1 THE SALTER MODEL STRUCTURE

The SALTER (Sectoral Analysis of Liberalising Trade in the East Asian Region) model is a computable general equilibrium model in the tradition of Whalley's (1985) models of world trade. Other models of this type include the WALRAS (World Agricultural Liberalisation Study) model used to analyse the economic implications of reducing agricultural assistance in member countries of the Organisation for Economic Co-operation and Development (Burniaux, Delorme, Lienert and Martin 1990), and the Michigan model of North–South trade relations between developed and developing countries (Deardorff and Stern 1986).

Like these models, the SALTER model is composed of regional submodels that describe the economic activities of firms, households and governments. The regional submodels are linked through international trade flows to form a general equilibrium model in which prices and quantities supplied and demanded are determined simultaneously in all primary factor markets and domestic and international commodity markets.

The SALTER model is normally used to simulate the effects of policy changes on equilibrium prices and quantities. Because it is general equilibrium in nature, it accounts for the feedback effects of a policy change throughout an economy and its effects on trading partners.

The model is comparative static. It reflects the completed adaptations that would occur as a result of a simulated policy change, subject to the constraints under which agents can make their decisions, relative to the position the economy would be in at the same point in time had the policy change not occurred. In this sense, the model is not dynamic, and the time path from the initial equilibrium to the new, policy-induced equilibrium cannot be followed.

The equations underlying the SALTER model can be classified as behavioural equations and accounting equations. Although the underlying behavioural equations are mostly non-linear, the entire model is linearised, as a first order approximation to the underlying model. As in the Johansen (1974) linearised model, most variables in the model are the percentage changes in quantities and prices that arise from the simulated policy change. A few variables are expressed in absolute change form. Although the model is specified as being approximately linear, it is possible to solve it in multiple steps, thus allowing any linearisation error to be made arbitarily small.

1.1 Regions and commodities

The SALTER model consists of sixteen countries or groups of countries centered on the Pacific Rim (Box 1.1). The world's major market oriented economies — Japan, the United States and the European Community — are explicitly modelled. The rapidly growing countries of Asia are represented by including the ASEAN countries, Hong Kong, Taiwan and the Republic of Korea (hereafter Korea). The People's Republic of China (hereafter China) is included because of its increasing importance in world trade and very large potential market for imports. The close economic ties Australia has with New Zealand are captured by including these two economies. Remaining regions are included in a 'rest of the world' aggregate. This aggregate region is composed of Africa, Latin America, the Pacific nations, Western European countries that do not belong to the European Community, nations classified until recently as 'centrally planned economies' (except China), the Middle-East, and Asian countries not already specified.

Box 1.1: **Regions in the SALTER model**

1	Australia	
2	New Zealand	
3	Canada	
4	United States	
5	Japan	
6	Republic of Korea	
7	European Community	(United Kingdom, France, Federal Republic of Germany, Italy, Belgium, Netherlands, Luxemburg, Denmark, Ireland, Greece, Spain, Portugal)
8	Indonesia	
9	Malaysia	
10	Philippines	
11	Singapore	
12	Thailand	
13	People's Republic of China	
14	Hong Kong	
15	Taiwan	
16	Rest of the world	

In each region, 37 commodities and industries are distinguished (Box 1.2). Concordances between standard commodity and industry classifications and the commodities in Box 1.2 are found in Hambley (1993). The amount of commodity detail was chosen so as to be able to model issues of concern to Australia and its trading partners. The model thus explicitly recognises the production of key agricultural commodities of importance to some countries in the Asian region, such as paddy rice and non-grain crops, and identifies separately Australia's major resource-based exports — wool, wheat and coal. Labour-intensive manufacturing industries such as textiles, wearing apparel and leather products (including footwear) are identified separately, as are the resource-based industries of lumber and wood products and pulp, paper and printing. The heavy manufacturing industries which have formed the basis of the rapid growth of several European economies, Japan and Korea are also recognised explicitly, as are several types of service activity.

Box 1.2: **Industry and commodity groupings in the SALTER model**

Agriculture

1	Paddy rice
2	Wheat
3	Other grains
4	Non-grain crops
5	Wool
6	Other livestock products

Resources

7	Forestry
8	Fishing
9	Coal
10	Oil
11	Gas
12	Other minerals

Food manufacturing

13	Processed rice
14	Meat products
15	Milk products
16	Other food products

Non-food manufacturing

17	Beverages and tobacco
18	Textiles
19	Wearing apparel
20	Leather products (including footwear)
21	Lumber and wood products
22	Pulp, paper and printing
23	Petroleum and coal products
24	Chemicals, rubber and plastic
25	Non-metallic mineral products
26	Primary iron and steel
27	Non-ferrous metal products
28	Fabricated metal products
29	Transport equipment
30	Other machinery and equipment
31	Other manufacturing

Services

32	Electricity, gas and water
33	Construction
34	Trade and transport
35	Other services (private)
36	Other services (government)
37	Other services (ownership of dwellings)

The model recognises three primary factors of production: labour, capital and farm land. While capital and labour are used by all industries, farm land is used only in agricultural industries. Each primary factor of production can be treated as mobile between the industries in which it is used. In contrast to capital and intermediate inputs, labour and farm land are not traded between regions in the model. The aggregate quantity of farm land available in each economy is fixed, but the level of employment in each region can be determined by the model. Capital can be traded internationally through an international market for debt.

1.2 The economic structure of the SALTER model

The SALTER model depicts the behaviour of households, firms, governments and investors in each of the regions listed in Box 1.1. Changes in equilibrium quantities and prices are determined by the specified behaviour of economic agents and the structure of international trade.

As already noted, the SALTER model is not dynamic, but rather a comparative static model. Reactions to a change in the economic conditions facing economic agents are represented by the adaptations they make in order to achieve a new equilibrium. The rate at which these adaptations occur is not determined by the model; rather the changes observed in a simulation are those that would result given enough time to attain a new equilibrium.

The remainder of the chapter provides a description of the SALTER model's theoretical structure. The discussion refers to equations found in Appendix A (Table A1). These equations are written in their linearised percentage or absolute change form, but the discussion in this chapter is couched in terms of the underlying level forms. Appendix A provides the reader with tools to convert an equation expressed in levels to its corresponding linear expression in terms of percentage or absolute changes.

Microeconomic behaviour

Households are assumed to maximise the utility derived from the consumption of commodities, while producers minimise production costs under perfectly competitive conditions. The government is assumed to minimise the cost of acquiring commodities for public consumption. Similarly, given an aggregate level of investment (also determined within the model), the cost of acquiring investment goods is minimised by choosing the least-cost sources of each commodity.

These microeconomic activities generate commodity flows within and between regions. The importance of international trade flows in the SALTER model is reflected in the detailed specification of the choices available to economic agents over the regional sources of commodities. The general equilibrium framework integrates the behaviour of these decision makers into a consistent framework in which macroeconomic identities are respected within each region and globally.

Overview of the model's equations

The equations listed in Appendix A are grouped by main topic:

SA: microeconomic behavioural equations defining demands for commodities;

SB: zero pure profit conditions at all levels of transactions;

SC: market clearing conditions;

SD: household income aggregates, supply of primary factors and savings;

SE: government budget;

SF: international trade equations;

SG: equations governing international capital mobility;

SH: national macroeconomic indicators;

SI: instruments to define different economic environments; and

SJ: global macroeconomic indicators.

Equation group SA uses the microeconomic choice framework outlined above to define firms' demands for primary factors and intermediate inputs for production purposes. The SA equation group also defines household, government and investment demands for commodities by source (ie. domestically produced or imported from a particular source country) as well as aggregate commodity prices for each demand category.

Equation group SB defines the zero pure profit conditions linking the price of goods at all stages to the cost of inputs. The basic price of a firm's production links the cost of intermediate inputs and the total returns to primary factors to the total market value of production. The prices of traded commodities are linked to production costs (basic prices) plus the relevant internal and border taxes and international transport costs.

Equation group SC equates supply to demand for domestically produced and imported commodities as well as making provision to equate the supply to demand for labour.

The SD equation group defines several household income aggregates, including gross income, disposable income, and disposable income net of transfer payments. Various aggregates covering the sources of household income are given, such as labour, property, equity and net interest income. Equation group SD also shows how household disposable income is split between consumption and saving and how population growth feeds through to labour supply.

The SE equation group similarly defines the sources of government income, with a breakdown of revenue by primary factor and commodity tax revenue by type of tax and commodity use. It also gives the disposition of government revenue among current expenditure, transfer payments and government saving.

The SF equation group gives an analysis of the terms of trade. This group also includes equations defining various indexes of volume, value and price of traded commodities. The SF equation group therefore defines several aggregates of nominal and real exports and imports, trade by each country, and trade by commodity including separate equations for trade in freight services.

Equation group SG models international capital mobility. It describes wealth accumulation by households and governments, given their saving behaviour. It also describes the resulting world capital stock and the allocation of this capital, along with investment spending, across industries and regions. The international allocation of capital and investment is governed by a series of international parity conditions on rates of return to various real and financial assets.

Equation group SH defines production, income and expenditure aggregates, both real and nominal, and gross and net of taxes, with relevant accompanying price indexes. The SH equation group also defines national aggregates of each final demand catagory, as well as price indexes for each final demand catagory.

The SI group of equations define several ratios, such as the public consumption to private consumption ratio, and ratios of various fiscal and external balance measures to gross domestic product. These ratios can be used to specify different closures to the model.

Finally the SJ equation group defines a number of world macroeconomic indicators such as world income and world gross product, along with a world factor price index which is used as the numeraire in the model.

Demands for commodities

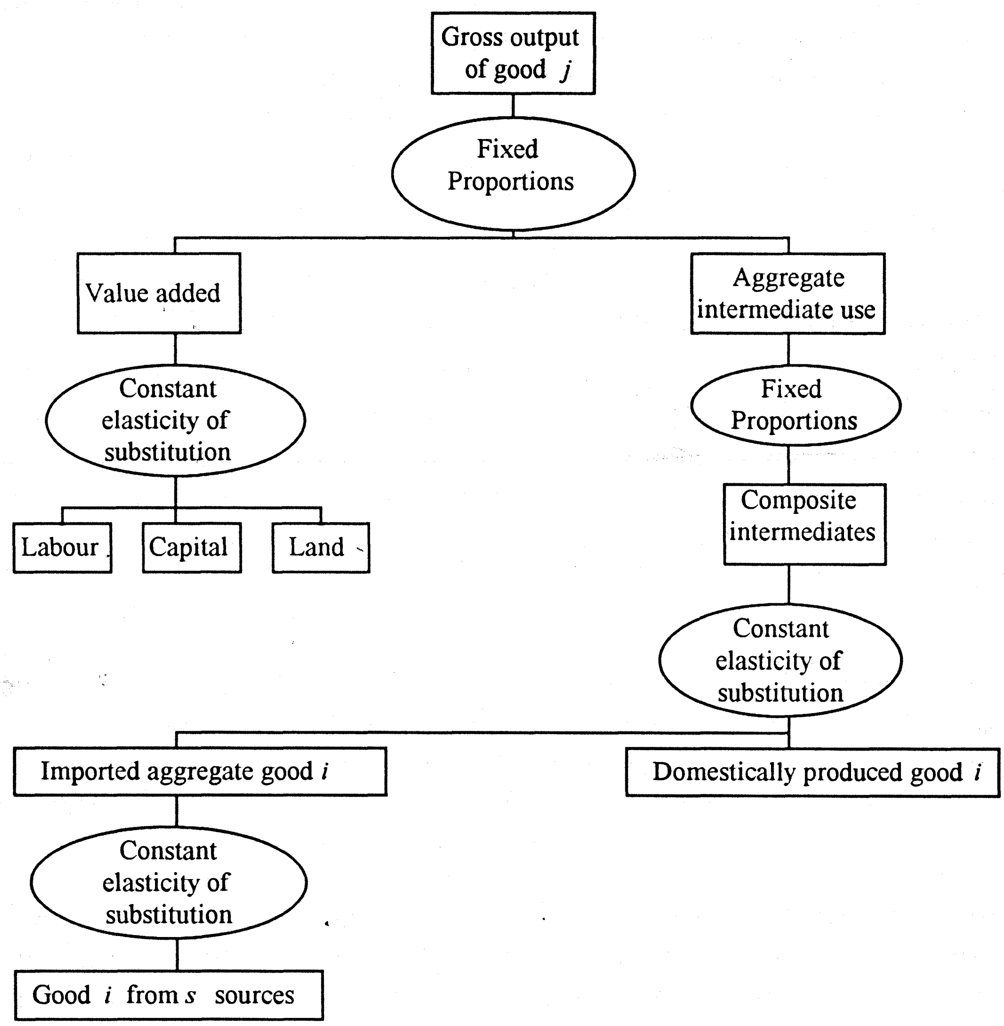
Firms' demands for inputs

Firms use primary factors along with intermediate inputs to produce output. In each region, single-output firms use a constant returns to scale technology. Given a level of output and technology to produce it, a representative firm for each industry is assumed to minimise the cost of acquiring inputs. Equations SA1–8 describe firms' derived demands for inputs. The figure in Box 1.3 is used to illustrate the structure of demand for inputs.

Individual firms are assumed to combine a bundle of intermediate inputs in fixed proportion with a bundle of primary factors. The demand for each separate intermediate input is also assumed to vary in fixed proportion with a firm's output. Hence, the demand for each intermediate input is determined once the level of output is determined. The Leontief structure implies that production processes are relatively inflexible in their use of intermediate inputs. However, firms are assumed to minimise the cost of acquiring each intermediate input by purchasing it domestically or from different foreign suppliers. This choice is constrained by the 'Armington assumption' (Armington 1969a,b) which governs the trade structure in the SALTER model. Domestic and imported commodities are imperfect substitutes and are substituted according to a constant elasticity of substitution. Similarly, an elasticity of substitution captures the degree of substitutability between imports from different sources.

This structure requires just two parameters. They are the elasticity of substitution constraining choices between a domestically produced commodity and an aggregate of the same imported commodity from different sources, along with the elasticity of substitution constraining choices among imports of a commodity from different sources.

Box 1.3: **Structure of production in a single-output industry of the SALTER model**



IC Chart

This nested structure of input demand is reflected by equations SA1–3. The nested demand equations use an average price of the commodity aggregate, with which the price of a particular commodity in the aggregate is compared. The average price calculations are found in equation SA4 for the average price of domestic and imported varieties, and in SA5 for the average price of imports from different sources.

A firm combines intermediate inputs with a bundle of primary factors. The bundle of primary factors (value added) comprises labour, capital and farm land. Farm land is used only in agricultural activities. The primary factors are combined to form value added according to a constant elasticity of substitution function. Thus if a particular primary factor becomes cheaper, firms have the opportunity to substitute it for other primary factors, to thereby reduce their production costs (equations SA6–8).

Changes in the production efficiency of inputs can also change a firm's demand for primary factors. In equations SA1–8, technical change variables are used to model a neutral, output-increasing technical change, a change affecting the use of a particular primary factor, a change affecting the use of all primary factors, or a change affecting the use of all intermediate inputs. Primary factors can be substituted for each other. Thus for a given level of output, for example, a technical improvement in the use of labour (a negative change in the labour productivity variable) may reduce or increase the demand for labour, depending on the share of labour in value added and the ease of substitution between labour and other primary factors. However, it will unambiguously reduce the demand for other primary inputs (capital and farm land).

Aggregate demand for primary factors is the sum of factor demands in individual industries (equations SA9–11). Since the supply of farm land within a region is fixed, only its reallocation among industries is possible; no growth in aggregate farm land use can occur. The aggregate demands for other factors in each region can be made to agree with the corresponding supplies.

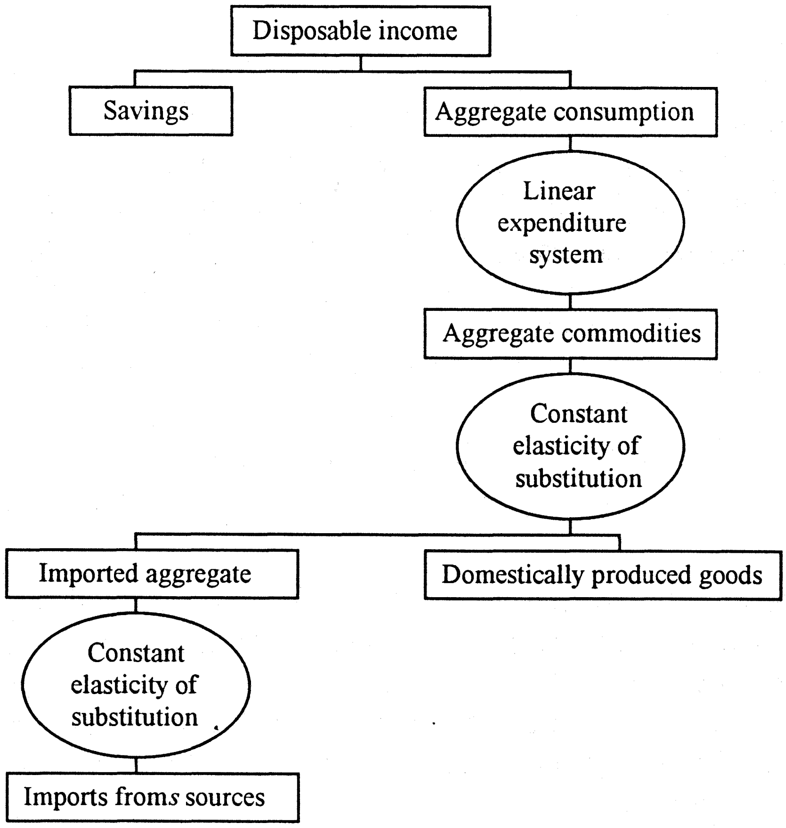
Consumer demand

Consumer demand is determined by assuming that a single representative consumer in each region maximises the utility derived from consuming a bundle of commodities. Equations SA12–17 describe consumer behaviour. The form of the utility function results in a linear expenditure system (Phlips 1974), expressed by equation SA12. Consumer demand for a commodity is a function of the price of the commodity paid by consumers, the prices of other commodities, and aggregate consumption expenditure. The linear expenditure system in equation SA12 expresses consumer demand in per capita terms, then aggregates over the population. The parameters in the system are the own-price and cross-price elasticities of household demand which reflect consumers' attitudes to a change in the relative prices of the components of the consumption bundle. The expenditure elasticity describes how household consumption of a commodity changes with a change in a household's aggregate consumption expenditure. With this system, assuming no change in the number of households, the consumption level of each commodity in each region can be determined once aggregate consumption expenditure and prices are known.

Commodities in the SALTER model are differentiated in terms of their origin. Thus, once consumers have determined the level of consumption of a commodity, they are assumed to minimise the cost of acquiring this commodity aggregate by choosing among different sources. These choices are constrained by the same type of Armington structure as the demand for intermediate inputs discussed above.

The schematic representation in Box 1.4 summarises how the representative household first allocates disposable income between savings and aggregate consumption expenditure (described later), and then follows a three-step procedure to determine the optimal quantity of each commodity, optimal quantities of imported and domestically produced commodities, and optimal quantities of imports from different sources. The latter choices are constrained by the Armington structure.

Box 1.4: **Structure of consumer expenditure and savings in the SALTER model**



IC Chart

In addition to supplying private savings and consuming commodities, households are assumed to own primary factors — labour, capital and farm land. Households receive the returns paid to primary factors in return for their services. This, and transfers from the government, provides households with income on which direct taxes are paid and out of which savings and consumption expenditures are allocated. The sources and disposition of household income are discussed in more detail below.

Other final demands

The theoretical structure of the SALTER model does not contain a detailed behavioural explanation of aggregate government final demand. Provision has been made to hold real aggregate government spending on commodities fixed, or to allow it to move in line with real aggregate household consumption (equation SI1). Government spending on each commodity within the aggregate moves in fixed proportions with aggregate government final demand. Government sourcing of commodities follows the same type of nested Armington structure as for household consumption and intermediate input demands (equations SA18–22).

In addition to demanding inputs and primary factors for current production, firms in aggregate demand resources for investment purposes. The amount of each commodity needed to satisfy investment purposes is assumed to vary in fixed proportions with the aggregate level of real investment in the region. The sourcing of each commodity used for investment purposes is determined using the same nested Armington structure as for household consumption and intermediate input demands (equations SA23–27).

The way in which aggregate real investment is determined in each region is discussed in more detail later. Briefly, global investment is determined within the model and is equal to global saving (via Walras law). Since in the long run, rates of return on capital are equated across regions, to maintain this equality over time global investment must be allocated across regions in such a manner that the rate of change in the rate of return on capital is equated across regions. This in turn determines aggregated real investment in each region.

The foreign demand for exports of each commodity from each source region is determined implicitly by the import demands for each commodity by each destination region.

The SALTER model differentiates between non-margins exports demanded in their own right in other regions, and margins exports used to facilitate the international shipment of the non-margins exports between regions. The theoretical structure makes provision for margins exports of all types of commodities, but the database records margins exports for one commodity only, namely, trade and transport services. Demand for these freight services is discussed later in the section on international trade.

Zero pure profit conditions

The prices for individual and composite commodities are used to define the zero pure profits conditions in equation group SB. Perfect competition is assumed to prevent firms from receiving excess profits. Alternatively, a firm with losses is assumed to withdraw from production. Thus the price received for a commodity is exactly equal to the sum of all costs of production (including returns to primary factors) plus indirect taxes levied on the value of industry production (equation SB1).

Competition also forces firms to reduce the price of their output in response to technological improvements. This is reflected by the last term in equation SB1, which is expanded in equation SB2: a 1 per cent technological gain in overall production reduces the price of output proportionally; a 1 per cent improvement in the use of intermediate inputs or primary factors reduces the price of output by the share of these inputs in the value of output.

The ex-factory price of output defined in equation SB1 is called the basic price, in the sense of United Nations (1990). The corresponding price of an import (the basic price of an import) is calculated as the sum of a 'world price' (defined further in equation SB14) and the relevant duty paid, expressed in local currency (equation SB3). Since commodities are defined in terms of their region of origin, an average price for a commodity aggregate composed of imports from all sources is calculated as a weighted average of the basic import prices paid for imports from all sources (equation SB4).

Equations SB5–SB12 calculate purchasers' prices for various users in each region as the product of the basic price and the *power* of a user-specific commodity tax, where the power of a tax is defined as one plus the tax rate. For a domestically produced commodity, the basic price is the ex-factory price. For an imported commodity, the basic price includes duties. Equation SB13 defines the fob export price of each commodity from each region as the product of the basic price of the domestically produced commodity and the power of a destination-specific export tax.

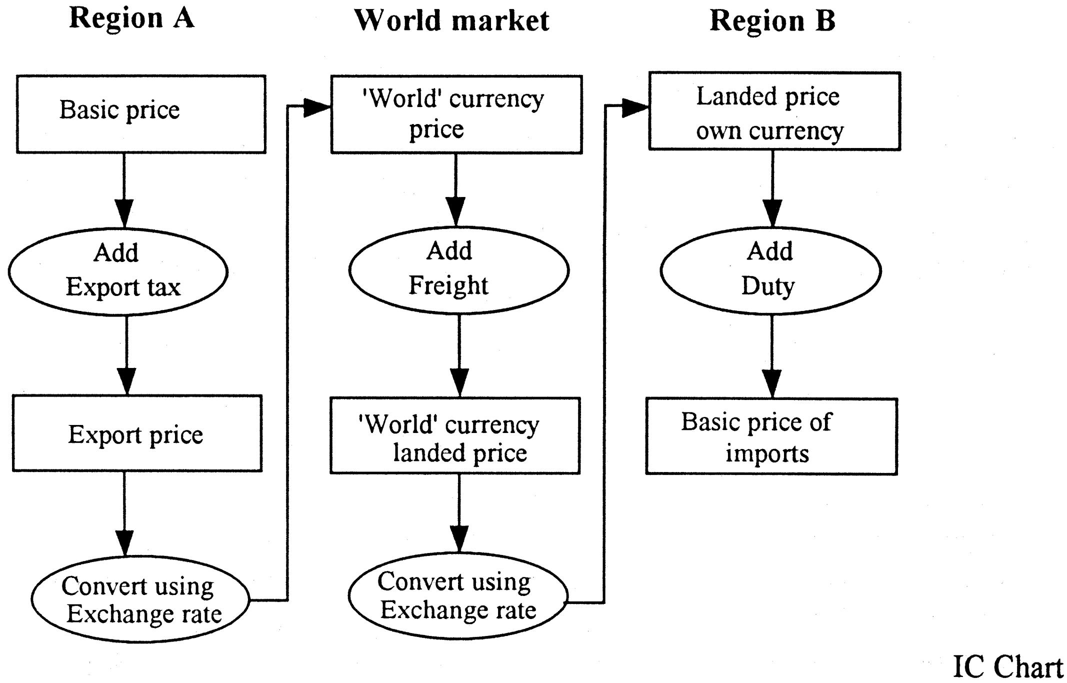
The 'world price' of a commodity exported from a particular region is calculated as the sum of the export price from that region, expressed in a common 'world' currency unit, and the cost of freight (equation SB14). Note that the model does not keep track of a full range of bilateral nominal exchange rates, but rather contains variables that measure each region's domestic currency price of a unit of some single neutral or 'world' currency (eg. the currency unit of some unchartered rock in the middle of the Pacific). This is the currency in which 'world' prices of exports from each region are expressed. The cost of freight (in world currency) which is also included in the 'world price' valuation of exports is calculated as the average price of margin commodities, with each region providing part of these freight services (equation SB15).

Box 1.5 summarises how prices are linked internationally when a product from region A is exported to region B.

Market clearing conditions

In each region, the sum of all demands for commodities is required to equal the supplies of each commodity. Provision is also made for the sum of demands for labour to equal supplies. These market clearing conditions are listed in equation group SC.

Box 1.5: **The international system of price transmission**



Domestic production of each commodity is required to equal the sum of all demands for the commodity (equation SC1). The relevant demands are for use as intermediate inputs, in household consumption, for investment purposes, by government and for export.

Market clearing of international commodity flows is ensured through equation SC2. The sum of all uses of an imported commodity from a specified source is required to equal imports of that commodity from that source.

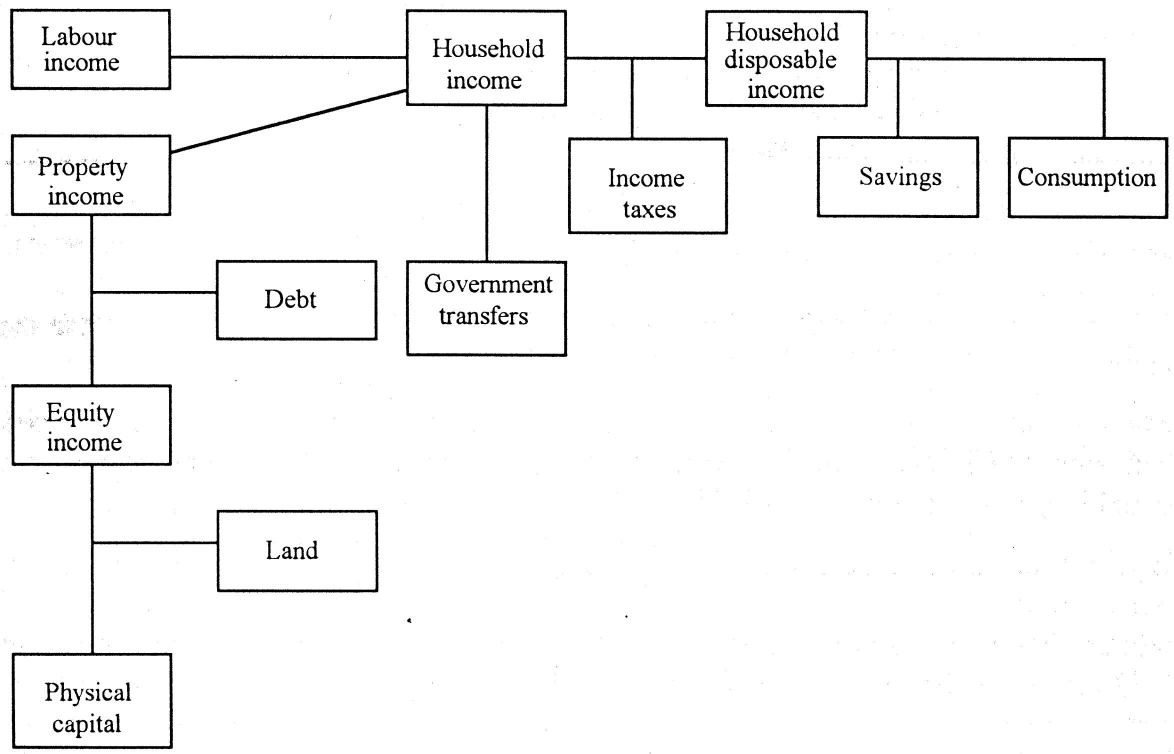
Equilibrium in the labour market is expressed in equation SC3 in terms of the rate of employment. The employment rate is calculated as the ratio of labour demand to labour supply. Equation SC3 enables the change in a region's employment rate to be held exogenously fixed in some simulations, thus imposing labour market clearing at some 'natural' rate of unemployment. Alternatively, a region's employment rate may be allowed to vary endogenously (with the region's wage rate fixed exogenously in either real or nominal terms).

Full employment of farm land and capital is nevertheless assumed. Market equilibrium for farm land is modelled by setting aggregate demand for farm land in each region as exogenously fixed. Demand for capital is also required to equal supply. Capital supplies may in turn change in long-run simulations because of international capital mobility, while in short-run simulations the supply of capital in each industry in each region can be held exogenously fixed. This aspect of capital markets is discussed further in the section on international capital mobility.

Sources and disposition of household income

As owners of primary factors, households receive the income generated by the primary factors' involvement in production. They also receive transfers from government and pay income tax. The disposable income remaining is allocated between savings and consumption. This part of the model linking consumption and savings to disposable income is one of the main characteristics of a general, as opposed to partial, equilibrium model. Box 1.6 summarises the sources and disposition of household income in each region.

Box 1.6: **Sources and disposition of household income**



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Households are paid a rental price for the primary factor services they provide. The rental price of labour is the wage rate. Provision has been made to hold the wage rate exogenously fixed in each region in either real or nominal terms (equation SD11). Labour income earned by housholds in each region is determined by the wage rate and the amount of labour employed (equation SD2). Note that because employment rates in each region need not equal 100 per cent initially, and may vary endogenously in some simulations, labour demand need not fully equal labour supply. Labour supply is modelled as being potentially wage-responsive (equation SD10), although in current versions of the model the wage elasticity of labour supply is set to zero.

The combined return on capital and land (net of depreciation on capital) provides household income from equity, since equity in each region's productive assets is assumed to be owned entirely by the household sector in that region (equation SD4–5). The interest rate on debt and household net bond holdings determine household net interest income (equation SD6). Household property income is defined as the sum of equity income and net interest income (equation SD3).

Note that the net interest income and net bond holding variables have been defined in absolute rather than percentage change form, and as ratios of household net interest income and net bond holding to household disposable income. Expressing these variables in absolute change form allows the model to handle the possibility that household net interest income and net bond holding may be positive or negative initially, and may change sign in response to some shock. For similar reasons, all rate of return variables, including the interest rate on debt, have been defined in absolute rather than percentage change form. This is discussed more fully in the section on international capital mobility.

The sum of labour and property incomes and transfers from the government constitutes aggregate household income (equation SD1).

Households then pay income taxes. Subtracting income taxes from household income yields household disposable income (equation SD7). A pre-transfer measure of household disposable income is also defined (equation SD9).

Households allocate disposable income in fixed proportions between consumption and savings. A savings-to-income ratio is defined (equation SD8), and normally set exogenously fixed. The household saving-income ratio is another variable that has been defined in absolute rather than percentage change form.

Thus aggregate household consumption expenditure is determined and can be allocated using the linear expenditure system and nested structure found in equations SA12–15. Once household savings are determined, they are allocated between changes in household asset positions, that is, between stocks of bonds and equity. This allocation is discussed further under international capital mobility.

Government budget

Transfers of various kinds occur between the private and government sectors. The government collects taxes from households in the form of income taxes and ad valorem commodity taxes on consumer purchases. In return, it redistributes income by distributing transfer payments to households.

Ad valorem commodity taxes are also levied on all other domestic uses of commodities — that is, on purchases by producers and the government and for investment purposes. In each region, governments also collect taxes on international trade, in the form of duties on imports and export taxes on exports. The government also collects industry taxes (net of subsidies) by taxing the value of industry production. Finally, the government receives net interest receipts from its net bond holdings, which are determined in the section on international capital mobility.

Government receipts are used to fund the transfers to households, along with government's expenditure on commodities. The difference between these outlays and government receipts constitutes the net government surplus.

The calculation of government receipts and outlays in each region is made in equation group SF. The government budget in each region is also described in Box 1.7. Government receipts are composed of the revenue from income taxes and indirect taxes, along with net interest receipts (equation SE1). Income tax revenues are the sum of tax revenues on labour and property incomes (equation SE2), which are calculated in turn as the product of an average tax rate specific to the type of income and the corresponding taxable income (equations SE3, 4 and SE16, 17).

Indirect tax revenues are the sum of tax revenues generated by industry taxes (net of subsidies) and each type of commodity tax (equation SE15). The model in turn calculates the contribution of each of these taxes to aggregate indirect tax revenues net of industry subsidies (equations SE6–12). These contributions are defined as the ratios of revenues from the particular tax to total government indirect tax revenue. The contribution of a particular tax has two components: a contribution due to an autonomous change in the tax rate and a feedback effect. The feedback effect comes from changes in the tax base: changing the tax schedule results in a reallocation of resources and expenditures which changes the value on which the tax is levied.

The government may borrow from or lend to the international bond market. Part of its income therefore comprises net interest receipts. These net receipts contribute to government receipts, and are calculated in each region as the product of the rate of return on bonds and government net bond holdings (equation SE5). If the government is a net lender, net bond holdings are positive and interest is added as part of receipts. Conversely if the government is a net borrower (as is normally the case), government net bond holdings are negative and interest payments on government debt reduce aggregate government receipts. As in the case of households, the government net interest receipt and net bond holding variables have been defined in absolute rather than percentage change form, and as ratios to government total receipts.

Box 1.7: The government budget in each region

Sources of funds	*Uses of funds*
Income taxes Tax on labour income Tax on property income	Government outlays Current consumption expenditure Transfers to households
Commodity taxes (net of subsidies) on imported and domestically produced commodities for: – consumer demand – government demand – investment demand – demand for intermediate inputs	Net government surplus
International trade taxes – export taxes – import duties	
Industry taxes (net of subsidies)	
Net interest receipts	
Total government receipts	Disposition of government receipts

Government receipts are allocated between current outlays and net government saving (equation SE13). Current outlays are composed of current government expenditure on goods and services and transfer payments to households (equation SE14). Transfer payments to households normally move in line with household pre-transfer disposable income, although provision is also made for autonomous changes in transfers (equation SE18).

Changes in government saving will feed through into government net bond holding, as discussed further in the section on international capital mobility. As for households, the government saving-to-income variable has been defined in absolute rather than percentage change form.

Public capital expenditures are excluded from the government's current account. They appear in investment expenditures along with private investment.

International trade flows

Trade in the SALTER model is created by the demands made by households, firms and governments for commodities from different sources. For a single region, exports are part of final demands. Imports are composed of final and intermediate demands for imports.

Several trade aggregates are calculated in the SALTER model. These different measures of trade flows are useful in interpreting model simulation results. Equations group SF summarises the trade flows in the model.

Equation SF1 establishes the notation for trade flows when they are described from the exporting region and the importing region. It simply states that the volume of non-margins exports of a particular commodity from region z to region s must equal the volume of imports of the same commodity by region s from region z. Equations SF2–7 specify trade indices. For each region, equation SF2 gives a value, and equation SF4 gives a volume index for imports of a given commodity from all sources, while equation SF3 gives a value of imports of all commodities from a given source. Both value aggregates are calculated at duty-free prices. These duty-free valuations allow the user to evaluate trade effects that are due to decisions in other regions, and are not clouded by a region's change in protection structure. Similarly, equation SF5 gives an fob value and SF7 gives a volume index for margin plus non-margin exports of a given commodity to all sources, while equation SF6 gives an fob value of non-margin exports of all commodities to a given destination.

The model also defines single-valued indexes of aggregate trade which are used in the standard macroeconomic identities in equation group SH. These indexes are for aggregate imports cif and exports (margin plus non-margin) fob. The corresponding volume indexes are obtained by deflating nominal values by the appropriate price indexes (equations SF8–11).

In the SALTER model, regions can exercise market power in both exporting and importing. This means that terms of trade effects can be important in explaining the gains or losses a region experiences as a result of changes in policies. Terms of trade effects can be analysed with equations SF12–22. McDougall (1993a) provides a thorough exposition and derivation of this terms of trade decomposition.

The ratio of export prices to import prices defines the terms of trade. The import prices used are evaluated net of duties and both prices are in the common 'world' currency. The overall change in the terms of trade of a region can be decomposed into contributions from three sources:

- the change in the average world prices of traded commodities, and whether a region is initially a net importer or a net exporter of those commodities (equations SF13–14);
- the change in the prices of exports from the particular region, relative to the changes in average world prices of those commodities (equations SF15–16); and
- the change in the prices of imports into the particular region, relative to the changes in average world prices of those commodities (equations SF17–18).

The first contribution can be measured by the covariation between average world price changes for commodities and a region's initial net export position. If a region is either a net exporter of commodities whose prices rise, or a net importer of commodities whose prices fall, its terms of trade would tend to improve and the contribution from this source would be positive.

Because traded commodities are distinguishable by source in SALTER, and because commodities from different sources are imperfect substitutes, the prices which a particular region receives for its exports or pay for its imports may deviate from the average world prices. If a region has a particularly large expansion in exports of a commodity to a particular destination, the price it receives is likely to rise by less, or fall by more, than the average world price. In this case the covariation between the export price received by the region and the average world price of the commodity would be negative, and would in turn contribute negatively to the overall terms of trade change.

Similarly, a region which experiences a particularly large expansion in imports from a particular source may be able to pay a price which rises less than the world average price, or falls by more. In this case, the covariation between the import price paid by the region and the average world price of the commodity would be negative, and would in turn contribute positively to the overall terms of trade change.

The three components of the terms of trade change are therefore defined by measures of covariation, firstly for each commodity individually and then in aggregate across all commodities. For purposes of interpretation, it is only necessary to note, for example, that if the three aggregate components are called C_1, C_2 and C_3, the overall change in the terms of trade is measured by $C_1 + C_2 - C_3$. Equations S19–22 define the relevant region-specific and world average price indexes used in the terms of trade decomposition.

Recall that in the earlier section describing final demands, it was noted that regions supply margins exports which are used to facilitate the international shipment of the goods and service exports demanded in their own right by users in other countries. Equations SF23 and SF24 specify implicitly (by choice of notation) that the supply of margins exports from each region must equal the demand for those services, and specify explicitly the nature of those so-called freight demands. Global demand for freight services moves in strict proportion to the global total volume of all goods and services being shipped (equation SF24). The demand for a particular freight service from a particular region depends on the global demand for all freight services from all regions, but also has a price-responsive component (equation SF23). A single elasticity of substitution governs the price sensitivity of a particular freight service from a particular region, relative to the global average price of all freight services from all regions.

Finally, equation SF25 defines a volume index of non-margins exports of a given commodity to all sources (excluding intra-regional exports) while equations SF26 and SF27 make provision for changes in import duty rates to be uniform across all source regions, and for changes in export tax rates to be uniform across all destinations.

International capital mobility

This section is a summary of McDougall (1993b), which describes the international capital mobility extension of the SALTER model in more detail. Equation group SG describes the system by which international investment decisions are made, capital is accumulated, and capital transferred from one region or industry to another.

The financial capital market in the SALTER model has two types of financial assets, bonds and equity in productive assets. Only debt in the form of bonds is traded internationally, since equity in each region's productive assets is owned entirely by the household sector in that region. However, because the net interest payments made by one region to another must be paid for out of the equity income generated in the region (see equation group SD), agents in one region can gain an indirect stake in the productive assets of another region by lending to that region.

The model keeps track of net foreign bond holding positions, not gross bond holdings or gross bond issues. Similarly, the model keeps track of net interest income flows rather than gross flows. This treatment avoids the need for a full accounting of portfolio allocation under uncertainty.

As a consequence, the model assumes that income taxes are levied on the net interest and property income accruing to domestic residents, but assumes no domestic taxes are levied on net interest payments to foreigners. Modelling the taxation of international capital flows more realistically would require a treatment of gross rather than net international interest income flows. This is because governments do not generally balance taxation of gross interest income payments to foreigners with subsidisation of gross interest income receipts from foreigners.

To model international capital mobility, SALTER has equations governing:

- the international allocation of capital;

- the world stock of capital;
- wealth accumulation; and
- the international allocation of investment.

Financial capital mobility is captured directly, and physical capital mobility indirectly, by a number of parity conditions.

Equilibrium in international financial markets requires international interest parity on bonds (equation SG11). Rate of return maximisation by households imposes parity between the interest rate on bonds and the rate of return on equity in each region, although provision has been made for the imposition of an exogenous equity premium (equation SG12).

The required or normal rate of return on physical capital in each industry in a region must equal the rate of return on equity in that region. The actual rate of return on physical capital in each industry in a region may include an abnormal return component (equation SG13). The actual rate of return on physical capital in each industry in a region is defined in turn as the rental price of capital services relative to the replacement cost of capital goods (equation SG14).

In the long run, physical capital mobility would ensure that the actual rate of return on capital was equal to the required rate. This is captured in long-run simulations by making the rate of abnormal return to capital in each industry in each region exogenously fixed. In short-run simulations, the capital stocks in each industry in each region would instead be held exogenously fixed, with the rates of abnormal return to capital allowed to vary.

Similarly, the required or normal rate of return on land in each region must equal the rate of return on equity in that region (equation SG15). However, in the case of land this equality is ensured in both short-run and long-run simulations by endogenous adjustment in the stock price of land.

Thus in the short run, abnormal returns may be earned on capital, but not on land. The reason is that the capital goods are produced, while land is not. So the stock price of capital goods is tied to their replacement cost, while the stock price of land is free to vary. Land prices accordingly adjust to maintain normal rates of return even over the short run, but capital goods prices do not. So capital typically earns some short-run abnormal return (which may be either positive or negative), but land does not.

As the functional forms of equations SG14 and SG15 make clear, all rate of return variables in the model are expressed in absolute rather than percentage change form. This allows the model to handle the possibility that rates of return may be positive or negative initially, and may change sign in response to some shock. A sign change is most likely to occur in the rates of abnormal return to capital, but could also occur in overall rates of return to capital, in short-run simulations in which there were particularly adverse effects on profitability in some industries.

Note that the international interest parity condition in equation SG11 does not include changes in the rates of currency depreciation in each region. Hence it does not appear to make provision for exchange gains or losses as part of the return on foreign bond holding. The reason is that the model is comparative static, capable of giving results in the form of 'deviations from control' at some future point in time (the terminal instant), but not of tracing the time paths of variables over the simulation period between initial and terminal instants. Thus the model cannot trace the actual rate of currency depreciation over the simulation interval. Instead, an assumption is simply made that at the terminal instant, the rate of currency depreciation in each region exactly offsets the domestic rate of inflation. Under this assumption, uncovered interest parity and purchasing power parity imply parity in real interest rates. This is the form in which equation SG11 is written.

Because of the assumption that international interest income flows are not taxed at source, the international interest parity condition applies to pre-tax interest rates. Similarly, because the model applies a common tax rate on household equity income and household net interest income, the domestic bond-equity parity condition could be applied to either pre-tax or post-tax rates of return, but is written in pre-tax form.

Finally, although provision has been made for the introduction of a non-zero equity premium in each region's bond-equity parity condition, the theoretical structure of the model is not conducive to interpreting this premium as a risk premium. This is because the model does not contain a full treatment of risk. Thus a positive premium could capture higher returns to risky assets, but the model would not capture the impact of the risk itself which would reduce the certainty-equivalent rate of return on equity to a level matching the return on bonds. For this reason, the model's database also records real rates of return on equity that are equal to the world real bond rate (Brown, Strzelecki and Watts 1993).

Equation group SG also contains a number of stock asset accounting relations. World net ownership of bonds is equal to the sum over regions of net ownership of bonds in each region (equation SG1). Net ownership of bonds in each region is equal to the sum of new ownership by households and by governments (equation SG2). Household wealth is equal to the sum of equity in that region's productive assets and net household ownership of bonds (equation SG3). Equity in a region's productive assets is equal to the stock value of capital plus the stock value of land (equation SG4), where these stock values are defined in equations SG6 and SG7 as the product of the prices and quantities of the stocks of capital and land, and a corresponding equity price index is defined in equation SG5.

These asset accounting equations for net bond ownership, both globally and by region, specify net bond ownership as the product of global or regional disposable income and a corresponding net bond-to-income ratio (where the latter are defined in absolute rather than percentage change form). This specification does not imply that net bond-to-income ratios are held constant, either by households or governments in each region. Instead, net bond holding by households and governments is determined by wealth accumulation equations, where wealth accumulation is in turn governed by the assumption that households and governments save a constant proportion of their disposable income. These accumulation relations are discussed shortly.

It is the case, however, that in long-run simulations, the world bond-income ratio is held exogenously fixed. This is to ensure that an initial database condition continues to be met, namely, that the world net ownership of bonds is zero. The world bond-income ratio is held fixed by allowing the world bond interest rate to vary.

The short run is a length of run over which stock variables do not change. The asset stock and wealth accumulation equations in the model ensure that if the stocks of capital and land are held fixed, as they are in short-run simulations, then the world stock of bonds will also be fixed. The initial database condition that world net ownership of bonds is zero is therefore maintained endogenously via the asset stock and wealth accumulation accounting; the world bond-income ratio no longer needs to be held fixed exogenously to ensure the condition is met. Thus the world bond-income ratio is endogenous in the short run, with the world bond interest rate being exogenously fixed.

Household and government wealth are modelled as the outcome of a wealth accumulation process whereby households and governments save or dissave some predetermined fraction of their net disposable income. Although the model is not explicitly intertemporal, the intrinsic dynamics of wealth accumulation out of disposable income can nevertheless be captured by assuming that the underlying growth path of disposable income is 'smooth'. The changes in wealth by households or governments in each region can then be described as quasi-intertemporal functions of changes in their savings ratio and changes in their disposable income, as well as changes in an asset price index capturing capital gains or losses. These household and government wealth accumulation equations are shown in equations SG8 and SG10, and the asset price index relevant for households is defined in equation SG9.

Given that equilibrium in the markets for capital and land as productive assets determine the level of equity in each region, the accumulation equations showing changes in total wealth by households and governments in each region determine their changes in bond holdings, and therefore the changes in their net interest income from abroad.

The household asset price index defined in equation SG9 is an index of the prices of equity and bonds, expressed in local currency. Stock prices for capital and land are readily available in the model. Under the assumption that equity prices reflect the prices of these underlying physical assets, the equity price index is just an index of the stock prices of capital and land. The construction of bond prices requires further comment.

The asset accounting discussed above was written entirely in value terms. The construction of a bond price index requires bond values to be split into a price and a quantity component. Since one region's lendings are another's borrowings, a common quantity unit is required to ensure consistency in the net bond holdings of all regions. A common quantity unit can be constructed by assuming that all bonds are denominated in the neutral 'world' currency. A further assumption is made that bond prices are indexed to the world consumption price index. These assumptions preserve the price homogeneity properties of the model: an increase in the world price level, or an increase in the domestic price level accompanied by a currency depreciation, confers no benefit on debtor regions, and imposes no cost on creditor regions. Thus the model abstracts from the redistributive effects of unanticipated price changes. The assumptions jointly imply that a local bond price index can be defined as the world consumption price index converted to local currency.

The form of the wealth accumulation equations also requires some comment. The term on the left hand side of each equation represents the change in nominal wealth at the terminal instant, relative to the control solution. The first term on the right hand side represents that part of the total change in wealth which is due to changes in the prices of assets held at the beginning of the simulation period. For households, the relevant price change is the change in the household asset price index just discussed. Since governments hold bonds but not equity, the price change relevant for governments is just the change in the price of bonds.

The second term on the right hand side of each wealth accumulation equation gives the change in nominal wealth which is due to (exogenous) changes in household or government savings ratios.

The third and fourth terms on the right hand side of these equations give the changes in nominal wealth arising from changes in nominal disposal incomes. The changes in total wealth from this source are split into the impact of changes in real disposable incomes and changes in prices. The reason that the coefficients on the price and real income components differ from each other is because of the assumption that real disposable incomes adjust smoothly over the simulation interval, but that price changes are concentrated at the beginning of the simulation period. Given the observed tendency of prices to overshoot in the short term in response to economic shocks, but for real activity to respond in a direction in the short term that may be the opposite to the longer term impact, the model's assumptions concerning the dynamic behaviour of prices and real incomes are more realistic than alternative characterisations of 'smooth' adjustment.

Finally, equation group SG contains equations governing the international allocation of investment. Global investment is equal to global savings, via Walras law. The international allocation of global investment across regions is based on the same parity conditions as the international allocation of physical capital.

In the long run, capital is allocated to equalise its rate of return across industries and regions. To maintain this equality over time, investment must be allocated across regions so as to equalise expected *time rates of change* in rates of return. The associated international interest parity and bond-equity parity conditions in expected rate of change form are shown in equations SG20 and SG21.

In the short run, however, it needs to be recognised that rates of return on capital in individual industries may deviate from parity. In the short run, the model assumes that investment is concentrated in regions with abnormally high rates of return, away from regions with abnormally low rates of return, so that abnormal returns would be gradually eliminated over time. This is discussed in more detail shortly.

The treatment of investment just outlined requires a treatment of the way expectations are formed over rates of return. Because the model is not explicitly intertemporal, fully consistent forward-looking expectations cannot be imposed exactly. Functional forms and parameter settings are nevertheless chosen so that expected rates of return are broadly consistent with the behaviour of actual rates of return in the model. The resulting expression for the expected time rates of change in rates of return on capital across regions is shown in equation SG16.

The expression in equation SG16 embodies the following assumptions about the way in which investors form their expectations (McDougall 1993b). The expected rate of return on capital at any point of time in the future depends only on the size of the capital stock at that point in time. Because the world economy grows over time, investors expect that capital stocks can also grow at some fixed positive rate without a decline in the rate of return. In parameterising the model, this fixed constant-expected-rate-of-return rate of growth in the capital stock is set equal to the actual rate of growth in the capital stock, as implied by the data on net investment and initial capital stocks embedded in the model's database.

The model then assumes a particular functional form showing how investor expectations of future rates of return vary around the 'steady state' rate of return, as the size of the future capital stock varies around that implied by the 'steady state' or constant-expected-rate-of-return growth rate. The functional form chosen is one in which the elasticity of the expected gross rate of return on capital with respect to the expected size of the capital stock, α^z, is fixed. In parameterising the model, a value is chosen for this elasticity that is consistent with the actual behaviour of the model. The value is found by performing a model simulation. A change in the required rate of return is introduced into the model through a shift in the equity premium, and the observed changes in actual returns and capital stocks are used to derive an initial value for the elasticity. This value is then inserted into the model's database, the simulation repeated, and the procedure iterated until the value of the elasticity converges. The resulting values for α^z are negative, but vary from region to region.

The first term on the right hand side of the equation SG16 therefore indicates that, the higher the level of investment in a region, relative to its capital stock, the more rapid the expected *decline* in the rate of return on capital. Equation SG16 therefore specifies a downward sloping investment schedule for each region. The second term on the right hand side of equation SG16 appears as a consequence of the constant-elasticity form of the underlying expected-rate-of-return equation. Because of this form, the greater the actual rate of return, for any given rate of growth of the capital stock, the greater the expected rate of change in the rate of return. The average actual rate of return across industries in each region, appearing in the second term of equation SG16, is defined in turn in equation SG17.

The remaining two equations in the SG group specify the process by which investment is allocated in the short term to equilibrate rates of return over time. The expected return on capital in each region can be written as the sum of an expected normal and an expected abnormal component. Thus the expected rate of change in the rate of return on capital is the sum of the expected rate of change in the normal component, equal to the expected rate of change in the return on equity, and the expected rate of change in the abnormal component. On the assumption that the abnormal component regresses to zero over time according to a Koyck process, the rate of change in the abnormal component will be inversely proportional to the size of the abnormal component, with an adjustment parameter reflecting the speed of adjustment. The size of the abnormal component, averaged across industries in each region, is defined in equation SG19. The resulting expression for the expected rate of change in the return on capital is shown in equation SG18. This becomes the expected-rate-of-change counterpart to the levels parity condition of equation SG13, except that the abnormal return to capital is now predetermined in expected-rate-of-change form via the Koyck adjustment process.

Now consider how the downward sloping investment schedule in equation SG16 interacts with the expected-rate-of-change parity condition for capital in equation SG18. In the long run, when abnormal returns to capital do not change, equation SG16 will determine the level of real investment in each region required to ensure that the expected rate of change in the return on capital equals, via equation SG18, the expected rate of change in the rate of return on equity.

In the short run, however, regions experiencing an increase in abnormal returns to capital will need, via equation SG18, an expected future rate of change in the overall return to capital that is more negative than the expected future rate of change in the return on equity. This requirement will ensure that abnormal returns are driven to zero over time. The requirement is met, via equation SG16, by having a higher rate of real investment than in the long run. Thus the two equations SG16 and SG18 ensure that in the short run, regions with higher abnormal returns receive a greater share of world investment.

Macroeconomic indicators

Equation group SH defines macroeconomic indicators of welfare and other regional aggregates. The macroeconomic aggregates are of three types: nominal values, aggregate price indices and real quantities. The latter are used as indicators of welfare and resource availability. Relations between the main aggregates are summarised in Box 1.8. The box also gives the equation references in which the corresponding nominal, real and price index components of each macroeconomic aggregate are defined.

Box 1.8: **Definitions of main regional macroeconomic aggregates**

Item		*Description*	*Equation reference* Nominal	Real	Price index
Income side					
GDP at factor cost	=	Sum of value added paid to primary factors (primary factor income)	SH2	SH21	SH18
GDP at market prices	=	GDP at factor cost + indirect taxes	SH22		
Net factor income	=	GDP at factor cost – depreciation	SH4		
National income (NNP)	=	Net factor income + indirect taxes + net interest income from overseas	SH24	SH29	SH28
GNP	=	GDP at factor cost + net interest income from overseas	SH23		
Expenditure side					
Expenditure on GDP	=	Household consumption + gross investment + government spending + exports – imports	SH1	SH5	SH19
GNE	=	Household consumption + gross investment + government spending	SH3	SH6	SH20
NNE	=	GNE – depreciation		SH7	
National consumption expenditure	=	Household consumption + government spending	SH26		SH28

Real national income is the preferred welfare measure in SALTER. Note from Box 1.8 that it is obtained by deflating net national product by the national consumption price deflator. The real income results reported in the model are calculated exactly, but for purposes of interpretation it is useful to note that real national income can also be approximated as follows:

$$\%\Delta\ (\text{real income}) \cong \%\Delta\ (\text{real GDP}) + S_T.\ \%\Delta\ (\text{terms of trade})$$
$$+\ \Delta\ (\text{net interest income from abroad as percentage of national income})$$

where S_T is the share of exports (or imports) in GDP, the terms of trade variable was defined in equation group SF and the net interest income to national income variable is defined (in absolute change form, as required) in equation SH25.

The above approximation is derived from the underlying macroeconomic identities but makes the following simplifying assumptions: it ignores the distinction between NNP and GNP, it assumes trade is balanced initially, it assumes the share of net interest income in national income is initially small, and that the consumption price deflator is approximately equal to the GNE deflator. It is therefore a better approximation for some regions and in some simulations than in others.

Equation SH27 defines the national saving-income ratio in each region, in absolute change form. Although household and government saving-income ratios are normally held fixed individually, the national (household plus government) saving-income ratio may still change endogenously because of compositional shifts which change the relative sizes of the household and government income in each region.

Finally, equations SH9–17 define the nominal, real or price index components not elsewhere defined for some of the building blocks of the major macroeconomic aggregates, including household consumption, investment, government spending, exports, imports and depreciation. Equation SH8 defines real household disposable income in each region by deflating nominal disposable income by the consumer price index.

Note that the price indexes defined throughout the model use value shares derived from the initial database as the weights for each individual price in an index. However, in the multiple-step solutions, which are used in order to reduce linearisation error, an updated database is used to calculate the index weights at each step of the solution procedure. This means the index weights change at each step of the solution procedure and the price indexes so derived are similar to Divisia indexes, which take into account changes in weights over a period of observation.

Equations for defining economic environments

Equations SI1 to SI5 define a number of ratios that may be used to specify different closures to the model. Equation SI1 defines the ratio of private consumption to public consumption expenditures. By holding the shift term in this equation exogenously fixed, a common rate of growth in private and public expenditures on goods and services can be maintained.

The remaining equations in this group define a region's fiscal surplus and various measures of its external surplus, all expressed in absolute change form and as ratios to regional GDP. While these measures would normally be allowed to vary endogenously, they could be made the targets of government policy by being held exogenously fixed, while endogenising some corresponding policy instrument variable.

Global macroeconomic indicators

The final group of equations defines a number of world macroeconomic indicators, including nominal world gross product (equation SJ1), nominal world income (equation SJ2), a world consumption price index (equation SJ3), world real income (equation SJ4), world net interest income from abroad (equation SJ5) and world net capital inflow (equation SJ6), with both these latter variables expressed in absolute change form and as ratios of world gross product, the world capital stock (equation SJ7) and world real investment (equation SJ8). Finally, equations SJ9 defines a world factor price index which is normally used as the model's numeraire.

1.3 Solving the linear system of equations

The SALTER model is specified as a linear approximation in terms of the percentage or absolute changes in its variables. Although the underlying relationships are highly nonlinear, it is assumed that a linear approximation can be a good approximation to the true outcome of a policy change — provided the policy change is small. The advantage of specifying the model as a linear approximation is that it can be solved by the relatively simple process of matrix inversion, rather than by more complex non-linear techniques. The SALTER model is implemented and solved in this fashion using the GEMPACK software suite. Codsi and Pearson (1988) give an overview of the software while Harrison and Pearson (1993a,b) describe its use in more detail.

The accuracy of the linear solutions depends on the degree of nonlinearity of the underlying model in the neighbourhood of the initial equilibrium, and the size of the policy shock being examined. The difference between the linearised solution and the (unknown) solution to the nonlinear problem is called linearisation error. Keller (1980) indicates 'that static general equilibrium systems are only moderately non-linear' when compared with dynamic systems. Linearisation errors limit the magnitude of changes that can be simulated, but Keller suggests that a 10 per cent change in taxes does not impair the accuracy of the linearised solution.

When policy changes being simulated are large, the Euler solution procedure can be used to obtain a more accurate solution of the model. The Euler procedure involves dividing a large policy change into a number of small changes in order to reduce linearisation error. A first simulation is performed using a fraction of the large change. This results in a certain number of linear changes in the endogenous variables. These changes are applied to the original database to obtain a new updated database on which a second simulation is performed applying a second small policy shock to obtain new linear responses with respect to the data resulting from the previous simulation. This process is repeated until the entire large change has been performed through the small changes.

The accuracy of such multi-step solutions increases with the number of small changes made, but increasing the number of steps also increases the time needed to obtain a solution. Dixon et al. (1982) indicate that a significantly improved solution can be obtained through an extrapolation based on two or three solutions obtained through Euler procedures with different numbers of steps. The Richardson extrapolation procedure (Dahlquist, Bjorck and Anderson 1974) uses the fact that increasing the number of steps in a Euler procedure improves the solution. The rate of improvement as the number of steps increases is used to extrapolate a new solution. Dixon et al. note that only small numbers of steps are necessary to obtain significantly improved solutions over those obtained through a Euler procedure without extrapolation.

Before such solution methods can be applied, the linearised model must be specified in a way that can be solved.

As in other general equilibrium models, the number of variables in SALTER exceeds the number of equations specified. Variables include policy instruments through which shocks can be applied to the model — that is, naturally exogenous variables — as well as variables whose behaviour is determined within the model — naturally endogenous variables. But in order to solve the system of equations, the number of endogenous variables must *exactly* equal the number of equations. The formal partitioning of variables into exogenous and endogenous subsets can be partially guided by which variables are naturally endogenous or exogenous, but the partitioning also has a critical role to play in determining the economic environments in which the simulated policy changes are assumed to take place. Two alternative partitionings, or closures, of the model are discussed in more detail shortly.

However, solving such a large linear system still requires a substantial amount of computational resources. By *condensing* variables out, the linear system to be solved can be made smaller. Condensation involves substituting out *endogenous* variables of relatively minor importance prior to solving the model. This is done by choosing an equation in which the variable appears, using this equation to express the endogenous variable as a function of other endogenous and exogenous variables appearing in that equation, then replacing the endogenous variable everywhere it appears in the model by this corresponding algebraic expression. This reduces both the number of endogenous variables to be solved for and the number of equations simultaneously, and can be performed by the computer using the GEMPACK software suite. The endogenous variables that are normally condensed out of the SALTER model are flagged with a '#' mark in Table A2 of Appendix A.

Another way of reducing the dimensions of the linear system is by simply *omitting* those *exogenous* variables which are not going to be shocked, since in this instance they essentially have no role to play. Once again, this procedure can be done by the computer using the GEMPACK software suite, but it is not normally performed on SALTER prior to solving.

1.4 Economic environments

It is possible to specify two broad economic environments for the SALTER model based on the ability of decision makers to adapt their resources in response to the simulated policy changes. In a *short-run* environment, adaptations that could be made within a one or two year time frame are assumed to be possible. A *long-run* environment would produce results of simulated changes around ten years hence. Recall that the SALTER model is not a dynamic model in that it does not track the time path by which these changes occur. It is a comparative static model in which a new equilibrium resulting from adaptations to new conditions can be compared to the outcome which would have arisen at the same point in time had the simulated policy change not occurred.

Defining the environment in which decision makers operate is necessary in order to be able to solve the model. The SALTER model is composed of a large number of equations, and an even larger number of variables. Solving a system of equations requires that the number of unknowns (endogenous variables) equal the number of equations used to specify the model. In order to obtain this, a number of variables need to be treated as exogenous to the model. Natural candidates are the policy instruments such as taxes, duties and subsidies, through which most shocks are modelled, as well as variables, such as the population in each region, whose behaviour is not determined within the model.

Choosing which variables are exogenous defines the closure of the model, but also determines the constraints faced by decision makers in adapting to new conditions. Usually, the SALTER model is used with a long-run closure, reflecting adaptations that can be made within ten years after a policy change. The list of variables treated as exogenous in a long-run closure is shown in Table A4 of Appendix A. The rationale for this list is now discussed, along with the closure changes required to give a short-run closure.

Adaptations in the long run

A constant rate of employment is assumed to prevail in each region in the long run. This means that percentage changes in labour supply and labour demand are equal in response to some shock (although the levels need not be equal initially). This is modelled by setting the change in the employment rate exogenously to zero. Wages in each region need to be sufficiently flexible to ensure this condition can be met. In particular, money wages need to be able to vary independently of the consumer price index. This requires setting the shift term relating nominal wages to the consumer price index in equation SD11 as endogenous.

Since the domestic supply of farm land is assumed to be fixed in each region, there is therefore a fixed supply of services from this primary factor of production. Hence the change in the aggregate supply (and by choice of notation, demand) for land is set exogenously to zero.

In the long run it is assumed that industries have the ability to change the size of their capital stock through investment, and that capital is mobile internationally. As discussed earlier, in long-run simulations the ratio of world net ownership of bonds to world income is held exogenously fixed to ensure continuity of the initial database condition that net global debt is zero. The change in the ratio of world net ownership of bonds to world income variable can indeed be held fixed by allowing the world bond interest rate variable to vary endogenously.

In long-run equilibrium, there is also full parity between the world bond rate and the rate of return on capital in each industry in each region. This is ensured by setting the absolute change in the rate of abnormal return on capital exogenously to zero in each industry in each region. The equity premium and its expected rate of change are also set exogenously to zero in each region.

Consumers are assumed to allocate a constant proportion of their disposable income to consumption and savings. In terms of the model's closure, this requires that the change in the household saving ratio be set exogenously to zero.

In the long run, the government is assumed to increase its current expenditure on goods and services and its transfers to households in line with increases in aggregate income. Thus the change in the ratio of private to public consumption expenditure is set exogenously equal to zero. Similarly, the change in the ratio of factor incomes to government transfers is set exogenously equal to zero. Governments are assumed to adjust budgets to meet these expenditure commitments while maintaining a constant savings ratio by adjusting labour and property income tax rates equiproportionately.

This is achieved by setting the change in the government saving ratio and the separate tax rate shifters for labour and property income exogenously to zero, but allowing the overall income tax rate shift variable (h^{z}_{YTR} in equations SE16 and 17) to vary endogenously.

Box 1.9: **Main elements of the long-run closure in the SALTER model**

1 Resource supply
- fixed labour employment rate in each region
- fixed supply of land in each region
- variable supply of capital in each region

2 Returns to capital
- fixed world bond to income ratio (zero world net ownership of bonds)
- fixed ratio of returns to equity to returns to debt (fixed equity premium)
- fixed rate of abnormal return to capital used in each industry in each region

3 Savings behaviour
- fixed saving-income ratios for households and governments in each region

4 Government spending and taxation
- fixed ratio of real government to private expenditures
- fixed ratio of government transfers to households and household income
- tax rates on labour and property income vary equipropertionately to preserve fixed government saving ratio

5 Technology
- no technological change

6 Population
- no change in population

Other exogenous variables are used to model shifts in policies or exogenous changes in conditions facing decision makers. Thus all the tax variables are set exogenously, as well as variables used to model technical changes and changes in population in each region.

Finally, nominal exchange rates in each region are set exogenously to zero, as is the world primary factor price index. The latter serves as the model's numeraire. Since the model's theoretical structure determines only relative prices and not absolute price levels, the model needs a numeraire price against which all other prices are measured. The world primary factor price index is deemed to be a relatively 'neutral' choice of numeraire.

The exogeneity of nominal exchange rates requires further comment. The SALTER model is well equipped to model changes in real exchange rates in each region. The real exchange rate of a region can be measured by eP^*/P, where e is the nominal exchange rate, P is some index of domestic prices and P^* some index of foreign prices. SALTER contains a full accounting of the price and cost structures in each region, and so captures real exchange rate changes through changes in P and P^*.

However, the model's theoretical structure is one in which nominal exchange rate changes will not normally feed through into real exchange rate changes without some accompanying change in a region's underlying relative cost structure. The reason is that in the absence of some nominal price rigidity in a region, a rise in e (a nominal depreciation) will feed fully through into a corresponding rise in P (domestic price increase), with no impact on the real exchange rate or other real variables in the model. Thus a real exchange rate depreciation cannot be engineered by a nominal depreciation without an element of domestic nominal price rigidity or some other mechanism (such as productivity or tax changes) which can generate a change in a region's cost structure relative to other regions. For this reason, holding the nominal exchange rate in each region constant simply removes one extraneous source of price level variation in each region, but does not affect the real results of the model in any way.

Adaptations in the short run

In a typical short-run closure it is assumed that producers have insufficient time to adjust capital stocks in each industry. Thus movements in the profitability of employing capital are reflected in movements in its rental price rather than adjustments in each industry's use of capital services. In order to model this, the industry-specific demands for capital services are made exogenous and industry-specific abnormal returns to capital are made endogenous.

As noted earlier, the change in the world net ownership of bonds to world income variable can also be allowed to vary endogenously in the short run, since in this case the requirement that net world ownership of bonds be zero is ensured by the model's internal accounting. In its place, the world real bond rate is set exogenously to zero. Note that in short-run simulations, the parameter measuring the length of the simulation interval should also be given a value of zero (McDougall 1993b).

In the short run, it may be appropriate to assume an element of wage rigidity in some or all regions. Real wage rigidity may be modelled by giving the parameter for indexing wages to the consumer price index (in equation SD11) a value of unity, and by setting the wage shift variable exogenously to zero, with the rate of employment instead being endogenous. Thus the rate of employment would adjust (equation SC3) to reflect the relative changes in labour demand and labour supply at the going real wage rate.

A further component of the short-run closure is the treatment of public sector savings rates. In the short term, the government in each region could have two options. First, it could allow income tax rates to vary to keep fixed the ratio of its net surplus to total receipts, as in the long run. Alternatively, it could hold income tax rates constant and allow the government savings ratio to vary. In a short-run closure, the latter assumption is often used.

Over the short run, however, households are still assumed to allocate disposable income in fixed proportions between consumption and savings. In all other respects as well, the short-run closure is the same as in the long run.

These two model closures are not the only two that are possible. As illustrated here, however, changing the environment in which decisions are assumed to be made involves carefully swapping between endogenous and exogenous variables in order to maintain the equality between the number of equations in the model and the number of endogenous variables.