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BOTTOMS-UP, TOPS-DOWN AND HYBRID METHODS  
FOR REGIONALIZING COMPUTABLE GENERAL  
EQUILIBRIUM MODELS : SOME COMPARISONS

by

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I INTRODUCTION

The primary obstacle to the incorporation of regional disaggregation into multi-sectoral policy models is data deficiencies. Data on inter-regional trade flows disaggregated by commodity and by user are especially scarce, yet these are essential for the implementation of a fully specified bottoms-up, multi-sectoral, multi-regional model. An alternative for generating regional economic policy analysis is the tops-down approach under which projections from an economy-wide model are mapped to a regional dimension, allowing no feedback from the regional to the economy-wide level. Tops-down methods require much less regional data than the bottoms-up approach but are less complete theoretically and are limited to the analysis of the regional impacts of economy-wide shocks. They are not suitable for the analysis of the economy-wide implications of regional shocks.

Researchers associated with the IMPACT economic research project<sup>1</sup> have developed a tops-down procedure for regional disaggregation of the project's multi-sectoral model, ORANI (Dixon, Parmenter, Sutton and Vincent (DPSV), 1982, especially chapter 6). Liew (1981) experimented with a bottoms-up regional model of the ORANI type but was forced to rely on mechanical methods, rather than primary sources, for the bulk of his regional data. Another development has been the implementation of hybrid bottoms-up, tops-down models in which a tops-down regional disaggregation package is driven by a partially regionalized economy-wide model (Higgs, Parmenter and Rimmer, 1983). The purpose of the hybrids is to ameliorate some of the most unsatisfactory aspects of the theoretical specification of tops-down models without incurring all the costs of moving to a full bottoms-up system.

In this paper, we report on the development of three small models designed to illustrate our versions of the bottoms-up, tops-down and hybrid approaches to regional modelling. The models have been implemented on compatible data bases, that is, on hypothetical data which aggregate to the same economy-wide picture. Apart from exploiting the pedagogic potential of the models, our aim is to investigate the comparative performance of the three methods. Relatively clean comparisons are possible because data differences are minimized.

The paper is organized as follows. Section II sets out the theoretical specifications of the three models and is centred around two tables (Tables 1 - 2) which give respectively the algebraic specifications

and definitions of the variables. The data required for each model are presented in section III (Figures 1 - 6) together with a description of all the parameters of the models' equations (Table 3). From the latter, the relationship between the data and the parameters can readily be deduced. A preliminary comparison between the models based on simulations of the effects of a general tariff increase is presented in section IV. Section V is a conclusion.

## II. THEORETICAL STRUCTURES

The models which we specify are all developments of the IMPACT Project's miniature ORANI (MO) model (DPSV, 1982, chapter 2). The basic theoretical assumptions made are as follows:

- (i) Households are price takers and maximize utility subject to an aggregate expenditure constraint. Utility functions are Leontief in "effective" commodity inputs, an effective unit of a commodity being a Cobb-Douglas aggregation of supplies of that commodity from domestic regions and imports. Hence, household demand for each commodity is a function of aggregate household spending and the relative prices of commodities. Regional shares in aggregate household spending are linked to regional shares in aggregate income.
- (ii) Foreign demand for domestic exports is determined according to constant-elasticity export-demand functions. Export-demand elasticities are generally assumed to be high, but not infinite.
- (iii) Production takes place in multi-product enterprises in which the input mix is assumed to be independent of the output mix. Producers are price takers in both output and

input markets. They choose their output mixes to maximise revenue subject to product-transformation frontiers specified as quarter ellipses. Hence, commodity supplies are functions of industries' activity levels and relative commodity prices. On the input side, producers choose their input mixes to minimize costs subject to constant-returns-to-scale production functions which are Leontief in "effective" inputs of materials and of primary factors. As in the households' demand specification, an effective unit of a material input is defined as a Cobb-Douglas combination of supplies of that material from domestic sources and imports. Similarly, an effective unit of primary factors is a Cobb-Douglas combination of labour and capital. Hence, the demand by an industry for each source-specific material is a function of that industry's activity level and of the relative prices of the material from each source. The demand for labour or capital is a function of activity and relative factor prices.

- (iv) Competitive market structures are imposed by assuming that no activity earns pure profits. Hence, revenues earned per unit of production in each industry are equal to unit costs, and the at-port domestic-currency prices of exports and imports are equal to their foreign-currency values converted by the exchange rate and inclusive of any trade taxes or subsidies.

- (v) Market clearing is assumed in commodity markets. The models lack a complete specification of the supply side of the factor markets. Exogenous factor supplies can be imposed with market-clearing assumptions determining factor prices. Alternatively, factor prices can be set exogenously with the aggregate employment of factors demand-determined.
  
- (vi) Miscellaneous equations are included in the models to compute trade aggregates, gross domestic and gross regional products and aggregate price indexes. Also included is a facility for indexing nominal wages to the domestic price level. Hence, wage rates can be set exogenously in real as well as nominal terms.

Three models, each incorporating these theoretical assumptions, were constructed. They are:

- (a) a multi-regional model (MRMO) in which all economic behaviour is specified at the regional level with economy-wide variables defined as explicit aggregations of the corresponding regional variables.
  
- (b) an economy-wide model (MO) which itself incorporates no regional disaggregation but to which can be appended a tops-down regional equation system (RES) which disaggregates the economy-wide results to a regional basis without feedback from the regional to the economy-wide results. The combined system is referred to as MORES.

- (c) an economy-wide model (HMO) containing some regional detail but using RES to derive a complete set of regional results. This second combined system is referred to as HMORES.

RES, the tops-down facility used to regionalize economy-wide results from MO and HMO, is based on a division of the commodities distinguished in the economy-wide model into non-overlapping groups: "national" commodities which are traded between domestic regions and "local" commodities which are non-traded. Industries producing national commodities are referred to as "national" industries, industries producing local commodities as "local" industries. Changes in the regional output levels of national industries are determined exogenously: an obvious possibility, for example, is to assume that regional shares in the aggregate output of these industries remain constant. The regional outputs of local industries are then fixed by imposing regional market-clearing constraints for local commodities, that is, by insisting that each region's production of local commodities be sufficient to meet the demand for them within the region. In computing regional demand for local commodities, RES accounts for intermediate demands in national and local industries and allows a link between regional household consumption and regional income.

The weakest feature of RES is the need to make exogenous assignments of output changes for national industries. Partial regionalization of national sectors in HMO is aimed at ameliorating this weakness. Regional outputs in the regionalized national sectors are then determined directly by the economy-wide model and the constant-regional-shares

assumption in RES is exactly correct. For example, the economy-wide model might include as a separate sector "Tasmanian fruit growing". RES would then insist that Tasmania retains a constant share in the total output of this sector (namely, 1) and that all other regions also retain constant shares (namely, 0). HMORES is in this sense a hybrid of the bottoms-up and tops-down approaches to regional modelling.

The equations for the model systems are listed in Table 1 with the notation defined in Table 2. The notation is chosen so that MRMO, MO and HMO can all be represented by the same equation list, the models differing algebraically only in the sub- or super-script ranges. The main difference is between MRMO and the other two models. Only for MRMO are the regional sub- or super-scripts relevant. Formally, this is covered in the notation by setting  $\tilde{R}$ , the number of regions, equal to 1 for MO and HMO. MO and HMO differ from each other only in the number of commodities ( $\tilde{G}$ ) and industries ( $\tilde{H}$ ) which are identified. HMO contains more commodities and industries than does MO because some of the economy-wide sectors defined in MO are split in HMO into their regional components. Both models, however, can formally be represented as single-region models ( $\tilde{R}=1$ ), the regionalization of sectors in HMO being treated just as additional sectoral disaggregation.<sup>2</sup> Given this similarity between MO and HMO it is clear that a single equation list can be used to represent RES whether it is to be appended to MO or HMO. Once again, only differences in sub- and super-script ranges are required.

### III. DATA REQUIREMENTS

The data requirements of our models can be deduced from Table 3, in which are listed and defined all of the parameters appearing in the equations in Table 1. It is readily apparent, with four exceptions, that the parameters are all shares or quantities which could be read or deduced from a detailed set of input-output accounts. The exceptions are the own- and cross-price household demand elasticities ( $\eta_{(is)(qt)}$ ), the reciprocals of the export-demand elasticities ( $\gamma_i$ ), the wage indexation factors ( $h^r$ ) and the coefficient ( $\gamma$ ) linking regional consumption and income shares. The last two of these are user-specified, while the first two must be assigned, preferably on the basis of econometric studies. For the nested Leontief-Cobb-Douglas utility function used in our models, the household demand elasticities are defined by the following formulae (cf. DPSV, 1982, subsection 5.1.1).

$$\eta_{(is)(qt)}^r = \begin{cases} \begin{cases} -S_{(qt)}^{(3)r} & i \neq q \\ \alpha_{(qt)}^{(3)r} - S_{(qt)}^{(3)r} - 1 & i = q, s = t \\ \alpha_{(qt)}^{(3)r} - S_{(qt)}^{(3)r} & i = q, s \neq t \end{cases} \end{cases}$$

The  $S_{(qt)}^{(3)r}$  are as defined in Table 3, namely the shares in aggregate household expenditure in region  $r$  accounted for by commodity  $q$  from source  $t$ . The  $\alpha$ 's are the exponents from the Cobb-Douglas nests in the utility functions, i.e.,  $\alpha_{(qt)}^{(3)r}$  is the share of source  $t$  in the total purchase of commodity  $q$  by households in region  $r$ . Note once again, that all these

shares can be computed from detailed input-output accounts. For the models described here, the export demand parameters were set as follows:

$$\gamma_i = \begin{cases} 0.5 & i \in E^*, \\ 0.05 & i \notin E^*, \end{cases}$$

where  $E^*$  is the set of commodities for which exports are endogenously determined (see Table 4).

Implementation of MRMO requires a complete set of multiregional input-output accounts. The hypothetical data set used to generate the results reported in section IV is given in Figure 1 (the absorption matrix) and Figure 2 (the make matrix). There are two domestic regions ( $\tilde{R}=2$ ), three industries ( $\tilde{H}=3$ ) and three commodities ( $\tilde{G}=3$ ). Industries 1 and 2 produce commodities 1 and 2 jointly, in both regions industry 1 specializing in the production of commodity 1 and industry 2 in the production of commodity 2. A large share (30 per cent) of total output of commodity 1 is exported overseas. International imports account for a significant share (30 per cent) of the domestic market for commodity 2, despite a 40 per cent ad valorem tariff. Commodities 1 and 2 are both traded between the domestic regions as well as internationally. Commodity 3, which is produced only by industry 3, is completely non-traded. Since the share of industry 1 in total regional value added in region 1 (30 per cent) is high relative to the share in region 2 (20 per cent), region 1 can be regarded as the export-oriented region. Region 2, on the other hand, has an industrial structure concentrated relatively heavily in production in industry 2,

hence it may be regarded as the import-competing region. Finally note that the share of region 1 in aggregate consumption (60 per cent) exceeds its share in aggregate value added (50 per cent). In computing the capital ownership shares ( $G_{(G+1,2)}^{r-}(js)$ , see Table 3) we assume therefore that region 1 has been a net exporter of capital to region 2.

To implement MO, we require an input-output data base with sectoral but not regional disaggregation. The data used in generating the results reported in section IV are given in Figures 3 and 4. These are just aggregations over the two domestic regions of Figures 1 and 2. The mapping, via RES, of economy-wide results from MO to regions requires some region-specific data, but much less than is included in the full multiregional data set. In fact, what is required is just aggregate output by industry and region and aggregate household spending by region. For the results from MORES reported in Section IV these were taken from the column totals of Figure 1. In generating the parameters for RES these data are then combined with an assumption that industries' cost coefficients and commodity shares in household demand are the same in each region as they are in the economy-wide data (Figure 3).

Figures 5 and 6 contain the input-output data required for the implementation of HMO. As is MO, HMO is a single-region model ( $\tilde{R}=1$ ) but it has four commodities and industries ( $\tilde{G}=\tilde{H}=4$ ) rather than the three distinguished in MO. In fact the first two commodities and industries in HMO (labelled 1.1 and 1.2 in Figures 5 and 6) are just regional disaggregations of commodity 1 and industry 1 from the MO data. That is,

rows 1.1 and 1.2 of Figure 5 contain exactly the same information as rows 1 and 4 of Figure 1 except that the two regional columns shown in Figure 1 for each of industries 2 and 3 and for household demand are aggregated in Figure 5 into single columns for economy-wide industries 2 and 3 and for economy-wide household demand. Note also that the row showing the disposal of international imports of commodity 1 has also been split into two rows in Figure 5. This split has been made so that users of commodity 1.1 have the same share of imports in their usage of that commodity as they do for their usage of commodity 1.2. For example, the share of imports in households' usage of 1.1 is  $1.71/9.71 = 0.2$  and the import share in their usage of 1.2 is also 0.2 (i.e.,  $1.29/7.29$ ). Their total usage of imports of commodity 1 is  $1.71 + 1.29 = 3$  as shown in Figure 1 (columns 7 and 8) or figure 3 (column 4). The first two columns of Figure 5 contain the same data as columns 1 and 4 of Figure 1, except that inputs of commodities 2 and 3 have been aggregated over the domestic sources and inputs of international imports of commodity 1 have been split as described above. Finally, the disaggregations in the first two rows and columns of Figure 6 follow those described for Figure 5. Thus Figure 6 shows industry 1.1 with the same output combination as industry 1 in region 1 in Figure 2 (column 1) and industry 1.2 with the same output combination as industry 1 in region 2 in Figure 2 (column 4).

The way in which the data for HMO has been derived from Figures 1 - 4 implies that HMO, although formally a single-region model, includes a regional disaggregation of industry 1 and commodity 1. The HMO data base includes data for industry 1 on regional differences in input structure and output mix, and for commodity 1 on regional differences in sales patterns.

As will be seen in the results in section IV, HMO is then able to project regional differences in the output response of industry 1 to shocks. However, formally the model treats the regional disaggregation of this sector as additional sectoral disaggregation.

To generate a complete set of regional projections from HMO we again use RES. The procedures used to generate the coefficients for the RES equations in HMORES are exactly as described for MORES. Again, the additional regional data required are taken from the column totals of Figure 1 but, in implementing the assumptions of regionally independent technology and household preferences, Figure 5 (rather than Figure 3) is used. Hence, the assumptions do not exclude the regional details included in HMO for industry and commodity 1.

Note finally that the data underlying the results from MORES and HMORES in section IV are fully consistent with those underlying the results from MRMO except to the extent that MORES and HMORES economize on regional data requirements by the assumptions that technology and household preferences are invariant across the domestic regions.

#### IV. RESULTS OF PRELIMINARY SIMULATIONS

In this section we report results of simulations from the three regional models; MRMO, MORES and HMORES. In each case, the shock imposed on the model was a one per cent increase in the power of the tariff (i.e., one plus the ad valorem tariff rate) levied against imports from overseas of commodity 2, the main import-competing commodity. The base-period ad valorem tariff rate on this commodity is 40 per cent, hence, our shock is equivalent to a 3.5 (= 1.4/0.4) per cent increase in the rate.

Comparing Tables 1 and 2, it is clear that MRMO, MO and HMO each contains  $(\bar{H}\bar{R} + \bar{G}\bar{R} + 3\bar{G} + \bar{R} + 2)$  fewer equations than variables. RES introduces an additional  $\bar{N}\bar{R}^*$  variables in excess of the number of equations which it contains. Simulations, therefore, require the exogenous setting of corresponding numbers of variables.

The exogenous variables for the simulations reported here are listed in Table 4. Foreign-currency import prices  $(p^*_{(i, \bar{R}+1)})$  and the powers of the tariff rates  $(t_{(i, \bar{R}+1)})$  are exogenous reflecting a small country assumption with tariffs as government policy instruments. The exogeneity of industry-specific capital stocks  $(k_{(jr)})$  implies a short-run time frame for the simulations. The wage shift variables  $(f^r_{\bar{G}+1, 1})$  are exogenous. Combined with the assumption that nominal wage rates are fully indexed to the consumer price index (i.e.,  $h^r = 1$ , for all  $r$  in equation (24) in Table 1), this implies that real wage rates are exogenous. In simulating the effects of the tariff change we hold real wages fixed (i.e.,

we set  $f_{(G+1,1)}^r = 0$ , for all  $r$ ). Employment is then demand determined ( $\ell^r$ , for all  $r$ , and  $\ell$  in equations (14) and (15) are endogenous). For each domestically produced commodity we set exogenously either the export subsidy ( $v_{(ir)}$ ) or the quantity of exports ( $x_{(ir)}^{(4)}$ ). The first alternative, which is applied to the major export commodities in the data,<sup>3</sup> allows export volumes to be determined endogenously but ties the domestic price to the world price (cf. equation (11) in Table 1). The second alternative allows the domestic price to move independently of the world price, the divergence being accounted for notionally by a change in the value of the endogenous export subsidy. For all commodities the exogenous variable  $f_{(ir)}^{(4)}$  allows for exogenous shifts in foreign demand curves for domestic exports. The last two variables on the exogenous list for MRMO, MO and HMO are aggregate real household spending ( $\bar{c}$ ) and the nominal exchange rate ( $\phi$ ). The latter of these is the numeraire in our simulations, hence changes in the domestic price indexes approximate closely changes in domestic prices relative to world prices.<sup>4</sup> Exogenising real household spending implies that only the foreign element of final demand is free to change and that changes in GDP must show up as changes in the balance of trade. Finally, to close RES, we set exogenously regional shares in the economy-wide output levels of national industries. In fact we hold these shares constant ( $g_{(jr)}^* = 0$ ) so that percentage changes in national-industry outputs are the same in each region (cf. equation (27) in Table 1).

Some results from our simulations are presented in Table 5, economy-wide variables in part (i) and regional outputs, employment and gross product in part (ii). Given the uniformity of theoretical specifica-

tion and economy-wide data, we should expect our three models to give very similar projections of the effects of the tariff increase on the economy as a whole. Part (i) of the table confirms this. According to all the models, the additional protection afforded by the tariff increase reduces aggregate imports but its inflationary consequences erode the competitiveness of the export sector, causing a reduction in exports. For both the balance of trade and aggregate employment, the export effect is dominant. Hence a move towards deficit in the balance of trade and a fall in aggregate employment are projected. The magnitudes of these effects differ very little across the models.

An interesting feature of the results not revealed by Table 5 is that, at the economy-wide level, no industry gains from the tariff increase. In our data, no industry specializes completely in the production of the import-competing commodity. Even for industry 2, which specializes relatively in import-competing production, the contractionary effect of the reduced profitability of exports is dominant.

In explaining the regional results it is easiest to begin with MORES, that is, with the second column of Table 5. Both industries producing tradeable commodities (i.e., industries 1 and 2) are treated as national industries and in allocating their output changes to the regions constant regional shares are assumed (i.e., in equation (27) of Table 1 the variable  $g^*_{(jr)}$  is set to zero for all  $j \in N^*$ ) Therefore, for both industries 1 and 2 the percentage change in output in each region is equal to the economy-wide change. Only for the local industry (industry 3) are regional differences in the output projections possible.

Industry 1 is the most rapidly declining industry because it is most heavily specialized in the production of the export commodity. The cost-price squeeze on exports reduces profitability, and hence activity, in industry 1 so much that, even though it increases the share of the import-competing commodity (2) in its output mix (i.e., moves around its production possibility frontier), in absolute terms its output of both commodities contracts. For industry 2 the squeeze in exports is less significant, although it still results in a small fall in the overall level of activity. The production of commodity 2 by this industry increases both relative to its production of good 1 and absolutely. Since the share of industry 1 (the most rapidly declining industry) in total activity is smaller in region 2 than in region 1, region 2 increases its share of gross national income and hence (via equation (30) in Table 1) its share of the economy's fixed level of aggregate consumption. The decline in the demand for local commodities (and hence the output of the local industry; cf. equations (28) and (29) in Table 1) is also smaller in region 2. The net effect is that both aggregate employment and gross regional product are projected to fall less in region 2 than in region 1. Note that in the case of MORES, these regional differences are accounted for mainly by the fact that region 2 has, in its industrial structure, a relatively low share of the most rapidly declining industry. The contribution of regional differences in performance within an industry (allowed only for industry 3) is comparatively minor.

In contrast to MORES, HMORES allows intra-industry differences across regions in the output response of industry 1. It is projected to decline more strongly in region 1 than in region 2. The main reason is that

in region 1, this industry is more heavily specialized in producing the export commodity 1 (see Figures 2 and 6). HMORES does not allow regional differences in the output change of industry 2. In both regions this industry is projected to decline by 0.01 per cent (see column 3 of Table 5), the same decline as was projected by MORES. The shift in activity in industry 1 from region 1 to region 2 in HMORES as compared to MORES further increases region 2's share in gross national income and in aggregate consumer spending. This is reflected in the performance of the industry producing local commodities. According to HMORES, industry 3 is projected to increase its output in region 2 whereas almost no change was projected by MORES. The projected fall in output for this industry in region 1 is correspondingly larger according to HMORES than according to MORES. The net outcome is that HMORES projects larger falls in employment and gross product in region 1 than does MORES and smaller falls in region 2.

MRMO allows intra-industry regional differences in the output responses of all three industries. A comparison of the first and third columns of part (ii) of Table 5 reveals that the regional projections from MRMO are very similar to those from HMORES. As would be expected, the main difference is in the performance of industry 2, the import-competing industry, for which regional differences in output response are allowed in MRMO but not in HMORES. MRMO projects that this industry would be affected by the tariff increase worse in region 2 than in region 1. There are two main reasons for this.

- (a) The share of the export commodity in the aggregate output of industry 2 in region 2 is slightly higher than in region 1 (see Table 2).

- (b) As a consequence of the tariff increase, the average cost of produced inputs used by the industry in region 2 rises more than does its average material-input cost in region 1. Columns two and four of Table 1 reveal that, for industry 2, the share of imports of commodity 2 in total costs is higher in region 2. In addition the cost of inputs of the non-traded commodity (3) is higher in region 2 than in region 1 because the output of the non-trading industry (3) is projected to fall in region 1 but to remain constant in region 2. Since each industry's capital stock is held fixed in these simulations, relatively lower outputs are usually associated with relatively lower prices. In fact the price of the non-traded good rises by 0.661 per cent in region 2 and 0.637 per cent in region 1.

## V. CONCLUSION

Given the practical difficulties of implementing bottoms-up multi-regional economic models, data-cheap tops-down methods are frequently used for analysing the regional impact of economic policy. The question of how results from these methods would compare to results from richer multi-regional specifications were the latter available is, therefore, of some practical importance. The research described in this paper is intended to contribute some general answers to such questions by comparing the performance of similar bottoms-up and tops-down models, all implemented on different disaggregations of essentially the same data.

In discussing results from preliminary simulations, we have attempted to show how differences across models can be traced, in some detail, to the differences in their specifications. The results exhibited some illuminating differences but quantitatively were quite similar. This reflects a good deal of inter-regional smoothing in the theory and data employed. Four points might be mentioned. Firstly, the incidence of multi-product technology in the traded-goods sector limits the degree of inter-sectoral diversity in the response of the economy to shocks which favour import-competing goods at the expense of exports. Secondly, in the data neither region is assumed to be very heavily specialized in exporting or import competing. Thirdly, in calculating gross regional incomes, that is, income accruing in each region as opposed to income generated there, we have assumed that owners of capital hold balanced portfolios of capital owned in both regions. This limits the extent to which regional

divergencies in productive activity translate into regional differences in final demand. Finally, our regional commodity distinctions are minimal. In particular we have assumed that foreigners regard as perfect substitutes supplies of the export commodity from the different domestic regions. Regional disaggregation of real (as opposed to hypothetical) economy-wide input-output data often exposes significant aggregation problems in the economy-wide data, with quite diverse commodities from different regions aggregated into single categories.<sup>5</sup> Our intention is to continue to experiment with the models, with a variety of shocks and with data bases which allow greater regional disparity.

Table 1. Algebraic Representation of MRMO, MORES and HMORES in Percentage Changes

Equations	(b), (c)	Sub- and super-script ranges (a)	Number of equations
(a) Equations defining MRMO, MO and HMO			
Household demand			
(1)	$x^{(3)r} = c^r + \sum_{q=1}^{\tilde{G}} \sum_{t=1}^{\tilde{R}+1} \eta^{(is)}(qt) P^{(qt)}$	$i=1, \dots, \tilde{G}$ $s=1, \dots, \tilde{R}+1$ $r=1, \dots, \tilde{R}$	$\tilde{G}\tilde{R}(\tilde{R}+1)$
(2)	$c^r = c + \gamma(gsi^r - gni)$	$r=1, \dots, \tilde{R}$	$\tilde{R}$
(3)	$gsi^r = G_{(G+1,1)}^r \left( P_{(G+1,1)}^r \ell^r \right) + \sum_{j=1}^{\tilde{H}} \sum_{s=1}^{\tilde{R}} G_{(G+1,2)}^r(j,s) \left( P_{(G+1,2)}^s + k_{(js)} \right)$	$r=1, \dots, \tilde{R}$	$\tilde{R}$
(4)	$gni = \sum_{r=1}^{\tilde{H}} \theta^r gsi^r$		1
Exports			
(5)	$p_i^* = -\gamma_i \sum_{s=1}^{\tilde{H}} S^{(4)}(is) x^{(is)} + f_i^{(4)}$	$i=1, \dots, \tilde{G}$	$\tilde{G}$

contd.....

Equations	(b), (c)	Sub- and super-script ranges	Number of equations
<u>Commodity outputs</u>	(6) $y_{(is)}(js) = z_{(js)} + \left[ p_{(is)} - \sum_{k=1}^{\tilde{G}} R_{(ks)}(js) \right] p_{(ks)}$	$i=1, \dots, \tilde{G}$ $j=1, \dots, \tilde{H}$ $s=1, \dots, \tilde{R}$	$\tilde{G}\tilde{H}\tilde{R}$
<u>Input demands</u>	(7) $x_{(is)}(jr) = z_{(jr)} - \left[ p_{(is)} - \sum_{t=1}^{\tilde{R}+1} S_{(it)}(jr) \right] p_{(it)}$	$i=1, \dots, \tilde{G}$ $j=1, \dots, \tilde{H}$ $s=1, \dots, \tilde{R}+1$ $r=1, \dots, \tilde{R}$	$\tilde{G}\tilde{H}(\tilde{R}+1)$
(8)	$x_{(\tilde{G}+1,1)}(jr) = z_{(jr)} - \left[ p_{(\tilde{G}+1,1)}^r - S_{(\tilde{G}+1,1)}^r p_{(\tilde{G}+1,1)}^r \right] p_{(\tilde{G}+1,2)}^r$	$j=1, \dots, \tilde{H}$ $r=1, \dots, \tilde{R}$	$\tilde{H}\tilde{R}$
(9)	$x_{(\tilde{G}+1,2)}(jr) = z_{(jr)} - \left[ p_{(\tilde{G}+1,2)}^r j - S_{(\tilde{G}+1,1)}^r p_{(\tilde{G}+1,1)}^r - S_{(\tilde{G}+1,2)}^r p_{(\tilde{G}+1,2)}^r \right] p_{(\tilde{G}+1,2)}^r$	$j=1, \dots, \tilde{H}$ $r=1, \dots, \tilde{R}$	$\tilde{H}\tilde{R}$

contd.....

Equations (b), (c)

Sub- and super-script ranges (a)

Number of equations

Zero pure profits

$$(10) \sum_{i=1}^{\tilde{G}} P_{(ir)} R_{(jr)} = \sum_{i=1}^{\tilde{G}} \sum_{s=1}^{\tilde{R}+1} P_{(is)} H_{(js)}$$

$$+ P_{(G+1,1)}^R H_{(G+1,1)}(jr) + P_{(G+1,2)}^R H_{(G+1,2)}(jr)$$

$\tilde{H}\tilde{R}$   
 $j=1, \dots, \tilde{H}$   
 $r=1, \dots, \tilde{R}$

$$(11) p_i^* + \phi + v_{(ir)} = P_{(ir)}$$

$\tilde{G}\tilde{R}$   
 $i=1, \dots, \tilde{G}$   
 $r=1, \dots, \tilde{R}$

$$(12) p_{(i, \tilde{R}+1)}^* + \phi + t_{(i, \tilde{R}+1)} = P_{(i, \tilde{R}+1)}$$

$\tilde{G}$   
 $i=1, \dots, \tilde{G}$

Market clearing

$$(13) \sum_{j=1}^{\tilde{H}} y_{(js)}(js) Q_{(js)}(js) = \sum_{j=1}^{\tilde{H}} \sum_{r=1}^{\tilde{R}} x_{(js)}(jr) W_{(js)}(jr)$$

$$+ \sum_{r=1}^{\tilde{R}} (3)r W_{(1s)}(1s) + x_{(1s)}(1s) W_{(1s)}(1s)$$

$\tilde{G}\tilde{R}$   
 $i=1, \dots, \tilde{G}$   
 $s=1, \dots, \tilde{R}$

contd.....

Equations	(b), (c)	Sub- and super-script ranges (a)	Number of equations
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Market clearing contd

$$(14) \quad \sum_{j=1}^{\tilde{H}} x(\tilde{G}+1,1)(j_r) W(\tilde{G}+1,1)(j_r) = \ell^F$$

$r=1, \dots, \tilde{R}$

$$(15) \quad \sum_{r=1}^{\tilde{R}} \ell^F W(\tilde{G}+1,1) = \ell$$

1

$$(16) \quad x(\tilde{G}+1,2)(j_r) = k(j_r)$$

$\tilde{H}\tilde{R}$

$$(17) \quad \sum_{j=1}^{\tilde{H}} k(j_r) W(\tilde{G}+1,2)(j_r) = k^F$$

$r=1, \dots, \tilde{R}$

$$(18) \quad \sum_{r=1}^{\tilde{R}} k^F W(\tilde{G}+1,2) = k$$

1

Equations (b), (c)	Sub- and super-script ranges	Number of equations
--------------------	------------------------------	---------------------

Trade aggregates

$$(19) \quad m = \sum_{i=1}^{\tilde{R}} N(i, \tilde{R}+1) \left[ P^*_{(i, \tilde{R}+1)} + \sum_{j=1}^{\tilde{R}} \sum_{r=1}^{\tilde{R}} X(i, \tilde{R}+1)(jr)^W (i, \tilde{R}+1)(jr) \right. \\ \left. + X^{(3)r}_{(i, \tilde{R}+1)} W^{(3)r}_{(i, \tilde{R}+1)} \right], \quad 1$$

$$(20) \quad e = \sum_{i=1}^{\tilde{R}} P^*_{i, r=1} \left( \sum_{r=1}^{\tilde{R}} N(ir) + \sum_{r=1}^{\tilde{R}} X^{(4)}_{(ir)} N^{(4)}_{(ir)} \right), \quad 1$$

$$(21) \quad \Delta B = (Ee - Mm)/100, \quad 1$$

Consumer price indexes

$$(22) \quad cpi^r = \sum_{i=1}^{\tilde{R}} \sum_{s=1}^{\tilde{R}+1} S^{(3)r}(is) P(is), \quad r=1, \dots, \tilde{R}$$

$$(23) \quad cpi = \sum_{i=1}^{\tilde{R}} \sum_{s=1}^{\tilde{R}+1} S^{(3)}(is) P(is), \quad 1$$

contd.....

Equations (b), (c)	Sub-/and super-script ranges (a)	Number of equations
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Base indexation

$$(24) \quad p_{(G+1,1)}^r = h^r \text{ cpi} + f_{(G+1,1)}^r$$

$r=1, \dots, \tilde{R}$

Aggregate real consumption

$$(25) \quad \bar{c} = c - \text{cpi} ,$$

1

Gross regional product

$$(26) \quad \text{GRP}^r = F_{(G+1,1)}^r \left[ p_{(G+1,1)}^r + \ell^r \right] + \sum_{j=1}^{\tilde{H}} F_{(G+1,2)j}^r \left[ p_{(G+1,2)j}^r + k_{(jr)} \right] ,$$

$r=1, \dots, \tilde{R}$

$\tilde{R}$

TOTAL

$$\begin{aligned} & \text{GHR}(\tilde{R}+1) + \text{GR}(\tilde{R}+1) \\ & + \text{GHR} + 4\text{HR} + 2\text{GR} + 2\text{G} \\ & + 7\tilde{R} + 8 \end{aligned}$$

Equations (b), (c)

Sub-/and super-  
script ranges (a)  
Number of  
equations

(b) Equations defining RES (d), (e)

Regional outputs of "national" industries

$$(27) z^*_{(jr)} = z_{(j1)} + s^*_{(jr)}$$

$J \in N^*$   
 $r=1, \dots, \tilde{R}^*$   
 $\tilde{N}R^*$

Commodity outputs of single-product, "local" industries

$$(28) y^*_{(ir)} = z^*_{(jr)}$$

$J \in M^*$   
 $r=1, \dots, \tilde{R}^*$   
 $i$  is the local commodity  
produced by industry  $j$   
 $\tilde{L}R^*$

Regional market clearing for "local" commodities

$$(29) y^*_{(ir)} = \sum_{n \in N^*} \hat{w}^r_{(ir)n} z^*_{(nr)} + \sum_{l \in M^*} \hat{w}^r_{(ir)l} z^*_{(lr)} + \hat{w}^r_{(ir)} x_{(ir)}^{(3)r^*}$$

$i \in L^*$   
 $r=1, \dots, \tilde{R}^*$   
 $\tilde{L}R^*$

Regional household consumption

$$(30) x_{(ir)}^{(3)r^*} = x_{(ir)}^{(3)1} + \gamma(gsi^{r^*} - gni^*)$$

$i \in L^*$   
 $r=1, \dots, \tilde{R}^*$   
 $\tilde{L}R^*$

contd.....

Equations (b), (c)

Sub- and super-  
script ranges (a)

Number of  
equations

Regional household consumption contd

$$(31) \quad g_{si}^{r*} = \sum_{j \in N^*UM^*} \left[ \hat{G}^{r*}_{(G+1,1)j} \left( P_{(G+1,1)}^{r*} + x_{(G+1,1)j}^{r*} \right) \right. \\ \left. + \sum_{s=1}^{\tilde{R}^*} \hat{G}^{sr*}_{(G+1,2)j} \left( P_{(G+1,2)j}^{r*} + x_{(G+1,2)j}^{r*} \right) \right]$$

r=1, ..., R\*

1

(32) gni\* = gni

$$(33) \quad x_{(G+1,s)j}^{r*} = z_{(jr)}^{r*} + x_{(G+1,s)(j1)}^{r*} - z_{(j1)}^{r*}$$

s=1, 2  
j ∈ N\*UM\*  
r=1, ..., R\*

2R\*

Real gross regional product

$$(34) \quad a_j^{r*} = \psi_j^{r*} z_{(jr)}^{r*}$$

j ∈ N\*UM\*  
r=1, ..., R\*

R\*

$$(35) \quad r_{grp}^{r*} = \sum_{j \in N^*UM^*} a_j^{r*}$$

r=1, ..., R\*

R\*

contd.....

Equations (b), (c)	Sub- and super-script ranges	Number of equations
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Real employment

$$(36) \quad \ell^{r*} = \sum_j \sum_n U_j^{r*} x_j^{r*} (G+1, 1) j$$

$r=1, \dots, \tilde{R}^*$

TOTAL  $4\tilde{H}R^*+2\tilde{L}R^*+3\tilde{R}^*+1$

Notes

(a) For the models reported in this paper the ranges are as follows

Symbol	Definition	MIRMO	MO	HMO
$\tilde{G}$	Number of commodities	3	3	4
$\tilde{H}$	Number of industries	3	3	4
$\tilde{R}$	Number of domestic regions	2	1	1

(b) The subscript  $\tilde{R}+1$  bracketted with a commodity subscript denotes imports from overseas.

(c) The subscript  $\tilde{G}+1$  denotes primary factors and is bracketted with either a 1 denoting labour or a 2 denoting capital.

contd.....

- (d)  $N^*$  is the set containing the  $\tilde{N}$  "national" industries,  $\tilde{R}^*$  is the number of regions distinguished in RES,  $L^*$  is the set containing the  $\tilde{L}$  local commodities and  $M^*$  is the set of the  $\tilde{L}$  single-product "local" industries which produce these local commodities. Note that  $\tilde{N} + \tilde{L} = \tilde{H}$  and usually  $\tilde{R}^* = \tilde{R}$ .
- (e) RES is appended only to MO and HMO both of which are formally single region models, i.e., models for which the number of regions  $\tilde{R}=1$ . In taking variables from MO or HMO into RES we therefore use a 1 in place of the regional sub or superscript. For example, the symbol  $z_{(j)}$ , appearing in equation (27) is to be interpreted as the percentage change in the economy wide output of industry  $j$  (taken from MO or HMO).

Table 2. Variables in MRMO, MORES and HMORES (Percentage Changes)

Symbol	Sub-/super- script range	Definition	No.
<u>(a) Variables originating in MRMO, MO and HMO <sup>(a)</sup></u>			
$x_{(is)}^{(3)r}$	$i=1, \dots, \tilde{G}$ $s=1, \dots, \tilde{R}+1$ $r=1, \dots, \tilde{R}$	Regional household demands for source-specific commodities	$\tilde{G}\tilde{R}(\tilde{R}+1)$
$c^r$	$r=1, \dots, \tilde{R}$	Aggregate nominal (regional) household spending	$\tilde{R}$
$P_{(is)}$	$i=1, \dots, \tilde{G}$ $s=1, \dots, \tilde{R}+1$	Source-specific commodity prices	$\tilde{G}(\tilde{R}+1)$
$c$		Economy-wide, aggregate nominal household spending	1
$gsi^r$	$r=1, \dots, \tilde{R}$	Gross regional income	$\tilde{R}$
$gni$		Gross national income	1
$P_{(\tilde{G}+1,1)}^r$	$r=1, \dots, \tilde{R}$	(Regional) wage rates	$\tilde{R}$
$P_{(\tilde{G}+1,2)j}^r$	$j=1, \dots, \tilde{H}$ $r=1, \dots, \tilde{R}$	Rental prices on (regional) industry-specific capital	$\tilde{H}\tilde{R}$
$\ell^r$	$r=1, \dots, \tilde{R}$	(Regional) aggregate employment	$\tilde{R}$
$k_{(jr)}$	$j=1, \dots, \tilde{H}$ $r=1, \dots, \tilde{R}$	Capital stocks	$\tilde{H}\tilde{R}$
$p_i^*$	$i=1, \dots, \tilde{G}$	Foreign-currency export prices	$\tilde{G}$
$x_{(is)}^{(4)}$	$i=1, \dots, \tilde{G}$ $s=1, \dots, \tilde{R}$	International export volumes of (source-specific) domestic commodities	$\tilde{G}\tilde{R}$

contd.....

Symbol	Sub-/super-script range	Definition	No.
$f_i^{(4)}$	$i=1, \dots, \bar{G}$	Shift terms for export demand	$\bar{G}$
$y_{(is)}(js)$	$i=1, \dots, \bar{G}$ $j=1, \dots, \bar{H}$ $s=1, \dots, \bar{R}$	Supplies of source-specific commodities by (regional) industries	$\bar{G}\bar{H}\bar{R}$
$z_{(jr)}$	$j=1, \dots, \bar{H}$ $r=1, \dots, \bar{R}$	(Regional) industry outputs	$\bar{H}\bar{R}$
$x_{(is)}(jr)$	$i=1, \dots, \bar{G}$ $s=1, \dots, \bar{R}+1$ $j=1, \dots, \bar{H}$ $r=1, \dots, \bar{R}$	Intermediate demands by (regional) industries for source-specific commodities	$\bar{G}\bar{H}\bar{R}(\bar{R}+1)$
$x_{(\bar{G}+1, s)}(jr)$	$s=1, 2$ $j=1, \dots, \bar{H}$ $r=1, \dots, \bar{R}$	Factor demands by (regional) industries	$2\bar{H}\bar{R}$
$\phi$		Nominal exchange rate	1
$v_{(ir)}$	$i=1, \dots, \bar{G}$ $r=1, \dots, \bar{R}$	Powers of (regional) export subsidies	$\bar{G}\bar{R}$
$p_{(i, \bar{R}+1)}^*$	$i=1, \dots, \bar{G}$	Foreign currency import prices	$\bar{G}$
$t_{(i, \bar{R}+1)}$	$i=1, \dots, \bar{G}$	Powers of tariff rates	$\bar{G}$

contd.....

Symbol	Sub-/super-script range	Definition	No.
$\ell$		Aggregate employment	1
$k^r$	$r=1, \dots, \bar{R}$	(Regional) aggregate capital stocks	$\bar{R}$
$k$		Aggregate capital stock	1
$m$		Aggregate foreign-currency import bill	1
$e$		Aggregate foreign-currency export receipts	1
$\Delta B$		The <u>change</u> in the trade balance	1
$cpi^r$	$r=1, \dots, \bar{R}$	(Regional) consumer price index	$\bar{R}$
$cpi$		Economy-wide consumer price index	1
$f^r_{(\bar{G}+1, 1)}$	$r=1, \dots, \bar{R}$	(Regional) wage-shift variable	$\bar{R}$
$\bar{c}$		Aggregate real household spending	1
$grp^r$	$r=1, \dots, \bar{R}$	Gross (regional) product	$\bar{R}$

$$\begin{aligned}
 \text{TOTAL} & \quad \bar{C}\bar{R}(\bar{R}+1) + \bar{C}\bar{R}(\bar{R}+1) \\
 & \quad + \bar{C}\bar{R} + 5\bar{R}\bar{R} + \bar{C}(\bar{R}+1) \\
 & \quad + 2\bar{C}\bar{R} + 4\bar{C} + 8\bar{R} + 10
 \end{aligned}$$

contd.....

Symbol	Sub-/super-script range	Definition	No.
<u>(b) Variables appearing only in RES</u>			
$z^*(jr)$	$j \in N^*UM^*$	Regional outputs of national and local industries	$\overline{NR}^*$
$g^*(jr)$	$j \in N^*$ $r=1, \dots, \overline{R}^*$	Regional shares in economy-wide outputs of national industries	$\overline{NR}^*$
$y^*(ir)$	$i \in L^*$ $r=1, \dots, \overline{R}^*$	Regional outputs of local commodities	$\overline{LR}^*$
$x^{(3)r*}(ir)$	$i \in L^*$ $r=1, \dots, \overline{R}^*$	Regional household consumption of local commodities	$\overline{LR}^*$
$gsi^{r*}$	$r=1, \dots, \overline{R}^*$	Gross regional income	$\overline{R}^*$
$gni^*$		Gross national income	1
$x_{(\overline{G}+1,s)j}^{r*}$	$s=1,2$ $j \in N^*UM^*$	Regional demand by national and local industries for primary factors (s=1 labour, s=2 capital)	$2\overline{NR}^*$
$\alpha_j^{r*}$	$j \in N^*UM^*$ $r=1, \dots, \overline{R}^*$	Industries contributions to the percentage change in regional value added	$\overline{NR}^*$
$rgrp^{r*}$	$r=1, \dots, \overline{R}^*$	Real gross regional product	$\overline{R}^*$
$\ell^{r*}$	$r=1, \dots, \overline{R}^*$	Regional employment	$\overline{R}^*$
		TOTAL	$4\overline{NR}^* + \overline{NR}^* + 2\overline{LR}^* + 3\overline{R}^* + 1$

Notes

- (a)  $\overline{G}$ ,  $\overline{N}$  and  $\overline{R}$  are respectively the numbers of commodities, industries and domestic regions. The subscript  $(\overline{G}+1)$  indicates primary factors i.e., labour  $(\overline{G}+1,1)$  or capital  $(\overline{G}+1,2)$ . The subscript  $(\overline{R}+1)$  denotes international imports.
- (b)  $N^*$  is the set of  $\overline{N}$  "national" industries,  $M^*$  the set of  $\overline{L}$  "local" industries (note,  $\overline{N} + \overline{L} = \overline{N}$ ) and  $L^*$  is the set of local commodities.  $\overline{R}^*$  is the number of domestic regions distinguished in RES. An asterisk (\*) attached to a variable symbol indicates that the symbol refers to the definition of that variable in RES - analogous variables may appear in MRMO, MO and HMO without asterisks.

Table 3. Parameters in MRMO, MORES and HMORES

Symbol	Sub-/super-script range	Definition
<u>(a) In MRMO, MO and HMO</u>		
$\eta_{(is)}^r(qt)$	$i, q=1, \dots, \tilde{G}$ $s, t=1, \dots, \tilde{R}+1$	Elasticity of household demand (in region r) for commodity i from source s with respect to price of commodity q from source t.
$\gamma$		User-specified parameter linking changes in regional consumption shares to changes in regional income share.
$G_{(\tilde{G}+1,1)}^r$	$r=1, \dots, \tilde{R}$	Share of labour income in aggregate income (owned in region r).
$G_{(\tilde{G}+1,2)}^r(js)$	$j=1, \dots, \tilde{H}$ $s, r=1, \dots, \tilde{R}$	Share of capital income generated in industry j (in region s) in aggregate income (owned in region r).
$\theta^r$	$r=1, \dots, \tilde{R}$	Share of region r in economy-wide aggregate value added.
$\gamma_i$	$i=1, \dots, \tilde{G}$	Reciprocal of the elasticity of foreign demand for exports of commodity i.
$S_{(is)}^{(4)}$	$i=1, \dots, \tilde{G}$ $s=1, \dots, \tilde{R}$	Share of domestic region s in total supply of exports of commodity i.
$R_{(is)}(js)$	$i=1, \dots, \tilde{G}$ $s=1, \dots, \tilde{R}$ $j=1, \dots, \tilde{H}$	Share of commodity i in the aggregate revenue of industry j (in region s).

contd.....

Symbol	Sub-/super-script range	Definition
$S_{(is)(jr)}$	$i=1, \dots, \tilde{G}$ $s=1, \dots, \tilde{R}+1$ $j=1, \dots, \tilde{H}$ $r=1, \dots, \tilde{R}$	Share of source $s$ in the total cost of inputs of commodity $i$ to industry $j$ (in region $r$ ).
$S_{(\tilde{G}+1,s)(jr)}$	$s=1, 2$ $j=1, \dots, \tilde{H}$ $r=1, \dots, \tilde{R}$	Share of labour ( $s=1$ ) or capital ( $s=2$ ) in the total primary-factor costs of industry $j$ (in region $r$ ).
$H_{(is)(jr)}$	$i=1, \dots, \tilde{G}$ $s=1, \dots, \tilde{R}+1$ $j=1, \dots, \tilde{H}$ $r=1, \dots, \tilde{R}$	Share of commodity $i$ from source $s$ in the total costs of industry $j$ (in region $r$ ).
$H_{(\tilde{G}+1,s)(jr)}$	$s=1, 2$ $j=1, \dots, \tilde{H}$ $r=1, \dots, \tilde{R}$	Share of labour ( $s=1$ ) or capital ( $s=2$ ) in the total costs of industry $j$ (in region $r$ ).
$Q_{(is)(js)}$	$i=1, \dots, \tilde{G}$ $s=1, \dots, \tilde{R}$ $j=1, \dots, \tilde{H}$	Share of industry $j$ in the total supply of commodity $i$ (from region $s$ ).
$W_{(is)(jr)}$	$i=1, \dots, \tilde{G}$ $s, r=1, \dots, \tilde{R}$ $j=1, \dots, \tilde{H}$	Share of industry $j$ (in region $r$ ) in the total usage of commodity $i$ from domestic source $s$ .
$W_{(is)}^{(3)r}$	$i=1, \dots, \tilde{G}$ $s, r=1, \dots, \tilde{R}$	Share of households (in region $r$ ) in the total usage of commodity $i$ from domestic source $s$ .
$W_{(is)}^{(4)}$	$i=1, \dots, \tilde{G}$ $s=1, \dots, \tilde{R}$	Share of international exports in the total usage of commodity $i$ from domestic source $s$ .

contd.....

Symbol	Sub-/super-script range	Definition
$W_{(\tilde{G}+1,s)}(jr)$	$s=1,2$ $j=1,\dots,\tilde{H}$ $r=1,\dots,\tilde{R}$	Share of industry $j$ in the total usage of labour ( $s=1$ ) or capital ( $s=2$ ) (in region $r$ ).
$W_{(\tilde{G}+1,s)}^r$	$s=1,2$ $r=1,\dots,\tilde{R}$	Share of region $r$ in the aggregate usage of labour ( $s=1$ ) or capital ( $s=2$ ).
$N_{(i,\tilde{R}+1)}$	$i=1,\dots,\tilde{G}$	Share of commodity $i$ in the aggregate import bill.
$W_{(i,\tilde{R}+1)}(jr)$	$i=1,\dots,\tilde{G}$ $j=1,\dots,\tilde{H}$ $r=1,\dots,\tilde{R}$	Share of industry $j$ (in region $r$ ) in the total usage of imports of commodity $i$ .
$W_{(i,\tilde{R}+1)}^{(3)r}$	$i=1,\dots,\tilde{G}$ $r=1,\dots,\tilde{R}$	Share of households (in region $r$ ) in the total usage of imports of commodity $i$ .
$N_{(ir)}$	$i=1,\dots,\tilde{G}$ $r=1,\dots,\tilde{R}$	Share of commodity $i$ from domestic source $r$ in aggregate export receipts.
$E$		Aggregate export receipts.
$M$		Aggregate import bill.
$S_{(is)}^{(3)r}$	$i=1,\dots,\tilde{G}$ $s=1,\dots,\tilde{R}+1$ $r=1,\dots,\tilde{R}$	Share of commodity $i$ from source $s$ in aggregate household expenditure (in region $r$ ).
$S_{(is)}^{(3)}$	$i=1,\dots,\tilde{G}$ $s=1,\dots,\tilde{R}+1$	Share of commodity $i$ from source $s$ in aggregate economy-wide household spending.

contd.....

Symbol	Sub-/super-script range	Definition
$h^r$	$r=1, \dots, \tilde{R}$	User specified, (region-specific) wage indexation factor ( $h^r=1$ implies full wage indexation).
$F_{(\tilde{G}+1,1)}^r$	$r=1, \dots, \tilde{R}$	Share of labour in gross regional product (in region r).
$F_{(\tilde{G}+1,2)j}^r$	$r=1, \dots, \tilde{R}$	Share of capital in industry j in gross regional product (in region r).

contd.....

Symbol	Sub-/super-script range	Definition
<u>(b) In RES</u>		
$\hat{W}_{(ir)j}^r$	$i \in L^*$ $r=1, \dots, \tilde{R}^*$ $j \in M^* \cup N^*$	Share of industry j in the total usage of local commodity i in region r.
$\hat{W}_{(ir)}^{(3)r}$	$i \in L^*$ $r=1, \dots, \tilde{R}$	Share of households in the total usage of local commodity i in region r.
$\hat{G}_{(\tilde{G}+1,1)j}^r$	$j=1, \dots, \tilde{H}$ $r=1, \dots, \tilde{R}^*$	Share of labour income earned in industry j in region r in the total income owned in the region.
$\hat{G}_{(\tilde{G}+1,2)j}^{sr}$	$j=1, \dots, \tilde{H}$ $s, r=1, \dots, \tilde{R}^*$	Share in the total income owned in region r of capital income generated in industry j in region s.
$\psi_j^r$	$j=1, \dots, \tilde{H}$ $r=1, \dots, \tilde{R}^*$	Share of industry j in aggregate value added in region r.
$U_j^r$	$j=1, \dots, \tilde{H}$ $r=1, \dots, \tilde{R}^*$	Share of industry j in total employment in region r.

Table 4 : List of Exogenous Variables for MRMO,  
MORES and HMORES Simulations

Symbol	Sub-, super- script range (a)	No.
(a) <u>To close MRMO, MO or HMO</u>		
$P^*(i, \tilde{R}+1)$	$i=1-\tilde{G}$	$\tilde{G}$
$t(i, R+1)$	$i=1-\tilde{G}$	$\tilde{G}$
$k(jr)$	$j=1-\tilde{H}, r=1-\tilde{R}$	$\tilde{H}\tilde{R}$
$f_{(\tilde{G}+1, 1)}^r$	$r=1-\tilde{R}$	$\tilde{R}$
$v(ir)$	$i \in E^*, r=1-\tilde{R}$	) $\tilde{G}\tilde{R}$
$x_{(ir)}^{(4)}$	$i \in E^*, r=1-\tilde{R}$	
$f_i^{(4)}$	$i=1-\tilde{G}$	$\tilde{G}$
$\bar{c}$		1
$\phi$		1
	TOTAL	$\tilde{H}\tilde{R} + \tilde{G}\tilde{R} + 3\tilde{G} + \tilde{R} + 2$
(b) <u>To close RES</u>		
$g^*(jr)$	$j \in N^*$ $r=1, \dots, \tilde{R}^*$	$\tilde{N}\tilde{R}^*$

Note

- (a)  $E^*$  is the set of commodities for which exports are endogenous. In the present simulations this set contains only commodity 1 for the case of MRMO and MO, and commodities 1.1 and 1.2 for HMO. (see Figures 1, 3 and 5).

Table 5 : Projections of the Effects of a 1 per cent  
Increase in the Power of the Tariff on  
Commodity 2 (Percentage Changes)

Variable		MRMO	Projections	
			MORES	HMORES
<u>(i) Economy-wide</u>				
cpi	Consumer Price Index	0.67	0.68	0.68
e	Aggregate exports	-0.40	-0.40	-0.40
m	Aggregate imports	-0.13	-0.12	-0.12
$\Delta B$	Balance of Trade <sup>(a)</sup>	-0.14	-0.14	-0.14
$\ell$	Aggregate employment	-0.17	-0.16	-0.16
<u>(ii) Regional</u>				
$z_{11}$	Output: Industry 1, region 1	-0.48	-0.42	-0.50
$z_{21}$	" " 2, " 1	0.03	-0.01	-0.01
$z_{31}$	" " 3, " 1	-0.10	-0.08	-0.11
$z_{12}$	" " 1, " 2	-0.34	-0.42	-0.31
$z_{22}$	" " 2, " 2	-0.06	-0.01	-0.01
$z_{32}$	" " 3, " 2	0.00	-0.00	0.04
$\ell^1$	Aggregate employment, " 1	-0.23	-0.19	-0.25
$\ell^2$	" " " 2	-0.10	-0.11	-0.05
$grp^1$	Real gross product, " 1	-0.18	-0.15	-0.19
$grp^2$	" " " 2	-0.07	-0.08	-0.03

(a) The balance of trade is measured as a change, not a percentage change.



Figure 2. Make Matrix for MRMO

		Industries						Commodity Outputs
		Region 1			Region 2			
		1	2	3	1	2	3	
----- Commodities -----	From Region 1	1	65	10				75
		2	16	50				66
		3			105			105
	From Region 2	1			40	15		55
		2			20	65		85
		3					95	95
Industry Outputs			81	60	105	60	80	95

Figure 3. Absorption Matrix for MO

	Industries			House- holds	Exports	-Duty	Row Totals
	1	2	3				
Domestic Commodities	1	23	30	18	14	45	130
	2	36	2	14	94	5	151
	3	20	15	25	140		200
Imports	1	1	5	2	3		10
	2	6	18	6	26	-16	40
	3						
Labour	30	50	115				195
Capital	25	20	20				65
Column Totals	141	140	200	277	50	-17	

Figure 4. Make Matrix for M0

		Industries			Commodity Outputs
		1	2	3	
Commodities	1	105	25		130
	2	36	115		151
	3			200	200
		114	140	200	

Figure 5. Absorption Matrix for HMO

	Industries				House- holds	Exports	-Duty	Row Totals
	1.1	1.2	2	3				
1.1	8	2	14	8	8	35		75
Domestic	1.2	7	6	16	10	6	10	55
Commodities	2	17	19	2	14	94	5	151
	3	10	10	15	25	140		100
1.1		0.25	2.33	0.89				
Imports	1.2		0.75	2.67	1.11			
	2	4	2	18	6	26	-16	40
	3							
Labour		20	10	50	115			
Capital		15	10	20	20			
Column Totals		81	60	140	200	277	50	-17

Figure 6. Make Matrix for HMO

		----- Industries -----				Commodity Outputs
		1.1	1.2	2	3	
----- Commodities -----	1.1	65		10		75
	1.2		40	15		55
	2	16	20	115		151
	3				200	100
Industry Outputs		81	60	140	200	

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NOTES

1. IMPACT is an economic research project sponsored jointly by the Australian government and a number of Australian universities.
2. An implication of this is that supplies of the regionalized commodities from the different domestic sources enter users' demand functions in a different way in HMO than in MRMO. In the latter model, substitution between domestic sources of any commodity is allowed, cf. equation (7) in Table 1. In HMO supplies of a regionalized commodity from different domestic sources are treated as different commodity categories and hence no substitution between them is allowed.
3. See the footnote to Table 4.
4. The correspondence would be exact if all foreign-currency export prices were exogenous, i.e., if all export demand elasticities were infinite.
5. Examples are noted for the case of Tasmania in Higgs, Parmenter and Rimmer (1983, section III).



