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# A HYBRID TOPS-DOWN BOTTOMS-UP REGIONAL COMPUTABLE GENERAL EQUILIBRIUM MODEL*

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## ABSTRACT

The paper compares tops-down and bottoms-up methods for obtaining regional projections for policy analysis using computable general equilibrium models. In view of the computing and data problems of bottoms-up, multisectoral models, a hybrid approach is proposed in which a partially regionalized computable general equilibrium model is used to drive a tops-down regional equation system. The hybrid avoids some of the most serious theoretical shortcomings of the tops-down approach but is much less data-demanding than a complete bottoms-up model. An application, based on the ORANI computable general equilibrium model of Australia, is presented with comparative tops-down and hybrid results.

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## 1. INTRODUCTION

Economic policy analysis often demands information on the regional, as well as the economy-wide, impact of policy changes. Two modelling methods are available to provide such information: the tops-down method in which economic behaviour is modelled at the economy-wide level and economy-wide projections are disaggregated to a regional basis without feedback from the regions; and the bottoms-up method in which the behavioural theory is applied at the regional level, with economy-wide projections derived as explicit aggregates of regional results. An extensive literature exists describing the operation of tops-down and bottoms-up regional econometric models.[1] This paper is concerned with the derivation of regional results from computable general equilibrium (hereafter CGE) models. These constitute a different modelling tradition, which is increasingly used in policy analysis.[2]

Despite its theoretical appeal, a bottoms-up CGE model poses daunting computing and data problems, especially since a CGE model usually incorporates a high level of sectoral disaggregation. We present a compromise between a tops-down regional model (based on the ORANI CGE model of the Australian economy; see Dixon, Parmenter, Sutton, and Vincent (1982)) and a full bottoms-up specification. The compromise is a hybrid method in which a partially regionalized CGE model is used to drive a tops-down regional equation system. We show how this hybrid ameliorates the most serious theoretical deficiency of the tops-down model without incurring all the computing and data costs of the bottoms-up approach, and apply it in simulations in which Tasmania (an island state of Australia) and the mainland are two separate regions.

The paper is organized as follows. In section 2, we outline the theoretical basis of ORANI and of the tops-down and hybrid systems. In section 3, we discuss data requirements, set out the details of a simulation used to compare the alternative regional modelling methods, and present the results of the comparison. We offer concluding remarks in section 4.

## 2. THEORETICAL OUTLINE

The ORANI model consists of equations that describe the following:

(a) the demand for commodities and primary factors (labour, capital, and agricultural land) by intermediate and final users;

(b) the supply of commodities by domestic producers;

(c) the relationship between commodity prices and the costs of production;

(d) balances between commodity and factor supplies and their demands;

and

(e) various descriptors of the macroeconomy (e.g. gross domestic product, the balance of trade, aggregate prices indexes) built up explicitly from their microeconomic components.

The equations are derived from microeconomic assumptions about the behaviour of producers and final consumers, about technology and household preferences and about market structures. A complete description of the ORANI model is contained in Dixon, Parmenter, Sutton, and Vincent (1982); however, the basic assumptions are set out below.

Current Production

There are 112 producers modelled in ORANI. No activity earns pure profits. Producers are assumed to be price takers in both input and output markets. Producers choose their input mixes to minimize costs subject to nested production functions. At the first level of the production functions, effective inputs of 114 classes of produced inputs, effective inputs of primary factors, and effective inputs of 'other costs'[3] are required in fixed proportions. At the second level, effective units of produced input i are defined as CES combinations of domestic supplies and imports of the $i^{th}$ commodity classification, and effective units of primary factors are defined as CRESH[4] combinations of fixed capital, agricultural land, and effective inputs of labour. Finally, at the third level effective inputs of labour are defined as CRESH combinations of labour of 10 occupational groups. Industries are modelled as singleproduct producers, with the exception of some agricultural industries where a multiproduct specification is used in which the output mix is assumed to be independent of the input mix, the former being chosen to maximize revenue subject to empirically estimated CRETH[5] transformation frontiers.

## Investment

The allocation of the economy-wide investment budget among sectors is assumed to respond to relative rates of return, which themselves respond to changes in the profitability of industries resulting from exogenous shocks. The time lag is such that investment undertaken within the solution period does not augment the usable capital stock, within that period. Investors are assumed to minimize the costs of capital formation subject to production functions for capital goods which allow substitution between foreign and domestic sources of supply.

## Household Consumption

Households are assumed to be price takers and to maximize utility subject to an aggregate expenditure constraint. The estimated household demand elasticities are based on an additive utility function which leads to characterization of consumer behaviour by the Linear Expenditure System. As with intermediate users and investors, a CES function is specified that allows direct substitution between domestic and imported sources of commodities.

## Government

At its present stage of development, ORANI models government demands as a function of real aggregate household expenditure and some shift terms. The standard assumption is that government demands move in line with real aggregate household expenditure, although the user is free to specify other relationships.

## Exports

Exports are endogenous for the major export commodities. The price elasticities of foreign demand are assumed to be high, but not infinite.

## Remaining Basic Assumptions

These can be summarized as follows:

(a) There is market clearing in commodity markets. The model lacks a complete specification of the supply side of the factor markets. Exogenous factor supplies can be imposed with factor prices determined by market-clearing. Alternatively, factor prices can be set exogenously with the aggregate employment of factors determined by demand.

(b) Trade and transport margins are modelled explicitly, so that producers' and purchasers' prices differ.

(c) An equation is included for indexing nominal wages to the domestic price level. Hence, wage rates can be set exogenously in real as well as nominal terms (see (a) above).

The ORANI model is non-linear in its variables when the latter are expressed in levels. This non-linearity originates mainly from the use of neoclassical production and utility functions to characterize economic behaviour, ORANI is solved not in terms of the levels of the variables, however, but in a linearized form (following Johansen (1960)) in which variables explicitly appearing are percentage changes of the original variables.

In ORANI, as in most CGE models, agents are defined at a sectorally disaggregated but regionally aggregated level. For example, ORANI models the representative producer in the steel industry and the representative household in the economy as a whole but it does not distinguish among the various households and steel producers in different regions. There is, however, no conceptual reason why the theory should not be used to describe the behaviour of agents identified by region as well as by sector. Liew (1981, 1984), for example, experimented with a multiregional, multisectoral CGE model of the Australian economy.[6] It is a completely bottoms-up model in which region-wide results are obtained by aggregation over the sectors operating in the region, sector-wide results are obtained by aggregating over the regional components of the sector, and economy-wide results are obtained by aggregating over both sectors and regions. The more typical, single region CGE model is a bottoms-up model only in that economy-wide results are aggregates of the sectoral results. Regional results can only be obtained via a tops-down disaggregation which allows no feedback from regions to the economy-wide level.

The main obstacles to the construction of detailed and fully specified multiregional multisectoral CGE models are computing problems and data deficiencies. If the model is highly disaggregated in the sectoral dimension, it is likely already to be quite large and the additional regional dimension might strain computing capacity even with linear solution methods. The implementation of a multiregional, multisectoral model requires a full multiregional input-output data base with inter-regional trade flows disaggregated by sector- and region-specific user as well as by commodity class and regional source. Such data are not available for most countries.[7]

Tops-down regional disaggregations of results from a single-region CGE model are much more modest in their data and computing demands, but much less satisfactory theoretically. The simplest tops-down approach is to assume that each region always produces a constant share of each sector's economy-wide output. For a CGE model solved in percentage changes, this approach makes the percentage change in the output of any sector in any region equal to the economy-wide change in output for that sector. Regional differences in gross regional product or aggregate regional employment depend only on differences in the sectoral structures of the regions.

The tops-down package which we use to regionalize results from ORANI is called the ORANI Regional Equation System (hereafter ORES). It is based on the method first used by Leontief, Morgan, Polenske, Simpson, and Tower (1965) to regionalize results from an input-output model of the U.S. ORES requires the division of commodities into non-overlapping sets: "national" commodities, which are tradeable between regions; and "local" commodities, which are non-traded. For national commodities the allocation to each region of economy-wide output changes is exogenous. The constant-regional-shares assumption described above is the obvious possibility but others will suffice, so long as they ensure that each national industry's economy-wide projection is a suitably weighted average of the regional projections. The local/national dichotomy is particularly apt in a regional analysis of Australia, where the main population centres are separated by large geographic distances. We classify about 60 per cent of total employment in local sectors.

For the local-commodity sectors, ORES recognizes the paramount importance of the regional location of demand in determining the regional allocation of output. Regional outputs for each local sector are endogenized by regional market-clearing constraints for local commodities. In computing the regional demands for local commodities, ORES accounts for intermediate and investment demand in national and local industries and allows for regional aggregate household expenditure to be linked to regional aggregate income. In ORES, differences in the responses of the regions to economy-wide shocks depend not only on differences in their industrial structures but also on regional income-expenditure multipliers that affect the local sectors.

Data for ORES come from the Australia input-output data base, and from information on the regional patterns of sectoral output and of final demand.[8] In order to impose regional market-clearing constraints for local commodities, we need to estimate intermediate and final demand for each local commodity in each region. We do this by assuming that in all regions industries have the same input-output coefficients and final-users the same budget shares for each local commodity.

The major deficiency of ORES is the exogenous regional allocation of the national sectors. The main purpose of the hybrid tops-down, bottoms-up procedure is to ameliorate this deficiency by exploiting a CGE model's ability to project regional output responses in "national" sectors without moving to a prohibitively costly multiregional specification. We do this by defining in ORANI regional subindustries in some selected national sectors, and treating the additional regional detail as additional sectoral disaggregation. We then use the partially regionalized ORANI to drive ORES. The constant-regional-shares assumption for the regionalized "national" sectors is then unexceptional. For example, in our application below we describe a partially regionalized version of ORANI (ORANI-TAS) in which one industry is "Fruit (Tasmania)" and another is "Sugar Cane (Mainland)". In the standard version of ORANI, these are aggregated into a single economy-wide sector called "Other Farming, Export Related". In coupling ORANI-TAS with ORES we assume that Tasmania's share in Fruit (Tasmania) is always 1 and the mainland share is always 0. For Sugar Cane (Mainland) we assume that Tasmania's and the mainland's shares are always 0 and 1, respectively.

In the hybrid approach, we retain ORES's regional demand specification to determine the regional output of local sectors. The extent to which the hybrid approach will produce better regional projections than the pure tops-down method depends on how reliably the partially regionalized CGE model projects responses to shocks of the subsectors of the regionalized "national" industries. The hybrid method will give the same results as the pure top-down method using the constant regional shares assumption if the CGE model gives identical results for all regional subsectors in a national industry (because identical percentage changes imply that the shares are constant).

The following are examples of situations in which the hybrid approach will give useful regional projections.

(a) The economy-wide data may contain significant aggregation problems which can be overcome by regionalization. There may be aggregate commodities which have quite different regional sales and production patterns. The aggregation of Tasmanian fruit and mainland sugar-cane, is an example; the former depends on the export market, while the latter sells to a processing sector. In ORANI-TAS, significant differences in the responses of the regional subsectors emerged.

(b) There may be technology differences between regions that are obscured in the economy-wide model. In agriculture for example, climatic differences require regional variations in technology.

(c) Regions vary in their remoteness from markets. ORANI contains a complete specification of trades and transport margins, so differences between regional sources in the costs of transporting export commodities to ports of exit can be recognized.

## 3. EMPIRICAL IMPLEMENTATION

ORANI-TAS is our regionalized version of ORANI which contains some Tasmania-specific sectors. As suggested above, separating Tasmanian from mainland components of a sector is worthwhile when the two have different sales patterns, technology, etc. Furthermore, the payoff from disaggregation will be greater the larger is the industry in the Tasmanian economy. Table 1 lists the six Tasmanian industries that are distinguished in ORANI-TAS, and the differing export orientation (sales pattern) or labour intensity (technology) that justify distinguishing them. Together the six account for about 36 per cent of value added in Tasmanian national industries.

TABLE 1 ABOUT HERE

### 3.1 Data Requirements

For each ORANI industry into which the Tasmanian industries listed in Table 1 are aggregated, rows and columns of the input-output table were split into Tasmanian and mainland components using information from the Tasmanian office of the Australian Bureau of Statistics and from the 1977/78 Tasmanian input-output tables (Edwards, 1981).[9] In the absence of estimates based on Tasmania-specific data, values of behavioural parameters are identical to those for the corresponding aggregated sectors in standard ORANI.

### 3.2 Specification of simulations

To illustrate the ORANI-TAS-ORES system, we simulated the short-run effects of a 25 per cent across-the-board increase in all tariff rates on imported commodities. The most important features of the closure of ORANI-TAS employed for this simulation are:[10]

(a) Industry-specific capital stocks in use are unaffected by the shock under analysis.

(b) Real domestic absorption and the shares in it of household consumption, investment, and government spending are exogenous and set to zero change. The model indicates the change in the balance of trade which would need to accompany the tariff increase in order to maintain a given level of real domestic absorption.

(c) Labor supply is perfectly elastic at going real wage rates, which are unaffected by the tariff changes. Employment, therefore, is demand determined.

(d) The nominal exchange rate is the numeraire, so that changes in domestic price indexes are changes in domestic relative to world prices.

## 3.3 Results

The macroeconomic results from ORANI and ORANI-TAS for Australia as a whole are listed in Table 2. The most striking feature is the similarity between the two sets of projections. This is reassuring as we would not expect significant differences merely from a disaggregation that leaves unaffected the overall size of input-output flows and the average values of parameters. Note that Tasmania is a relatively small State accounting for only 3 per cent of Australian GDP. Both ORANI and ORANI-TAS project a fall in aggregate imports and a rise in consumer prices. Since we assume fixed real wage rates, there is a wage-price spiral and an increase in the nominal costs of producers. Because exporters face high price elasticities, cost increases reduce exports. The fall in exports is enough to outweigh the effect of the fall in imports on the balance of trade, and the effect of the expansion in the import-competing sector on aggregate employment.

TABLE 2 ABOUT HERE

The reason the columns of Table 2 are slightly different is that ORANI-TAS treats the economy as slightly more export oriented than does ORANI. We made endogenous the exports of all commodities for which exports are at least 20 per cent of total sales. In ORANI-TAS both Fruit (Tasmania) and Milk Products (Tasmania) meet the criterion (see Table 1), although the economy-wide categories in which they are aggregated in ORANI do not. Thus in ORANI-TAS a slightly higher share of total exports responds to a cost-price squeeze on account of the tariff increase and exports fall slightly more. Similarly, in ORANI-TAS, the weight in the consumer price index of commodities whose domestic prices are held down by world-market competition is slightly greater so that the index and wage costs rise slightly less. Domestic import-competing industries, therefore, replace slightly more imports.

In Table 3 we compare output projections from ORANI-TAS for the Tasmanian and mainland components of the regionalized industries with the corresponding ORANI projections. The payoff from our approach is clear. The ORANI-TAS projections for the mainland components are always very close to the ORANI projections, because the Tasmanian components are very small relative to the economy-wide aggregates. The real payoff is in the very different results for the Tasmanian components.

TABLE 3 ABOUT HERE

We now concentrate on differences between ORANI-TAS projections for Tasmanian industries and ORANI projections for the corresponding economy-wide sectors. For two Tasmanian industries, Fruit and Milk Products, exports are endogenous in ORANI-TAS but exogenous in ORANI (where they are aggregated with Sugar Cane (Mainland)and Milk Products (Mainland) respectively). Table 1 shows that the Tasmanian components are much more export-dependent than their mainland equivalents. Hence, ORANI-TAS has the Tasmanian subsectors contract sharply as a consequence of the cost-price squeeze induced by the tariff increase, while ORANI had the equivalent economy-wide sectors pass on cost increases without losing export sales.

Three other Tasmanian sectors -- Fishing, Metallic Minerals, and Basic Metals -- are export-oriented industries, and exports are endogenous in ORANI-TAS and also in the equivalent aggregated sector in ORANI. For these, regional differences in input structures cause the differences in results. The share of fixed factors (i.e., capital and agricultural land) in aggregate primary-factor costs is particularly important, because the higher it is, the lower is the industry's short-run supply elasticity.[11]

The last regionalized sector is Pulp and Paper, an import-competing sector. ORANI-TAS projects a Tasmanian output response which is only slightly less than the response projected by ORANI.

Finally, we will compare the results from ORANI-TAS and ORANI for Tasmania and Australia as a whole. Both models project that the tariff increase would cause a decline in Australia's gross product (ORANI project -0.12 per cent while ORANI-TAS projects -0.11 per cent) and aggregate employment (ORANI and ORANI-TAS both project a 0.20 per cent fall). The models also agree that the effects of the tariff increase on Tasmania are more severe than on the national economy. However ORANI-TAS suggests that the effect on Tasmania (a 1.40 per cent fall in Gross State Product and a 1.59 per cent fall in aggregate employment) would be significantly greater than does ORANI (which projects only a 0.54 per cent fall in Gross State Product and a 0.66 per cent fall in aggregate employment). Table 3 showed that on average the Tasmanian components of the regionalized industries in ORANI-TAS did worse than the corresponding economy-wide industries in ORANI. This accounts for 0.11 of the 0.86 percentage points difference between the two Tasmanian Gross State Product projections. The remaining 0.75 percentage points are accounted for by reduced output in Tasmanian 'local' industries, due to negative multiplier effects.

## 4. CONCLUSION

Our work reflects a pragmatic approach to policy-oriented economic research. Adding piecemeal regional detail to an economy-wide CGE model allows it to show how regional subsectors respond differently to national shocks. It is then appropriate to use the partially regionalized CGE model to drive a tops-down regional system in which the regional allocation of trading-sector responses is exogenous. The hybrid system is suited primarily to the analysis of the regional impact of economy-wide shocks, not the economy-wide impact of regional shocks. However, it can handle some regional shocks, in particular ones that directly affect the subsectors of the regionalized industries (a discriminating export subsidy, for example). Analysis of region-wide shocks requires the more demanding bottoms-up approach in which regionalization of the model extends to final demands and factor supplies.

Our work on ORANI-TAS commenced in 1981 (see Higgs, Parmenter, Rimmer, and Liew (1981)) and has subsequently been adopted by the Centre for Regional Economic Analysis located at the University of Tasmania. They have extended ORANI-TAS to include more regional subsectors, updated its data base, and applied it to a wide range of policy issues; see, for example, Hagger, Challen, and Madden (1982), and Challen, Hagger, and Madden (1983). The hybrid approach developed here has also been applied to Western Australia; see Ernst and Parmenter (1984).

TABLE 1 : TASMANIAN INDUSTRIES DISTINGUISHED IN ORANI-TAS AND THE CRITERIA USED FOR THEIR SELECTION[a]

| Industry | Share in Value Added of Tasmanian "National" Industries | Exports/Value of Total Output | | | Labour Costs/Total Primary-Factor Costs | | |
|---|---|---|---|---|---|---|---|
| | | Tasmanian Industry | Equivalent Mainland Industry | | Tasmanian Industry | Equivalent Mainland Industry | |
| Fruit | 0.02 | 0.60 | Sugar Cane | 0.11 | 0.66 | Sugar Cane | 0.42 |
| Fishing | 0.01 | 0.27 | | 0.52 | 0.59 | | 0.52 |
| Metallic Minerals[b] | 0.12 | 0.07 | Iron | 0.65 | 0.49 | Iron | 0.13 |
| | | | Other Metallic Minerals | 0.37 | | Other Metallic Minerals | 0.48 |
| Milk Products | 0.01 | 0.23 | | 0.11 | 0.70 | | 0.62 |
| Pulp and Paper | 0.09 | 0.05 | | 0.01 | 0.59 | | 0.91 |
| Basic Metal Products[c] | 0.11 | 0.33 | Basic Iron and Steel | 0.13 | 0.50 | Basic Iron and Steel | 0.63 |
| | | | Other Basic Metals | 0.29 | | Other Basic Metals | 0.53 |

(a) Data are for 1968/69 and are from the standard ORANI data base (Dixon, Parmenter, Sutton, and Vincent 1982, chapter 4) and Edwards (1981).

(b) The Tasmanian industry contains both Iron and Other Metallic Minerals.

(c) The Tasmanian industry contains both Basic Iron and Steel and Other Basic Metals.

TABLE 2 : THE EFFECTS ON MACROECONOMIC VARIABLES IN ORANI AND ORANI-TAS OF A 25 PER CENT ACROSS-THE-BOARD TARIFF INCREASE [(a)]

| Variable | PROJECTIONS | |
|---|---|---|
| | ORANI | ORANI-TAS |
| Index of Consumer Prices | 2.23 | 2.19 |
| Aggregate Exports (foreign currency value) | -2.55 | -2.56 |
| Aggregate Imports (foreign currency value) | -1.60 | -1.62 |
| Balance of Trade | -0.03 | -0.03 |
| Aggregate Employment | -0.20 | -0.20 |

(a) All projections are percentage changes with the exception of the balance of trade which has the units billions of 1968/69 Australian dollars

TABLE 3 : THE PERCENTAGE CHANGE EFFECTS ON OUTPUT FROM ORANI AND ORANI-TAS FOR INDUSTRIES REGIONALISED IN ORANI-TAS OF A 25 PER CENT ACROSS-THE-BOARD TARIFF INCREASE

| ORANI | | ORANI-TAS | |
|---|---|---|---|
| Industry | Projection | Industry | Projection |
| Other Farming Export | -1.42 | Fruit (T)[a] | -4.94 |
| | | Sugar Cane (M) | -1.39 |
| | | Fishing (T) | -2.00 |
| Fishing | -2.54 | Fishing (M) | -2.53 |
| Iron | -0.28 | Metallic Minerals (T) | -2.13 |
| Other Metallic Minerals | -1.85 | Iron (M) | -0.27 |
| | | Other Metallic Minerals (M) | -1.74 |
| | | Milk Products (T) | -4.11 |
| Milk Products | 0.01 | Milk Products (M) | 0.02 |
| | | Pulp and Paper (T) | 0.27 |
| Pulp and Paper | 0.31 | Pulp and Paper (M) | 0.31 |
| Basic Iron and Steel | -2.18 | Basic Metals (T) | -2.04 |
| Other Basic Metals | -2.25 | Basic Iron and Steel (M) | -2.16 |
| | | Other Basic Metals (M) | -2.25 |

(a) (T) = Tasmania; (M) = Mainland.

Footnotes

1. See, for example, the symposium on multiregional forecasting and policy simulation models in Journal of Regional Science (1980), Adams and Glickman (1980), and Issaev, Nijkamp, Rietveld, and Snickers (1982).

2. See, for example, Shoven and Whalley (1984), Borges (1986), and Decaluwe and Martens (1986).

3. 'Other costs' include production taxesand the costs of working capital.

4. CRESH (Constant Ratios of Elasticities of Substitution, Homothetic) is a generalization of CES in which the Allen-Uzawa partial elasticities of substitution between pairs of inputs can differ but are constrained to exhibit constant ratios; see Hanoch (1975).

5. CRETH (Constant Ratios of Elasticities of Transformation, Homothetic) is the output analogue of CRESH; see Vincent, Dixon, and Powell (1980).

6. Note that multi-country CGE models are formally similar; see, for example, Deardorff and Stern (1985) and Whalley (1986).

7. An exception is Polenske (1972-78). Liew (1981, 1984) was forced to rely on a gravity model to generate his interregional flow data.

8. ORES's data requirements are described in Lawson and Parmenter (1979) and Lawson and Vincent (1979).

9. A detailed description of the ORANI-TAS data base is in Higgs, Parmenter, Rimmer, and Liew (1981).

10. A complete list of the exogenous variables, which is essential documentation for reproducing our results, is in Higgs, Parmenter and Rimmer (1983, Appendix).

11. The nested CES production functions in ORANI and ORANI-TAS imply a supply function for industry j:

$$z_j = (p_j - \tilde{p}_j)\ \sigma\ (1 - F_j)/(F_j H_j) \quad ;$$

where $z_j$, $p_j$, and $\tilde{p}_j$ are the percentage changes for industry j in output, output price, and the average price of purchased inputs; $\sigma$ is the elasticity of substitution between primary factors; and $F_j$ and $H_j$ are the shares of fixed factors in aggregate primary factor costs and of aggregate primary factor costs in total costs. See Higgs (1986) for the derivation of the supply function.

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