Economy-Wide Analysis of Regulatory and Competition Policy

A Prototype General Equilibrium Model*

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Abstract:

This document describes the structure and behaviour of a numerical comparative static model of an "almost small" open economy with five primary factors and any number of product markets. Unlike most such models, all firms in all sectors are oligopolistic in behaviour, with the degree of product market power depending on the size of recurrent fixed costs per plant, the elasticity of demand faced by each and the level of strategic interactions between firms, as captured by calibrated "conjectural variations" parameters. Demand facing each firm comprises final consumption, intermediate use and exports, each of which is differently elastic. Physical capital earns a constant, international, rate of return and the length of run is set so that the home capital stock is flexible. Shocks that raise the home capital stock, however, also raise foreign ownership. The policy instruments currently represented are tariffs, export taxes and export subsidies.

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1. Introduction:

The first version of the model was developed by Gunasekera and Tyers (1990) who followed pioneering research into the representation of imperfect competition in general equilibrium by Harris (1984) and Horridge (1987). Further development took place in the early 1990s with applications to Australia, Korea, the Philippines and Japan by Tyers (2004) and Tyers et al. (2004). The model was later extended to allow either quantity interaction with homogeneous product oligopoly or price interaction with differentiated products in each domestic product market (Golley 1993). Further improvements were made on the same basic structure in the late 1990s. The currently operational version of the model is described here.[1]

To keep the model manageable, its structure has been made simpler than many modern computable general equilibrium models. A complete mathematical description is given in Section 3. A broad summary follows. Institutions, principally households and government, are represented by a single consuming household with Cobb-Douglas preferences among types of goods and CES subaggregation of home goods with imports. Firms in all 12 sectors are oligopolistic in their product pricing behaviour, each holding calibrated conjectural variations. Each also bears fixed capital and skilled labour costs, enabling the representation of unrealised economies of scale. But home products in each sector are homogeneous and output is Cobb-Douglas in variable factors and intermediate inputs. The latter are CES subaggregates of home and imported products. The existence of oligopoly power in product markets notwithstanding, firms are price takers in the markets for both primary factors and intermediate inputs.

The five primary factors are capital, skilled labour, production labour, arable land and mineral/energy resources. In the length of run assumed, physical capital is homogeneous and fully mobile internationally while the domestic endowments of the

[1] Note that the version described here differs substantially from the model detailed in the papers describing work with earlier versions, including those by Gunasekera and Tyers (1990), Golley (1993), Tyers (2004) and Tyers et al. (2004). The major differences are in the treatment of intermediate input demand and the pricing behaviour of firms.

other factors are fixed. Land and mineral resources are sector-specific in all lengths of run. Domestically-owned capital is fixed in quantity, so that changes in the domestic capital stock affect the level of income repatriated abroad and hence they have implications for the balance of payments. But, depending on the closure chosen, firms need not earn market returns on capital in this model. If, for example, the entry and exit of firms are prohibited (or even if they are costly) then economic profits or losses occur.

The economy modelled is "almost small" following Harris (1984). It has no power to influence the border prices of its imports but its exports are differentiated from competing products abroad and hence face finite-elastic demand. An exchange rate is defined and its value set to retain any gap in the current account of the balance of payments evident from the model's initial database. Devaluations which retain this degree of imbalance raise the relative cost of imports in the home market and lower the prices of exports relative to competing goods in foreign markets. The numeraire used is a Cobb-Douglas index of composite (home product and import) prices, derived from the single household's expenditure function.[2]

The model was originally designed for solution using two "Walrasian adjustment" algorithms.[3] It has since been written for solution using the Gempack modelling software. This software is particularly useful where numerous changes of closure are required, such as enable the comparison of solutions with, free entry and exit of firms on the one hand and restricted entry on the other.

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[2] Databases, comprising full social accounting matrices, were originally developed for four countries (Australia, the Philippines, Korea and Japan) as detailed by Tyers et al. (1993, Appendix 2).

[3] It was first developed as a FORTRAN program. If firm entry and exit were prohibited, corresponding to the "short run" closure of Harris (1984), the exchange rate and the prices of the four factors which are not internationally mobile were adjusted to remove any excess payments imbalance and to achieve the appropriate degree of factor market clearance. If firm entry and exit were permitted, this solution was embedded in a second iterative process which adjusted the numbers of firms in each sector until incentives for entry and exit no longer existed.

2. Economic Structure and Behaviour

The databases for the model originate with social accounting matrices (SAMs) social accounting matrices of a particular structure (Tyers et al. 2004). These are based on inter-industry transaction accounts with trade flows distinguished and in which payments by firms to each of the primary factors and indirect taxes are identified. Payments to physical capital include pure profits, which are also separated out. The latter are calculated by first applying a “market” rate of return to the capital stock in each identified industry and subtracting the resulting payment from the sector’s capital earnings.

The model is available in two versions. The first has each sector comprising a number of identical oligopolistic firms with each firm bearing recurrent fixed costs. These firms interact on quantity produced. In the second, firms in any sector supply differentiated products and interact on price. In either case, the minimum efficient scale (MES) of firms is defined (following Harris) as the level of output at which average cost exceeds marginal cost by one per cent. Cobb-Douglas production function drives variable costs so that average variable costs are constant if factor and intermediate product prices do not change. Consequently, average total cost always declines with output. The magnitude of recurrent fixed costs can then be calibrated. It depends on the MES and the slope of the average total cost curve. Estimates for these parameters are derived using the Harris approach, as explained in Tyers et al. (2004, Appendix 2).

Of course, to cover fixed costs, firms must be able to set prices above their average variable costs – they must charge a “mark-up”. Their capacity to do this without being undercut by existing competitors then determines the level of any pure profits and the potential for the entry of new firms (new firms always add to each sector’s fixed costs). If entry is free, pure profits attract new entrants and the mark-up over variable costs is exhausted entirely by fixed costs. When the initial pure profits are the result of a distortionary policy, this result is termed "inefficient entry" (Eastman and Stykolt 1966, Horstman and Markusen 1986).

The key, therefore, to the characterisation of imperfectly competitive manufacturing firms is in their product pricing behaviour and, in particular, their capacity to maintain mark-ups over average variable costs. The way policy shocks affect this behaviour, however, and the extent of excessive entry, depends on the number of "representative" identical firms in each sector.

The number of representative identical firms:

The necessity to work with a manageable number of industry categories stretches the assumption that firms in each are identical. The distribution of firm size in such broadly defined industry categories often has a modest number of very large firms and a large number of small firms. This pattern is interpreted as representing small numbers of oligopolistic leading firms depending upon large numbers of relatively competitive suppliers of components.[4] It is then most realistic to model this as an oligopoly among the large firms, each of which incorporates its suppliers of components.[5]

Unrealised scale economies:

A crude indication of the extent to which there has been inefficient entry can be obtained from the ratio of the MES and the average output of representative firms in each industry. The extent to which this exceeds unity indicates the level of unrealised scale economies and hence the extent of prior "excessive entry".

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[4] This characterisation seems particularly appropriate in the cases of Japan and Korea, where large oligopolistic firms have large numbers of smaller affiliates which supply inputs. See, for example, Fruin (1992).

[5] In the cases of the original data bases for Australia, Korea, Japan and the Philippines, the size distribution of manufacturing firms is available in terms of employment. The number of representative firms was then chosen as that including firms with more than 200 employees in the Philippines (World Bank 1987), more than 300 in Japan (Statistics Bureau 1986), and more than 500 in Australia (ABS 1989) and the Republic of Korea (UN 1987).

Pricing behaviour:

The luxuries of excessive entry and pure profits are afforded only by virtue of oligopoly pricing. Two alternative approaches to this are available in the model, both of which capture firms' interactions through conjectural variations parameters.

Interaction on quantities:

In setting their prices, firms are assumed to know the level and elasticity of sectoral demand and the number of their identical competitors. They play a game in the selection of quantities. For this comparative static analysis it is convenient to abstract from the multi-period nature of this game and to represent their capacity to collude by a fixed conjectural variations parameter, μ_i, defined as the influence any individual firm has over the entire output of industry i. Thus, the profit-maximising mark-up, derived by setting marginal revenue equal to marginal cost, $\mathbf{v}_i$ is

$$(1) \quad m_i = \frac{p_i}{v_i} = \frac{1}{1 + \frac{\mu_i}{n_i \varepsilon_i}} \qquad \forall\, i$$

Where ε_i is the price elasticity of demand for home goods in industry i (defined negative), n_i is the number of firms, and the conjectural variations parameter is

$$\mu_i = \frac{\partial Q_i}{\partial q_i}$$

where Q_i and q_i are industry and firm output. Notable values of the conjectural variations parameter are $\mu_i = 0, 1, n_i$, representing perfect competition, non-collusive (Cournot) oligopoly or a colluding cartel.

Interaction on prices:

In this case each firm in industry *i* is regarded as producing a unique variety of its product and it faces a downward-sloping demand curve with elasticity ε_i (<0). The optimal mark-up is then simply:

$$(2) \quad m_i = \frac{p_i}{v_i} = \frac{1}{1+\frac{1}{\varepsilon_i}} \qquad \forall\, i$$

Firms choose their optimal price taking account of the price-setting behaviour of other firms. The conjectural variations parameter is then defined as the influence of any individual firm, *k*, on the price of firm *j*:

$$\mu_i = \frac{\partial p_{ij}}{\partial p_{ik}} \; .$$

Thus, when an industry is a non-collusive (Bertrand) oligopoly in which each firm chooses a price taking the prices of all other firms as given, the conjectural variations parameter is zero. When firms behave as a perfect cartel, it has the value unity. This conjectural variations parameter enters the analysis through the formulation of the varietal demand elasticity.

Elasticities of demand:

The product of each industry can either be consumed directly, used as an intermediate input in another industry or it can be exported. Irrespective of whether the pricing behaviour derives from quantity or price interaction, the elasticity ε_i therefore depends on the shares of the home product going to each of the three markets and the elasticities in each. As explained in the next section, the elasticities of final consumption and export demand depend principally on the elasticities of substitution between home goods and their foreign substitutes. Importantly, in this formulation the precise values of ε_i depend only very weakly on border distortions. When trade policy is changed, the principal mechanism by which ε_i is altered is the redistribution of demand amongst its three, differently elastic, components.

Calibration of key parameters:

Once the fixed cost per firm or plant is established, the conjectural variations parameter, μ_i, can be calibrated from the mark-up indirectly from equations (1) or (2), in the latter case in combination with expressions for the varietal elasticity. The mark-up can, in turn, be derived from the fact that mark-ups over average variable cost cover both fixed costs and pure profits. It can be estimated as the ratio of the sum of these and total product value, drawn from the SAM.

3. The Model in Detail:

Components of the model are presented in the order in which they appear in its original solution algorithm. Although the model is now solved using the Gempack software, the old solution sequence has economic logic and is therefore retained here. The Gempack TAB file, appended to this paper, lists the code used for its solution. An electronic version is available from the author.

A "no entry" solution, in which the numbers of firms is held constant, is first derived. This solution iterates on the vector [e,**w**], comprising the exchange rate, e (expressed as foreign currency units per unit of local currency) and a vector of non-capital factor rewards, **w**. In the reference equilibrium, all elements of this vector are unity, and the search for counterfactual equilibria generally begins with these values. Next, product prices and the quantities produced, consumed and traded are calculated, from which are derived any foreign payments imbalance or any non-capital factor market excess demands or supplies. Depending on the closure chosen, acceptably small values may be required for these disequilibria. To achieve these targets, the exchange rate and the factor rewards are adjusted and the no-entry solution recomputed. If firm entry and exit are permitted, the no-entry solution is tested for economic profits or losses in each industry. If these exceed an acceptable tolerance level, the vector of firm numbers in each sector, **n**, is adjusted and a new no-entry solution is sought. This process is repeated until convergence is achieved and no further incentive remains for firm entry or exit.

The no-entry solution for given [e,**w**]:

The number of representative identical firms, **n** = [n_i, i=1,N sectors] is held constant. The rate of return on capital, r, is also exogenous, since capital is homogeneous and internationally mobile. The initial vector of unit rewards to domestic factors is **w** = [w_k, k=1,K non-capital factors]. The steps are as follows:

1. Demand elasticities facing domestic industries, **ε**

These must be calculated first, since oligopoly pricing behaviour depends on them. They depend on many other variables in the model, however, so it is best that their formulation be described once the core equations of the model have been presented. For now we will take these as given.

2. Mark-ups over marginal (unit variable) cost

In the case of firms interacting on quantity in homogeneous domestic markets, the profit-maximising mark-up is derived by setting marginal revenue equal to unit variable (or marginal) cost, **v**. The result is

$$(3) \qquad m_i = \frac{p_i}{v_i} = \frac{1}{1 + \frac{\mu_i}{n_i \varepsilon_i}} \qquad \forall i$$

Where

$$\mu_i = \frac{\partial Q_i}{\partial q_i}$$

and Q_i and q_i are industry and firm output in sector i, respectively. Note that $\mu_i = 0,1,n_i$ implies, respectively, perfect competition, Cournot oligopoly or a colluding cartel.

Where firms interact on price in differentiated product markets, the mark-up is set at:

$$(4) \qquad m_i = \frac{p_i}{v_i} = \frac{1}{1+\frac{1}{\varepsilon_i}} \qquad \forall i$$

The conjectural variations parameter is then defined as the influence of any individual firm, *k*, on the price of firm *j*:

$$\mu_i = \frac{\partial p_{ij}}{\partial p_{ik}} \; .$$

3. Domestic prices of imported goods

$$(5) \qquad p_i^* = \frac{P_i\,(1+t_i)}{e} \qquad \forall i$$

Where P_i is the (exogenous) foreign currency price of goods produced in the rest of the world, and t_i is the equivalent ad valorem tariff rate.

4. Domestic prices of home products

Production is Cobb-Douglas in variable factors and inputs, with output elasticities α_i for capital, β_{ki} for factors k and γ_{ji} for inputs j. The subaggregation of imported and domestic inputs is CES.

First, unit variable costs are calculated as:

$$(6) \qquad v_i = b_i\, r^{\alpha_i} \prod_{k=1}^{K} w_k^{\beta_{ki}} \prod_{j=1}^{N} [\hat{P}_j^I]^{\gamma_{ji}} \qquad \forall i$$

Where the scale coefficient, b_i, is calibrated from the SAM, as are all the exponents in the equation, and $\hat{P}^I_{ij}$ is a CES composite of home and imported input prices weighted by the domestic and imported shares specific to consuming industry j:

$$\text{(7)} \qquad \hat{P}^I_{ij} = \left[\phi_{ij} p_j^{(1-\sigma_j)} + (1-\phi_{ij}) p_j^{*(1-\sigma_j)} \right]^{\frac{1}{1-\sigma_j}}$$

where ϕ_{ij} is the domestic share of inputs from industry *i* in use by industry j.

Then, domestic prices follow as:

$$\text{(8)} \qquad p_i = m_i v_i \qquad \forall i$$

Together, (6) and (8) yield a set of N log-linear simultaneous equations in p_i which is readily solved by matrix inversion.

5. Unit factor and input demands

These follow from cost minimisation by firms whose production is Cobb-Douglas in variable factors and inputs. Although these firms are oligopolistic in product markets, they are price takers in both factor and input markets.

The unit factor demands for capital and other factors, respectively, are:

$$\text{(9)} \qquad u_i^K = \frac{\alpha_i v_i}{r} \qquad \forall i \text{, and}$$

$$\text{(10)} \qquad u_{ki}^L = \frac{\beta_{ki} v_i}{w_k} \qquad \forall k, i \ .$$

The corresponding unit input demands are just Leontief input-output coefficients, except that their values depend on product and input prices. For home-produced and imported inputs of the product of industry *j* in industry *i*, respectively, they are:

$$\text{(11)} \qquad A_{ij} = \gamma_{ij} \frac{\phi_{ij} v_j}{n_i \hat{P}^I_{ij}} \left(\frac{p_i}{\hat{P}^I_{ij}} \right)^{-\sigma_i} \qquad \forall i, j$$

(12) $$A^*_{ij} = \gamma_{ij} \frac{\left(1-\phi_{ij}\right) v_j}{n^*_i \hat{P}^I_{ij}} \left(\frac{p^*_i}{\hat{P}^I_{ij}}\right)^{-\sigma_i} \qquad \forall\, i, j$$

6. Prices of home product exports in foreign markets:

These depend on the domestic price, p_i, the ad valorem export subsidy rate (with border price as denominator), s_i and the ad valorem equivalent import tariff rate in foreign markets, t_i^*.

(13) $$p^e_i = \frac{p_i\, e\,(1+t^*_i)}{(1+s_i)} \qquad \forall\, i$$

7. Exports:

Foreigners subaggregate home exports and foreign products with elasticity of substitution σ_i^* (defined positive). Their demand for product group i has elasticity $-\Omega_i$ (where Ω_i is also defined positive).

(14) $$X_i = \frac{E_i\, \theta_i\, [\theta_i\, p_i^{e(1-\sigma_i^*)} + (1-\theta_i)\, P_i^{(1-\sigma_i^*)}]^{\rho_i}}{(p^e_i)^{\sigma_i^*}} \qquad \forall\, i$$

Where

$$\rho_i = \left(\frac{\sigma_i^* - \Omega_i}{1 - \sigma_i^*}\right)$$

and θ_i is the calibrated reference share of the home export in total consumption. Note that, when exports are small compared with foreign markets (θ_i is small), foreign demand for home product i has approximate elasticity $-\sigma_i^*$, irrespective of the foreign elasticity of demand for that product group. E_i is also a calibrated constant. These equations combine to form the simpler relation:

(15) $$X_i = \frac{\theta_i}{n_i} \frac{E_i}{\left(\hat{P}^X_i\right)} \left(\frac{p_i}{\hat{P}^X_i}\right)^{-\sigma_i^*} ,$$

where $\hat{P}^{X}_{ij}$ is a CES composite of home and foreign product prices in the foreign market, weighted by foreign consumption shares:

$$(16) \qquad \hat{P}^{I}_{ij} = \left[\phi_{ij} p_j^{(1-\sigma_j)} + \left(1-\phi_{ij}\right) p_j^{*(1-\sigma_j)} \right]^{\frac{1}{1-\sigma_j}} .$$

Thus far, we have been able to solve directly for domestic and imported product prices, the volume of exports and unit factor demands. Despite the simplifying dependence of this solution on an exchange rate and factor prices which are (at this stage) exogenous, solving for the other key variables which characterise the equilibrium involves unavoidable simultaneity. The additional relationships on which the simultaneous solution is based are those which follow.

8. Final demand:

Home consumers are assumed to subaggregate home goods and imports with elasticity of substitution σ_i. They have Cobb-Douglas utility and hence expenditure shares across product groups are constant. Final demand for home goods is therefore:

$$(17) \qquad D_i = \frac{a_i \, Y \, \delta_i \, p_i^{-\sigma_i}}{\delta_i \, p_i^{(1-\sigma_i)} + (1-\delta_i) \, p_i^{*(1-\sigma_i)}} \qquad \forall \, i$$

Where a_i is the calibrated reference expenditure share of product group i, δ_i is the corresponding share of home goods in final demand for group i and Y is aggregate income (GNP). This demand expression can be similarly simplified on the definition of a composite price of home and imported goods:

$$(18) \qquad D_i = \delta_i \frac{a_i Y}{\hat{P}^{F}_{i}} \left(\frac{p_i}{\hat{P}^{F}_{i}} \right)^{-\sigma_i} ,$$

where the composite price is

(19) $$\hat{P}_i^F = \left[\delta_i p_i^{(1-\sigma_j)} + (1-\delta_i) p_j^{*(1-\sigma_j)} \right]^{\frac{1}{1-\sigma_j}},$$

and, in the formulation with firms interacting on price the home share is replaced by:

$$\delta_i = \left(\frac{n_i}{n_i + n_i^*} \right).$$

Similarly, final demand for imports is

(20) $$M_i^D = \frac{a_i Y (1-\delta_i) p_i^{*-\sigma_i}}{\delta_i p_i^{(1-\sigma_i)} + (1-\delta_i) p_i^{*(1-\sigma_i)}} \qquad \forall i$$

Note that, if imports dominate final demand (δ_i approaches zero), the price elasticity of final demand for home goods is approximately $-\sigma_i$. If, on the other hand, home goods dominate the domestic market, the Cobb-Douglas utility in broad categories of goods ensures that the elasticity is approximately -1.

Taking advantage of (A1.14), this demand can also be formulated in terms of the composite price of home and foreign goods in the home market:

(21) $$M_i^D = (1-\delta_i) \frac{a_i Y}{\hat{P}_i^F} \left(\frac{p_i^*}{\hat{P}_i^F} \right).$$

9. Demand for inputs:

This is derived from the input-output coefficients and gross industry output, **Q**. For home inputs of type j it is

(22) $$I_j = \sum_{j=1}^{N} A_{ji} Q_i \qquad \forall j$$

For the corresponding imported inputs it is

(23) $$I_j^* = \sum_{j=1}^{N} A_{ji}^* Q_i \qquad \forall j$$

10. Total imports:

This is simply the sum of final demand with intermediate demand for imported goods.

(24) $M_i = M_i^D + I_i^* \qquad \forall\, i$

11. Gross industry output:

In matrix form, where **Q**=[q_i], this is

(25) $Q = (I - A)^{-1}[D + X]$.

Note that intermediate demand is captured in the inverse Leontief matrix, so that the final parentheses require only final and export demand.

12. Economic profits or losses:

This is revenue derived from mark-ups over unit variable costs, less total fixed costs. For sector i it is

(26) $\pi_i = (p_i - v_i)\, Q_i - n_i\,(r\, f_i^K + w_l\, f_i^L) \qquad \forall\, i$

Where n_i is the number of firms, f_i^K is the fixed capital requirement per firm and f_i^L is the fixed skilled labour requirement per firm in sector i.

13. National income (GNP):

This is the sum of payments to domestically owned factors, the home share of any profits or losses made, net income from tariffs and export subsidies and the net inflow of unrequited transfers, including financial aid.

(27) $Y = r\, K_D + \sum_{k=1}^{K} w_k L_k + \left(\frac{K_D}{K_T}\right)\sum_{i=1}^{N} \pi_i + \sum_{i=1}^{N} p_i^* M_i \left(\frac{t_i}{1+t_i}\right) - \sum_{i=1}^{N} p_i X_i \left(\frac{s_i}{1+s_i}\right) + \frac{B}{e}$

where B is the (exogenous) net inflow of aid, borrowings and other unrequited transfers, measured in foreign currency. K_D is that part of the capital stock which is domestically owned. It is also held constant. By comparison, the measure of GDP referred to in the paper incorporates all income to capital but omits the transfer from abroad.

$$(28) \qquad GDP = r\,K_T + \sum_{k=1}^{K} w_k L_k + \sum_{i=1}^{N} \pi_i + \sum_{i=1}^{N} p_i^* M_i \left(\frac{t_i}{1+t_i}\right) - \sum_{i=1}^{N} p_i X_i \left(\frac{s_i}{1+s_i}\right)$$

14. Total factor demands:

In the case of capital, which is infinitely elastic in supply at exogenous interest rate r, the capital stock, K_T, is the value of capital demanded.

$$(29) \qquad K_T = \sum_{i=1}^{N} (u_i^K Q_i + n_i f_i^K) \ .$$

The demand for skilled labour is

$$(30) \qquad L_1 = \sum_{i=1}^{N} (u_{1i}^L Q_i + n_i f_i^L) \ ,$$

and that for the other factors is

$$(31) \qquad L_k = \sum_{i=1}^{N} u_{ki}^L Q_i \qquad k = 2, K \ .$$

15. Calculating imbalances:

Once the above equations have been used to solve recursively for $\mathbf{p}^*$, $\mathbf{p}$, $\mathbf{p}^e$, and $\mathbf{X}$, and simultaneously for $\mathbf{D}$, $\mathbf{I}$, $\mathbf{M}$, $\mathbf{Q}$, $\boldsymbol{\pi}$, $\mathbf{Y}$, K_T, and $\mathbf{L}$, any imbalances in foreign payments and domestic factor markets can be calculated.

Inflows and outflows on the balance of payments are calculated in domestic currency. Inflows combine export earnings with net transfers, B (set as exogenous in foreign currency).

(32) $$\text{Inflows} = \frac{B}{e} + \sum_{i=1}^{N} p_i X_i$$

Outflows are repatriated earnings on foreign owned capital, the pre-duty cost of imports and the cost of export subsidies.

(33) $$\text{Outflows} = r\,(K_T - K_D) + (1 - \frac{K_D}{K_T}) \sum_{i=1}^{N} \pi_i + \sum_{i=1}^{N} \frac{p_i^* M_i}{1+t_i} + \sum_{i=1}^{N} p_i X_i \left(\frac{s_i}{1+s_i} \right)$$

The external imbalance is then

(34) $$\Delta_e = \frac{\text{inflows}}{\text{outflows}} - 1$$

The corresponding factor market imbalances follow directly from equations (30) and (31), above. They are

(35) $$\Delta_k^L = \frac{L_k}{\bar{L}_k} - 1 \qquad \forall\, k$$

Where $\bar{L}_k$ is the full domestic endowment of factor k. These imbalances enter the algorithm by which the exchange rate and factor prices are adjusted in search of the no-entry general equilibrium.

16. The solution algorithm

The objective is to calculate the vector [e,**w**], which we shall call $\boldsymbol{\omega}$, yielding a vector of imbalances $\boldsymbol{\Delta}=[\Delta_e,\boldsymbol{\Delta}^L]$ which is suitably close to **0**. A variant of Newton's Method is used. Extensive use is made of the above no-entry solution for given $\boldsymbol{\omega}$. At the outset, a matrix of derivatives is calculated by imposing small shocks on $\boldsymbol{\omega}$ and calculating the associated changes in $\boldsymbol{\Delta}$. This matrix, **H**, has the following elements:

(36) $$h_{ij} = \frac{\Delta_i^1 - \Delta_i^0}{\left(\frac{\omega_j^1 - \omega_j^0}{\omega_j^0} \right)} \qquad \forall\, i, j$$

Where the superscript 0 indicates reference values and superscript 1 indicates those following s small shock to **ω**.

In any iteration m,

$$(37) \qquad \Delta^{m} - \Delta^{m-1} = H\left(\frac{\omega^{m} - \omega^{m-1}}{\omega^{m}}\right)$$

But the objective is to choose the new values of **ω**, $\boldsymbol{\omega}^{m}$, so that $\boldsymbol{\Delta}^{m}=\mathbf{0}$. Imposing this yields

$$(38) \qquad \omega^{m} = \omega^{m-1}(1 - H^{-1}\Delta^{m-1})$$

Thus, the solution is derived by successive application of (A1.29) until **Δ** is within a suitable tolerance of **0**.

The solution with firm entry and exit

Where firm entry and exit are allowed, a common closure requires that this take place to exhaust all economic profits. The objective is then to calculate the vector **n** which yields **π**(**n**)=**0**. The imbalance used in this case is the excess rate of return on capital.

$$(39) \qquad \Delta_i^{n} = \frac{\pi_i}{K_i} \qquad \forall i$$

where K_i is the total demand for capital in sector i.

$$(40) \qquad K_i = u_i^{K} Q_i + n_i f_i^{K} \qquad \forall i$$

The algorithm used is very similar to that used in the no-entry solution to solve for **ω**. A matrix of derivatives is approximated by first disturbing elements of the vector **n** slightly and using the complete no-entry solution to calculate the resulting changes in **π**, and hence in $\boldsymbol{\Delta}^{n}$. An adjustment rule identical to equation (A1.29) is then applied at each iteration, until $\boldsymbol{\Delta}^{n}$ is within a suitable tolerance of **0**.

The elasticity of demand facing domestic industries

The sources of demand for home products are final demand, intermediate demand and export demand. For sector i, the elasticity sought is a composite of the elasticities of all three sources of demand.

$$(41) \qquad \varepsilon_i = s_i^F \varepsilon_i^F + s_i^I \varepsilon_i^I + s_i^X \varepsilon_i^X \qquad \forall i$$

Where s here designates the volume share of the home product in each source of demand (thus, $s_i^F + s_i^I + s_i^X = 1 \quad \forall i$). In the solution to the model the aggregation of (42) is done in such a way as to ensure that all the shares, s_i^F, s_i^I, s_i^X and s_{ij}^I are fully endogenous: they are up-dated at each iteration. The values of the elasticities, however, differ depending on whether firms interact on quantity or price.

Firms interact on quantities:

Beginning with final demand, differentiating (A1.12) yields

$$(42) \qquad \varepsilon_i^F = -\sigma_i + \left(\frac{p_i D_i}{a_i Y} \right) (\sigma_i - 1) \qquad \forall i$$

Where the share in parentheses is that of home goods in final demand for product group i. Its value in the reference SAM is δ_i.

Turning then to export demand, differentiating (A1.11) yields

$$(43) \qquad \varepsilon_i^X = -\left(\frac{\theta_i \Omega_i p_i^{e(1-\sigma_i^*)} + (1-\theta_i) \sigma_i^* P_i^{(1-\sigma_i^*)}}{\theta_i p_i^{e(1-\sigma_i^*)} + (1-\theta_i) P_i^{(1-\sigma^*)}} \right) \qquad \forall i$$

Note that this is a weighted average of the elasticities $-\Omega$ and $-\sigma^*$. In the likely even that θ_i is small, the approximate value of this elasticity is $-\sigma_i^*$.

Finally, turning to intermediate demand, we follow Harris (1984) in approximating this component elasticity on the assumption that gross sectoral output, $\mathbf{Q}_j$, is unaffected by the price of any individual input, i. Analytical expressions for ε_i^I, for the case in which this assumption is relaxed, are available on request from the authors. These lengthy expressions have not been used in the current version.

From (22)

$$(44) \qquad \frac{\partial I_i}{\partial p_i} = \sum_{j=1}^{N} Q_j \frac{\partial A_{ij}}{\partial p_i} \qquad \forall i$$

Then, expanding A_{ij} using (6) and (11) then deriving the elasticity:

$$(45) \qquad \varepsilon_i^I = \sum_{j=1}^{N} s_{ij}^I \left[-\sigma_i + \phi_i \left(\gamma_{ij} - 1 \right) \left(\frac{p_i}{\hat{P}_i^I} \right)^{1-\sigma_i} \right],$$

Where s_{ij}^I is the share of industry j in the total intermediate demand for input i.

Firms interact on prices:

The corresponding expressions for the case where firms interact on price depend, additionally, on the numbers of home and foreign firms and the conjectural variations parameters. These elasticity expressions are due to Golley (1993). For final demand we have:

$$(46) \qquad \varepsilon_i^F = -\sigma_i + \mu_i \left(\sigma_i - 1 \right) \left(\frac{n_i}{n_i + n_i^*} \right) \left(\frac{p_i}{\hat{P}_i^F} \right)^{1-\sigma_i} .$$

For exports:

$$(47) \qquad \varepsilon_i^X = -\sigma_i + \mu_i \left(\sigma_i^* - \Omega_i \right) \theta_i \left(\frac{p_i}{\hat{P}_i^F} \right)^{1-\sigma_i} .$$

Recall that θ_i is the share of home varieties in foreign markets for the good *i*.

And, for intermediate demand the precise formulation is:

$$(48) \qquad \varepsilon_i^I = \sum_{j=1}^{N} s_{ij}^I \left[-\sigma_i + \mu_i \left(\gamma_{ij} + \sigma_i - 1 \right) \left(\frac{n_i}{n_i + n_i^*} \right) \left(\frac{p_i}{\hat{P}_i^I} \right)^{1-\sigma_i} \right],$$

where s_{ij}^I is the share of industry j in the total intermediate demand for input *i*.

4. Developments in Progress

At present, the model has three important deficiencies for regulatory analysis. First, it represents a single collective household for which saving and investment are not distinguished. This implies the assumptions that the saving-investment balance is fixed at the exogenous capital account constant, B, and that the composition of investment demand in the home economy is the same as the combination of final and intermediate demand. These assumptions are acceptable so long as experiments do not shock the international rate of return. They are inappropriate for regulatory analysis, however, wherein rates of return are policy targets.

Second, it does not distinguish the government from the collective household. Net revenues from tariffs and export taxes are transferred to the collective household lump sum. This assumption is acceptable for work on trade reforms. For regulatory analysis, however, a more complete representation of government consumption and fiscal behaviour is required. And third, there is no non-border tax system. This is required in order that the regulatory environment of oligopolistic firms might be accurately represented. During 2004 funding is being sought to support the extension of the model in these three areas.

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Appendix
Tablo Input File for Gempack Software

```
!--------------------------------------------------------------------!
!                  Mixed TABLO Input file for the                    !
!                Imperfect competition CGE (D version)               !
!                                                                    !
!         Gempack version of IC CGE, version with differentiated     !
!           products by firm, single open economy.                   !
!                                                                    !
!--------------------------------------------------------------------!

! Text between exclamation marks is a comment.                       !
! Text between hashes (#) is labelling information.                  !

!--------------------------------------------------------------------!
!     Set default values                                             !
!--------------------------------------------------------------------!

VARIABLE (DEFAULT = LEVELS) ;
EQUATION (DEFAULT = LEVELS) ;
COEFFICIENT (DEFAULT = PARAMETER) ;
FORMULA (DEFAULT = INITIAL) ;

!--------------------------------------------------------------------!
!       Files                                                        !
!--------------------------------------------------------------------!

FILE  cgeddata # File containing the parameter values #;
FILE (NEW) cgedbase # File for initial values of endogenous variables
# ;


!--------------------------------------------------------------------!
!      Sets                                                          !
!--------------------------------------------------------------------!

SET IND # Industries #
(agriculture,
mining,
services,
processfood,
textiles,
woodpaper,
chemicals,
petrolmcoal,
mineralprod,
transptequip,
machinery,
miscmanuf);

SET KNC # Non-capital factors #  (skill, labour, land, minres);


!--------------------------------------------------------------------!
!      Levels variables                                              !
!--------------------------------------------------------------------!
```

```
!       Database and parameters                                          !
!------------------------------------------------------------------------!

COEFFICIENT(INTEGER) (all,k,KNC)                             FTYPE(k)
        # indices from set KNC, for IF conditions # ;

COEFFICIENT (all,i,IND)                                      AS(i)
        # share of product i in home final consumption #;

COEFFICIENT  (all,i,IND)                                     B(i)
        # coefficient of variable cost fn #;

COEFFICIENT (all,i,IND)                                      EC(i)
        # coef of world demand function for commodity i #;

COEFFICIENT (all,i,IND)                                      ALPHA(i)
        # output elasticity of K in industry i #;

COEFFICIENT (all,i,IND)                                      DELTA(i)
        # home share in final demand for product i #;

COEFFICIENT (all,i,IND)                                      THETA(i)
        # home share in foreign demand for product i #;

COEFFICIENT (all,i,IND)                                      SIGMAF(i)
        # el of subsn final demand imports to home #;

COEFFICIENT (all,i,IND)                                      SIGMAI(i)
        # el of subsn intermediate demand imports to home #;

COEFFICIENT (all,i,IND)                                      SIGMAW(i)
        # el of subsn foreign demand home goods to foregn #;

COEFFICIENT (all,i,IND)                                      OMEGA(i)
        # elast of world demand for product i, defined +ve #;

COEFFICIENT (all,i,IND)                                      FK(i)
        # fixed capital requirement per firm in i #;

COEFFICIENT (all,i,IND)                                      FL(i)
        # fixed labour requirement per firm in i #;

COEFFICIENT (all,i,IND) (all,k,KNC)                          BETA(i,k)
        # output elasticity of factor k in industry i #;

COEFFICIENT (all,i,IND) (all,j,IND)                          GAMA(i,j)
        # share of input i in total variable cost of j #;

COEFFICIENT (all,i,IND) (all,j,IND)                          PHI(i,j)
        # reference home share of input i in industry j #;


!------------------------------------------------------------------------!
!     Exogenous variables                                                !
!------------------------------------------------------------------------!

!       Policy variables                                                 !
```

```
!-------------------------------------------------------------------!

VARIABLE                                                  RR
        # exogenous foreign real rate of return #;

VARIABLE                                                  KD
        # domestically owned capital #;

VARIABLE (all,i,IND)                                      PW(i)
        # foreign currency price of foreign-sourced products #;

VARIABLE (all,i,IND)                                      TMD(i)
        # power of home ad-valorem tariff on imports #;

VARIABLE (all,i,IND)                                      SXD(i)
        # power of home ad-valorem export subsidy #;

VARIABLE (all,i,IND)                                      TMF(i)
        # power of foreign ad-valorem tariff on home exports #;

VARIABLE (all,i,IND)                                      CONVA(i)
        # conjectural variations parameter in i #;

VARIABLE                                                  BAL
        # net inflow balancing item on BOP #;

VARIABLE (all,k,KNC)                                      LBAR(k)
        # endowment of domestic non-capital factors #;

VARIABLE (all,i,IND)                                      ND(i)
        # no. varieties produced in domestic industry i #;


!-------------------------------------------------------------------!
!     Endogenous variables                                          !
!-------------------------------------------------------------------!
!-------------------------------------------------------------------!

!     Those that switch with BAL, LBAR(k) and ND(i)                 !
!-------------------------------------------------------------------!

VARIABLE                                                ER
        # exchange rate, foreign/home #;

VARIABLE (all,k,KNC)                                    W(k)
        # unit factor rewards, non-capital # ;

VARIABLE (all,i,IND)                                    PI(i)
        # economic profit in industry i #;


!        Variables that are always endogenous                       !
!-------------------------------------------------------------------!
!                                                                   !
!            Prices                                                 !
!-------------------------------------------------------------------!

VARIABLE (all,i,IND)                                    PSTAR(i)
        # home price of imports in i #;
```

```
VARIABLE (all,i,IND)                                    P(i)
        # home price of home products in i #;

VARIABLE (all,i,IND)                                    PE(i)
        # foreign currency price of home goods #;

VARIABLE (all,i,IND)                                    PINDF(i)
        # price index of i in final demand: home & imports #;

VARIABLE (all,i,IND) (all,j,IND)                        PINDI(i,j)
        # price index, input i industry j: home prod & imports #;

VARIABLE (all,i,IND)                                    PINDX(i)
        # price index of i abroad: exports & foreign products #;

VARIABLE (all,k,KNC)                                    RW(k)
        # Real unit factor rewards, non-capital # ;

VARIABLE                                                CPI
        # Cobb-Douglas consumer price index #;


!        Elasticities and demand shares                          !
!----------------------------------------------------------------!

VARIABLE (all,i,IND)                                    EPS(i)
        # elast of total demand facing home firms in i #;

VARIABLE (all,i,IND)                                    EPSF(i)
        # elast of final demand facing home firms in i #;

VARIABLE (all,i,IND)                                    EPSI(i)
        # elast of intermediate demand facing home firms in i #;

VARIABLE (all,i,IND)                                    EPSX(i)
        # elast of export demand facing home firms in i #;

VARIABLE (all,i,IND)                                    SF(i)
        # final demand share in i #;

VARIABLE (all,i,IND)                                    SI(i)
        # intermediate demand share in i #;

VARIABLE (all,i,IND) (all,j,IND)                        SIND(i,j)
        # share of industry j in total int demand for i #;

VARIABLE (all,i,IND)                                    SX(i)
        # export demand share in i #;


!        Qantities                                               !
!----------------------------------------------------------------!

VARIABLE (all,i,IND)                                    Q(i)
        # gross output of home industry i #;

VARIABLE (all,i,IND)                                    DF(i)
        # home final demand for home product i #;
```

```
VARIABLE (all,i,IND)                                MF(i)
        # home final demand for imports of i #;

VARIABLE (all,i,IND)                                DI(i)
        # home intermediate demand for home produced i #;

VARIABLE (all,i,IND)                                MI(i)
        # home intermediate demand for import i #;

VARIABLE (all,i,IND)                                M(i)
        # total import demand for i #;

VARIABLE (all,i,IND)                                X(i)
        # export demand for home product i #;

VARIABLE (all,i,IND) (all,j,IND)                    A(i,j)
        # home i in home industry j per unit output of j #;

VARIABLE (all,i,IND) (all,j,IND)                    ASTAR(i,j)
        # imported i in home industry j per unit output of j #;


!         Miscellaneous                                       !
!--------------------------------------------------------------------!

VARIABLE                                            GNP
        # GNP #;

VARIABLE                                            GDP
        # GDP #;

VARIABLE                                            RGNP
        # Real GNP #;

VARIABLE                                            RGDP
        # Real GDP #;

VARIABLE                                            KT
        # total capital use #;

VARIABLE                                            INFLOW
        # BOP inflows #;

VARIABLE                                            OUTFLW
        # BOP outflows # ;

VARIABLE                                            KSURP
        # Surplus on capital account of BOP #;

VARIABLE                                            XRNGS
        # Export earnings on BOP #;

VARIABLE                                            RINFLO
        # Real BOP inflows #;

VARIABLE                                            FRETN
        # Foreign return on capital in BOP #;
```

```
VARIABLE                                                RPROF
        # Repatriated profits in BOP #;

VARIABLE                                                CIMPT
        # Real cost of imports on BOP #;

VARIABLE                                                CXS
        # Cost of export subsidies in BOP #;

VARIABLE                                                ROUTFL
        # Real outflow on the BOP #;

VARIABLE (all,k,KNC)                                    L(k)
        # total non-capital factor use #;

VARIABLE (all,i,IND)                                    MKUP(i)
        # markup ratio in industry i #;

VARIABLE (all,i,IND)                                    UVC(i)
        # unit variable cost in i #;

VARIABLE (all,i,IND)                                    FC(i)
        # total fixed cost in industry i #;

VARIABLE (all,i,IND)                                    UK(i)
        # unit capital demand in i #;

VARIABLE (all,i,IND) (all,k,KNC)                        UF(i,k)
        # unit non-capital factor demand in i #;


!--------------------------------------------------------------------!
!      Reads from the data file                                      !
!--------------------------------------------------------------------!

READ FTYPE from FILE cgeddata HEADER "FTP";
READ RR     FROM FILE cgeddata HEADER "RR";
READ KD from FILE cgeddata HEADER "KD";
READ KT from FILE cgeddata HEADER "KT" ;
READ W from FILE cgeddata HEADER "W" ;
READ LBAR from FILE cgeddata HEADER "LBAR";
READ FL from FILE cgeddata HEADER "FL" ;
READ FK from FILE cgeddata HEADER "FK" ;
READ TMD from FILE cgeddata HEADER "TMD" ;
READ TMF from FILE cgeddata HEADER "TMF" ;
READ SXD from FILE cgeddata HEADER "SXD" ;
READ ND from FILE cgeddata HEADER "ND" ;
READ OMEGA from FILE cgeddata HEADER "OMEG" ;
READ SIGMAF from FILE cgeddata HEADER "SIGF" ;
READ SIGMAI from FILE cgeddata HEADER "SIGI" ;
READ SIGMAW from FILE cgeddata HEADER "SIGW" ;
READ DELTA from FILE cgeddata HEADER "DELT" ;
READ THETA from FILE cgeddata HEADER "THTA" ;
READ EC from FILE cgeddata HEADER "EC" ;
READ CONVA from FILE cgeddata HEADER "CONV" ;
READ ALPHA from FILE cgeddata HEADER "ALPH" ;
READ (all,i,IND) (all,k,KNC) BETA(i,k)
```

```
      FROM FILE cgeddata HEADER "BETA";
READ (all,i,IND) (all,j,IND) GAMA(i,j)
      FROM FILE cgeddata HEADER "GAMA";
READ AS from FILE cgeddata HEADER "AS" ;
READ B from FILE cgeddata HEADER "B" ;
READ (all,i,IND) (all,j,IND) PHI(i,j)
      FROM FILE cgeddata HEADER "PHI";
READ BAL FROM FILE cgeddata HEADER "BAL";
READ GNP FROM FILE cgeddata HEADER "GNP";
READ Q FROM FILE cgeddata HEADER "Q";


!-------------------------------------------------------------------!
!       Formulae to set fixed parameters not read in                !
!-------------------------------------------------------------------!

 FORMULA (all,i,IND) PW(i) = 1.0/TMD(i) ;


!-------------------------------------------------------------------!
!       Formulae to set initial values of some endogenous vbles     !
!-------------------------------------------------------------------!

FORMULA (all,i,IND) P(i) = 1.0 ;


FORMULA  ER = 1.0 ;

FORMULA (all,k,KNC) W(k) = 1.0 ;

FORMULA
(all,i,IND) PSTAR(i) = PW(i) * TMD(i)/ER ;

FORMULA
(all,i,IND) PE(i) = P(i)*ER*TMF(i)/SXD(i) ;

FORMULA
(all,i,IND) PINDF(i) = (DELTA(i)*P(i)^(1-SIGMAF(i))+(1-DELTA(i))*
                        PSTAR(i)^(1-SIGMAF(i)))^(1/(1-SIGMAF(I))) ;

FORMULA
(all,i,IND) (all,j,IND) PINDI(i,j) = (PHI(i,j)*P(i)^(1-
      SIGMAI(i))+
                        (1-PHI(i,j))*PSTAR(i)^(1-SIGMAI(i)))
                        ^(1/(1-SIGMAI(i))) ;

FORMULA
(all,i,IND) PINDX(i) = (THETA(i)*PE(i)^(1-SIGMAW(i))+(1-THETA(i))*
                        PW(i)^(1-SIGMAW(i)))^(1/(1-SIGMAW(i))) ;

FORMULA
(all,i,IND) UVC(i) = EXP(LOGE(B(i)) + ALPHA(i)*LOGE(RR) +
         SUM(k,KNC,BETA(i,k)*LOGE(W(k))) +
       SUM(j,IND,GAMA(j,i)*LOGE(PINDI(j,i)))) ;

FORMULA
(all,i,IND) MKUP(i) = P(i)/UVC(i) ;
```

```
FORMULA
(all,i,IND) UVC(i) = EXP(LOGE(B(i)) + ALPHA(i)*LOGE(RR) +
         SUM(k,KNC,BETA(i,k)*LOGE(W(k))) +
       SUM(j,IND,GAMA(j,i)*LOGE(PINDI(j,i)))) ;

FORMULA
(all,i,IND) UK(i) = ALPHA(i)*UVC(i)/RR ;

FORMULA
(all,i,IND) (all,k,KNC) UF(i,k) = BETA(i,k)*UVC(i)/W(k);

FORMULA
(all,i,IND) (all,j,IND) A(i,j) = (GAMA(i,j)*PHI(i,j)*UVC(j)
          /PINDI(i,j))*(P(i)/PINDI(i,j))^(-SIGMAI(i)) ;

FORMULA
(all,i,IND) (all,j,IND) ASTAR(i,j) = (GAMA(i,j)*(1-PHI(i,j))*
          UVC(j)/PINDI(i,j))*(PSTAR(i)/PINDI(i,j))^(-SIGMAI(i)) ;

FORMULA
(all,i,IND)  X(i) = (THETA(i)*EC(i)/PINDX(i)^OMEGA(i))*
                     (PE(i)/PINDX(i))^(-SIGMAW(i));

FORMULA

(all,i,IND)  DF(i) = (DELTA(i)*AS(i)*GNP/PINDF(i))*(P(i)/
                     PINDF(i))^(-SIGMAF(i));

FORMULA
(all,i,IND)  MF(i) = ((1-DELTA(i))*AS(i)*GNP/PINDF(i))*(PSTAR(i)/
                     PINDF(i))^(-SIGMAF(i));

FORMULA
(all,i,IND)  DI(i) = SUM(j,IND,A(i,j)*Q(j));

FORMULA
(all,i,IND)  MI(i) = SUM(j,IND,ASTAR(i,j)*Q(j));

FORMULA
(all,i,IND)  M(i) = MF(i)+MI(i);

FORMULA
(all,i,IND) FC(i) = ND(i)*(RR*FK(i)+SUM(k,KNC,0+
                    IF(FTYPE(k)=1,W(k)*FL(i)))) ;

FORMULA
(all,k,KNC)  L(k) = SUM(i,IND,UF(i,k)*Q(i)+IF(FTYPE(k)=1,ND(i)*FL(i)))
;

FORMULA
             KT = SUM(i,IND,UK(i)*Q(i)+ND(i)*FK(i));

FORMULA
(all,i,IND)  PI(i) = (P(i)-UVC(i))*Q(i)-FC(i) ;

FORMULA
              GDP = RR*KT+SUM(k,KNC,W(k)*L(k))
                   +SUM(i,IND,PI(i))
               +SUM(i,IND,PSTAR(i)*M(i)*(TMD(i)-1)/TMD(i))
```

```
                    -SUM(i,IND,P(i)*X(i)*(SXD(i)-1)/SXD(i));

FORMULA
             INFLOW = BAL/ER + SUM(i,IND,P(i)*X(i));

FORMULA
             OUTFLW = INFLOW ;

FORMULA
(all,i,IND)  SF(i) = DF(i)/Q(i);

FORMULA
(all,i,IND)  SI(i) = DI(i)/Q(i);

FORMULA
(all,i,IND) (all,j,IND)  SIND(i,j) = A(i,j)*Q(j)/DI(i);

FORMULA
(all,i,IND)  SX(i) = X(i)/Q(i);

FORMULA
(all,i,IND)  EPSF(i) = -SIGMAF(i)+(SIGMAF(i)-1)*(DELTA(i)/ND(i))*
                       (1+(ND(i)-1)*CONVA(i))*
                   (P(i)/PINDF(i))^(1-SIGMAF(I));

FORMULA
(all,i,IND)  EPSI(i) = SUM(j,IND,SIND(i,j)*(-SIGMAI(i)+
                       (GAMA(i,j)+SIGMAI(i)-1)*(PHI(i,j)/ND(i))*
                       (1+(ND(i)-1)*CONVA(i))*
                   (P(i)/PINDI(i,j))^(1-SIGMAI(I))));

FORMULA
(all,i,IND)  EPSX(i) = -SIGMAW(i)+(SIGMAW(i)-OMEGA(I))*
                       (THETA(i)/ND(i))*
                       (1+(ND(i)-1)*CONVA(i))*
                   (PE(i)/PINDX(i))^(1-SIGMAW(I));

FORMULA
(all,i,IND)  EPS(i) = SF(i)*EPSF(i)+SI(i)*EPSI(i)+SX(i)*EPSX(i);

FORMULA
             CPI = EXP(SUM(i,IND,AS(i)*LOGE(PINDF(i)))) ;

FORMULA
(all,k,KNC) RW(k) = W(k)/CPI ;

FORMULA
             RGNP = GNP/CPI ;

FORMULA
             RGDP = GDP/CPI ;

FORMULA
             KSURP = BAL/(ER*CPI);

FORMULA
             XRNGS = SUM(i,IND,P(i)*X(i))/CPI ;

FORMULA
```

```
              RINFLO = KSURP + XRNGS ;

FORMULA
              FRETN = RR*(KT-KD)/CPI ;

FORMULA
              RPROF = (1-KD/KT)*SUM(i,IND,PI(i))/CPI ;

FORMULA
              CIMPT = SUM(i,IND,PSTAR(i)*M(i)/TMD(i))/CPI ;

FORMULA
              CXS = SUM(i,IND,P(i)*X(i)*(SXD(i)-1)/SXD(i))/CPI ;

FORMULA
              ROUTFL = FRETN+RPROF+CIMPT+CXS ;


!--------------------------------------------------------------------!
!      Writes to the database file                                   !
!--------------------------------------------------------------------!

WRITE P TO FILE cgedbase HEADER "P"  LONGNAME
"Home prices" ;

WRITE ER TO FILE cgedbase HEADER "ER"  LONGNAME
"Exchange rate" ;

WRITE W TO FILE cgedbase HEADER "W"  LONGNAME
"Non-capital unit rewards" ;

WRITE RW TO FILE cgedbase HEADER "RW"  LONGNAME
"Real non-capital unit rewards" ;

WRITE PSTAR TO FILE cgedbase HEADER "PSTR"  LONGNAME
"Home prices of imports" ;

WRITE PINDF TO FILE cgedbase HEADER "PNDF"  LONGNAME
"Index of final demand prices" ;

WRITE PINDI TO FILE cgedbase HEADER "PNDI"  LONGNAME
"Index of intermediate prices" ;

WRITE PINDX TO FILE cgedbase HEADER "PNDX"  LONGNAME
"Index of prices abroad" ;

WRITE CPI TO FILE cgedbase HEADER "CPI"  LONGNAME
"Consumer price index" ;

WRITE UVC TO FILE cgedbase HEADER "UVC"  LONGNAME
"Unit variable cost" ;

WRITE MKUP TO FILE cgedbase HEADER "MKUP"  LONGNAME
"Mark-up ratios" ;

WRITE UK TO FILE cgedbase HEADER "UK"  LONGNAME
"Unit capital demand" ;

WRITE UF TO FILE cgedbase HEADER "UF"  LONGNAME
```

```
"Unit non-capital demand" ;

WRITE A TO FILE cgedbase HEADER "A"  LONGNAME
"Home good i demand in industry j " ;

WRITE ASTAR TO FILE cgedbase HEADER "ASTR"  LONGNAME
"Import i demand in industry j" ;

WRITE X TO FILE cgedbase HEADER "X"  LONGNAME
"Exports" ;

WRITE DF TO FILE cgedbase HEADER "DF"  LONGNAME
"Final demand" ;

WRITE MF TO FILE cgedbase HEADER "MF"  LONGNAME
"Final demand for imports" ;

WRITE DI TO FILE cgedbase HEADER "DI"  LONGNAME
"Intermediate demand for home goods" ;

WRITE MI TO FILE cgedbase HEADER "MI"  LONGNAME
"Intermediate demand for imports" ;

WRITE M TO FILE cgedbase HEADER "M"  LONGNAME
"Total import demand" ;

WRITE FC TO FILE cgedbase HEADER "FC"  LONGNAME
"Total fixed cost" ;

WRITE L TO FILE cgedbase HEADER "L"  LONGNAME
"Non-capital factor use" ;

WRITE KT TO FILE cgedbase HEADER "KT"  LONGNAME
"Total capital use" ;

WRITE PI TO FILE cgedbase HEADER "PI"  LONGNAME
"Pure profits" ;

WRITE GDP TO FILE cgedbase HEADER "GDP"  LONGNAME
"GDP" ;

WRITE INFLOW TO FILE cgedbase HEADER "INFL"  LONGNAME
"Inflows on BoP" ;

WRITE OUTFLW TO FILE cgedbase HEADER "OUTF"  LONGNAME
"Outflows on BoP" ;

WRITE SF TO FILE cgedbase HEADER "SF"  LONGNAME
"Final demand share" ;

WRITE SI TO FILE cgedbase HEADER "SI"  LONGNAME
"Intermediate demand share" ;

WRITE SX TO FILE cgedbase HEADER "SX"  LONGNAME
"Export demand share" ;

WRITE SIND TO FILE cgedbase HEADER "SIND"  LONGNAME
"Share of industry j in total intermediate demand for product i" ;
```

```
WRITE EPSF TO FILE cgedbase HEADER "EPSF"  LONGNAME
"Elasticity of final demand" ;

WRITE EPSI TO FILE cgedbase HEADER "EPSI"  LONGNAME
"Elasticity of intermediate demand" ;

WRITE EPSX TO FILE cgedbase HEADER "EPSX"  LONGNAME
"Elasticity of export demand" ;

WRITE EPS TO FILE cgedbase HEADER "EPS"  LONGNAME
"Elasticity of total demand" ;

WRITE RGNP TO FILE cgedbase HEADER "RGNP"  LONGNAME
"Real GNP" ;

WRITE RGDP TO FILE cgedbase HEADER "RGDP"  LONGNAME
"Real GDP" ;

WRITE KSURP TO FILE cgedbase HEADER "KSRP"  LONGNAME
"Real value of the capital account surplus" ;

WRITE XRNGS TO FILE cgedbase HEADER "XRNG"  LONGNAME
"Real export earnings" ;

WRITE RINFLO TO FILE cgedbase HEADER "NFLO"  LONGNAME
"Real inflow on the BoP" ;

WRITE FRETN TO FILE cgedbase HEADER "FRTN"  LONGNAME
"Real foreign repatriation of market capital returns" ;

WRITE RPROF TO FILE cgedbase HEADER "RPRF"  LONGNAME
"Real foreign repatriation of pure profits" ;

WRITE CIMPT TO FILE cgedbase HEADER "CMPT"  LONGNAME
"Real cost of imports" ;

WRITE CXS TO FILE cgedbase HEADER "CXS"  LONGNAME
"Real cost of export subsidies on BoP" ;

WRITE ROUTFL TO FILE cgedbase HEADER "ROUT"  LONGNAME
"Real outflow on the BoP" ;


!--------------------------------------------------------------------!
!       Levels equations                                             !
!--------------------------------------------------------------------!

!       Prices                                                       !
!--------------------------------------------------------------------!

EQUATION home_price
   # home price depends on markup rate #
(all,i,IND) P(i) = MKUP(i)*UVC(i) ;

EQUATION markup
   # markup rate depends on elasticity #
(all,i,IND) MKUP(i) = EPS(i) / (1 + EPS(i));

EQUATION import_price
```

```
   # home price of imports #
(all,i,IND) PSTAR(i) = PW(i)*TMD(i)/ER ;

EQUATION Export_price
    # price of exports in foreign currency #
(all,i,IND) PE(i) = P(i)*ER*TMF(i)/SXD(i) ;

EQUATION indexf
   # index of final demand prices #
(all,i,IND) PINDF(i) = (DELTA(i)*P(i)^(1-SIGMAF(i))+(1-DELTA(i))*
                        PSTAR(i)^(1-SIGMAF(i)))^(1/(1-SIGMAF(I))) ;

EQUATION indexi
   # index of intermediate demand prices #
(all,i,IND) (all,j,IND) PINDI(i,j) = (PHI(i,j)*P(i)^(1-
      SIGMAI(i))+
                        (1-PHI(i,j))*PSTAR(i)^(1-SIGMAI(i)))
                        ^(1/(1-SIGMAI(i))) ;

EQUATION indexw
   # index of export demand prices #
(all,i,IND) PINDX(i) = (THETA(i)*PE(i)^(1-SIGMAW(i))+(1-THETA(i))*
                        PW(i)^(1-SIGMAW(i)))^(1/(1-SIGMAW(i))) ;

EQUATION CPIndex
   # consumer price index #
 CPI = EXP(SUM(i,IND,AS(i)*LOGE(PINDF(i)))) ;

EQUATION rwage
   # real unit factor rewards #
(all,k,KNC) RW(k) = W(k)/CPI ;


!-------------------------------------------------------------------!
!           Production, consumption and factor use                  !
!-------------------------------------------------------------------!

EQUATION unit_cost
   # unit variable cost #
(all,i,IND) UVC(i) = EXP(LOGE(B(i)) + ALPHA(i)*LOGE(RR) +
         SUM(k,KNC,BETA(i,k)*LOGE(W(k))) +
       SUM(j,IND,GAMA(j,i)*LOGE(PINDI(j,i)))) ;

EQUATION unitk_demand
    # unit capital demand #
(all,i,IND) UK(i) = ALPHA(i)*UVC(i)/RR ;

EQUATION unitfactor_demands
    # unit non-capital factor demands #
(all,i,IND) (all,k,KNC) UF(i,k) = BETA(i,k)*UVC(i)/W(k);

EQUATION IOcoefs_home
    # input output coeffs for home goods #
(all,i,IND) (all,j,IND) A(i,j) = (GAMA(i,j)*PHI(i,j)*UVC(j)
         /PINDI(i,j))*(P(i)/PINDI(i,j))^(-SIGMAI(i)) ;

EQUATION IOcoefs_imports
    # input output coeffs for imports #
(all,i,IND) (all,j,IND) ASTAR(i,j) = (GAMA(i,j)*(1-PHI(i,j))*
```

```
          UVC(j)/PINDI(i,j))*(PSTAR(i)/PINDI(i,j))^(-SIGMAI(i)) ;

EQUATION Exports
    # Export volume #
(all,i,IND)  X(i) = (THETA(i)*EC(i)/PINDX(i)^OMEGA(i))*
                     (PE(i)/PINDX(i))^(-SIGMAW(i));

EQUATION Final_demandH
    # Final demand for home goods #
(all,i,IND)  DF(i) = (DELTA(i)*AS(i)*GNP/PINDF(i))*(P(i)/
                     PINDF(i))^(-SIGMAF(i));

EQUATION Final_demandM
    # Final demand for imports #
(all,i,IND)  MF(i) = ((1-DELTA(i))*AS(i)*GNP/PINDF(i))*(PSTAR(i)/
                     PINDF(i))^(-SIGMAF(i));

EQUATION Input_demandH
    # Input demand for home goods #
(all,i,IND)  DI(i) = SUM(j,IND,A(i,j)*Q(j));

EQUATION Input_demandM
    # Input demand for imports #
(all,i,IND)  MI(i) = SUM(j,IND,ASTAR(i,j)*Q(j));

EQUATION Total_imports
    # Total imports #
(all,i,IND)  M(i) = MF(i)+MI(i);

EQUATION Gross_output
    # Gross output of home goods #
(all,i,IND)  Q(i) = DF(i)+X(i)+DI(i);

EQUATION Fixed_cost
    # Fixed cost in i #
(all,i,IND) FC(i) = ND(i)*(RR*FK(i)+SUM(k,KNC,0+
                    IF(FTYPE(k)=1,W(k)*FL(i)))) ;

EQUATION GNP_equation
    # GNP #
              GNP = RR*KD+SUM(k,KNC,W(k)*L(k))
                   +(KD/KT)*SUM(i,IND,PI(i))
               +SUM(i,IND,PSTAR(i)*M(i)*(TMD(i)-1)/TMD(i))
                   -SUM(i,IND,P(i)*X(i)*(SXD(i)-1)/SXD(i))
               +BAL/ER;

EQUATION Real_GNP
   # Real GNP #
              RGNP = GNP/CPI ;

EQUATION GDP_equation
    # GDP #
              GDP = RR*KT+SUM(k,KNC,W(k)*L(k))
                   +SUM(i,IND,PI(i))
               +SUM(i,IND,PSTAR(i)*M(i)*(TMD(i)-1)/TMD(i))
                   -SUM(i,IND,P(i)*X(i)*(SXD(i)-1)/SXD(i));

EQUATION Real_GDP
   # Real GDP #
```

```
             RGDP = GDP/CPI ;

EQUATION Capital
    # Total capital use #
            KT = SUM(i,IND,UK(i)*Q(i)+ND(i)*FK(i));

EQUATION Factor_use
    # Total use of factors #
(all,k,KNC)  L(k) =
SUM(i,IND,UF(i,k)*Q(i)+IF(FTYPE(k)=1,ND(i)*FL(i)));


!-------------------------------------------------------------------!
!      Balance of payments: inflows and outflows                    !
!-------------------------------------------------------------------!

EQUATION BOP_Kinflow
    # Surplus on capital account, deflated by CPI #
            KSURP = BAL/(ER*CPI);

EQUATION BOP_Xearnings
    # Export earnings, deflated by CPI #
            XRNGS = SUM(i,IND,P(i)*X(i))/CPI ;

EQUATION BOP_inflow
    # Balance of payments: nominal inflows #
            INFLOW = BAL/ER + SUM(i,IND,P(i)*X(i));

EQUATION BOP_rinflow
    # Balance of payments: real inflows #
            RINFLO = KSURP + XRNGS ;

EQUATION BOP_mktrtn
    # Market return on foreign-owned capital, deflated by CPI #
            FRETN = RR*(KT-KD)/CPI ;

EQUATION BOP_exprof
    # Repatriated profits, deflated by CPI #
            RPROF = (1-KD/KT)*SUM(i,IND,PI(i))/CPI ;

EQUATION BOP_Cimports
    # Cost of imports, deflated by CPI #
            CIMPT = SUM(i,IND,PSTAR(i)*M(i)/TMD(i))/CPI ;

EQUATION BOP_CXsubs
    # Cost of export subsidies, deflated by CPI #
            CXS = SUM(i,IND,P(i)*X(i)*(SXD(i)-1)/SXD(i))/CPI ;

EQUATION BOP_outflow
    # Balance of payments: nominal outflows #
            OUTFLW = RR*(KT-KD)+
          (1-KD/KT)*SUM(i,IND,PI(i))+
          SUM(i,IND,PSTAR(i)*M(i)/TMD(i))+
          SUM(i,IND,P(i)*X(i)*(SXD(i)-1)/SXD(i));

EQUATION BOP_Routflow
    # Balance of payments: real outflows #
            ROUTFL = FRETN+RPROF+CIMPT+CXS ;
```

```
!-------------------------------------------------------------------!
!      Closure equations                                            !
!-------------------------------------------------------------------!

EQUATION BOP_balance
    # Balance of payments #
           INFLOW = OUTFLW;

EQUATION Factor_balance
    # Non-capital factor mkt equilibrium #
(all,k,KNC)  L(k) = LBAR(k);

EQUATION Profits
    # Economic profits #
(all,i,IND)  PI(i) = (P(i)-UVC(i))*Q(i)-FC(i) ;


!-------------------------------------------------------------------!
!      Equations for endogenous elasticities and shares             !
!-------------------------------------------------------------------!

EQUATION Final_share
    # Share of final demand in gross output #
(all,i,IND)  SF(i) = DF(i)/Q(i);

EQUATION Intmdt_share
    # Share of intermediate demand in gross output #
(all,i,IND)  SI(i) = DI(i)/Q(i);

EQUATION Indshr_int
    # Share of industry j in total int demand for i #
(all,i,IND) (all,j,IND)  SIND(i,j) = A(i,j)*Q(j)/DI(i);

EQUATION Export_share
    # Share of export demand in gross output #
(all,i,IND)  SX(i) = X(i)/Q(i);

EQUATION Final_elast
    # Final demand elasticity #
(all,i,IND)  EPSF(i) = -SIGMAF(i)+(SIGMAF(i)-1)*(DELTA(i)/ND(i))*
                       (1+(ND(i)-1)*CONVA(i))*
                   (P(i)/PINDF(i))^(1-SIGMAF(I));

EQUATION Intmdt_elast
    # Intermediate demand elasticity #
(all,i,IND)  EPSI(i) = SUM(j,IND,SIND(i,j)*(-SIGMAI(i)+
                       (GAMA(i,j)+SIGMAI(i)-1)*(PHI(i,j)/ND(i))*
                       (1+(ND(i)-1)*CONVA(i))*
                   (P(i)/PINDI(i,j))^(1-SIGMAI(I))));

EQUATION Export_elast
    # Export demand elasticity #
(all,i,IND)  EPSX(i) = -SIGMAW(i)+(SIGMAW(i)-OMEGA(I))*
                       (THETA(i)/ND(i))*
                       (1+(ND(i)-1)*CONVA(i))*
                   (PE(i)/PINDX(i))^(1-SIGMAW(I));

EQUATION Demand_elast
    # Overall demand elasticity #
```

```
(all,i,IND)  EPS(i) = SF(i)*EPSF(i)+SI(i)*EPSI(i)+SX(i)*EPSX(i);

!--------------end of TABLO Input file-------------------------------!
```