USAGE-ITC: Theoretical Structure

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Abstract

The US International Trade Commission (ITC) and the Centre of Policy Studies (CoPS) are creating a detailed dynamic general equilibrium model of the US economy, USAGE-ITC. The new model will be used for forecasting and policy analysis and for simulating and explaining periods of history. A feature of the model will be its capacity to provide estimates of adjustment costs in the US associated with changes in tariffs and other trade policies. The starting point for USAGE-ITC is the MONASH model which has had a prominent role in the Australian policy debate for many years. This paper sets out the theoretical structure of USAGE-ITC.

1. Introduction

The US International Trade Commission (ITC) uses general equilibrium models in analyzing the effects in the US and in other countries of changes in trade policies. To a large extent the ITC has relied on static models. These provide no insights on the path between equilibria. This is unfortunate because in public discussions the path is often of central interest. In the absence of comprehensive dynamic analysis, contributors to these discussions have claimed, without formal quantification, that trade and other microeconomic reforms impose significant labor market adjustment costs. With a static model, little can be gleaned concerning this issue.

The ITC and the Centre of Policy Studies (CoPS) are now developing the USAGE-ITC model of the US economy together with several add-on programs. The model and the add-on programs will have the four characteristics required for quantification of adjustment costs. These are:

(1) an economy-wide focus;

(2) detail;

(3) dynamics; and

(4) forecasting capabilities.

Characteristic (1) is required because we need to look at how a policy, which causes adjustment problems in one part of the labor market, can reduce problems in another part. Characteristic (2) is required because adjustment problems are about: regions (e.g Detroit); specific occupations (e.g. vehicle spray painter); and particular industries (e.g. motor vehicles). Characteristic (3) is required because central to adjustment problems are changes in the *rates* at which people are required to move between regions, occupations and industries to maintain employment. Characteristic (4) is required because the costs associated with a microeconomic reform (e.g. a tariff cut) that reduces employment in category i (defined by region, occupation and industry) depend on whether the reduction is handled by retrenchments or by a lower rate of hiring, and this, in turn, depends on i's employment growth in the absence of the microeconomic reform.

USAGE-ITC will have a similar structure to that of Australia's MONASH model (Dixon and Rimmer, 2002). At this stage we have a preliminary 514-industry version of USAGE-ITC built around the 1992 benchmark input-output table for the US. USAGE-ITC will be accompanied by add-on programs that extend its results to regions and occupations via tops-down calculations. A further add-on program will compute adjustment costs.

The remainder of this paper is organized as follows. In section 2 we describe the USAGE-ITC theory. We discuss closures and set out a schematic version of the equations. This is sufficient to explain many aspects of the model without encumbering the reader with overwhelming detail. Section 3 discusses our tops-down approach to regions and occupations, and our computation of adjustment costs. Concluding remarks are in section 4.

2. The theoretical structure of USAGE-ITC: a schematic version

2.1. Four closures of USAGE-ITC

USAGE-ITC encompasses four closures: historical; decomposition; forecast; and policy. With these closures, the model will produce: estimates of changes in technologies and consumer preferences (historical closure); explanations of historical developments such as the rapid growth since the mid-1980s in US international trade (decomposition closure); forecasts for industries, regions and occupations (forecast closure); and projections of the deviations from forecast paths that would be caused by the implementation of proposed policies and by other shocks to the economic environment (policy closure). Simulations run under all four closures can play a role in a single study. For example, in a study of the effects of US agricultural subsidies we might use: an historical simulation to estimate rates of technological progress in US agricultural industries; a decomposition simulation to estimate the relative importance to US agriculture in the recent past of subsidy programs compared with technological progress and other relevant variables; a forecast simulation to project employment and output in the agricultural sector in the absence of further subsidies; and a policy simulation to compute deviations away from forecast paths in agricultural employment and output and in non-agricultural variables caused by new agricultural subsidies.

Many of the special features of the USAGE-ITC theory are connected with the four closures. This is illustrated in the next subsection in which we work through a schematic version of the USAGE-ITC equations. There we will find: definitions of variables at different levels of aggregation to facilitate the use of published data in historical simulations; accumulation relationships incorporating smooth-growth assumptions to facilitate decomposition simulations; slack variables in macro relationships to facilitate the use of extraneous projections in forecast simulations; and equations involving deviations from forecast paths to facilitate policy simulations.

2.2. Equations of the schematic model

Table 2.1 lists the equations in a schematic version of USAGE-ITC. Table 2.2, which is presented in three parts, defines the notation used in Table 2.1. The first two parts of Table 2.2 list the exogenous and endogenous variables in a typical policy closure. The third part lists other notation from Table 2.1. In this subsection we work through the equations in Table 2.1.

(a) Results of optimizing decisions

Equations (2.1) to (2.19) are schematic versions of the equations in USAGE-ITC describing: the commodity composition of output by industries; the demands for inputs by industries, capital creators and households; and the composition of imports by origin and exports by destination. The USAGE-ITC equations corresponding to (2.1) to (2.19) are, for the most part, the outcome of optimizing behavioral assumptions.

The first nine equations in Table 2.1 are concerned with the compositions of industry outputs and inputs. For most industries, production is dominated by a single commodity and for most commodities, production is dominated by a single industry. However, because the MAKE matrix in the US input-output data is far from diagonal, it is convenient to allow every industry in USAGE-ITC the possibility of producing every commodity.

For each industry j, the commodity composition of output is chosen to maximize revenue subject to a transformation frontier. This gives commodity-supply functions of the forms shown in (2.2) and (2.1). In (2.2) the total output [X0DOM(i)] of domestic commodity i, that is the output of (i,1),[1] is the sum over industry outputs [X0(i,1,j), j∈IND] of this commodity. and in (2.1) the output of (i,1) by industry j is a function of the prices (P_1) of domestic commodities, of technology variables [A0(i,j), i∈COM], and of the level of j's activity [Z(j)]. Domestic prices appear on the RHS of (2.1) because industry j can transform its commodity mix in favor of corn, for example, and away from wheat if the price of corn rises relative to the price of wheat. Technology variables on the RHS of (2.1) allow for increased output of commodity i by industry j with no change in the industry's outputs of other commodities or in its activity level. The average over commodities of the A0(i,j)s is defined in (2.3). The level of j's activity appearing on the RHS of (2.1) determines the distance of j's transformation frontier from the origin. We assume that an *x* per cent increase in Z(j) allows industry j to produce *x* per cent more of all commodities. We also assume that an *x* per cent increase in activity can be achieved with an *x* per cent increase in all inputs. This assumption, combined with our assumptions on outputs [(2.1)] implies constant returns to scale.

Reflecting constant returns to scale, demands for inputs by any industry j are specified in (2.4) to (2.6) as being proportional to Z(j). In (2.4), industry j's demands for intermediate inputs of domestic and imported good i depend on the prices [$P_1(i)$, $P_2(i)$] of these two commodities but not on other prices. This reflects the assumption adopted in USAGE-ITC that domestic and imported good i are substitutes but that good i cannot be substituted for other intermediate inputs or for primary factors. Similarly, in (2.5) and (2.6) the only price variables are those for labor and capital [W(j) and Q(j)]. While USAGE-ITC recognizes price-induced substitution between labor and capital, it does not allow price-induced substitution between primary factors and other inputs.

USAGE-ITC contains many types of input-affecting technical change. In (2.4) to (2.6) we include some representative examples. A1(i) appearing in (2.4) allows for i-using technical change in all industries and $A_{PF}(j)$ appearing in (2.5) and (2.6) allows for primary-factor-using technical change in industry j. TWIST(i) in (2.4) allows for a shift in technology in all industries that favors the use of imported good i relative to domestic good i without affecting the overall input of i per unit of activity in any industry. Similarly, in (2.5) and (2.6), TWLK(j) introduces a technology shift in industry j that favors the use of labor relative to capital without affecting the overall input of primary factors per unit of activity in industry j.

Through (2.7) and (2.8), we can introduce uniform primary-factor-saving technical changes and labor/capital twists across industries. This can be done by shocks to FFA_{PF} and FFTWLK. FFTWIST in (2.9) can be used to introduce uniform import/domestic twists across all commodities.

Capital creators in industry j are assumed in USAGE-ITC to choose their input mix to minimize the costs of producing Y(j) units of capital subject to a constant-returns-to-scale capital-creation function. Equation (2.10) is a schematic version of the resulting demand functions for inputs into investment. Consistent with the capital-creation functions used in USAGE-ITC, the

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[1] Domestically produced commodities are identified in USAGE-ITC and in the schematic version by (i,1). The i identifies one of the N_C commodities in COM and the 1 identifies domestic. Imported commodities are identified by (i,2) for i∈COM.

only prices shown in (2.10) as affecting the demand for domestic and imported inputs of good i to capital creation in industry j are the prices of these inputs. As with inputs to current production, we assume in capital creation that domestic and imported inputs of i are substitutes but that inputs of i are not substitutable for inputs of other commodities. Unlike current production, for capital creation there are no inputs of primary factors. The use of primary factors in capital creation is recognized via inputs of construction and other investment-related services. The USAGE-ITC equations for inputs to capital creation contain a large array of technical change variables. For the purposes of our schematic model, it is sufficient to include only domestic/import twists. With technical change restricted to twists (which leave overall inputs per unit of capital creation unchanged), the cost of a unit of capital in industry j [PI(j)] depends, as shown in (2.11), only on input prices (P_1 and P_2).

Demands for commodities by households are derived in USAGE-ITC from utility maximization subject to a budget constraint. The utility function is nested. At the top level, utility is derived from consumption of commodities 1, …, N_C. At the second level, consumption of each commodity i is defined as an aggregation of consumption of domestic and imported commodity i, with the aggregation function being linearly homogeneous. A schematic version of the resulting demand functions is given by (2.12) to (2.15). Equation (2.12) relates household demand for commodity i to: the vector (P3) of consumer prices of goods 1, …, N_C; the household budget (C); and variables allowing changes in household preferences [$A_3(i)$/A3AVE]. In equation (2.13), the consumer price of good i is defined as a linearly homogeneous function of the consumer prices of domestic and imported good i [$P3_1(i)$ and $P3_2(i)$] and in (2.14) the demands for domestic and imported good i are expressed as functions of: the consumption of i determined in (2.12); the prices of domestic and imported good i; and the domestic/import twist. The Ψ_{3is} functions in (2.14) are homogeneous of degree zero in prices. In (2.15) we define an average (A3AVE) of the preference variables A3(1), …, A3(N_C). As can be seen from (2.12), we allow household demand for commodity i to be affected not by A3(i) alone but by A3(i)/A3AVE. This ensures that movements in the A3's do not lead to changes in consumption that violate the budget constraint. In other words, we restrict movements in preferences so that (2.12) to (2.15) always imply that:

$$\sum_i \sum_s P3_s(i) * X3(i,s) = C \quad .$$

The prices used in (2.12) to (2.14) are *purchasers'* prices. In USAGE-ITC, all demands for commodities depend on purchasers' prices. In the schematic version we simplify USAGE-ITC by assuming that margins occur only on commodity flows to households and that the only indirect taxes are tariffs, export taxes, production taxes and taxes on consumption. Thus, in (2.4) and (2.10), where we were concerned with demands for intermediate inputs and demands for inputs to capital creation, we used basic prices.[2]

To facilitate the analysis of free-trade agreements and other discriminatory trade policies, USAGE-ITC distinguishes imports by region of origin and exports by region of destination. We imagine that imports are purchased at US ports of entry by a mixing agent. This agent treats imports of commodity i from different regions as imperfect substitutes and chooses the mix of regional supplies [X0IMPR(i,r), r∈REGIMP] to minimize the landed-duty-paid cost of supplying the required overall quantity [X0IMP(i)] of imported i. The overall quantity of imported i is defined as a CES function of imports of i from the different supplying regions. The cost-minimizing problem solved by the mixing agent produces equations (2.16) and (2.17). In (2.16),

[2] The basic price of a domestic commodity is the price received by producers and the basic price of an imported commodity is the landed-duty-paid price. As we will see, agents in USAGE-ITC use composite imports, i.e. their inputs of imported commodity i are a combination of imports differentiated by region of origin. The basic price of an import composite is the landed-duty-paid price of its constituents.

the demand for imports of i from region r is proportional to the overall demand for imports of i and also depends on the landed-duty-paid prices of i from different regions [$P_{2r}(i,r)$, r∈REGIMP]. In equation (2.17) the basic price of imported i [$P_2(i)$] is defined as a linearly homogeneous function of the $P_{2r}(i,r)$s. $P_2(i)$ is the cost of the bundle of imports of i that satisfies a unit demand for imported i [X0IMP(i) = 1] at minimum cost.

For exports, we introduce an allocating agent that purchases good i from domestic producers and allocates it between alternative destinations. If the allocating agent purchases X4(i) units of good i from domestic producers, then it can supply any combination of exports by destination [X4D(i,d), d∈DEST] that satisfies a CET restriction of the form

X4(i) = CET[X4D(i,d), d∈DEST] .

On the assumption that the allocating agent is a constrained revenue maximizer, we obtain (2.18) and (2.19). In (2.18), the supply of exports of good i to region d is proportional to the total supply of exports of i (defined above as a CET combination of exports to different destinations) and also depends on domestic currency receipts per unit of export of i to different destinations [$P_1(i,dd)$, dd∈DEST]. As we will see shortly, domestic currency receipts include f.o.b. prices and export subsidies. In (2.19), we define the basic price of domestic good i [$P_1(i)$]. This is the maximum revenue that can be derived from a unit of exports of i [X4(i) = 1] and is the price received per unit of output of i by domestic producers.[3]

(b) Other demands (government and inventory)

In USAGE-ITC, equations such as (2.20) allow for different treatments of government demands for commodities. If F5(i,s) and F5TOT are held constant, then government demand for each commodity moves by the same percentage as real private consumption (CR). Thus, for example, in a long-run analysis of the effects of a welfare-enhancing policy change, we can assume that the private and public sectors benefit by equal percentages. Changes in the ratios of government demands for commodities relative to private consumption can be introduced exogenously by shocks to F5(i,s) and F5TOT. Alternatively, F5TOT can be used endogenously to adjust government spending to meet a budget constraint.

While not indicated in the schematic model, USAGE-ITC includes inventory demands. In most simulations inventory demands are set exogenously on zero change for nearly all commodities.[4] However, for some commodities (e.g. agricultural commodities) we may have information on the rate at which inventories are being accumulated or decumulated. For these commodities, non-zero settings are appropriate. For some simulations we may have information on the output of a commodity (e.g. a crop forecast). This information can be absorbed by exogenizing the relevant output and leaving inventory demand for the commodity to be determined endogenously.

(c) Demands for exports

In equation (2.21) we relate demand for US good i in destination d [X4D(i,d)] to the foreign-currency price [PE(i,d)] and to shift variables [F4(i,d), F4C(i), F4D(d) and F4GEN]. If the shift variables are exogenous, then by shocking them we can simulate the effects of movements in the foreign-demand curves: for particular commodities in particular destinations; for particular

[3] Recall that in the schematic model, but not in USAGE-ITC, we assume that there are no margins or taxes involved in the transfer of i from producers to ports of exit. The allocating agent however may be subject to export taxes and subsidies and these are reflected in the $P_{1d}(i,d)$s.

[4] Otim (1999) includes in a dynamic CGE model equations relating changes in inventory demands to acceleration in sales. In future work we plan to add such equations to USAGE-ITC.

commodities in all destinations; for all commodities in particular destinations; and for all commodities in all destinations. Alternatively, endogenous shifts can be used to accommodate exogenous export forecasts at different levels of detail.

(d) Demands for margin services

The role of margins is to facilitate flows of commodities from points of production or ports of entry to either domestic users or to ports of exit. USAGE-ITC recognizes eight margin commodities: Railroad services, Trucking services, Water transport, Air transport, Pipelines except natural gas, Natural gas transportation, Wholesale trade and Retail trade. In the schematic model, all commodities are treated as though they can be used as margin services. In both USAGE-ITC and the schematic version, all margin demands are met by domestic production (the use of imported margin commodities is deemed to be direct use not margin use). In connection with this assumption, it is worth emphasizing that margin demands relate only to the facilitation of commodity flows within the US.

In USAGE-ITC, we model demands for margin services as the product of a technology variable and an underlying flow variable. This is illustrated in the schematic model by (2.22). With the technology variable A3MAR(k,s,i) set exogenously, (2.22) implies that the use of commodity i (e.g. retail trade) as a margin service in facilitating the flow of commodity (k,s) from producers or ports of entry to households is proportional to household demand for (k,s). USAGE-ITC contains equations similar to (2.22) for flows of commodities to all users. As mentioned in the discussion of (2.12) to (2.15), in the schematic version we assume that there are no margins services associated with commodity flows except those to households.

(e) Supply equals demand for commodities

In (2.23) we equate the supply (output) of commodity (i,1) to the sum of demands for (i,1). Similarly, in (2.24) we equate the supply (imports) of (i,2) to the sum of demands for (i,2). Consistent with USAGE-ITC, imported commodities are not directly exported or used to satisfy margin demands.

(f) Zero profits in production, importing, exporting and distribution

Equations (2.25) to (2.28) are schematic versions of the USAGE-ITC zero-pure-profits conditions for production, importing, exporting and distribution. The LHS of (2.25) is revenue in industry j. The RHS is j's costs, including production taxes. The LHS of (2.26) is the price [P_{2r}(i,r)] paid by the import-mixing agent for commodity i from region r. As can be seen from the RHS, P_{2r}(i,r) is made up of the foreign-currency price [PM(i,r)] converted to domestic currency via the region-r/US exchange rate [Φ(r)] and inflated by the power of the tariff [TM(i,r)]. The LHS of (2.27) is the revenue received by the allocating agent for a unit of commodity i exported to destination d. This is equated to the RHS which is the foreign-currency price [PE(i,d)] converted to domestic currency and deflated by the power of the export tax [T4(i,d)]. The LHS of (2.28) is the price paid by households for commodity (k,s). This is equal to the cost of supplying a unit of (k,s) to households, made up of the price received by producers or importers [P_s(k)] inflated by the power of the consumption tax [T3(k,s)] *plus* the costs of transferring units of (k,s) from producers or ports of entry to households. As mentioned earlier, we assume that transferring (margin) activities use only domestic commodities, e.g. domestic transport and domestic retail trade. Thus the cost of commodity i used in transferring a unit of (k,s) to households is the price of domestic commodity i [P_1(i)] multiplied by the number of units of i [A3MAR(k,s,i)] required per unit of transfer.

(g) Genuine and phantom indirect taxes

USAGE-ITC contains many equations expressing the power (one plus the rate) of an indirect tax as a product of powers of genuine taxes (indicated by G) and phantom taxes (indicated by PH). Equations (2.29) to (2.31) are examples. Genuine taxes are those collected by the government. Phantom taxes are those used to reconcile contradictory data items on prices and costs. For example, in a simulation in which we are using USAGE-ITC to reproduce a period of history, we allow endogenous movements in the phantom export taxes to reconcile data on export prices and the cost of exporting. If our data for commodity i indicate an increase in costs per unit of exports of 10 per cent and an increase the price of exports of 15 per cent, then reconciliation is achieved by an endogenous phantom export tax of 5 per cent.

In (2.29), the power of the tax on production in industry j is shown as the product of only one genuine and one phantom tax. However, in (2.30) we allow for two phantom powers and in (2.31) we allow for two phantom and two genuine powers. The first phantom power [T4PH(i)] in (2.30) affects only the tax on exports of commodity i, whereas the second [T4SPH(i)] affects both export taxes and consumption taxes [see (2.31)]. Movements in the first phantom power are used in historical and forecast simulations to absorb data and forecasts for export prices that we judge to have little significance for the determination of domestic prices. Movements in the second phantom power are used for export prices that we judge to be dominant in the determination of domestic prices. The two genuine powers in (2.31) allow us to simulate changes in government-imposed taxes applying to the consumption of particular commodities (not distinguished by source) and to the consumption of all commodities. With DOM(s) being 1 for s = domestic and 0 for s = imported, the phantom powers in (2.31) affect only the taxes on the consumption of domestically produced commodities. We used T3PH(i) in historical simulations to absorb data on the consumption price of i, and T4SPH(i) to spread data on export prices to implications for consumption prices.

(h) Definitions of macro variables

Equations (2.32) to (2.48) are a sample of the macro definitions in USAGE-ITC. Equation (2.32) defines the consumer price index (CPI) as a function of the vectors [$P3_1$ and $P3_2$] of consumer prices for domestic and imported goods. Similarly, (2.33) defines the price index for public consumption as a function of the prices to government of domestic and imported goods[5]. Equations (2.34) and (2.35) define real private and public consumption as nominal private and public consumption deflated by the relevant price indexes. Nominal public consumption (G) is defined in (2.36) as the sum of public expenditures on individual goods.[6] The real wage rate is defined in (2.37) as the nominal wage rate deflated by the CPI. Equations (2.38) and (2.39) define total employment and total capital stock as sums across industries. Equation (2.40) is the GDP identity in nominal terms. Equations (2.41) to (2.43) define aggregate quantity indexes for exports, imports and investment as functions of commodity or industry components. Equations (2.44) to (2.46) define the real balance of trade, real consumption (private and public) and real GDP. Equation (2.47) defines the terms of trade as a function of f.o.b. export prices and c.i.f. import prices. Finally, (2.48) defines an average (e.g. trade weighted) exchange rate (Φ) as a function of bilateral exchange rates.

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[5] These are basic prices because in the schematic model (but not in USAGE-ITC) we assume that margins apply only to sales to households.

[6] Recall that nominal private consumption (C) is defined implicitly through (2.12) to (2.15) as the sum of private expenditures on individual goods.

(i) Capital, investment and rates of return

Equation (2.49) relates the capital stock in industry j at the end of the year [K_{+}(j)] to the depreciated capital stock from the beginning of the year [(1-D(j))*K(j)] and to investment during the year [Y(j)]. Equation (2.50) defines the ratio of investment to capital in industry j. When the shift variables, F_{KG}(j) and FF_{KG}, in (2.51) are exogenous, capital growth in industry j during the year, and hence investment, responds to movements in j's expected rate of return [EROR(j)]. Changes in j's capital growth and in capital growth in all industries can be imposed independently of changes in expected rates of return via shocks to F_{KG}(j) and FF_{KG}. Equation (2.52) defines the expected rate of return in industry j as a function of the current rental rate [Q(j)] and asset price [PI(j)] of j's capital. Under this definition, expectations are static or adaptive. USAGE-ITC contains additional equations and variables that allow for forward-looking expectations. Equation (16.53) allows all expected rates of return to be moved together through shocks to $FTOT_{EROR}$. It also allows for different movements in expected rates of return across industries through movements in F_{EROR}(j).

With equations such as (2.49) to (2.53), USAGE-ITC accommodates two broad treatments of capital and investment. The first, involving direct assumptions about movements in rates of return and investment/capital ratios, is suitable for long-run comparative-static simulations. In such simulations, we are concerned with the effects of a policy or other shock after a considerable time, say 6 years. In these circumstances, USAGE-ITC allows us to assume directly that the shock under examination does not affect rates of return. In terms of the schematic model we treat EROR(j) and $FTOT_{EROR}$ as exogenous variables, and F_{EROR}(j) as an endogenous variable. With EROR(j) set on zero change, we assume that industries favored by the shock attract capital until their rental rates [Q(j)] fall sufficiently to drive rates of return back to their initial (basecase forecast) levels. Similarly, industries for which the shock is unfavorable lose capital until their rates of return increase to their initial levels. Having, in this way, tied down the long-run effect of a shock on start-of-year capital stocks [K(j)], we can tie down the effect on industry investment levels by exogenizing IKRATIO(j) for all j on zero change and turning off (2.51) by endogenizing F_{KG}(j). We assume that if a shock applied in year t causes capital in industry j at the start of year t+6 to be 20 per cent greater than it otherwise would have been, then it also causes investment in industry j in year t+6 to be increased by 20 per cent.

Several variations on the basic long-run comparative-static treatment of capital and investment are available in USAGE-ITC. For example, USAGE-ITC contains equations that can be used to make the movement in an industry's rate of return over an historical period (say 6 years) depend on:

(a) the industry's simulated rate of capital growth over the period;

(b) the industry's rate of return at the beginning of the period; and

(c) the sector to which the industry belongs.

Factor (a) has a useful damping effect. Via (a), favorable developments for an industry in an historical period have positive effects not only on its simulated capital growth but also on its simulated rates of return. By allowing some of the influence of historical developments to be dissipated in a rate-of-return movement, we prevent USAGE-ITC from generating either an unrealistically high or low outcome for the industry's rate of capital growth. Via (b) we recognize that industries which at the beginning of an historical period had below average rates of return are likely to have higher rates of return at the end of the period, reflecting weak investment and increasing scarcity of capital. Factor (c) allows USAGE-ITC to generate rate-of-return movements compatible with sectoral information on profitability.

The second broad treatment of capital and investment in USAGE-ITC involves explicit capital-supply functions, and is used in year-to-year simulations, i.e., simulations tracing out the paths of variables for years t, t+1, t+2, etc. In each year of year-to-year simulations, we assume that industries' capital growth rates (and thus investment) are determined according to functions which specify that investors are willing to supply increased funds to industry j in response to increases in j's expected rate of return. However, investors are cautious. In any year, the capital-supply functions in USAGE-ITC limit the growth in industry j's capital stock so that disturbances in j's rate of return are eliminated only gradually. In terms of the schematic model, the year-to-year approach to capital growth and investment can be implemented with: $F_{KG}(j)$ and FF_{KG} exogenous; K(j) exogenous or predetermined; EROR(j) endogenous; $F_{EROR}(j)$ endogenous and $FTOT_{EROR}$ exogenous; and IKRATIO endogenous.

(j) Equations for facilitating historical and forecast simulations

Data and forecasts in the US on outputs, inputs, prices and other variables occur in various industrial/commodity classifications. So that we can use these data and forecasts, we include in USAGE-ITC many equations that define variables at different levels of aggregation. This is illustrated by (2.54) which defines employment [LG(q)] in the qth group of industries, e.g. all industries in the agricultural sector. In most simulations, sectoral variables such as LG(q) are endogenous. However, in historical and forecast simulations they may be exogenized and given shocks reflecting observed or forecast movements. In this case, we need additional equations and variables to ensure that exogenously given values for sectoral variables are distributed across individual industries in a theoretically satisfactory manner. In the schematic model we have included equations that allow given changes in LG(q) to be distributed across industries in sector q to equalize implied changes in labor productivity. Through equations (2.55) to (2.57) we define labor productivity in each industry. Then, by exogenizing FLPROD(j) on zero change, we can ensure via (2.57) that movements in labor productivity in all industries j in group q equal the movement in the variable FLPRODG(q).

Further examples of equations designed to facilitate historical and forecast simulations are given in the schematic model by (2.58) to (2.61). Provided that we endogenize FWTOT, we can use shocks to FW(j) in (2.58) to introduce observed or forecast changes in wage relativities across industries. FWTOT must be endogenous when the FW(j)s are exogenous to avoid conflicts between the average wage across industries implied by (2.58) and the average wage across industries defined by (2.59). Equations such as (2.60) and (2.61) are used in USAGE-ITC historical and forecast simulations to introduce observed and forecast changes in commodity prices. With ADJP3 and ADJPE treated as endogenous variables, vectors of observed or forecast changes in consumer and export prices can be introduced as shocks to P3OBS(i) and PEOBS(i,d) and then modified so that the consumer and export prices [P3(i) and PE(i,d)] feeding into the rest of the model are compatible with macro observations or forecasts for average consumer and export prices.

(k) Equations for facilitating policy simulations

Policy results are generated in USAGE-ITC as deviations from explicit forecasts. This requires several equations that relate policy values for variables to forecast values. For example, as indicated by (2.62), we often assume in policy simulations that the proportionate deviation in year t in the real wage rate from its forecast value [$WR/WR_f - 1$] equals the proportionate deviation in year t-1 [$WR_{lag}/WR_{f,lag} - 1$] *plus* a positive multiple of the proportionate deviation in year t in total employment [$LTOT/LTOT_f - 1$]. Thus we assume that while employment is above its forecast level, the real wage deviation will be increasing and while employment is below its forecast level, the real wage deviation will be decreasing. Under this specification, policy shocks produce a sticky wage response that gradually adjusts wages so that employment is eventually returned to its forecast path. In simulations in which we want a different approach to wage determination, we can endogenize the shift variable F_{WR}.

(l) The government accounts

Equation (2.63) defines the public sector deficit (PSD) as government consumption expenditures *less* tax collections *plus* transfers. In this schematic equation, we recognize only the genuine taxes (on consumption, imports, exports and production) appearing in other schematic equations and we treat transfers as a single item with no explaining equations. USAGE-ITC contains numerous other taxes (e.g., income taxes) and other sources of government income. It also contains separate equations for each of the main categories of transfers. For modeling interest on the public debt, we include in USAGE-ITC dynamic equations determining the level of public debt at the start of year t as a function of the level of public debt at the start of year t-1 and the public sector deficit in year t-1.

(m) Equations for facilitating decomposition simulations

In decomposition simulations we explain economic developments between two widely separated years, a base year (e.g. 1992) and a final year (e.g. 1998). In these simulations, there is no explicit modeling of variables for intermediate years.

To avoid intermediate years, we adopt smooth growth assumptions. For example, in our specification of movements in net foreign liabilities, we adopt smooth growth assumptions for capital. This gives implicit intermediate-year values for investment. Similarly, we adopt smooth growth assumptions for domestic savings by assuming smooth growth in GNP and in the average propensity for private and public consumption [APC in (2.66)]. With investment and savings implicitly determined for intermediate-years, we can determine intermediate-year values for the current account deficit and net foreign liabilities. Thus, through smooth growth assumptions, we are able to relate the value of total net foreign liabilities in foreign currency at the start of the final year (NFLF) to its value at the start of the base year ($NFLF_{-\tau}$) and to growth between the two years in total capital, GNP and the average propensity to consume. This is indicated by the schematic equation (2.64). The USAGE-ITC equation corresponding to (2.64) includes changes between the base and final years in various prices (particularly asset prices). In (2.64) we leave out all the price variables except the average exchange rate.

With the introduction in (2.64) of GNP as a variable, we require a defining equation. This is provided by (2.65) which defines GNP as GDP less the domestic-currency value of net interest and dividend payments to foreigners.

For year-to-year simulations, equations such as (2.64) can be turned off by endogenizing their shift variables (F_{NFLF}).

(n) Balance of payments

USAGE-ITC contains a detailed description of the balance of payments. This includes equations for the year-to-year accumulation of different types of foreign assets and liabilities and equations for associated incomes and payments. In the schematic version given in (2.67) and (2.68), we show a single accumulation equation relating the end-of-year foreign-currency value of net foreign liabilities to the start-of-year value and to the foreign-currency value of the current account deficit (CAD*Φ). The current account deficit is shown as the trade deficit (imports less exports) plus interest and dividend payments on net foreign liabilities.

(o) Household disposable income and consumption function

Equation (2.69) defines household disposable income as GNP *less* taxes *plus* transfers. The corresponding USAGE-ITC representation includes more tax terms than are shown in (2.69) and also includes net transfers from foreigners in addition to those from the government. With the shift variable F_C set exogenously, (2.70) links movements in total household expenditure to movements in household disposable income.

3. Extending the USAGE-ITC results through tops-down add-ons

An effective way to extend the range of application of a CGE model is through add-on programs. These take CGE results as an input and produce results for variables not included in the original model.

We plan three add-on programs for USAGE-ITC. These will translate USAGE-ITC results into implications for: economic activity in sub-national regions (e.g. States); employment in highly disaggregated occupations; and adjustment costs associated with changes in the regional, occupational and industrial composition of employment.

Relative to fully integrated models, models with add-ons have computational advantages. However, their main advantage is organizational. Add-ons can be designed by people working independently of the creators of the core CGE model. This facilitates productive cooperation between CGE modelers and applied economists with specialized knowledge in other areas.

The main disadvantage of the add-on approach is that it allows no feedback. Thus, for example, a regional add-on is a poor vehicle for analyzing the national impact of shocks to regional variables.

3.1. Generating results for sub-national regions

In federations such as the US, economic projections for individual States are of considerable policy interest. To disaggregate USAGE-ITC results to the State level we plan to implement a modified LMPST method (Leontief *et al*., 1965). The LMPST method was first used to disaggregate results from a US input-output model to the fifty US states.

The main attraction of the LMPST method is that its data requirements are modest. The only unavoidable data are commodity outputs in each region. Given these data, USAGE-ITC forecasts or policy deviations will be allocated to States in three steps.

First, each of the approximately 500 USAGE-ITC commodities will be classed as either "national" or "local". National commodities are those that can be traded easily across State boundaries. Examples include most agricultural and mining commodities. The essential characteristic of a national commodity is that its output in each region is determined largely independently of demand in the region. Local commodities have the opposite characteristic. They are commodities for which demand in each region must be satisfied mainly from production in the region. Examples include perishable items such as bread, and services such as retail trade and mechanical repairs.

Second, growth rates compatible with the US-wide USAGE-ITC results will be assigned to State outputs of national commodities. The simplest approach is uniform assignment:

$g(j,s) = g(j)$ for all s,

where

$g(j,s)$ is the growth rate of output for national commodity j in State s; and

$g(j)$ is the USAGE-ITC-generated US-wide growth rate.

Third, growth rates will be calculated for the outputs of local commodities in each State under the assumption that State outputs equal State demands. In calculating a State's demand for a local commodity, account is taken of: intermediate and investment demands by local industries and by the parts of the national industries located in the State; demands by the State's households which are a function of State population and employment; and government demand. As with national commodities, we ensure that the State outputs of local commodities sum to the USAGE-ITC-generated US-wide outputs.

Through the modeling of local commodities, the modified LMPST method introduces State multiplier effects. If a State has an over-representation of fast-growing national industries, then the effect on its overall growth is magnified by fast growth in intermediate, investment and consumption demands (via employment) for its local commodities.

The LMPST approach is effective in analyzing the State implications of policy and other shocks initiated at the national level. For such shocks it is reasonable to assume that there are no significant changes in relative costs of production across regions. However, the LMPST approach is less suitable for analyzing shocks initiated at the regional level, such as cuts in taxes in one region but not in others. For such shocks, changes in relative regional competitiveness may be the most important issue.

3.2. Generating results for detailed occupations

Disaggregated employment forecasts are required by Federal and State government departments concerned with: education and vocational training; career advising; and job placement. In these roles, governments want to know what types of jobs are likely to be available in the future.

We plan to use USAGE-ITC to generate projections for employment in 750 occupations [the Standard Occupational Classification (SOC) system used by the Bureau of Labor Statistics (BLS)] through the equations:

$$\ell_{ij} = \ell_{\bullet j} + q_{ij} , \qquad i = 1, \dots, 750 \text{ and } j = 1, \dots, 500 \qquad (3.1)$$

and

$$\ell_{i\bullet} = \sum_j S_{ij} * \ell_{ij} , \qquad i = 1, , \dots, 750 \qquad (3.2)$$

where

ℓ_{ij} is the percentage change from year t-1 to t in the demand for labor in occupation i and industry j;

$\ell_{\bullet j}$ is the percentage change in aggregate employment in industry j;

q_{ij} , termed an occupation-share effect, is a projection of the extent to which growth in employment of occupation i in industry j will differ from growth of aggregate employment in industry j;

$\ell_{i\bullet}$ is the percentage change in employment in occupation i; and

S_{ij} is the share of occupation i’s employment accounted for by industry j.

Thus, the occupational projections ($\ell_{i\bullet}$) will reflect all of the factors influencing USAGE-ITC employment projections ($\ell_{\bullet j}$) for industries including the state of the business cycle, government policies, world commodity prices, production technologies and consumer preferences. The occupational projections will also reflect changes in the occupational composition of employment within industries, the q_{ij}s. Forecasts of the q_{ij}s will be made by extrapolating trends estimated from data supplied by the BLS.

3.3. Adjustment costs

We have developed an index of labor market adjustment costs which can be computed from USAGE-ITC results. Comparison of the paths of the index in basecase-forecast and policy simulations indicates the policy’s contribution to labor market adjustment costs.

The index measures the loss of labor input associated with the flows of people between various labor market states. We call this the Labor Input Loss Index (LILI).

The construction of LILI starts with the classification of people into the following labor market states: unemployed (U), not in the labor force (NLF) and employed in category i (E_i) where categories are defined by industry, occupation and region. Our aim is to identify the annual flows of people from one labor market state to another and to measure the adjustment costs that these flows impose.

Figure 3.1 contains our classification of labor market states and indicates the flows between these states. In year t+1, people that were employed in year t can remain employed, either in the same category (E_ESC) or in a different category (E_EOC), they can become unemployed (E_U) or they can leave the labor force (E_NLF). A person who is unemployed in year t can, in the following year, become employed (U_E), remain unemployed (U_U) or can leave the labor force (U_NLF). A person who is not in the labor force in year t may enter the labor force in the following year and join the ranks of either the employed (NLF_E) or the unemployed (NLF_U), or may remain outside the labor force (NLF_NLF).

The value of LILI for the year t to t+1 is a weighted sum of the flows identified in Figure 3.1 expressed as a percentage of the labor force in year t, that is

$$LILI(t, t+1) = \frac{100}{LF_t} \sum_k w_k M_k(t, t+1) \tag{3.3}$$

where LF_t is the number of people in the labor force in year t, the w_ks are weights and the M_ks are the flows (E_ESC), (E_EOC) etc., appearing in Figure 3.1. To calculate LILI we need values for the w_ks reflecting the relative costs of different labor market flows and estimates of the M_ks.

In setting the w_ks we assume that moves from one labor market state to another occur evenly over year t to t+1. Thus we assume that the loss of productive capacity associated with the movement of a person into or out of unemployment is 0.50 worker-years. A whole worker-year is lost if a person that is unemployed in year t remains so in year t+1. We assume that the loss of productive capacity caused by the need for training is equivalent to 0.25 worker-years. Training/re-training is assumed to be required by anyone that moves into employment in category i from another category, from unemployment or from outside the labor force.

Figure 3.1. Labor Market Flows

Year t+1	Employed		Unemployed	Not in Labor Force
Year t	Same Category	Other Category		
Employed	E_ESC	E_EOC	E_U	E_NLF
Unemployed	U_E		U_U	U_NLF
Not in Labor Force	NLF_E		NLF_U	NLF_NLF

To facilitate the estimation of the M_ks we make several assumptions about how and why people move from one labor market state to another. These assumptions, which are explained in detail in Dixon and Rimmer (2002, section 40), enable us to evaluate the M_ks using employment and labor force projections (E_{it},LF_t) obtained from USAGE-ITC. Examples of the equations used in the computation of the labor flows in LILI are as follows:

$$E\_ESC = \sum_j \min\{(1-\alpha)E_{jt} - VD_j \,;\, E_{jt+1}\} \quad , \tag{3.4}$$

$$VD_i = \sum_{j \neq i} V_{ij} \quad \text{, and} \tag{3.5}$$

$$V_{ij} = \phi * S_i * \delta_{ij} * \max(0\,;\, E_{jt+1} - (1-\alpha)E_{jt} + VD_j) \quad . \tag{3.6}$$

In (3.4) the number of persons that were employed in category j in year t and remain employed in category j in year t+1 is the minimum of two numbers. The first is the number of people employed in j in year t who *wish* to remain employed in that category in year t+1. This is calculated as employment in j in year t (E_{jt}) less voluntary retirements (the fraction α of E_{jt}) and voluntary departures (VD_j) from category j to employment in other categories. The second is employment in j in year t+1 (E_{jt+1}). The second number will be operative only if employment in j in year t+1 is insufficient to provide jobs for all of the people employed in j in year t who wish to remain employed in j in year t+1. Equation (3.5) equates the number of voluntary departures from employment category i to the sum over all j, $j \neq i$, of the flow of people from i to j (V_{ij}). Equation (3.6) models the flow from category i to category j as a product of four terms. In understanding (3.6) it is helpful to start by noting that the last term is the number of vacancies in category j available to people not initially employed in j. If δ_{ij} is the same number for all i, then (3.6) implies that the fraction of these vacancies filled by voluntary movements from category i is proportional to the share (S_i) of i in aggregate employment. However the suitability of people for filling vacancies in j varies across i. We recognize this through non-uniform settings of the δ_{ij}s. These parameters measure the closeness of employment categories. If i and j are in the same region and require similar skills then we set δ_{ij} =1. If i and j are in different regions and require dissimilar skills, then we set δ_{ij} close to zero. We set the parameter ϕ so that the overall level of voluntary movements implied by (3.6) in a typical year is consistent with mobility data.

4. Concluding remarks

The MONASH model of the Australian economy provides a comprehensive template for USAGE-ITC. The main challenge is to adapt MONASH so that USAGE-ITC is consistent with US rather than Australian institutions and so that USAGE-ITC makes best use of the rich database that is available for the US.

With regard to institutional factors, the development of USAGE-ITC is likely to require adjustment to the MONASH treatment of wage determination. As reflected in MONASH, wage movements in Australia are strongly influenced by bargaining between the Government, employer organizations and trade unions. This system produces sluggish wage responses to variations in demand and supply for labor with consequent long periods of high unemployment. It is likely that equations describing wage movements in the US are different from those that are suitable for Australia. Similarly, US trade policy is different from Australian trade policy. For the US, regional trade agreements (e.g. NAFTA) are much more important than for Australia. As described in section 3, we have responded to this by equipping USAGE-ITC with multiple origins of imports and destinations for exports. In MONASH, imports and exports are not distinguished by origin or destination.

With regard to data, the US is much better placed than Australia. For the US we have a 500-order input-output table and supporting data for 1992 published by the Bureau of Economic Analysis (BEA), and comprehensively updated 192-order input-output tables for every year from 1983 to 1998 published by the BLS. For Australia, there is no time series of comparable input-output tables and the published tables available from the Australian Bureau of Statistics are about 100 order. So that we can make best use of the US data, we and our colleagues from the ITC are making considerable efforts to understand all of the conventions underlying both the BEA and BLS input-output tables. Some of this work is described in the data paper for USAGE-ITC being presented at this conference.

References

Dixon, P.B. and M.T. Rimmer (2002), *Dynamic General Equilibrium Modelling for Forecasting and Policy: a Practical Guide and Documentation of MONASH,* Contributions to Economic Analysis, North Holland Publishing Company, Amsterdam (forthcoming).

Leontief, W., A. Morgan, K. Polenske, D. Simpson and E. Tower (1965), "The Economic Impact — Industrial and Regional — of an Arms Cut", *Review of Economics and Statistics,* XLVII, August, pp. 217-241.

Otim, S. (1999), Inventories and Economic Fluctuations: a Computable General Equilibrium Analysis of the Australian Economy, Ph. D. thesis, Monash University, Australia.

Table 2.1. Schematic Representation of the USAGE-ITC Equations

		Dimension	Identifier
(a) Results of optimizing decisions			
Composition of outputs and inputs			
$X0(i,1,j) = Z(j)*\psi_{0i1j}[P_1; A0(1,j), \ldots, A0(N_C,j)]$	$i\in COM, j\in IND$	$N_C N_I$	(2.1)
$X0DOM(i) = \Sigma_{j\in IND}\, X0(i,1,j)$	$i\in COM$	N_C	(2.2)
$A0AVE(j) = \psi_{0j}[A0(1,j), \ldots, A0(N_C,j)]$	$j\in IND$	N_I	(2.3)
$X1(i,s,j) = Z(j)*\psi_{1isj}\, [P_1(i), P_2(i), A1(i), TWIST(i)]$	$i\in COM, s\in SOURCE, j\in IND$	$N_C N_S N_I$	(2.4)
$L(j) = Z(j)*\psi_{Lj}[W(j), Q(j), A_{PF}(j), TWLK(j)]$	$j\in IND$	N_I	(2.5)
$K(j) = Z(j)*\psi_{Kj}[W(j), Q(j), A_{PF}(j), TWLK(j)]$	$j\in IND$	N_I	(2.6)
$A_{PF}(j) = FA_{PF}(j) + FFA_{PF}$	$j\in IND$	N_I	(2.7)
$TWLK(j) = FTWLK(j) + FFTWLK$	$j\in IND$	N_I	(2.8)
$TWIST(i) = FTWIST(i) + FFTWIST$	$i\in COM$	N_C	(2.9)
Inputs to capital creation and asset prices			
$X2(i,s,j) = Y(j)*\psi_{2isj}[P_1(i), P_2(i), TWIST(i)]$	$i\in COM, s\in SOURCE, j\in IND$	$N_C N_S N_I$	(2.10)
$PI(j) = \psi_{PIj}(P_1, P_2)$	$j\in IND$	N_I	(2.11)
Household demands for commodities			
$X3C(i) = \psi_{3i}[C, P3, A3(i)/A3AVE]$	$i\in COM$	N_C	(2.12)
$P3(i) = \psi_{P3i}[P3_1(i), P3_2(i)]$	$i\in COM$	N_C	(2.13)
$X3(i,s) = X3C(i)*\psi_{3is}[P3_1(i), P3_2(i), TWIST(i)]$	$i\in COM, s\in SOURCE$	$N_C N_S$	(2.14)
$A3AVE = \psi_{A3}[A3(1), \ldots, A3(N_C)]$		1	(2.15)
Composition of imports by region of origin and of exports by destination			
$X0IMPR(i,r) = X0IMP(i)*\psi_{ir,imp}(P_{2r}(i,rr), rr\in REGIMP)$	$i\in COM, r\in REGIMP$	$N_C N_R$	(2.16)
$P_2(i) = \psi_{P2i}(P_{2r}(i,rr), rr\in REGIMP)$	$i\in COM$	N_C	(2.17)
$X4D(i,d) = X4(i)*\psi_{idexps}(P_{1d}(i,dd), dd\in DEST)$	$i\in COM, d\in DEST$	$N_C N_D$	(2.18)
$P_1(i) = \psi_{P1i}(P_{1d}(i,d), d\in DEST)$	$i\in COM$	N_C	(2.19)
(b) Other demands			
$X5(i,s) = F5(i,s)*F5TOT*CR$	$i\in COM, s\in SOURCE$	$N_C N_S$	(2.20)

….continued

Table 2.1 continued

		Dimension	Identifier
(c) Demands for exports			
$X4D(i,d) = \psi_{idexpd}(PE(i,d)) + F4(i,d) + F4C(i) + F4D(d) + F4GEN$	$i \in COM, d \in DEST$	$N_C N_D$	(2.21)
(d) Demands for margin services			
$X3MAR(k,s,i) = A3MAR(k,s,i)*X3(k,s)$	$k \in COM, s \in SOURCE, i \in COM$	$N_C N_S N_C$	(2.22)
(e) Supply equals demand for commodities			
$X0DOM(i) = \Sigma_j X1(i,1,j) + \Sigma_j X2(i,1,j) + X3(i,1) + X4(i) + X5(i,1) + \Sigma_k \Sigma_s X3MAR(k,s,i)$	$i \in COM$	N_C	(2.23)
$X0IMP(i) = \Sigma_j X1(i,2,j) + \Sigma_j X2(i,2,j) + X3(i,2) + X5(i,2)$	$i \in COM$	N_C	(2.24)
(f) Zero profits in production, importing, exporting and distribution			
$\Sigma_{i \in COM} P_1(i)*X0(i,1,j) = \Sigma_i \Sigma_s P_s(i)*X1(i,s,j) + W(j)*L(j) + Q(j)*K(j) + [T0(j)-1]*\Sigma_{i \in COM} P_1(i)*X0(i,1,j)$	$j \in IND$	N_I	(2.25)
$P_{2r}(i,r) = [PM(i,r)/\Phi(r)]*TM(i,r)$	$i \in COM, r \in REGIMP$	$N_C N_R$	(2.26)
$P_{1d}(i,d) = [PE(i,d)/\Phi(d)]/T4(i,d)$	$i \in COM, d \in DEST$	N_C	(2.27)
$P3_s(k) = P_s(k)*T3(k,s) + \Sigma_i P_1(i)*A3MAR(k,s,i)$	$k \in COM, s \in SOURCE$	$N_C N_S$	(2.28)
(g) Genuine and phantom indirect taxes			
$T0(j) = T0G(j)*T0PH(j)$	$j \in IND$	N_I	(2.29)
$T4(i,d) = T4G(i,d)*T4PH(i)*T4SPH(i)$	$i \in COM, d \in DEST$	$N_C N_D$	(2.30)
$T3(i,s) = T3G(i)*T3TG*[T3PH(i)*T4SPH(i)]^{DOM(s)}$	$i \in COM, s \in SOURCE$	$N_C N_S$	(2.31)
(h) Definitions of macro variables			
$CPI = \psi_{CPI}(P3_1, P3_2)$		1	(2.32)
$P5 = \psi_{P5}(P_1, P_2)$		1	(2.33)
$CR = C/CPI$		1	(2.34)
$OTHREAL = G/P5$		1	(2.35)
$G = \Sigma_s \Sigma_i P_s(i)*X5(i,s)$		1	(2.36)
$WR = WTOT/CPI$		1	(2.37)

….continued

Table 2.1 continued

		Dimension	Identifier
$LTOT = \Sigma_j L(j)$		1	(2.38)
$KTOT = \Sigma_j K(j)$		1	(2.39)
$GDP = C + \Sigma_j PI(j)*Y(j) + G + \Sigma_i\Sigma_d [PE(i,d)/\Phi(d)]*X4D(i,d)$			
$- \Sigma_i\Sigma_r [PM(i,r)/\Phi(r)]*X0IMPR(i,r)$		1	(2.40)
$EXPVOL = \psi_{EXP}[X4(1), \ldots, X4(N_C)]$		1	(2.41)
$IMPVOL = \psi_{IMP}[X0IMP(1), \ldots, X0IMP(N_C)]$		1	(2.42)
$IR = \psi_{INV}[Y(1), \ldots, Y(N_I)]$		1	(2.43)
$BOTR = EXPVOL - IMPVOL$		1	(2.44)
$CR_{PP} = CR + OTHREAL$		1	(2.45)
$GDPR = CR_{PP} + BOTR + IR$		1	(2.46)
$TOFT = \psi_{TOFT}[PE(i,d)/\Phi(d), PM(i,r)/\Phi(r); i\in COM, d\in DEST, r\in REGIMP]$		1	(2.47)
$\Phi = \psi_{\Phi}(\Phi(q), q\in DEST\cup REGIMP)$		1	(2.48)
(i) Capital, investment and rates of return			
$K_+(j) = (1-D(j))*K(j) + Y(j)$	$j\in IND$	N_I	(2.49)
$IKRATIO(j) = Y(j)/K(j)$	$j\in IND$	N_I	(2.50)
$EROR(j) = \psi_{KGj}[K_+(j)/K(j) - 1] + F_{KG}(j) + FF_{KG}$	$j\in IND$	N_I	(2.51)
$EROR(j) = \psi_{ERORj}[Q(j), PI(j)]$	$j\in IND$	N_I	(2.52)
$EROR(j) = F_{EROR}(j) + FTOT_{EROR}$	$j\in IND$	N_I	(2.53)
(j) Equations for facilitating historical and forecast simulations			
$LG(q) = \Sigma_{j\in G(q)}L(j)$	$q\in LABGP$	N_{LG}	(2.54)
$LPROD(j) = X0IND(j)/L(j)$	$j\in IND$	N_I	(2.55)
$X0IND(j) = \psi_{X0INDj}[X0(1,1,j), \ldots, X0(N_{JC},1,j)]$	$j\in IND$	N_I	(2.56)
$LPROD(j) = \Sigma_{q\in LABGP}DLG(j,q)*FLPRODG(q) + FLPROD(j)$	$j\in IND$	N_I	(2.57)
$W(j) = WTOT*FW(j)*FWTOT$	$j\in IND$	N_I	(2.58)
$WTOT = \psi_{WTOT}[W(1), \ldots, W(N_I)]$		1	(2.59)
$P3(i) = P3OBS(i) + ADJP3$	$i\in COM$	N_C	(2.60)

….continued

Table 2.1 continued

Equation		Dimension	Identifier
$PE(i,d) = PEOBS(i,d) + ADJPE$	$i \in COM, d \in DEST$	$N_C N_D$	(2.61)
(k) Equations for facilitating policy simulations			
$\left[\frac{WR}{WR_f} - 1\right] = \left[\frac{WR_{lag}}{WR_{f,lag}} - 1\right] + \alpha\left[\frac{LTOT}{LTOT_f} - 1\right] + F_{WR}$		1	(2.62)
(*l*) The government accounts			
$PSD = \Sigma_s \Sigma_i P_s(i)*X5(i,s) - \Sigma_s \Sigma_k [T3G(k)*T3TG - 1]*P_s(k)*X3(k,s)$			
$- \Sigma_i \Sigma_r (TM(i,r)-1)*[PM(i,r)/\Phi(r)]*X0IMPR(i,r) - \Sigma_i \Sigma_d (T4G(i,d)-1)*P_{1d}(i,d)*X4D(i,d)$			
$- \Sigma_{j \in IND}[T0G(j)-1]*\Sigma_{i \in COM} P_1(i)*X0(i,1,j) + TRANSFERS$		1	(2.63)
(m) Equations for facilitating decomposition simulations			
$NFLF = \psi_{NFLF}(NFLF_{-\tau}, KTOT/KTOT_{-\tau}, APC*GNP/[APC_{-\tau}*GNP_{-\tau}], \Phi/\Phi_{-\tau})$			
$+ F_{NFLF}$		1	(2.64)
$GNP = GDP - R0IF*(NFLF/\Phi)$		1	(2.65)
$C + G = APC*GNP$		1	(2.66)
(n) Balance of payments			
$NFLF_+ = NFLF + CAD*\Phi$		1	(2.67)
$CAD = \Sigma_i \Sigma_r [PM(i,r)/\Phi(r)]*X0IMPR(i,r) - \Sigma_i \Sigma_d [PE(i,d)/\Phi(d)]*X4D(i,d)$			
$+R0IF*(NFLF/\Phi)$		1	(2.68)
(o) Household disposable income and consumption function			
$HDY = GNP - \Sigma_s \Sigma_k [T3G(k)*T3TG - 1]*P_s(k)*X3(k,s)$			
$- \Sigma_i \Sigma_r (TM(i,r)-1)*[PM(i,r)/\Phi(r)]*X0IMPR(i,r) - \Sigma_i \Sigma_d (T4G(i,d)-1)*P_{1d}(i,d)*X4D(i,d)$			
$- \Sigma_{j \in IND}[T0G(j)-1]*\Sigma_i P_1(i)*X0(i,1,j)+TRANSFERS$		1	(2.69)
$C = F_C * HDY$		1	(2.70)
Total number of equations:			
$N_C N_S N_C + 2N_C N_S N_I + N_C N_I + 4N_C N_S + 2N_C N_R + 4N_C N_D + 17N_I + 10N_C + N_{LG} + 28$			

Table 2.2. Notation in the Schematic Model

		Dimension
I. Exogenous variables in a typical policy closure		
A0(i,j)	Allows for output-augmenting technical changes in joint-product industries	$N_C N_I$
A1(i)	Allows for commodity-i-using technical changes	N_C
A3(i)	Allows for commodity-using household preference changes	N_C
A3MAR(k,s,i)	Margin use of commodity i (domestic) per unit flow of (k,s) to households	$N_C N_S N_C$
ADJP3	Adjustment to observed consumer prices	1
ADJPE	Adjustment to observed export prices	1
Φ(q)	Bilateral exchange rates	N_R+N_D
F4(i,d)	Commodity/destination shifter in export-demand functions	$N_C N_D$
F4C(i)	Commodity shifter in export-demand functionsN_C	
F4D(d)	Destination shifter in export-demand functionsN_D	
F4GEN	Allows uniform horizontal shift in export demands	1
F5(i,s)	Allows commodity-composition shifts in other demands	$N_C N_S$
F5TOT	Allows uniform shift in other demands for commodities	1
F_C	Average propensity to consume out of household income	1
F_{KG}(j)	Industry-specific capital-growth shift term	N_I
F_{WR}	Slack in wage-determination equation	1
FA_{PF}(j)	Allows for primary-factor-augmenting changes by industry	N_I
FF_{KG}	All-industry capital-growth shift term	1
FFA_{PF}	Allows for all-industry primary-factor augmenting technical change	1
FFTWIST	Allows for all-commodity import/domestic twist	1
FFTWLK	Allows for all-industry labor/capital twist	1
FLPRODG(q)	Can be used to impose assumptions for labor productivity in industry groups	N_{LG}
$FTOT_{EROR}$	Overall shifter for rates of return	1
FTWLK(j)	Allows for labor/capital twist by industry	N_I
FTWIST(i)	Allows for import/domestic twist by commodity	N_C
FW(j)	Industry shifter for the price of labor	N_I

….continued

Table 2.2 continued

		Dimension
K(j)	Start-of-year capital stock in industry j	N_I
$LTOT_f$	Forecast for total employment	1
NFLF	Start-of-year net foreign liabilities in foreign currency	1
PM(i,r)	Foreign currency c.i.f. prices of imports from region r	$N_C N_R$
ROIF	Rate of interest or dividend on net foreign liabilities	1
T0G(j)	Power of genuine tax on production in industry j	N_I
T0PH(j)	Powers of phantom taxes on production	N_I
T3G(k,s)	Allows changes in power of genuine tax on household consumption of (k,s)	$N_C N_S$
T3PH(i)	Powers of phantom taxes on household consumption	N_C
T3TG	Allows uniform changes in powers of genuine taxes on household consumption	1
T4G(i,d)	Power of genuine tax on exports of commodity i to destination d	$N_C N_D$
T4PH(i)	Powers of non-spreading phantom taxes on exports	N_C
T4SPH(i)	Powers of spreading phantom taxes on exports	N_C
TM(i,r)	Power of tariff on imports of commodity i from region r	$N_C N_R$
TRANSFERS	Transfers from the public sector to households, e.g., unemployment benefits and interest on the public debt	1
WR_{lag}	Real wage rate in previous year	1
$WR_{f,lag}$	Forecast for real wage rate in previous year	1
WR_f	Forecast for real wage rate	1
II. Endogenous variables in a typical policy closure		
A0AVE(j)	Average output-augmenting technical change	N_I
A3AVE	Average of commodity-augmenting changes in household tastes	1
A_{PF}(j)	Primary-factor-augmenting technical change	N_I
APC	Average propensity to consume (public and private) out of GNP	1
BOTR	Real balance of trade	1
C	Total household expenditure	1
CAD	Current account deficit	1

….continued

Table 2.2 continued

		Dimension
CPI	Consumer price index	1
CR	Real household consumption	1
CR_{PP}	Real consumption, private and public	1
EROR(j)	Expected rate of return in industry j	N_I
EXPVOL	Aggregate volume of exports	1
Φ	Exchange rate (average of bilateral rates)	1
F_{EROR}(j)	Industry-specific shifter for rates of return	N_I
F_{NFLF}	Slack in decomposition equation for net foreign liabilities	1
FLPROD(j)	Allows labor productivity to vary between industries in the same group q, $q \in LABGP$	N_I
FWTOT	All-industry shifter on wage rates	1
G	Government expenditure	1
GDP	Gross domestic product, nominal	1
GDPR	Gross domestic product, real	1
GNP	Gross national product	1
HDY	Household disposable income	1
IKRATIO(j)	Ratio of investment to capital in industry j	N_I
IMPVOL	Aggregate volume of imports	1
IR	Total real investment	1
K_+(j)	End-of-year stock of capital in industry j	N_I
KTOT	Total start-of-year capital stock	1
L(j)	Employment in industry j	N_I
LG(q)	Employment in qth group of industries	N_{LG}
LPROD(j)	Labor productivity by industry	N_I
LTOT	Total employment	1
$NFLF_+$	End-of-year net foreign liabilities in foreign currency	1
OTHREAL	Real government expenditure	1
P_1(i)	Basic prices of domestic commodities	N_C

….continued

Table 2.2 continued

		Dimension
P_{1d}(i,d)	Basic prices of domestic commodities	$N_C N_D$
P_2(i)	Basic prices of composite imported commodities	N_C
P_{2r}(i,r)	Basic prices of imported commodity i from region r	$N_C N_R$
P3(i)	Price to households of commodity i	N_C
$P3_1$(i),	Vector of household purchasers' prices for domestic commodities	N_C
$P3_2$(i)	Vector of household purchasers' prices for imported commodities	N_C
P3OBS(i)	Observed consumer prices	N_C
P5	Price index for government expenditure	1
PE(i,d)	Foreign-currency prices of exports i	$N_C N_D$
PEOBS(i,d)	Observed export prices	$N_C N_D$
PI(j)	Asset price of capital in industry j	N_I
PSD	Public sector deficit	1
Q(j)	Rental rate on capital in industry j, j∈IND	N_I
T0(j)	Power of tax (1 + rate) on production in industry j	N_I
T3(i,s)	Power of tax on consumption commodity (i,s)	$N_C N_S$
T4(i)	Power of tax on exports of commodity i	N_C
TOFT	Terms of trade	1
TWIST(i)	Import/domestic twist by commodity	N_C
W(j)	Wage rates by industry	N_I
WR	Real wage rate	1
WTOT	Average wage rate across industries	1
X0(i,1,j)	Output of commodity (i,1) by industry j	$N_C N_I$
X0DOM(i)	Total output of commodity (i,1), i∈COM	N_C
X0IMP(i)	Overall imports of commodity i	N_C
X0IMPR(i,r)	Imports of commodity i from region r	$N_C N_R$
X0IND(j)	Output of industries, j∈IND	N_I
X1(i,s,j)	Input of (i,s) to production in industry j	$N_C N_S N_I$
X2(i,s,j)	Input of (i,s) to j's capital creation	$N_C N_S N_I$

….continued

Table 2.2 continued

		Dimension
X3(i,s)	Household consumption of commodity (i,s)	$N_C N_S$
X3C(i)	Household consumption of commodity i	N_C
X3MAR(k,s,i)	Margin use of domestic good i in facilitating the flow of (k,s) from producers and ports of entry to households	$N_C N_S N_C$
X4(i)	Overall exports of commodity i	N_C
X4D(i,d)	Exports of commodity i to destination d	$N_C N_D$
X5(i,s)	Government consumption of good (i,s)	$N_C N_S$
TWLK(j)	Labor/capital twist by industry	N_I
Y(j)	Investment in industry j	N_I
Z(j)	Activity level in industry j	N_I

Total number of endogenous variables:

$N_C N_S N_C + 2N_C N_S N_I + N_C N_I + 4N_C N_S + 2N_C N_R + 4N_C N_D + 17N_I + 10N_C + N_{LG} + 28$

III. Other notation

α	Positive parameter
$APC_{-\tau}$	Base year average propensity to consume (private and public) out of GNP
COM	Set of commodities
DEP(j)	Depreciation rate in industry j, treated as a parameter
DEST	Set of regions of destination for exports
DLG(j,q)	One if industry j is in the qth labor group, otherwise zero
DOM(s)	One if s = domestic, zero if s = imported
$\Phi_{-\tau}$	Exchange rate in base year (τ years earlier than solution year)
G(q)	Set of industries in the group q
$GNP_{-\tau}$	Base year gross national product
IND	Set of industries
$KTOT_{-\tau}$	Total capital stock in base year (τ years prior to solution year)
LABGP	Set of sectors for which there are historical employment data
N_C	Number of commodities (504 in USAGE-ITC)
N_D	Number of regions of destination for exports

….continued

Table 2.2 continued

N_I	Number of industries (514 in USAGE-ITC)
N_R	Number of regions of origin for imports
N_S	Number of sources (2 in USAGE-ITC, namely domestic and imported)
N_{LG}	Number of sectors for which historical data on employment are available
$NFLF_{-\tau}$	Start-of-year net foreign liabilities in foreign currency in base year (τ years earlier than solution year)
REGIMP	Set of regions of origin for imports
SOURCE	Set of sources of commodities (domestic and imported)
Ψ's	Functions