(3)} \left( p_{(is)} - \sum_{s=1}^2 S_{is}^{(3)} p_{(is)} \right)$	$i = 1, \dots, g$ $s = 1, 2$	2g	Household demands for commodities by source
(24)	$x_i^{(3)} - q = \epsilon_i (c - q) + \sum_{k=1}^g \eta_{ik} p_k^{(3)}$	$i = 1, \dots, g$	g	Household demands for commodities undifferentiated by source
(25)	$p_k^{(3)} = \sum_{s=1}^2 S_{ks}^{(3)} p_{(ks)}$	$k = 1, \dots, g$	g	General price of goods to households
(27)	$p_i^e = \gamma_i x_i^{(4)} + f_i^{(4)}$	$i = 1, \dots, g$	g	Export demands
(28)	$x_{is}^{(5)} = c_R h_{is}^{(5)} + f_{is}^{(5)}$	$i = 1, \dots, g$ $s = 1, 2$	2g	Other demands
(29)	$c_R = c - \epsilon^{(3)}$		1	Defines aggregate real consumption
(30)	$\epsilon^{(3)} = \sum_i \sum_s W_{is}^{(3)} p_{(is)}$		1	Defines country consumer price

Identification	Equation	Subscript Range	Number of Equations	Description
(32)	$\sum_{i=1}^g P(i1) \cdot C(i1)_j = \sum_{i=1}^g \sum_{s=1}^2 P(is) \cdot H^{(1)}(is)_j + \sum_{\ell=1}^n P_{\ell}^N H_{\ell j}^N$ $+ \sum_{q=1}^r P_{1,q} \cdot L_{1,q,j} + \sum_{v=2}^3 P_{vj} H_{vj}^P + P_{ij}^O H_j^O$	$j = 1, \dots, h$	$h$	Zero pure profits in production
(34)	$\pi_j = \sum_{i=1}^g \sum_{s=1}^2 P(is) \cdot H^{(2)}(is)_j$	$j = 1, \dots, h$	$h$	Zero pure profits in capital creation
(36)	$P_{i2} = P_{i2}^m + t_i + \phi$	$i = 1, \dots, g$	$g$	Zero pure profits in importing
(37)	$P_{\ell}^N = P_{\ell}^{Nm} + t_{\ell}^N + \phi$	$\ell = 1, \dots, n$	$n$	
(39)	$P_i^e + v_i + \phi = P_{i1}$	$i = 1, \dots, g$	$g$	Zero pure profits in exporting
(44)	$r_j(0) = Q_j (P_{2j} - \pi_j)$	$j = 1, \dots, h$	$h$	Rate of return on capital
(45)	$-\beta_j \left[ k_j(1) - k_j(0) \right] + r_j(0) = \lambda$	$j = 1, \dots, h$	$h$	Equality of rates of return
(46)	$k_j(1) = k_j(0) \left[ 1 - G_j \right] + y_j G_j$	$j = 1, \dots, h$	$h$	Capital accumulation

Identification	Equation	Subscript Range	Number of Equations	Description
(47)	$\sum_j (\pi_j + y_j) T_j = i$		1	Investment budget
(53)	$x_{i1}^{(4)} = \sum_{j=1}^h x_{(i1)j}^{(1)B(i1)j} + \sum_{j=1}^h x_{(i1)j}^{(2)B(i1)j}$ $+ x_{i1}^{(3)B(i1)} + x_{i1}^{(4)B(i1)} + x_{i1}^{(5)B(i1)}$	$i = 1, \dots, g$	g	Supply equals demand for domestically produced commodities
(54)	$x_{i1} = \sum_{j=1}^h x_{(i1)j}^{D(i1)j}$	$i = 1, \dots, g$	g	Total output of good i
(55)	$l_q = \sum_{j=1}^h x_{1,q,j}^P B_{1,q,j}$	$q = 1, \dots, r$	r	Supply equals demand for labour of each occupation
(56)	$k_{j(0)} = x_{2j}^P$	$j = 1, \dots, h$	h	Supply equals demand for capital
(56A)	$n_j = x_{3j}^P$	$j = 1, \dots, h$	h	Supply equals demand for agricultural land
(58)	$x_{i2} = \sum_{j=1}^h x_{(i2)j}^{(1)B(i2)j} + \sum_{j=1}^h x_{(i2)j}^{(2)B(i2)j}$ $+ x_{i2}^{(3)B(i2)} + x_{i2}^{(5)B(i2)}$	$i = 1, \dots, g$	g	Competitive import volume

Identification	Equation	Subscript Range	Number of Equations	Description
(59)	$x_{\ell}^N = \sum_{j=1}^h x_{\ell j}^N B_{\ell j}^N$	$\ell = 1, \dots, n$	n	Non-competitive import volume
(61)	$m = \sum_{i=1}^g \left( p_{i2}^m + x_{i2} \right) M_{i2} + \sum_{\ell=1}^n \left( p_{\ell}^{Nm} + x_{\ell}^N \right) M_{\ell}^N$		1	Aggregate foreign currency value of imports
(63)	$e = \sum_{i=1}^g \left( p_i^e + x_i^{(4)} \right) E_i$		1	Aggregate foreign currency value of exports
(65)	$100\Delta B = Ee - Mm$		1	Balance of trade
(66)	$i_R = i - \epsilon^{(2)}$		1	Defines real investment spending
(67)	$\epsilon^{(2)} = \sum_{j=1}^h T_j \pi_j$		1	Defines country capital goods price index
(68)	$i_R = c_R + f_R$		1	Relationship between real consumption and real investment



Identification	Quation	Subscript Range	Number of Equations	Description
((69))	$l = \sum_{q=1}^r l_q \psi$		1	Aggregate employment
(70)	$k_{(o)} = \sum_{j=1}^h k_j(0) \psi$		1	Aggregate capital stock
(71)	$p_j^o = h_j^o \epsilon^{(3)} + f_j^o$	$j = 1, \dots, h$	$h$	Sets price of other costs
(72)	$p_{l,q,..} = h_{l,q,..} \epsilon^{(3)} + f_{l,q,..} + f_l$	$q = 1, \dots, r$	$r$	Allows for exogenous setting of occupational wages
(73)	$gdp = S_c c_R + S_i i_R + S_g x_G + S_e e + S_m m$		1	Defines gdp
(74)	$x_G = \sum_i \sum_s x_{is}^{(5)} S_{is}^{(5)}$		1	Aggregate other demands
Total equations:	$5 gh + nh + 12h + rh + 12g + 2n + 2r + 14$			

Table 2

Standard Country Model: List of Variables

Variable	Subscript	Number	Description (all variables are in percentage changes with the exception of $\Delta B$ )
$z_j$	$j = 1, \dots, h$	$h$	Industry activity levels
$x_{(is)j}^{(1)}$	$i = 1, \dots, g$ $s = 1, 2$	$2gh$	Demands for inputs (domestic and imported) for current production
$x_{(is)j}^{(2)}$	$j = 1, \dots, h$	$2gh$	Demands for inputs (domestic and imported) for capital creation
$x_{lj}^N$	$l = 1, \dots, n$ $j = 1, \dots, h$	$nh$	Demands for non-competing imports
$x_{j..}^O$	$j = 1, \dots, h$	$h$	Demands for other costs
$x_{vj}^P$	$v = 1, 2, 3$ $j = 1, \dots, h$	$3h$	Industry demands for labour in general, fixed capital and land
$x_{1,q,j}^P$	$q = 1, \dots, r$ $j = 1, \dots, h$	$rh$	Demands for labour by occupation and industry
$x_{(i1)j}$	$i = 1, \dots, g$ $j = 1, \dots, h$	$gh$	Supplies of commodities by industry
$x_{is}^{(3)}$	$i = 1, \dots, g$ $s = 1, 2$	$2g$	Household demands for domestic and imported goods
$x_{is}^{(5)}$	$i = 1, \dots, g$ $s = 1, 2$	$2g$	Other demands for domestic and imported goods
$x_i^{(3)}$	$i = 1, \dots, g$	$g$	Household demands for goods undifferentiated by source
$x_i^{(4)}$	$i = 1, \dots, g$	$g$	Export demands
$x_{i1}$	$i = 1, \dots, g$	$g$	Total supplies of domestic commodities
$y_j$	$j = 1, \dots, h$	$h$	Capital creation by using industry
$P_{(i1)}$	$i = 1, \dots, g$	$g$	Price of domestically produced goods
$P_{(i2)}$	$i = 1, \dots, g$	$g$	Domestic price of competing imports
$P_j^O$	$j = 1, \dots, h$	$h$	Price of other costs
$P_l^N$	$l = 1, \dots, n$	$n$	Domestic price of non-competing imports
$P_1$		$1$	Economy wide price of labour in general
$P_{2j}$	$j = 1, \dots, h$	$h$	Rental price of capital in each industry
$P_{3j}$	$j = 1, \dots, h$	$h$	Rental price of land in each industry

Variable	Subscript Range	Number	Description (all variables are in percentage changes with the exception of $\Delta B$ )
$p_{1,q,..}$	$q = 1, \dots, r$	$r$	Price of labour by occupation
$p_k^{(3)}$	$k = 1, \dots, g$	$g$	Price of consumer goods by type but not by source
$p_{i1}^e$	$i = 1, \dots, g$	$g$	F.o.b. foreign currency export prices
$p_{i2}^m$	$i = 1, \dots, g$	$g$	c.i.f. foreign currency prices for competing imports
$p_\ell^{Nm}$	$\ell = 1, \dots, n$	$n$	c.i.f. foreign currency prices for non-competing imports
$\pi_j$	$j = 1, \dots, h$	$h$	costs of units of capital
$q$		$1$	Number of households
$c$		$1$	Aggregate money consumption
$c_R$		$1$	Aggregate real household expenditure
$\epsilon^{(3)}$		$1$	Consumer price index
$f_i^{(4)}$	$i = 1, \dots, g$	$g$	Shift term for exports
$f_{is}^{(5)}$	$i = 1, \dots, g$ $g = 1, 2$	$2g$	Shift term for other demands by source
$t_i$	$i = 1, \dots, g$	$g$	One plus the ad valorem tariff on competing commodities
$t_\ell^N$	$\ell = 1, \dots, n$	$n$	One plus the ad valorem tariff on non-competing commodities
$\phi$		$1$	Exchange rate (domestic currency/foreign currency)
$v_i$	$i = 1, \dots, g$	$g$	One plus the ad valorem export subsidies
$r_j(0)$	$j = 1, \dots, h$	$h$	Industry rates of return to capital
$k_j(0)$	$j = 1, \dots, h$	$h$	Current capital stocks
$k_j(1)$	$j = 1, \dots, h$	$h$	Future capital stocks
$k(0)$		$1$	Economy aggregate capital stock
$\lambda$		$1$	Economy wide expected rate of return
$i$		$1$	Aggregate nominal investment
$i_R$		$1$	Aggregate real investment
$\ell_q$	$q = 1, \dots, r$	$r$	Employment of labour by occupation
$n_j$	$j = 1, \dots, h$	$h$	Supply of land in each industry

Variable	Subscript Range	Number	Description (all variables are in percentage changes with the exception of $\Delta B$ )
$x_{i2}$	$i = 1, \dots, g$	$g$	Competitive import volume
$x_{\ell}^N$	$\ell = 1, \dots, n$	$n$	Non-competitive import volume
$m$		1	Foreign currency value of imports
$e$		1	Foreign currency value of exports
$\Delta B$		1	Balance of trade
$\epsilon^{(2)}$		1	Capital goods price index
$f_R$		1	Shift term to set relationship between aggregate consumption and investment
$l$		1	Aggregate employment
$f_j^O$	$j = 1, \dots, h$	$h$	Shift term for other costs
$f_{1,q,.}$	$q = 1, \dots, r$	$r$	Shift term for occupational wages
$gdp$		1	Real gross domestic product
$x_G$		1	Aggregate other demands
$f_1$		1	Economy wide wage shift variable
Total variables: $5gh + nh + 15h + rh + 18g + 4n + 3r + 19$			

input flows  $x_{(is)j}^{(1)}$  and  $x_{(is)j}^{(2)}$  are eliminated by substituting (10) and (19) into (53) and (58). Similarly 2g equations and variables are eliminated by successive substitutions of (25) and (24) into (23). Further substantial eliminations occur because of the sparseness of the  $C_{(i1)j}$  parameter matrix. That is, only a few industries are modelled as producing more than one product and then only 2 or 3. It should be noted that those variables substituted from the system are not 'lost' from the model. Their solution values can be derived from the solution values of remaining endogenous variables.

### 2.15.2 Parameters

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Table 3 contains the complete list of model parameters. Many of these, such as the various cost and sales shares, are directly obtainable from the base year I-O flows outlined in Figure 1. This figure requires for its construction a country I-O table and information about joint production of commodities in industries, the structure of the labour market and the structure of capital in each industry. Many other parameters however such as the substitution elasticities between imported and domestic commodities in various end uses, the substitution parameters between various occupations and between primary factors, the transformation parameters between competing products and the parameters that specify consumer demand, investment demand and export demand behaviour must be obtained from other sources.

Given the ambitiousness of the scope of the analysis and the very large number of parameters involved, it is necessary for us to rely heavily on the applied econometrics literature for parameter estimates.<sup>1</sup>

A legitimate criticism of the theoretical framework in Table 1 would be that it incorporates too much parameter flexibility given the rather limited availability of parameter estimates.

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<sup>1</sup> Econometric estimation will be carried out in instances where the appropriate country data base is sufficiently well developed to provide a reasonable prospect of success.

Table 3

Standard Country Model: List of Parameters

Equation	Parameter	Description	Source (a)
10	$\sigma_{ij}^{(1)}$	Elasticity of substitution between domestic and foreign sources of good i for use as an input in production in industry j.	Econometric.
	$S_{(is)j}^{(1)}$	Share of good i from source s (domestic or imported) in industry j's purchases of i for inputs to current production.	IO. $S_{(i1)j}^{(1)}$ is ijth element of $\tilde{A}$ divided by the sum of the ij elements of $\tilde{A} + \tilde{F}$ . $S_{(i2)j}^{(1)}$ is $1 - S_{(i1)j}^{(1)}$ .
11		No parameters.	
12 and	$\sigma_{vj}^P$	Substitution parameter for primary factor v in industry j.	Econometric.
12A	$S_{vj}^*$	Modified cost share of primary factor v (v = 2 fixed capital, v = 3 land) in total primary factor costs in industry j.	IO. and econometric. $S_{2j}$ is jth element of $\tilde{L}$ divided by jth column total of $\tilde{K} + \tilde{L} + \tilde{M}$ . $S_{3j}$ is jth element of $\tilde{M}$ divided by jth column total of $\tilde{K} + \tilde{L} + \tilde{M}$ . $S_{vj}^* = S_{vj} \sigma_{vj}^P / \sum_{v'=1}^v S_{v'j} \sigma_{v'j}^P$ .
	$S_{1j}^*$	Modified cost share of labour in general in total primary factor costs in industry j.	IO. and econometric. $S_{1j}$ is the sum of the j column elements of $\tilde{K}$ divided by the j-th column total of $\tilde{K} + \tilde{L} + \tilde{M}$ . $S_{1j}^* = S_{1j} \sigma_{1j}^P / \sum_{v'=1}^v S_{v'j} \sigma_{v'j}^P$
13	$\sigma_{1,q,j}$	Substitution parameter for labour of occupation q in industry j.	Econometric.
	$S_{1,q,j}^*$	Modified cost share of labour of occupation q in total labour costs of industry j.	IO and econometric. $S_{1,q,j}$ is qjth element of $\tilde{K}$ divided by jth column total of $\tilde{K}$ . $S_{1,q,j}^* = S_{1,q,j} \sigma_{1,q,j} / \sum_{q=1}^r S_{1,q,j} \sigma_{1,q,j}$

Equation	Parameter	Description	Source (a)
13A		No parameters.	
14	$S_{l,q,.}$	Cost share of labour of type q in the economy's total labour cost.	IO. $S_{l,q,.}$ is qth row sum of $\tilde{K}$ divided by the sum of all elements in $\tilde{K}$ .
16	$\sigma_{(i1)j}^T$	Transformation parameter for commodity i produced in the multiproduct bundle of industry j.	Econometric.
	$C_{(i1)j}^*$	Modified revenue share of commodity i in the total revenue of industry j.	IO. and econometric. $C_{(i1)j}$ is the ijth element of $\tilde{O}$ divided by the jth column sum of $\tilde{O}$ . $C_{(i1)j}^* = C_{(i1)j} \sigma_{(i1)j}^T / \sum_{i=1}^g C_{(i1)j} \sigma_{(i1)j}^T$
19	$\sigma_{ij}^{(2)}$	Elasticity of substitution between domestic and imported sources of good i when used as an input to capital formation in industry j.	Econometric.
	$S_{(is)j}^{(2)}$	Share of good i from source s in industry j's total purchases of i for inputs to capital creation.	IO. $S_{(i1)j}^{(2)}$ is ijth element of $\tilde{B}$ divided by the sum of the ij elements of $\tilde{B} + \tilde{C}$ . $S_{(i2)j}^{(2)}$ is $1 - S_{(i1)j}^{(2)}$ .
23	$\sigma_i^{(3)}$	Elasticity of substitution between domestic and imported sources of good i when used for household consumption.	Econometric.
	$S_{is}^{(3)}$	Share of the value of good i from source s in the total purchases of good i by households.	IO. $S_{i1}^{(3)}$ is the ith element of $\tilde{C}$ divided by the sum of the ith elements of $\tilde{C} + \tilde{H}$ . $S_{i2}^{(3)}$ is $1 - S_{i1}^{(3)}$ .

Equation	Parameter	Description	Source <sup>(a)</sup>
24	$\epsilon_i$	Household expenditure elasticity of good i (from domestic or imported sources).	Econometric.
	$\eta_{ik}$	Household cross price elasticities of demand for good i in general with respect of changes in the general price of good k.	Econometric.
25	$S_{ks}^{(3)}$	Defined in 23.	
27	$\gamma_i$	Reciprocal of the foreign elasticity of demand for country good i.	Econometric
28	$h_{is}^{(5)}$	Indexing parameter to fix relationship between aggregate real consumption and other demands for good i from source s.	Determined by model user.
29		No parameters.	
30	$W_{is}^{(3)}$	Weight of good i from source s in the country consumer price index.	IO. $W_{i1}^{(3)}$ is the ith element of $\tilde{C}$ divided by the sum of all elements in $\tilde{C} + \tilde{H}$ . $W_{i2}^{(3)}$ is the ith element of $\tilde{H}$ divided by the sum of all elements in $\tilde{C} + \tilde{H}$ .
32	$C_{(i1)j}$	Defined in 16.	
	$H_{(i2)j}^{(1)}$	Cost share of good i from source s in the total costs of industry j.	IO. $H_{(i1)j}^{(1)}$ is the ijth element of $\tilde{A}$ divided by the total costs of industry j. These are computed as the jth column sum of $\tilde{A} + \tilde{F} + \tilde{J} + \tilde{K} + \tilde{L} + \tilde{M} + \tilde{N}$ . $H_{(i2)j}^{(1)}$ is the ijth element of $\tilde{F}$ divided by the total costs of industry j.
	$H_{lj}^N$	Cost share of non-competing import l in total costs of industry j.	IO. $l$ jth element of $\tilde{J}$ divided by the total costs of industry j.



Equation	Parameter	Description	Source (a)
	$L_{1,q,j}$	Cost share of labour of occupation $q$ in the total costs of industry $j$ .	IO. $q$ th element of $\tilde{K}$ divided by the total costs of industry $j$ .
	$H_{vj}^P$ $v = 2,3$	Cost share of primary factor $v$ in the total costs of industry $j$ .	IO. $H_{2j}^P$ is the $j$ th element of $\tilde{L}$ divided by the total costs of industry $j$ . $H_{3j}^P$ is the $j$ th element of $\tilde{M}$ divided by the total costs of industry $j$ .
	$H_j^O$	Cost share of other costs in the total costs of industry $j$ .	IO. $j$ th element of $\tilde{N}$ divided by the total costs of industry $j$ .
34	$H_{(is)j}^{(2)}$	Share of good $i$ from sources in industry $j$ 's total purchases of good $i$ for inputs to capital creation.	IO. $H_{(i1)j}^{(2)}$ is the $ij$ th element of $\tilde{B}$ divided by the sum of the $ij$ th elements of $\tilde{B} + \tilde{G}$ . $H_{(i2)j}^{(2)}$ is $1 - H_{(i1)j}^{(2)}$ .
36		No parameters.	
37		No parameters.	
39		No parameters.	
44	$Q_j$	Ratio of gross (before depreciation) to net (after depreciation) rate of return in industry $j$ .	Econometric.
45	$\beta_j$	Elasticity of the expected rate of return schedule in industry $j$ with respect to increases in the planned capital stock in industry $j$ .	Econometric.
46	$G_j$	Ratio of industry $j$ 's gross investment to its following year capital stock.	Econometric.
47	$T_j$	Share of total investment accounted for by industry $j$ .	IO. First sum the column elements of $\tilde{B} + \tilde{G}$ . $T_j$ is the $j$ th element in the array of the column sums of $\tilde{B} + \tilde{G}$ divided by the sum of the elements in the array.

Equation	Parameter	Description	Source <sup>(a)</sup>
53	$B_{(i1)j}^{(1)}$	Share of the total sales of domestic good $i$ which is absorbed by industry $j$ as an input into current production.	IO. $B_{(i1)j}^{(1)}$ is the $ij$ th element of $\tilde{A}$ divided by the total sales of domestic good $i$ , i.e., the sum over the $i$ th row of $\tilde{A} + \tilde{B} + \tilde{C} + \tilde{D} + \tilde{E}$ .
	$B_{(i1)j}^{(2)}$	Share of the total sales of domestic good $i$ which is absorbed by industry $j$ as an input into capital creation.	IO. $B_{(i1)j}^{(2)}$ is the $ij$ th element of $\tilde{B}$ divided by the total sales of domestic good $i$ .
	$B_{i1}^{(3)}$	Share of the total sales of domestic good $i$ which is absorbed by household consumption.	IO. $B_{i1}^{(3)}$ is the $i$ th element of $\tilde{C}$ divided by the total sales of domestic good $i$ .
	$B_{i1}^{(4)}$	Share of the total sales of domestic good $i$ which is absorbed by exports.	IO. $B_{i1}^{(4)}$ is the $i$ th element of $\tilde{D}$ divided by the total sales of domestic good $i$ .
	$B_{i1}^{(5)}$	Share of the total sales of domestic good $i$ which is absorbed by other demands.	IO. $B_{i1}^{(5)}$ is the $i$ th element of $\tilde{E}$ divided by the total sales of domestic good $i$ .
54	$D_{(i1)j}$	Share of the total output of domestic commodity $i$ which is produced in industry $j$ .	IO. $D_{(i1)j}$ is the $ij$ th element of $\tilde{O}$ divided by the sum of the elements in the $i$ th row of $\tilde{O}$ .
55	$B_{1,q,j}$	Share of the economy-wide employment in occupation $q$ which is accounted for by industry $j$ .	IO. $B_{1,q,j}$ is the $qj$ th element of $\tilde{K}$ divided by the $q$ th row sum of $\tilde{K}$ .
56		No parameters.	
56A		No parameters.	
58	$B_{(i2)j}^{(1)}$	Share of the total sales of imported good $i$ which is absorbed by sales to industry $j$ for current production.	IO. $B_{(i2)j}^{(1)}$ is the $ij$ th element of $\tilde{F}$ divided by the total sales of imported good $i$ , i.e., $i$ th row sum of $\tilde{F} + \tilde{G} + \tilde{H} + \tilde{I}$ .
	$B_{(i2)j}^{(2)}$	Share of the total sales of imported good $i$ which is absorbed for capital creation in industry $j$ .	IO. $B_{(i2)j}^{(2)}$ is the $ij$ th element of $\tilde{G}$ divided by the total sales of imported good $i$ .

Equation	Parameter	Description	Source (a)
	$B_{i2}^{(3)}$	Share of the total sales of imported good $i$ absorbed by household consumption.	IO. $B_{i2}^{(3)}$ is the $i$ th element of $\tilde{H}$ divided by the total sales of imported good $i$ .
59	$B_{lj}^N$	Share of the total sales of non-competing imports of good $l$ absorbed by industry $j$ .	IO. $B_{lj}^N$ is the $lj$ th element of $\tilde{J}$ divided by the $l$ th row sum of $\tilde{J}$ .
61	$M_{i2}$	Share of the total foreign currency cost of imports accounted for by imports of good $i$ .	IO. $i$ th row sum of $\tilde{F} + \tilde{G} + \tilde{H} + \tilde{I} + (-\tilde{Z})$ divided by the total foreign currency cost of imports i.e., the sum of all elements in $\tilde{F} + \tilde{J} + \tilde{G} + \tilde{H} + \tilde{I} + (-\tilde{Z}) + (-\tilde{Y})$ .
	$M_{l2}^N$	Share of the total foreign currency cost of imports accounted for by imports of non-competing import good $l$ .	IO. $l$ th row sum of $\tilde{J} + (-\tilde{Y})$ divided by the total foreign currency cost of imports.
63	$E_i$	Share of total export earnings accounted for by exports of good $i$ .	IO. $E_i$ is the $i$ th element of $\tilde{D}$ divided by the total of all elements in $\tilde{D}$ .
65	$E$	Aggregate foreign currency value of export goods.	IO. Sum of the elements in $\tilde{D}$ .
	$M$	Aggregate foreign currency value of imports.	IO. Sum of all elements in $\tilde{F} + \tilde{G} + \tilde{H} + \tilde{I} + \tilde{J} + (-\tilde{Z}) + (-\tilde{Y})$ .
66		No parameters.	
67	$T_j$	Defined in (47).	
68		No parameters.	
69	$\psi_{1q}$	Share of aggregate employment accounted for by employment of occupation $q$ .	Econometric.
70	$\psi_{2j}$	Share of capital employed in industry $j$ in the economy's total capital stock.	

Equation	Parameter	Description	Source <sup>(a)</sup>
71	$h_j^o$	Indexes prices of other costs to consumer price index.	Determined by model user.
72	$h_{l,q,.}$	Indexes occupational wage rate to consumer price index.	Determined by model user.
73	$\left. \begin{array}{l} S_c \\ S_i \\ S_g \\ S_e \\ S_m \end{array} \right\}$	Respectively, the shares of gross domestic product accounted for by aggregate consumption demand, investment demand, other demand, export demand and import demand.	Calculated from IO or National Accounts data. Sum of all shares is unity.
74	$S_{is}^{(5)}$	Share of the total other demands accounted for by the other demand for good i from source s.	IO. $S_{i1}^{(5)}$ is the ith element $i1$ of $\tilde{E}$ divided by the total of all elements in $\tilde{E} + \tilde{I}$ . $S_{i2}^{(5)}$ is the ith element of $\tilde{I}^2$ divided by the total of all elements in $\tilde{E} + \tilde{I}$ .

(a) Parameter sources are the country base year input-output flows matrix as assembled in Figure 1 (denoted IO) or an alternative source (generally denoted Econometric).

However, while it may prove impossible to assemble genuine estimates of all the parameters for each country, the applied economics literature is comprehensive enough to provide "ball-park" estimates in most cases. Of course, sensitivity analysis to a range of parameter estimates can easily be carried out.

### 3. Two Examples of Model Closure: the Long Run and the Short Run

In section 2 we noted that the choice of exogenous and endogenous variables was determined by the model user according to the characteristics of the particular experiment under investigation. Here we provide two examples of model closure, one which we specify in a long run environment and the other in a short run environment. The main purpose of the examples is to illustrate the interpretation of the short run and the long run in this type of model framework which is essentially of a comparative-static nature.

A typical model result for a particular country is of the form, given a policy change of type A of  $x$  per cent in a specified country macroenvironment B then, in the short run or long run, variable C will differ from the value it would have had in the absence of the policy change by  $y$  per cent. The possible set of policy changes, A, is very large. A might include for example commodity tariff changes, exchange rate changes, import price or export price changes, changes in the level and composition of government expenditure, changes in wage rates, changes in export volumes or alternatively export subsidies and changes in the industry-specific costs of holding liquidity to name but a few. The specification of the macroeconomic environment B can also vary substantially according to the choice of exogenous and endogenous variables and the values allocated to key parameters. B could specify macroenvironments of a Keynesian or a neo-classical flavour. Examples of variables C for which projections can be made

are any 'sensible'<sup>1</sup> subset of  $5g_h + n_h + 12h + r_h + 12g + 2n + 2r + 14$  variables from the complete list in Table 2. Perhaps the most interesting are outputs by commodity and industry, imports and exports by commodity, occupational labour demands, wage rates, the balance of trade and domestic prices. In what follows we set up model closures to illustrate the interpretation of short run and long run response.

### 3.1 The Short Run Effects of an x per cent Across the Board Increase in Tariffs

The aim of the experiment is to assess the short run impact (on industrial and workforce composition, patterns of exports and imports and the gdp etc.) of an increase of x per cent in the ad valorem tariff rates for all commodities. Table 4 sets out one possible choice of exogenous variables. The first group of exogenous variables are the industry specific capital stocks. It is the inclusion of these variables on the exogenous list that defines our concept of the short run. An obvious though difficult question is how long is the short run? The short run in this experiment must be long enough for local prices of imports to fully adjust to the tariff increases, for users of imports to decide whether or not to switch to domestic suppliers, for domestic suppliers to hire labour and to expand their output as well as alter its product composition with their existing plant and for price increases to be passed into wages and wages back to prices. It must be short enough such that changes in the level of capital stocks in use in each industry can be ignored but long

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<sup>1</sup> Not all model closures are permissible. For example, at least one monetary variable should appear on the exogenous list in order for the model to be able to determine the absolute price level. Also it is of course not permissible to set all variables in an equation exogenously. As a general working rule, if a price appears on the exogenous list, then a corresponding quantity should appear on the endogenous list. For example, if tariffs are exogenous then imports will be endogenous, if wages are endogenous then employment should be exogenous etc..

Table 4: Exogenous Variable Selection for Short Run Tariff Increase Experiment

Exogenous Variable	Number	Description
$k_j(0)$	h	Current capital stocks
$p_{i2}^m$	g	Foreign currency prices of competing imports
$p_{\ell}^{Nm}$	n	Foreign currency prices of non-competing imports
$f_i^{(4)}$	g	Shift term for exports
$t_i$	g	One plus the ad valorem tariffs on competing and non-competing imports
$t_{\ell}^N$	n	
$\phi$	1	Exchange rate
$c_R$	1	Real aggregate household expenditure
$i_R$	1	Real aggregate investment
q	1	Number of households
$f_{is}^{(5)}$	2g	Shift term for other demands by source
$f_{l,q,.}$	r	Shift term for occupational wages
$f_l$	1	Economy-wide wage shift term
$f_j^o$	h	Shift term to set price of other costs
$n_j$	h	Supply of land by industry
$v_i \ (i \in G)$	g	One plus the ad valorem export subsidy for endogenously determined export commodities
$x_i^{(4)} \ (i \notin G)$		Exports for those commodities for which exports are to be set exogenously

Total:  $6g + 3h + r + 2n + 5$

enough for changes in investment plans initiated by the shock to affect the demands faced by industries producing capital goods. The calendar time interpretation of this process will depend how quickly these adjustments are considered to be transmitted through the economy under study. Somewhere in the vicinity of 2 years would seem reasonable.

The second and third groups of variables are the foreign currency import prices. The model framework is specific to an individual country and contains no equations describing foreign supply conditions. We assume for each country that world import prices are independent of that country's import demands.

Next we have the export demand shift variables. Their role is to simulate shifts in foreign demands for a country's exports, hence they would always be determined exogenously in our framework.

These are followed by one plus the ad valorem tariffs. Since shifts in these variables constitute the exogenous shock they appear on the exogenous list.

Next is the exchange rate, which in this experiment is simply acting as the numeraire. With  $\phi$  set exogenously the ratio of the domestic cost level to the foreign currency prices of traded goods is endogenous. The model has nothing to say about how to partition this relative price change into movements in domestic inflation and exchange rate changes. To achieve this requires additional information from the model user.

Next we note that the elements of real absorption (aggregate real household expenditure, aggregate real investment and aggregate other demands) are set exogenously in this experiment by the inclusion of  $c_R$ ,  $i_R$  and  $f_{is}^{(5)}$  on the exogenous list (and the setting of  $h_{is}^{(5)}$  to unity). That is, we are making the assumption that real aggregate domestic



absorption can be thought of as being determined independently of changes in commodity tariffs. (An alternative approach would be to set  $\Delta B$  and  $f_R$  exogenously in place of  $c_R$  and  $i_R$ . The model would then indicate the change in the level of absorption (at a fixed allocation between consumption and investment) which would need to accompany a tariff increase to maintain a given balance of trade.)

The next exogenous variable is the number of households. This will always be exogenous in our framework. The model does not attempt to explain household formation.

Next we have a group of shift terms,  $f_{1,q,..}$ , the shift terms for occupational wages,  $f_1$ , the economy-wide wage shift term and  $f_j^0$ , the shift term for other costs in each industry. The inclusion of  $f_{1,q,..}$  and  $f_1$  on the exogenous list indicates that labour market prices rather than employment levels are treated exogenously in the short run. Thus the level of employment is treated as being demand determined in each occupation with employers being able to employ as much labour as they like at the exogenously specified wage. With the parameter  $h_{1,q,..}$  set to unity for all  $q$  real wages for each occupation are set exogenously. The usefulness of  $f_j^0$  in model simulations is illustrated in section 4. In the tariff experiment, by setting  $f_j^0$  to zero and  $h_j^0$  to unity for all  $j$  ensures that the unit price of other costs is assumed to remain constant in real terms under the influence of higher tariffs.

The next exogenous variable is the supply of land by industry. With this set exogenously, the model determines the change in the rental prices of land in each of the land using industries which can be attributed to the exogenous shock.

The final group of exogenous variables are the export subsidies  $v_i$  ( $i \in G$ ) and the exports  $x_i^{(4)}$  ( $i \notin G$ ) where  $G$  is a user specified subset of the  $g$  commodities and contains the labels of those commodities for which the model is allowed to explain exports. That is, if exports of a commodity are deter-

mined endogenously then the corresponding export subsidy is set exogenously and vice versa. Normally we would allow the model to explain exports only for those commodities whose behaviour is such that their domestic currency prices can be regarded as being set by their corresponding world prices. Exports take place according to the differential between world prices and domestic production costs. For non-export commodities or commodities with only a small proportion of their total sales passing to exports we would set  $x_i^{(4)}$  exogenously. The model would then determine the export subsidy required to achieve the exogenously specified export level.

In assigning values to the exogenous variables (which are in percentage changes) all except the  $t_i$  and  $t_\ell^N$  would be set to zero. The values for  $t_i$  would be set to

$$x \frac{T_i}{1 + T_i} \text{ and those for } t_\ell^N \text{ to } x \frac{T_\ell^N}{1 + T_\ell^N}$$

where  $T_i$  is the base period ad valorem tariff on competing commodity  $i$  and  $T_\ell^N$  is the base period ad valorem tariff on non-competing commodity  $\ell$ .<sup>1</sup>

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<sup>1</sup> Recall that the  $t_i$  and  $t_\ell^N$  in Table 4 refer to percentage changes in one plus the ad valorem tariffs. Hence to change the ad valorem tariff by  $x$  per cent requires an  $x \frac{T_i}{1 + T_i}$  per cent change in the one plus ad valorem tariffs.

3.2 The Long Run Effects of an x per cent Increase in  
the World Price of Commodity i (Say Crude Oil)  
Relative to all Other World Commodity Prices

With the comparative-static model framework outlined in Table 1, the simplest way of formulating a long run solution is via what is termed the snapshot approach. This approach involves building a picture of the economy in a typical future year. In a model such as ours where variables are in percentage change form, the solution tells us how outputs, employment, etc. in a typical year say five years hence will differ as a result of the exogenous change from the levels they would have reached in year five in the absence of the change. The great advantage of the snapshot approach is that it avoids problems in specifying a fully intertemporal model. However, questions concerning the path by which the economy reaches the snapshot year are left unanswered.

Table 5 provides one suitable selection of exogenous variables.

The exogenous list in Table 5 differs from that in Table 4 in three important respects;

(i) The  $k_j(0)$  are determined endogenously while the  $r_j(0)$  are set exogenously, (ii) the components of real domestic absorption ( $c_R$ ,  $i_R$  and  $x_G^1$ ) are determined endogenously while the balance of trade  $\Delta B$  is set exogenously, (iii) the economy-wide wage is endogenous while aggregate employment is exogenous.

The distinguishing feature of the long run environment is the abandonment of the capital fixity assumption at the industry level and/or at the aggregate level. Consider for example the first option, capital mobility at both the industry and aggregate level. This is achieved by allowing  $k_j(0)$  and  $k(0)$  to be endogenously determined by fixing both the absolute rate of return to capital in the economy and the relative

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<sup>1</sup> Note that setting  $f_{is}^{(5)}$  exogenously is equivalent via equations (74) and (28) to setting the  $x_G$  exogenously.

Table 5: Exogenous Variable List for Long Run Oil Pricing Experiment

Exogenous Variable	Number	Description
$r_j(0)$	h	Industry specific rates of return to capital
$p_{i2}^m$	g	Foreign currency prices of competing imports
$p_\ell^{Nm}$	n	Foreign currency prices of non-competing imports
$f_i^{(4)}$	g	Shift term for exports
$t_i$	g	One plus the ad valorem tariffs on competing and non-competing imports
$t_\ell^N$	n	
$\phi$	1	Exchange rate
$\Delta B$	1	Balance of trade
$f_R$	1	Shift term to set relationship between aggregate consumption and investment
q	1	Number of households
$\ell$	1	Aggregate employment
$f_{l,q,.}$	r	Shift term for occupational wages
$f_{(is)}^{(5)}$	2g	Shift term for other demands by source
$f_j^0$	h	Shift term to set price of other costs
$n_j$	h	Supply of land by industry
$v_i (i \in G)$	g	One plus the ad valorem export subsidy for endogenously determined export commodities
$x_i^{(4)} (i \notin G)$		
Total: $6g + 3h + r + 2n + 5$		

rates of return across industries. That is, we are assuming that in the long run these will reflect foreign rates - the supply price of capital for investment in a particular country is as given on world markets. Capital flows between the rest of the world and the country concerned are then viewed as being the vehicle by which rates of return are exogenously given to the domestic economy. Implied with the assumption of capital mobility in the domestic economy is that the model's solution or snapshot year is far enough into the future such that changes in relative rates of return between industries in the domestic economy that are initially induced by the exogenous shock are eliminated by capital mobility between industries. (Whether the response period allowed is long enough to accommodate the reconfiguration of the capital stock that takes place can easily be checked ex post.) If we were following this view of the long run then capital flows could be determined endogenously by the attachment of the additional equations in Appendix A to the basic system of equations in Table 1. Alternatively, the capital flows could be specified exogenously.

The second option, that of a fixed aggregate capital stock but capital mobility between industries in the domestic economy, is achieved by allowing the absolute rate of return in the economy to be determined endogenously. (That is, all  $r_j(0)$  are allowed to change by the same amount to achieve no change in  $k(0)$ ). This story implies that in the long run, capital mobility between industries in the domestic economy takes place but there is a barrier to capital flows between the domestic economy and the rest of the world. As a result of this barrier, the absolute rate of return in the domestic economy is allowed to deviate from the rate prevailing in the rest of the world.

The empirical evidence is somewhat unclear as to the extent to which differences in rates of return on capital between countries are eliminated by capital flows, at least in the medium term.<sup>1</sup> In some of our sample of countries the evidence would suggest that the fixed aggregate capital stock assumption may be the more appropriate one given the sorts of exogenous shocks we intend to investigate and the time horizon chosen. (See Section 4 for further details).

The second major distinguishing feature of the long run closure of Table 5 from the short run closure of Table 4 is the assumption of a long run balance of trade constraint facing the country. The model then determines the change in domestic economic activity which must accompany an exogenous shock given the exogenously specified balance of trade constraint.

The third major distinguishing feature of the long run closure from the short run closure is in the treatment of the labour market. From Table 5 we note that the exogenous shock is assumed to have no necessary implications for the aggregate level of employment in the economy. It does however have implications for the real wage level associated with a given level of employment. That is, aggregate employment,  $l$ , appears on the exogenous list while the economy-wide wage,  $f_1$ , is determined endogenously.<sup>2</sup> (Compare this with the short run closure where wages were exogenous and occupational labour demands were endogenous).

Given the twin assumptions of a balance of trade constraint and exogenous employment, any tendency for the world

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<sup>1</sup>See Agarwal (1980) for a recent survey of the evidence.

<sup>2</sup>Note that in both Tables 4 and 5 real wage relativities are determined exogenously. Their endogenous determination would require the addition to the model of a theory to explain occupational labour supply.

commodity price changes to alter the net foreign exchange position of the economy must be eliminated by an adjustment of the domestic price level relative to world prices sufficient to bring about the required redirection of resources between the traded and non-traded sectors of the economy.

For the experiment all variables in Table 5 except  $p_{i2}^m$  where  $i = \text{crude oil}$  and  $f_i^{(4)}$  where  $i = \text{crude oil}$  would be assigned zero values.  $p_{i2}^m$  and  $f_i^{(4)}$  ( $i = \text{crude oil}$ ) would be assigned the values  $(1 + x)^t$  where  $t$  is the number of years envisaged for the long run. That is, world oil prices are assumed to increase by  $x$  per cent per year relative to all other commodity prices for a period of  $t$  years.

#### 4. Simulating some Aspects of UNCTAD Plans for Commodity

##### Market Reform

We now turn to the policy problem central to the construction of the country models - determining the divergent economic interests of individual countries with respect to UNCTAD plans for international commodity market regulations. As stated earlier our planned approach is to transmit the appropriate shock to each country model separately. Before doing this two key issues must be resolved; (i) the choice of a suitable model closure and (ii) the formulation of the appropriate exogenous shock.

##### 4.1 Model Closure

Our concern is essentially with the medium term about five years hence. We would therefore use the snapshot approach to construct a picture of each economy five years from the

base period. The long run model closure as set out in Table 5 is broadly appropriate. That is, we would assume capital mobility within the domestic economy, we would view the exogenous shock as having implications for real wage rates at any given level of employment rather than as influencing the level of employment that could be achieved and we would view real domestic absorption as being endogenously determined subject to some form of balance of trade constraint. Within these three broad features of the long run environment variations across countries might be imposed according to institutional features specific to each country. For example in a country whose domestic capital market was freely exposed to the world capital market we might seek to endogenise long run capital inflow by using the additional equations in Appendix A. Also, institutional labour market features might lead us to close labour markets for different occupations in different ways.

#### 4.2 The Formulation of the Exogenous Shock

The essential aims of the proposal at UNCTAD for an Integrated Programme of Commodities are twofold;<sup>1</sup> (i) a stabilisation of selected commodity prices, (ii) an increase in these prices relative to other commodity prices. We consider the second aim first, that of raising some world commodity prices relative to others.

The size of this relative price change, its duration and how it is achieved are three issues exogenous to our model framework. Hence relative world commodity price scenarios need to be constructed. These scenarios must of course resemble 'real world' possibilities and hence will need to reflect the extent to which the planned commodity market regulations are likely to improve the terms of trade

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<sup>1</sup>See UNCTAD (1975).



for a particular commodity. We can of course investigate a range of exogenous scenarios involving alternative price linkage arrangements between UNCTAD core commodities and other internationally traded commodities. One such scenario might be of the form; suppose the world price of all UNCTAD core commodities were to increase by 5 per cent per year relative to all non-core commodities and that this price differential was sustained for five years. Thus the elements in  $p_i^m$  and  $f_i^{(4)}$  (for  $i =$  UNCTAD core commodity) would be set to  $(1.05)^5$  and all other elements to zero.

Note that it is the foreign demand curve shift variable for exports  $f_i^{(4)}$ , rather than the f.o.b. export price variable  $p_i^e$ , that is used to transmit the change in world commodity prices to each country. Recall from (27) that the  $p_i^e$  are in fact endogenous. That is, each country by way of export supply response can influence the f.o.b. world price. Whether or not  $f_i^{(4)}$  should be allowed to differ from  $p_i^e$  depends on what sort of country supply response to the higher prices is envisaged by the UNCTAD scheme, which in turn depends on the intervention mechanism to achieve the terms of trade change. If the UNCTAD proposals require country-specific export quotas on commodities to prevent the initial terms of trade change being dissipated by increased exports and a movement down the foreign demand curve facing a particular country's exports then equation (27) plays no role. That is, the appropriate  $x_i^{(4)}$  would be set exogenously and  $p_i^e$  would be fixed exogenously to  $f_i^{(4)}$  (for  $i =$  UNCTAD core commodities). If however the initial price shock is imposed independently of any export supply constraints then with exports of the core commodities being determined endogenously, equation (27) has an important role to play. In such a case, the values for  $\gamma_i$ , which set the slopes of the foreign demand curves for exports, are important. Appendix B provides some guidance on how the  $\gamma_i$  may be determined.

The specification of the other aim, that of price stability, is especially vague. In order to be able to model its effects requires that we interpret it in a quantitative fashion such as for example a given percentage reduction in the variance or coefficient of variation of a commodity price for a stated period. The model of Table 1 is however of a comparative-static nature. That is, it does not permit the tracing of movements in variables from one year to the next over the simulation period. With no year to year dynamics it is not possible to impart the reduction in price variance through the price variable itself. The incorporation of a reduction in price variance must occur through one or more of the exogenous variables in the list of Table 5. In order to determine which of these variables are appropriate for the task we first need to identify the range of responses, likely within an economy to a reduction in world commodity price variance.

The types of response to a reduction in price instability might include:

- (a) a response by producers of that commodity for export,
- (b) a response by importers of that commodity for processing,
- (c) a response at the macroeconomic level.

How a producer will respond to the knowledge of more stable prices for his output<sup>1</sup> will depend on his degree

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<sup>1</sup>Note that UNCTAD aims to stabilise the world price of a commodity, not the price at the farm gate or factory or mine. In several countries in our sample, well developed domestic pricing mechanisms exist to filter out world price instability and present the farmer with a more stable supply price. In such countries the reduction in world price instability need have no effects on the supply behaviour of producers.

of risk aversion. The evidence suggests that the bulk of farmers are risk averse. We might therefore propose that in an uncertain output pricing environment producers would tend to maintain excessive reserves of liquidity and adopt a more diversified product mix than would be the case in a more certain environment. This view would treat uncertainty as an additional cost the producers must bear, a cost which includes the need to maintain liquid reserves to meet unforeseen contingencies.<sup>1</sup> A reduction in price uncertainty therefore reduces the costs of holding liquidity per unit of output or alternatively increases the net or value added price of the output. In our system, this would be simulated by an exogenous reduction in  $f_j^0$  (for  $j$  = the industry in which the commodities whose prices are stabilised are produced). To make this method operational requires establishing, for a given decrease in commodity price variance over a stated time period, the appropriate per unit output reduction in the costs associated with price uncertainty. This issue is at present unresolved.

The second type of producer response, that of a change in the output mix of products (together with changes in the mix of purchased inputs), cannot be incorporated in the model as it now stands. To do this would require the addition of product and factor augmenting technical change variables to the model equations.<sup>2</sup> These would be shifted exogenously according to a specified scenario about likely changes in production technology associated with

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<sup>1</sup>Mayer (1980) provides some theoretical justification for modelling price risk as an additional cost of production within a utility maximising mean-variance framework.

<sup>2</sup>For a model which includes such variables see Dixon (1980).

the exogenous shock.<sup>1</sup>

Importers of the raw commodities for processing will achieve a reduction in their working capital or stock holding costs when the price instability of their major material input is reduced. This can be simulated by an appropriate reduction in  $f_j^0$  (for  $j$  = industry importing the commodity whose price is being stabilised). Again, the key information required is the per unit reduction in production costs associated with a given reduction in the price instability of the commodity.

We might also expect a reduction in commodity price instability to exert an influence at the macro level. A characteristic of a number of LDC's in our country sample is their heavy reliance for foreign exchange on the sales proceeds of a small number of commodities whose world prices are unstable. Stabilisation of such prices may<sup>2</sup> lead to a reduction in the instability of export earnings which could have implications for aggregate expenditure. For example, an economy faced with chronic instability of foreign exchange earnings could be expected to hold higher (than otherwise would be the case) foreign exchange reserves as a contingency measure. (Alternatively, such an economy might incur costs from alternative arrangements undertaken to finance imports when export earnings are low). If it could be established for example that with commodity price stability this contingency reserve could be reduced, then the once and for all advantage to the economy

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<sup>1</sup>The information on which to base such a scenario would be hard to find. In any case, the economy-wide effects are likely to be very small. The incidence of joint production among our sample of countries is confined to only a few industries.

<sup>2</sup>Whether a reduction in price variability leads to a reduction in revenue variability depends on the size and direction of the covariance between export price and quantity for a particular commodity and LDC. This in turn depends on the outcome of a number of economic factors. See Donges (1979) for a discussion of the key issues.

of running down the foreign exchange reserves could be simulated by simply allowing the economy to run a balance of trade deficit (of the size of the change in reserves) in the snapshot year. That is, the economy would be allowed to spend more on imports than it earned on exports while still meeting the balance of trade constraint.<sup>1,2</sup>

The implications for aggregate household consumption expenditure of a change in the stability of household incomes (which could be expected to result from a change in export earnings stability in commodity exporting LDC's where the nexus between households and producers is strong) are less certain. Whether say a reduction in foreign exchange instability will increase or decrease the ratio of aggregate consumption to aggregate investment expenditure is a matter of some debate.<sup>3</sup> The economy-wide implications of alterations (in both directions) of the aggregate consumption to investment ratio can be simulated in our system by the exogenous manipulation of  $f_R$ .

#### 4.3 Second-Round Price Effects

In section 4.2 we discussed the incorporation of the exogenous shock. The initial component of the shock was specified as a given increase in the price of UNCTAD core

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<sup>1</sup>Alternatively, if it was believed that price stabilisation would accentuate foreign exchange instability then the relevant simulation might require forcing the economy to hold more foreign exchange.

<sup>2</sup>The exogenous manipulation of the balance of trade variable,  $\Delta B$ , in conjunction with other variables also provides the model user with a method of simulating the resource allocative implications of say an import rationing approach to a foreign exchange shortage. Consider for example an economy which decided in the face of a shortage of foreign exchange to ration imports according to some allocative mechanism. The economy-wide effects of this sort of approach could be simulated by exogenously setting the vector of imports according to the chosen rationing mechanism to consume the available foreign exchange.

<sup>3</sup>For a summary of the issues see Lim (1976).

commodities relative to non-core commodities. The question arises as to whether over the time horizon envisaged for the simulations, second-round price effects should be incorporated via further modification of the exogenous scenario. These second-round effects are the modifications to the initial 'UNCTAD-inspired' change in world price relativities that result from shifts in the rest of the world commodity demand and supply curves as end users in the rest of the world respond to the initial set of relative price changes. On the basis of such expected shifts it is often argued that over the long term, attempts to artificially shift the terms of trade between commodities in defiance of underlying market forces are likely to be self-defeating. The argument goes something like this. Suppose for example that the world price of sugar was raised (by some unspecified interference with the market) above its long run trend price. This would imply initially a resource transfer from sugar consuming to producing countries. However, consumers would react by switching consumption to sugar substitutes. Sugar producers would also react by increasing production. While the producer supply response could be controlled in the major exporting country within the umbrella of the price fixing arrangement, this would not be the case in net importing countries. These events would operate to shift the free market world demand curve for sugar to the left and also the supply curve to the right thus making it increasingly difficult for the price fixing authorities to maintain sugar's relative price advantage and reducing the size of the resource transfer from consuming to producing countries. It might also be argued that the price fixing arrangements introduce resource misallocation within the international economy, the consequences for which will be felt by both producing and consuming countries. To some extent, this downwards pressure on price which can be attributed to rest of the world response to the initial relative price increase

might be offset by an upwards pressure on price from the rest of the world's response to the increased price predictability.<sup>1</sup>

It might be possible to capture some of these effects in a multicountry economic framework which specifically included linkages in consumption between competing products and feedbacks to producing countries. However, such linkages are not part of our framework. We assume that these linkages come into force beyond the time horizon of our focus. That is, our model solutions for individual countries should be interpreted as indicating the resource allocative and welfare implications of a given initial change in the terms of trade for selected commodities over a period sufficiently short such that the feedback effects on world commodity demands and hence prices from substitution in consumption can be ignored. However, increases in raw commodity prices can be expected to flow through quickly into production costs and hence the prices of manufactured products. It will be important to include these effects especially in the case of countries which are both exporters of the raw commodity and importers of a manufactured product which uses that commodity and vice versa. If we do not allow the price increase in the raw material to feed through into the price of the manufactured product then we will obtain a distorted picture of the likely terms of trade change confronting such countries. Perhaps the simplest world price model we could use to trace the direct and indirect effects of increases in prices of core commodities on the prices of other commodities which use inputs of core commodities in their production process is that obtained as the dual to the basic Leontief static I-O model. This model is set out in Appendix C.

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<sup>1</sup>In the case of a raw material competing in end-use with a synthetic substitute whose supply is not subject to the vagaries of weather, end users can be expected (other things being equal) to increase their share of use of the raw material counterpart in their total usage of that commodity type (from both raw material and synthetic sources) as the user costs associated with the instability of the price of the raw material are reduced.

#### 4.4 Alternative Methods of Transferring Resources to Less Developed Countries

Underlying the UNCTAD proposals for commodity market reform is a desire to redistribute income from the wealthier (UNCTAD core-commodity consuming) countries to the poorer (UNCTAD core-commodity producing) countries or at least to arrest the historic terms of trade drift facing certain raw materials producing economies. Of course alternative methods of achieving this, to that of distorting relative world commodity prices, can be proposed. An alternative transfer mechanism for example which would avoid the longer term problems associated with market intervention measures, would be simply to transfer foreign exchange from rich to poor countries. The economy-wide implications for our sample of countries of free 'gifts' of foreign exchange can be simulated simply by exogenously relaxing the foreign exchange constraint, that is by allowing foreign exchange expenditure on imports to exceed foreign exchange export earnings by the magnitude of the 'gift' of foreign exchange.

#### 5. Linking Results Across Countries

The construction of an integrated system of economy-wide models within a world model framework is clearly beyond the scope of this project. The question remains however of how the results from each of the sample of countries for which the equations of Table 1 are fitted can be used to generate results for the large number of LDC's which lie outside our country sample. One simple method of linking results across countries is by using regression analysis. Suppose for example that each of our sample of 10 country models were closed using a common set of exogenous variables then shocked with say a 10 per cent



increase in the real price of crude oil. Model solutions would indicate how endogenous variables such as gdp, exports, imports etc. in each of the 10 economies responded to the change. Suppose furthermore that we wished to estimate the effect on say the gdp's of a further 20 LDC's (outside our sample of 10 modelled countries) of the 10 per cent increase in real oil prices under the same assumptions about the macroeconomic environment for these countries as those implied by the form of model closure chosen for the 10 countries in the experiment. The first step would be to closely examine the underlying linkages in each of the modelled economies that are required to 'justify' the resultant movement in the gdp. Such an examination would identify a small number of specific characteristics in each economy whose values were critical in determining the size of the response in gdp. These characteristics would be combinations of I-O coefficients and econometric parameters. They might include for example in the case of an explanation of gdp, the share of oil revenue in total export earnings for an oil exporting LDC (or alternatively the share of expenditure on oil imports out of total import expenditure for oil importing LDC's) and the share of crude oil costs in the economy's total costs (i.e., the oil intensity of the country's industrial production technology).

The next step is to fit a regression equation of the form;

$$Y_i = \alpha_0 + \alpha_1 B_{1i} + \alpha_2 B_{2i} + \dots + E_i \quad (75)$$

where  $Y_i$  is the percentage change in gdp in country  $i$ ,  $B_1$  and  $B_2$  are the chosen explanatory variables of the variation in gdp across countries,  $E_i$  is an error term and  $\alpha_0$ ,  $\alpha_1$  and  $\alpha_2$  are regression coefficients. Provided that (75) yields a satisfactory<sup>1</sup> explanation of the variation in

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<sup>1</sup>Equation (75) would need to explain a reasonable percentage of the variation in  $Y_i$  with the parameter estimates  $\alpha_1$  and  $\alpha_2$  being of the correct sign and statistically significant.

gdp across countries, then the predictive equation

$$\hat{Y}_i = \hat{\alpha}_0 + \hat{\alpha}_1 E_{1i} + \hat{\alpha}_2 E_{2i} \quad (76)$$

could be used to generate the gdp response for the remaining LDC's (the  $\hat{Y}_i$  for  $i = \text{LDC}$  outside the sample of (76)) simply by providing values for these LDC's of the explanatory variables  $E_1$  and  $E_2$ . Of course, the utility of this method of projecting results beyond the sample of modelled countries depends on (75) being of a satisfactory fit and the set of  $E$  explanatory variables required to satisfactorily explain  $Y$  being relatively small. If this outcome is achieved then (75) and (76) provide a relatively simple yet powerful procedure for broadening enormously the scope of our quantitative framework.

## 6. Concluding Remarks

This paper has outlined a flexible computable general equilibrium model framework in which to analyse in detail at the individual country level, a wide range of economic policy problems. The paper provides some guidance as to how problems concerning the resource allocative effects in LDC's of UNCTAD plans for commodity market reform may be investigated within this framework. While the structural equation framework is country specific, a simple method for linking solutions across country models is proposed in order to enable inferences to be made of the effects of a given exogenous shock on countries not modelled in detail.

As is clear from the size of the parameter list in Table 3, the specification of the structural system for each country model is a non-trivial task. However, while

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<sup>1</sup>Equation (75) would need to explain a reasonable percentage of the variation in  $Y_i$  with the parameter estimates  $\alpha_1$  and  $\alpha_2$  being of the correct sign and statistically significant.

many of the model parameters cannot be hoped to be known with certainty sufficient evidence is available to indicate the plausible range within which they can be expected to lie.

From the discussion in section 4, it is obvious that the model is capable of endogenising only a small subset of the issues surrounding UNCTAD plans for commodity market reform. It has nothing to say for example about the extent of the terms of trade change and the reduction in commodity price variability that can be achieved in each commodity market nor the best method of bringing this about. Nor does it make any contribution to the issue of how to finance the proposed commodity market intervention. All this remains exogenous to the model. Hence the need for detailed scenario writing of the alternatives. However, given these scenarios, the model provides a rigorous and comprehensive framework for determining their resource allocative implications in considerable economy-specific detail.

Appendix A: Endogenising Net Capital Inflow in Long Run Simulations

As noted in Section 2.14 the basic model structure of Table 1 is unable to endogenise the change in the net capital inflow position of the economy in the future snapshot year. For most experiments and countries this deficiency is not likely to prove of any consequence. In these cases the preferred simulation would involve setting  $\Delta B$  exogenously. However, in certain circumstances we might envisage that  $\Delta B$  should in fact be determined endogenously in long run experiments. In order to achieve this, several revisions<sup>1</sup> to the model when it is set up to reflect long run closure are required.

These involve;

- (i) the deletion of equation (68) which exogenously fixes the relationship between aggregate real investment  $i_R$  and aggregate real consumption  $c_R$ .
- (ii) the addition of an equation to explain aggregate real investment expenditure  $i_R$  in the snapshot year.
- (iii) the addition of equations to explain domestic savings in the snapshot year.

With the addition of these equations the long run balance of trade deficit,  $\Delta B$ , which represents the net capital inflow position of the economy in the future or snapshot year, can be endogenised as being the difference between aggregate investment and domestic savings in the future year.

In deriving these additional equations we use a notation different from that in Table 1. Once the derivation is complete we express the additional equations in terms of the Table 1 notation. For illustrative purposes we denote the base year as 1980 (85) and the snapshot year as 1990 (90).

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<sup>1</sup> These revisions are essentially along the lines suggested by Dixon et al (1981).

(a) Specifying a Domestic Savings Function

First we express the level of domestic savings in year 90,  $S_{90}$ , as a function of the level of wage income,  $W_{90}$ , the level of capitalist income,  $\Pi_{90}$ , and the share of the capital stock in year 90 which is owned domestically,  $M_{90}$ .

$$(A1) \quad S_{90} = s_1 W_{90} + s_2 (\Pi_{90} M_{90})$$

where  $s_1$  and  $s_2$  are respectively the fractions of wages and of domestic capitalist income that are saved. Expressing (A1) in percentage change form gives;

$$(A2) \quad s_{90} = w_{90} \left( \frac{s_1 W_{90}}{S_{90}} \right) + (\pi_{90} + m_{90}) \left( \frac{s_2 \Pi_{90} M_{90}}{S_{90}} \right)$$

where lower case variables denote percentage changes in the corresponding upper case variables. The terms in square brackets in (A2) will be treated as parameters. They are respectively the share of savings from wages in total domestic savings and the share of savings from domestic capitalist income in total domestic savings in 1990.

The next and most difficult step is to establish how the domestic savings share of capitalist income would change in 1990 under the influence of the given shock. That is, we need to endogenise  $m_{90}$ . Getting back into levels we would expect  $M_{90}$  to depend on  $M_{80}$  (the domestic savings share in the base year economy) and on the growth in capital stock over the 1980-1990 period relative to the growth in domestic saving over this period. That is,  $M_{90}$  would be higher than  $M_{80}$  if the growth in capital for the 1980-1990 period is high compared with the growth in domestic savings.

We write that;

$$(A3) \quad M_{90} = f \left( M_{80}, K_{(80,90)}, S_{(80,90)} \right)$$

where  $K_{(80,90)}$  is the aggregate amount of capital creation and  $S_{(80,90)}$  the aggregate amount of domestic savings between years 80 and 90. We can write that;

$$(A4) \quad M_{90}K_{90} = M_{80}K_{80} + S(80,90)$$

That is, total domestic savings in 1990,  $M_{90}K_{90}$ , equals domestic savings in the base year,  $M_{80}K_{80}$ , plus the growth in savings over the period,  $S(80,90)$ . Hence from (A4) we see that;

$$(A5) \quad M_{90} = \frac{M_{80}K_{80}}{K_{90}} + \frac{S(80,90)}{K_{90}}$$

Expressing (A5) in percentage change form gives;

$$(A6) \quad m_{90} = m_{80} + k_{80} - k_{90} \left( \frac{M_{80}K_{80}}{M_{90}K_{90}} \right) \\ + \left( s(80,90) - k_{90} \right) \left( \frac{S(80,90)}{K_{90}M_{90}} \right)$$

where the terms in square brackets are treated as parameters. The first parameter in (A6) represents the ratio of domestic savings in the base year to those in the snapshot year while the second parameter represents the ratio of domestic savings over the snapshot period to total domestic savings in the snapshot year. The next step is to endogenise  $s(80,90)$ . (It is likely that the term  $\left( \frac{S(80,90)}{K_{90}M_{90}} \right)$  will be close to zero for medium term planning horizons and hence the second part of (A6) would exert negligible influence on  $m_{90}$ ). However, we could add an equation of the form;

$$(A7) \quad S_{80,90} = S_{90} - S_{80}$$

which, expressed in percentage change form gives;

$$(A8) \quad s_{80,90} = s_{90} \left( \frac{S_{90}}{S_{80,90}} \right) - s_{80} \left( \frac{S_{80}}{S_{80,90}} \right)$$

where the terms in square brackets are again to be regarded as parameters.

(b) Specifying an Aggregate Investment Function

We assume a constant rate of growth ( $g$ ) of the capital stock over the snapshot period and in the snapshot year. This allows us to express investment in year 90 ( $I_R^{90}$ ) as a function of the aggregate capital stocks in year 80 and year 90 ( $K_{80}$ ) and ( $K_{90}$ ). We write;

$$(A9) \quad K_{90} = K_{80}(1 + g)^t$$

(where  $t = 10$  in our example)

and

$$(A10) \quad K_{91} = K_{90}(1 + g)$$

then

$$(A11) \quad I_R^{90} = K_{91} - (1-d)K_{90}$$

where  $I_R^{90}$  is aggregate real gross investment in the snapshot year and  $d$  is the economy-wide average annual depreciation rate of the capital stock in year 1990. From (9) we can see that

$$(A12) \quad g = \left(\frac{K_{90}}{K_{80}}\right)^{\frac{1}{t}} - 1$$

Hence (A11) can be expressed as;

$$(A13) \quad I_R^{90} = K_{90}(g + d)$$

Substituting (A12) into (A13) gives;

$$(A14) \quad I_R^{90} = K_{90} \left( \left(\frac{K_{90}}{K_{80}}\right)^{\frac{1}{t}} - 1 + d \right)$$

Writing (A14) in percentage changes gives;

$$(A15) \quad i_R^{90} = \left( k_{90} + \frac{1}{t} (k_{90} - k_{80}) \right) \left( \frac{K_{90}}{I_R^{90}} \cdot \left(\frac{K_{90}}{K_{80}}\right)^{\frac{1}{t}} \right) - k_{90} \left( \frac{K_{90}}{I_R^{90}} (1-d) \right)$$

where the terms in square brackets are again treated as parameters.

In summary we have the following equations;

$$(A2') \quad s_{90} = w_{90}\psi_1 + (\pi_{90} + m_{90})\psi_2$$

$$(A6') \quad m_{90} = (m_{80} + k_{80} - k_{90})\psi_3 + (s_{(80,90)} - k_{90})\psi_4$$

$$(A8') \quad s_{80,90} = s_{90}\psi_5 - s_{80}\psi_6$$

$$(A15') \quad i_R^{90} = \left(k_{90} + \frac{1}{t}(k_{90} - k_{80})\right)\psi_7 - k_{90}\psi_8$$

where the composition of the  $\psi$  parameters is as given earlier. The final step is to rewrite these equations in terms of the notation of the model in Table 1. The variables with a subscript, 90, refer to variables in the year of the model's solution. To be consistent with the notation of Table 1, these variables are written without the time subscript (with the exception of the capital stock variables). The variables which carry the subscript, 80, refer to the base year of the model. These variables have zero value in our system and can therefore be omitted. We write

$$w_{90} = \sum_{q=1}^r (p_{1,q} + l_q)\psi_{1q}$$

$$\pi_{90} = \sum_{j=1}^h (p_{2j} + k_j(0))\psi_{2j}$$

$m_{90} = m$  (percentage change in the share of the future year capital stock that is owned domestically).

$$k_{90} = k(0)$$

$s_{(80,90)} = s_{(0,1)}$  (percentage change in the growth in savings over the snapshot period).

$s_{90} = s$  (percentage change in the future year level of savings)

$$i_R^{90} = i_R$$



Substituting these definitions into equations (A2'), (A6'), (A8') and (A15') gives our final system of additional equations. These are;

$$(A16) \quad s = \left( \sum_{q=1}^r (p_{1,q} + l_q) \psi_{1q} \right) + \left( \sum_{j=1}^h (p_{2j} + k_{j(0)}) \psi_{2j} + m \right) \psi_2$$

$$(A17) \quad m = -k_{(0)} \psi_3 + s \psi_4 \psi_5 - k_{(0)} \psi_4$$

$$(A18) \quad i_R = k_{(0)} \left( 1 + \frac{1}{t} \psi_7 - \psi_8 \right)$$

These three additional equations introduce two additional variables (s and m) to the variable list of Table 2. Hence the revised model with these equations appended is capable of endogenising one more variable from Table 5 that was previously set exogenously, the balance of trade,  $\Delta B$ . Note however that these additional equations have introduced a set of additional parameters ( $\psi_1, \psi_2, \psi_3, \psi_4, \psi_5, \psi_7, \psi_8$ ). In order to specify these parameters we will have to project the underlying growth path of economic aggregates (capital stocks and savings) for the time horizon of the experiments.

Appendix B. Terms of Trade Power in Commodity Markets

It is obvious from the trade flow statistics that no country in our sample can exert an influence on the world price of any of the core commodities by virtue of its volume of imports. However a feature of a number of sample countries<sup>1</sup> is that exports of a particular core commodity constitute a sufficiently large percentage of total world demand for that commodity to enable that country's export volume to influence the world price.<sup>2</sup> For such countries the slopes of the foreign demand curves facing such commodity exports are of particular importance.

Given the rather unsatisfactory outcomes of past econometric attempts to estimate the slopes of the foreign demand curves for commodities facing particular countries we propose a simple synthetic approach. We begin with the assumption of a homogenous commodity  $i$ , ignore transport costs and assume a freely competitive world market. We assume further that the rest of the world supply and demand functions from the point of view of country  $j$  may be written as;

$$(B1) \quad D_i^W = F_{1i}^W p_i^{-\eta_i}$$

$$(B2) \quad S_i^W = F_{2i}^W p_i^{\epsilon_i}$$

where  $D_i^W$  is the rest of the world demand for commodity  $i$ ,  $S_i^W$  is the rest of the world supply of commodity  $i$ ,  $p_i$  is the world price,  $\eta_i$  and  $\epsilon_i$  are values of price elasticities of demand and supply,  $F_{1i}^W$  is an index of demand shift factors (e.g. income and population) for commodity  $i$  and  $F_{2i}^W$  is an index of supply factors (e.g. technology and investment).

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<sup>1</sup> This feature of heavy concentration in a particular commodity market formed one criterion determining the selection of sample countries.

<sup>2</sup> Prominent examples are Malaysia (which produces over 30 per cent of the world's tin and 45 per cent of the world's rubber) and Brazil (which produces 45 per cent of the world's sisal and 16 per cent of the world's coffee).

Country j's net trade (either exports and imports) function is:

$$(B3) \quad X_i^j = D_i^W - S_i^W$$

Suppose that X in (B3) refers to exports, which is the case we are interested in. Then we can write that

$$(B4) \quad x_i^j = \frac{D_i^W}{X_i^j} \left( f_{1i}^W - \frac{S_i^W}{D_i^W} f_{2i}^W \right) - \frac{D_i^W}{X_i^j} \left( \eta_i + \frac{S_i^W}{D_i^W} \epsilon_i \right) p_i$$

where the lower case symbols represent logarithmic differentials of corresponding upper case variables. Expressing (B4) with  $p_i$  as the dependent variable gives:

$$(B5) \quad p_i = \frac{\left( f_{1i}^W - f_{2i}^W \frac{S_i^W}{D_i^W} \right)}{\left( \eta_i + \epsilon_i \frac{S_i^W}{D_i^W} \right)} - \frac{\left( X_i^j \right)}{\left( D_i^W \left( \epsilon_i \frac{S_i^W}{D_i^W} + \eta_i \right) \right)} x_i$$

Equations (B4) and (B5) contain a number of interesting properties. From (B4) it can be seen that the effects of country j's exports of commodity i on its world price declines as  $X_i^j/D_i^W \rightarrow 0$ , that is, as country j's trade in i declines relative to world demand for i.

Note that equation (B5) is in fact the export demand equation (27) in Table 1. By looking at (B5) we gain some insights into the properties of (27). The first term in square brackets can be thought of as a foreign demand curve shift **factor**. It represents the contribution made to the **change** in the world price of commodity i ignoring changes in exports of i from country j. In our experiments, this term will be shifted exogenously. An examination of its components however does provide us with a guide to the combination of events that would be required **for** such a shift in world price to be sustained. For example, as  $X_i^j/D_i^W \rightarrow 0$  shifts in the world market price will focus on the relative rates of shift in the world supply and demand curves,

$f_{1i}^W$  and  $f_{2i}^W$ , respectively.<sup>1</sup> The term constituted by the second square bracket in (B5), the coefficient on  $x$ , constitutes the reciprocal of the foreign demand elasticity for commodity  $i$  from the point of view of producing country  $j$  ( $\gamma_i$  in equation (27)). From (B5) we see that estimates of  $\gamma_i$  can be obtained from estimates of its components ( $\epsilon_i$ ,  $\eta_i$  and  $X_i^j/D_i^W$ ). The term  $X_i^j/D_i^W$  can be obtained from commodity trade flow statistics while estimates for  $\epsilon_i$  and  $\eta_i$  are generally available in the literature.

Of course, particular details of the world commodity pricing arrangements we wished to impose on each model might preclude any feedback effects on world prices by country  $j$ 's exports - that is, both the world price of commodity  $i$  and country  $j$ 's exports of  $i$  may be determined exogenously as part of the commodity arrangements, in which case equations (B5) and (27) play no role in our system.

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<sup>1</sup> Note that  $S_i^W/D_i^W = (D_i^W - X_i^j) / D_i^W = 1 - X_i^j / D_i^W$ .

Appendix C. Relating Exogenous Changes in UNCTAD Core Commodity  
Prices to Changes in the World Price of Other  
Commodities

As noted in section 4, the model framework of Table 1 does not allow for feedback effects whereby a change in the world price of one commodity may affect the world prices of other commodities exported and imported by a particular country. This omission of a linkage mechanism between world commodity prices is likely to be of significance in certain cases. Consider for example the case of Korea which is both an importer of raw sugar and an exporter of the refined product. An increase in the world price of raw sugar can be expected, at least in the short term, to result in an increased price for the refined product. Failure to account for this would, in the case of this example, lead to an overstatement of the terms of trade deterioration imposed on the Korean economy by the raw sugar price increase.

Precise estimates of the linkages between world commodity prices would require an integrated world model system which traced resource flows between producing and consuming agents and countries. In the absence of such a framework we turn to the basic Leontief open static I-O model. We imagine that 'average' world industrial production technology for the set of commodities recognized in our country model (both UNCTAD core commodities and other commodities) can be depicted by a matrix of conventional I-O coefficients. This allows us to make use of the following price model to trace the direct and indirect effects of higher priced UNCTAD commodities on the prices of non-UNCTAD commodities.

$$(C1) \quad P' = P'A_1 + P'_U A_2 + P' K \hat{R} + W\lambda$$

where the notation is as follows;

$P'$  :  $1 \times n$  vector of world commodity prices for non-core commodities,

$A'$  :  $n \times n$  matrix of 'average world' intermediate input coefficients.  $A_1$  has typical element  $a_{1ij}$  representing the amount of non-UNCTAD core commodity  $i$  to produce a unit of output of non-UNCTAD core commodity  $j$ .

- $P_U^1$  :  $1 \times m$  vector of world prices of UNCTAD core commodities,  
 $A_2$  :  $m \times n$  matrix of 'average world' I-O coefficients whose typical element  $a_{2ij}$  represents the input of UNCTAD core commodity  $i$  required to produce a unit of output of non-UNCTAD core commodity  $j$ .  
 $K$  :  $n \times n$  matrix of capital requirements coefficients, with typical element  $k_{ij}$  representing the quantity of non-UNCTAD core commodity  $i$  required in the capital stock necessary to support the production of one unit of output of non-UNCTAD core commodity  $j$ ,  
 $\hat{R}$  :  $n \times n$  diagonal matrix of gross rates of return to capital in industries producing non-UNCTAD core commodities,  
 $W$  : wage cost variable,  
 $\ell$  :  $1 \times n$  matrix of labour requirements coefficients. A typical coefficient  $\ell_j$  represents the quantity of labour required to produce a unit of output of non-UNCTAD core commodity  $j$ .

The interpretation of (C1) is as follows: The world price of a unit of non-UNCTAD core commodity is composed of the intermediate input unit costs of non-UNCTAD core commodities ( $P^1 A_1$ ) and UNCTAD core commodities ( $P_U^1 A_2$ ), the unit cost of capital ( $P^1 K \hat{R}$ ) and the unit cost of labour ( $W\ell$ ). In our experiment  $P_U^1$  would be set exogenously according to whatever terms of trade shock was envisaged. We would assume that unit labour costs were fixed and then solve (C1) for  $P^1$ . That is, we interpret  $P^1$  as representing the vector of non-UNCTAD core commodity price changes that would follow from a given initial increase in  $P_U^1$  relative to the world cost of labour. We would then have a complete vector of commodity price changes, that enforced some consistency between processed and unprocessed commodity prices, with which to confront our country specific general equilibrium model.<sup>1</sup> To solve (C1) we would need an appropriate set of technology coefficients. In the absence of a complete set of such coefficients, a less formal approach which took account of the major linkages on the cost side could be implemented.

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<sup>1</sup> The resultant vector is of course subject to the restrictions of the Leontief framework, in particular the assumption of zero substitution between inputs. Thus we could only assume (C1) to hold for a limited time horizon.

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