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THE ROLE OF MINIATURES IN COMPUTABLE GENERAL EQUILIBRIUM MODELLING: EXPERIENCE FROM ORANI

by

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Contents

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I. INTRODUCTION

The ORANI model (Dixon, Parmenter, Sutton and Vincent [1982][1]) of the IMPACT Project[2] is a large, highly developed computable general equilibrium (CGE) model of the Australian economy which is routinely used by government and economic policy analysts. The experience gleaned during two full cycles of ORANI's development[3] and numerous policy applications[4] has revealed four important uses for miniature models in applied research on large CGE systems. These are:

(a) Heuristics   ORANI distinguishes 230 commodities, 113 types of capital, up to 70 types of labor, 6 regions, and numerous substitution and transformation relationships. Notwithstanding the structural simplicity engendered by an explicit basis in microeconomic theory, the rationalization of any particular result obtained from ORANI in terms of a subset of its scalar equations is often time-consuming, and always involves superior powers of discrimination between trees and forests. Appropriately constructed miniatures are able to encapsulate the major mechanisms in the large model which are responsible for particular simulation results, and to make these mechanisms transparent for model users with only a limited command over the intricacies of the full system.[5]

(b Error detection   With large systems the scope for errors in computing and data handling is immense. The model builder must provide detailed evidence, to himself and to model users, that the results do, in fact, follow from the theory and data. Corroborative calculations using miniatures are an important source of such evidence.

(c) Sensitivity analysis Modifications to a miniature can give, at low cost, an indication of how some particular set of projections from a large CGE model would respond to changes in underlying assumptions and data. This is especially valuable for observers who lack access to the computing system for the full model.

(d) Prototype development Rather than working immediately with the full model, experiments with new modeling developments are usually made more conveniently with miniatures. In this way the key theoretical issues involved can be highlighted, enabling the development of a new structural form without the impediments of inevitably slower work on a detailed data base and computing system for the full CGE model. A recent example is Dixon, Parmenter and Rimmer [forthcoming 1983].

In this paper we concentrate on (a) and (b). Indeed we wish to investigate, by example, just how far these two roles can be developed.

In the standard didactic miniature of ORANI, MO (DPSV [1982, Ch.2]), one might reasonably expect to obtain results which are qualitatively similar to those obtained from the full model; with questions which can be addressed in terms of the limited supply of variables available in MO, one is not disappointed. Is it possible to do better than this? Could one infer that the value of some key endogenous variable in ORANI should increase by 5 (as distinct from 10) per cent as the result of some contemplated policy shock?

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11. For the total of 12 results reported in Table I for the first 3 shocks the standard error computed was $\{\Sigma[(Bi-Oi)/Oi]^2/12\}^{\frac{1}{2}}$, where Oi and Bi respectively are the ith ORANI and BOTE results.

12. We work towards a reduced form for ξ by first using equations (6), (7) and (8) to express q^n in terms of w, ξ, a, x^e, p^n, p_m^n and p_m^c. Then we use this expression to eliminate q^n from (5). Finally we substitute into (9) to obtain (16)-(18). Fortunately it is not necessary for our purposes to proceed to a complete reduced form by eliminating x^e.

13. The seminal work is Johansen [1960].

Clearly a general purpose miniature does not exist. If one is interested in (say) the chemical industry, then to be of use, a miniature must explicitly recognize this industry (or at minimum, a group of industries sharing a common fate with the chemical industry under the shock in question). For quantitative validation[6] of particular results from a large CGE model, therefore, application-specific miniatures are required. Each such miniature potentially differs from others in complexity, in the level and type of aggregation scheme adopted, and in the number of equations and variables explicitly recognized.

In this paper we use a single special purpose miniature, BOTE (back-of-the-envelope model), to explain results from ORANI under four shocks which alter the real exchange rate. Something of the art and science of building miniatures is revealed by this exercise. A spin-off is an empirically established result concerning the aggregation of elasticities of substitution in ORANI.

The paper is structured as follows. In Section II we summarize the more important assumptions underlying the ORANI simulations. In Section III the principal ORANI results are given. Section IV contains the specification of BOTE, and initial results from it, of which one set cannot be matched satisfactorily with ORANI. This problem is diagnosed as one of parameter aggregation in Section V, where appropriate amendments are made to BOTE. Our research perspectives from the overall exercise are contained in Section VI.

II. MAJOR ASSUMPTIONS UNDERLYING THE ORANI SIMULATIONS

ORANI can be used to generate either short-run or long-run conditional projections. These are of the form : given a shock A, and assuming a macroeconomic environment B, then in the short run (long run) variable C will differ by x per cent (y per cent) from the value it would have had in the absence of the shock. The four shocks, A, to be considered in this paper are:

(i) a 10.6 per cent across-the-board increase in the nominal rates of protection for the import-competing sector,

(ii) a 0.57 per cent increase in real hourly wage rates,

(iii) a change in crude-oil pricing policy leading to a 26 per cent increase in the basic price of domestically refined oil products, and

(iv) a balanced 0.45 per cent increase in real aggregate domestic absorption (i.e., an increase in the domestic component of aggregate demand which leaves unchanged the shares of consumption, investment and government spending).

Each of the above impinges on issues relevant to Australian macroeconomic policy. The sizes of the shocks were selected to make comparisons easier. Each shock is projected by ORANI to yield an identical decrease of one per cent in the real exchange rate. Because of this, there is a strong similarity across the four shocks in projected effects on the agricultural sector, which is heavily involved in international trade.

ORANI users must introduce their own assumptions about the macroeconomic environment, B. This is because there are three important macroeconomic aspects of the effects of shocks to the economy about which the model offers no guidance. They are:

FOOTNOTES

* The authors are grateful to Mike Kenderes and Tony Lawson for comments.

1. Abbreviated below as DPSV [1982].

2. IMPACT is an economic and demographic research project conducted by Australian Federal Government agencies in association with the Faculty of Economics and Commerce at the University of Melbourne and the School of Economics at La Trobe University. The aims and strategy of the project are set out in Powell [1977]. Briefer material is available in Powell and Parmenter [1979] and in Powell [forthcoming 1983].

3. The state of ORANI at the completion of its first and second full cycles of development is reported respectively in Dixon, Parmenter, Ryland and Sutton [1977] and in DPSV [1982].

4. An overview of applications of ORANI is given in section 50 of DPSV [1982].

5. Related ideas are in Taylor and Lysy [1979].

6. We use the term validation in this article to mean confirmation that a purported general equilibrium result does indeed follow from the assumptions, data base, and parameter files of the model. For a discussion of an approach to validation of CGE models in the time series sense, see Powell [1981], 241-7.

7. Aggregate absorption is defined as the sum of consumption, investment, and government spending.

8. The effects of cost increases are projected to be less severe in the import competing than in the export sector since the typical elasticity of substitution between imports and domestic commodities in the ORANI data base is only about 2 (DPSV [1982], subsection 29.1) whereas foreign demand elasticities for exportables are, on average, about 16 (DPSV [1982], subsection 29.6).

9. The full technological assumptions are that gross output is Leontief in material inputs and an index of value added; and that the value added index is CES in labor and capital.

10. In the demand equations for each good (e.g., footwear) the relevant substitution terms in ORANI take the form $\sigma SR(p - p^*)$ where p and p^* are the percentage changes in the basic prices of the domestic and imported good, e.g., p is the percentage change in the producer price of domestically produced footwear and p^* is the percentage change in the landed-duty-paid price of imported footwear; R is the average ratio of the basic price of footwear to the various purchasers' prices; S is the share of imported footwear in the total sales of footwear; and σ is the elasticity of substitution between imported and domestic footwear (i.e., the Armington elasticity). In the ORANI data base, average values for σ , S and R are 1.8, 0.07 and 0.8.

With the art and science of large scale applied general equilibrium modeling now in its third decade[13], practitioners are attempting to put their policy-analytic work on a routine basis. We see a definite role for miniatures of the type described in this paper as part of this effort.

(a) the extent to which induced changes in the buoyancy of the labor market will be realized as changes in real wages or as changes in employment;

(b) the extent to which induced changes in national income will be realized as changes in aggregate absorption[7] or as changes in the balance of trade; and

(c) the extent to which induced changes in the real exchange rate will be realized as changes in the domestic inflation rate relative to the foreign rate or as changes in the nominal exchange rate.

In the current application we have assumed that:

(A) labor-market effects appear as changes in the overall level of employment and not as changes in real wages. Thus, real wages were set exogenously. For the wage shock, the increase in real wages was set at 0.57 per cent. In the other simulations, zero change was assumed. An interpretation of this assumption is that real hourly wage costs are fully indexed to the CPI and that excess labor is available at the going real wage.

(B) changes in national income appear as changes in the balance of trade and not as changes in aggregate absorption (which was set exogenously). In the simulation of an expansion in demand, the increase in real absorption was set at 0.45 per cent; elsewhere, zero change was assumed. The exogenous treatment of aggregate absorption reflects the existence of fiscal and monetary instruments which are not modeled in ORANI but whose separate exercise can stabilize aggregate demand in the face of shocks affecting relative prices in the economy.

(C) changes in the real exchange rate appear as changes in the domestic inflation rate relative to the foreign rate and not as changes in the nominal exchange rate. In all simulations the change in the nominal exchange rate was fixed exogenously at zero. We also assume that the shocks under consideration have negligible effects on foreign rates of inflation. Thus in our ORANI simulations, adjustments in the real exchange rate are reflected by adjustments in the domestic CPI. There would have been no difference in the ORANI results for real variables if we had, instead, fixed the CPI and allowed the nominal exchange rate to adjust.

Finally, with regard to timing, we have adopted the neo-classical short-run. This is a period sufficiently long for the shock-induced changes in trading conditions to work their way through the economy and for producers and consumers to adjust their behaviour accordingly. In the case of producers, this includes revisions of investment plans which in turn affect the demands faced by industries supplying capital goods. The period is sufficiently short, however, to ignore changes induced by the shocks in physical capital available for use in each industry. This short run has been estimated to be about 2 years (see Cooper and McLaren [1981]).

VI. RESEARCH PERSPECTIVES

We have shown how a very small model (BOTE), constructed on an application-specific basis, can produce results which, to a good approximation, mirror those of a very large CGE model (ORANI). The motivation for such an exercise is threefold. First, since the miniature model incorporates only the mechanisms thought to be a major influence in the production of the results of the large model, the model user gains confidence in his understanding of the large model by such an exercise. Second, the likelihood of an undiscovered computer or data handling error in the big model is reduced when results can be replicated in a miniature. Finally, since policy-analytic results must be explainable, the miniature provides for policy makers a valuable window into what might otherwise remain to them an unopened (and therefore useless) black box.

Given the success of our BOTE calculations in explaining the ORANI results, it might be tempting to conclude that we do not need large detailed models. It is worth emphasising, however, that in our BOTE calculations, ORANI gave us some important help. The parameter aggregation problem treated in Section V, for example, simply could not have become explicit in a reference frame which included only the miniature. Nor is the help provided by a large CGE model confined to the detection of important compositional effects. More generally, it is difficult to imagine convincing calculations from miniatures in the absence of a detailed model. For example, imagine that a large CGE model incorporates factors A,B,C, ..., Z, whereas the small model includes factor A alone. If the small model accurately describes a particular large model result, then we can conclude that for this result factors B,C,...,Z are not important. With the small model alone, factors B,C,...,Z could not be dismissed.

industries with high shares of their costs accounted for by capital tend to have low labor shares in primary factor costs and vice-versa. In constructing our BOTE description of the ORANI simulations, it is not clear how we should evaluate $S_k^n/(\sigma^n V_\ell^n)$. Certainly the use of aggregate shares will produce a value which is far from 'typical' of the industries aggregated within sector n. Given the strong negative correlation between numerator and denominator, the use of aggregate shares would be expected to generate an inappropriately low value. Consequently, we feel justified in recomputing our BOTE results with

(19) $$S_k^n/(\sigma^n V_\ell^n) = 0.893 ,$$

rather than the original value of 0.500. (Notice that 0.893/0.500 equals 1/0.56. The value 0.893 was chosen with a view to raising our BOTE result for the CPI for $a = 0.45$ from the initial value of 0.56 to a value closer to 1.) To achieve (19) we have reset σ^n to 0.28 rather than 0.5. S_k^n and V_ℓ^n have been left at the values shown in Table II.

The revised results are shown in rows 3, 6, 9, and 12 of Table I. In the case of the previously satisfactory results, a slight deterioration has taken place (standard error 17, versus 15, percent). The results for the real absorption shock, however, have been brought into much better agreement with the corresponding ORANI results.

III. THE ORANI PROJECTIONS

Rows 1, 4, 7 and 10 of Table I contain ORANI projections of the effects of our four shocks on employment at the economy-wide level and on employment and real income in the agricultural sector. They also confirm (column 2) that we have normalized the shocks so that each leads to a one per cent reduction in the real exchange rate. In each case, this is associated with reductions in agricultural employment and income.

In qualitative terms the ORANI results in Table I are easily explained. We start with the CPI results. Shocks (i) - (iii) are exogenous increases in prices : the domestic prices of imported commodities, of all categories of labor, and of oil. Rises in the prices of imports and oil increase the CPI directly. Each of the first three shocks raises domestic production costs and the prices of domestically produced commodities. Thus, further increases in the CPI are projected. Recall that in these ORANI simulations, nominal wages are indexed to the CPI. Increases in money wages matching initial increases in the CPI produce yet further increases in production costs and the CPI. Successive rounds of price and wage increases ensure that the total projected effects of the shocks on the CPI are very much greater than their initial effects.

In the case of shock (iv) there are no exogenous price changes but the increase in domestic absorption is projected to increase output, especially in the non-traded sector. Because the capital stock in each industry is assumed fixed, the model implies upward sloping supply curves. Thus the exogenous increase in absorption raises prices and the CPI. As with shocks (i) - (iii), the initial increase in the CPI is magnified in ORANI by a price-wage spiral.

TABLE I

COMPARISON OF ECONOMY-WIDE AND AGRICULTURAL SECTOR RESULTS
FROM ORANI AND BOTE*

Shock		Row	Calculation Method	Economy-Wide Results: Aggregate Employment (hours)	Economy-Wide Results: Real Exchange Rate (-CPI)#	Agricultural Sector: Employment (hours)	Agricultural Sector: Real Factor Income
				(1)	(2)	(3)	(4)
(i)	10.6% Increase in all Tariffs	1	ORANI	-0.15	-1.00	-1.31	-1.8
		2	BOTE (σ^n = 0.50)	-0.20	-0.97	-1.40	-2.0
		3	BOTE (σ^n = 0.28)	-0.21	-1.01	-1.45	-2.0
(ii)	0.57% Increase in Hourly Real Wage Costs	4	ORANI	-0.46	-1.00	-1.85	-1.9
		5	BOTE (σ^n = 0.50)	-0.56	-1.02	-2.07	-2.3
		6	BOTE (σ^n = 0.28)	-0.49	-0.86	-1.83	-2.0
(iii)	26% Rise in Domestic Price of Crude Oil	7	ORANI	-0.50	-1.00	-1.93	-2.7
		8	BOTE (σ^n = 0.50)	-0.47	-1.12	-1.70	-2.4
		9	BOTE (σ^n = 0.28)	-0.41	-0.99	-1.49	-2.1
(iv)	0.45% Rise in Real Absorption	10	ORANI	0.07	-1.00	-1.26	-1.7
		11	BOTE (σ^n = 0.50)	0.24	-0.56	-0.67	-1.0
		12	BOTE (σ^n = 0.28)	0.13	-0.85	-1.13	-1.5

* All results are percentage changes relative to the values which the variables would have had in the absence of the shock. The projected timing of these changes is about two years after the shock. Real factor income in column (4) is the total return in the agricultural sector to labor (hired and owner-operator), capital and land deflated by the CPI.

\# Under assumption C in section II, the percentage change in the real exchange rate is the negative of the percentage change in the CPI.

Source : The simulations were conducted with ORANI 78 with the exogenous variables as listed in Table 23.3 of DPSV [1982] and with standard 1974/5 input-output data.

V. REPAIRING THE MINIATURE

BOTE is a <u>very</u> small model. One might therefore feel surprised that overall it did so well in replicating ORANI results. Nevertheless, its failure in the case of one of four broadly similar shocks was puzzling. The puzzle can be resolved by appeal to the following partially reduced form equation for the CPI[12]:

(16) $$\xi = \psi_2 \Big\{ \big[W_m + (\psi_1 W_n S_k^n \eta_2 Q_m^c/(\sigma^n V_\ell^n))\big] p_m^c + (W_o + \psi_1 W_n S_o^n) p^o + (W_e + \psi_1 W_n S_e^n) p^e + (\eta_1 \psi_1 W_n S_k^n/(\sigma^n V_\ell^n)) a + \psi_1 W_n (S_\ell^n + S_k^n) w + \psi_1 W_n \big[S_m^n + S_k^n(\eta_2 Q_m^n/(\sigma^n V_\ell^n))\big] p_m^n + \psi_1 W_n \big[S_k^n (1-\eta_1)/(\sigma^n V_\ell^n)\big] x^e \Big\} ,$$

where

(17) $$\psi_1 = 1 \Big/ \big[1 + (\eta_2 S_k^n/(\sigma^n V_\ell^n))\big] ,$$

and

(18) $$\psi_2 = 1 \Big/ \big[1 - \psi_1 W_n (S_\ell^n + S_k^n + S_i^n)\big] .$$

In (16) we see that the value of the coefficient of a is approximately proportional to the value adopted for the ratio $S_k^n/(\sigma^n V_\ell^n)$ which also affects the coefficients of the other variables because it enters ψ_1 (see equation (17)). However, it is clear that changes in the value of $S_k^n/(\sigma^n V_\ell^n)$ will have a greater impact on the a coefficient than on the others. This suggests that the poor performance of BOTE in describing the CPI results for ORANI simulation (iv) could be associated with a mis-evaluation of this ratio.

The values for S_k^n and V_ℓ^n in Table II are aggregate shares for the non-export sector taken from the ORANI data base. If we consider the S_k and V_ℓ shares for individual non-export industries in ORANI, we find that

Table II

PARAMETER VALUES FOR THE BOTE MODEL[(a)]

1. Production Sectors

	Export Sector	Non-export Sector
Labor share in primary factor costs :	$V^e_\ell = .61$	$V^n_\ell = .740$
Capital share in primary factor costs :	$V^e_k = .39$,	$V^n_k = .260$
Labor share in total costs :	$S^e_\ell = .37$,	$S^n_\ell = .526$
Capital share in total costs :	$S^e_k = .24$,	$S^n_k = .185$
Other input share in total costs :	$S^e_i = .39$	
Oil share in total costs :		$S^n_o = .006$
Share of the exportable in total costs :		$S^n_e = .078$
Imported input share in total costs :		$S^n_m = .086$
Miscellaneous input share in total costs :		$S^n_i = .119$
Capital/labor substitution elasticity :	$\sigma^e = .50$,	$\sigma^n = .50$[(b)]
Demand function parameters		$\eta_1 = .1$
(see equation (12)) :		$\eta_2 = .04$

2. Weights in the CPI

Non-export good :	$W_n = .881$
Imports :	$W_m = .050$
Export good :	$W_e = .060$
Oil :	$W_o = .009$

3. Shares in aggregate imports

Industry usage :	$Q^n_m = .75$
Consumption :	$Q^c_m = .25$

4. Tariff rates(c)

Industry inputs : $T^n = 0.19$

Consumer goods : $T^c = 0.28$

(a) The parameter values were selected with reference to the ORANI data base described in detail in DPSV [1982], ch.4. In this paper we used an updated data base incorporating the recently available 1974/75 input-output table.

(b) In our ORANI simulations, the capital/labor substitution elasticity was set at 0.5 for all industries. This was the value which we initially adopted for both sectors of our BOTE model. Subsequently we changed σ^n to 0.28 (see the discussion in Section V).

(c) These are weighted averages of commodity tariff rates using as weights commodity shares in the aggregate value of imports directly consumed and commodity shares in the aggregate value of imports used as intermediate inputs.

Next we note that the increases in real wages and oil prices both lead to approximately the same decrease in aggregate employment (i.e., about 0.5 per cent). General increases in domestic costs, unaccompanied by compensating shifts in the demand curves for domestic products, are projected to reduce activity, especially in the exporting and import competing sectors where the scope for passing on cost increases into selling prices is constrained by international competition.[8] In cases in which tariff rates remain fixed, the change in the real exchange rate is a good indicator of the change in the international competitiveness of the import-competing as well as the export sector. When (as in the first simulation) tariff rates are increased, the competitiveness of the import-competing sector is influenced by the consequent increase in the domestic prices of imports as well as by the change in the real exchange rate. This explains why, according to ORANI, a one per cent deterioration in the real exchange rate induced by a general tariff increase causes a smaller reduction in aggregate employment than the same deterioration brought about by wage or oil-price increases.

The final shock, an absorption increase, generates a small rise in aggregate employment in spite of the deterioration in the real exchange rate. The increased demand stimulates output and employment in the non-trading sector and in the import competing sector where the assumption of imperfect substitution between imports and domestic supplies prevents the demand increase from spilling entirely into imports. Note, however, that ORANI indicates that, because of the contractionary effects of the accompanying deterioration in the real exchange rate, demand expansion is not a very effective method of increasing employment. According to ORANI, most of the demand expansion is accommodated by a deterioration in the balance of trade.

The ORANI results for the agricultural sector in Table I reflect the fact that about 70 per cent of agricultural output is exportable either directly or after only minor processing in manufacturing. In all simulations export-related activity in agriculture is projected to decline with the real exchange rate. In simulations (i) and (iv), the sector gains some relief via its non-export-related activities (e.g., tobacco, vegetables and cotton) which benefit from expansion in the import-competing (simulation (i)) and the non-trading sectors (simulation (iv)). Thus, the deterioration in the real exchange rate is associated with less severe effects on agricultural income and employment in simulations (i) and (iv) than in simulations (ii) and (iii).

IV. A BACK-OF-THE-ENVELOPE (BOTE) VERSION OF ORANI

In this section our aim is to explain the ORANI results of Table I quantitatively, not merely qualitatively. For example, rather than being satisfied with understanding why ORANI projects a decline in the real exchange rate under a 10.6 per cent increase in all rates of protection, we will now be concerned with why the projected decline is one per cent instead of (say) two per cent. For this purpose we build a back-of-the-envelope (BOTE) miniature which includes the main mechanisms responsible for the results reported above.

A key to understanding ORANI results is the distinction made between export and non-export commodities. For the former category, domestic prices are assumed to be determined almost entirely by exogenous developments in world markets. For the latter, domestic prices are assumed to adjust to shifts in domestic demand and supply curves. In BOTE we therefore include two sectors, one producing an exportable and the other a non-exportable commodity.

changes). The shares in equations (13) and (14), taken from the ORANI data base, indicate that 70 per cent of the output of the agricultural sector consists of commodities which are exportable directly or after processing in the manufacturing sector. The shares in equation (15) reflect the fact that about 12 per cent of the workforce is occupied in the production of exportable commodities.

Our data base for BOTE, shown in Table II, is an aggregation of the ORANI data base. The aggregate share terms (S, V, W, Q and η_1) are easily obtained since they simply involve reaggregation of dollar values and computation of the required ratios. The behavioral parameters η_2, σ^e and σ^n are less obviously dealt with. In the case of η_2, however, an argument based on average values of ORANI's underlying parameters (see footnote 10) produced a satisfactory aggregation scheme. Since the micro-parameters in ORANI corresponding to σ^e and σ^n all have the common value 0.5, we thought it safe to assign that value to σ^e and σ^n in BOTE. The results obtained on this basis are shown in rows 2, 5, 8 and 11 of Table I. Comparison of these results with the corresponding ORANI results reveals that BOTE (with σ^n = 0.5) gives a reasonable approximation to ORANI in the case of the first three shocks (standard error 15 percent of the ORANI value[11]), but gives serious errors in the case of the real expenditure shock. This failure caused us to retrace our steps.

$$(12) \qquad x^n = \eta_1 a + (1-\eta_1)x^e - \eta_2\left[p^n - (Q^n_m p^n_m + Q^c_m p^c_m)\right] \quad ,$$

where a is the percentage change in real absorption, and Q^n_m and Q^c_m respectively are the shares of total imports absorbed by inputs to production and by consumers. η_1 is the share of the output from sector n used in domestic absorption and $(1-\eta_1)$ is the share used as an input to sector e. The first two terms on the RHS of (12) mean that in the absence of price changes, the percentage change in demand for commodity n is a suitably weighted average of the percentage changes in aggregate absorption and the output of sector e. In view of the ORANI data base, a reasonable value to adopt for η_1 is 0.96. The final term on the RHS of (12) allows for import substitution. Given the substitution parameter values used in ORANI, a reasonable value for η_2 is 0.1.[10]

Equations (1) - (12) constitute a system of 12 equations in 18 variables. Of the latter, output (x^e, x^n), employment of labor (ℓ^e, ℓ^n), rental prices on capital (q^e, q^n), primary factor income (r^e, r^n), prices of imports (p^n_m, p^c_m), consumer prices (ξ) and the price of the non-export commodity (p^n) are endogenous. The exogenous variables driving the system are the prices of the exportable (p^e) and of oil (p^o), tariff rates (t^c, t^n), real absorption (a) and the real wage (w). The last five of these are necessary to inject the shocks described in Section III.

To this basic system we append the following three equations which can be solved recursively from it:

$$(13) \qquad \ell^a = .70\ell^e + .30\ell^n \quad ,$$

$$(14) \qquad r^a = .70r^e + .30r^n \quad ,$$

and

$$(15) \qquad \ell = .12\ell^e + .88\ell^n \quad .$$

These equations define respectively employment in the agricultural sector, factor income therein, and economy-wide employment (all as percentage

We describe activity in the exporting sector (sector e) by the equations:

$$(1) \qquad p^e = S^e_\ell(w + \xi) + S^e_k q^e + S^e_i \xi \quad ,$$

$$(2) \qquad \ell^e = \sigma^e(q^e - w - \xi) \quad ,$$

$$(3) \qquad x^e = V^e_\ell \ell^e$$

and

$$(4) \qquad r^e = V^e_\ell(\ell^e + w) + V^e_k(q^e - \xi) \quad .$$

The variables are:

- p^e, the percentage change in the domestic price of the exportable product;
- w, the percentage change in the real wage rate;
- ξ, the percentage change in the consumer price index;
- q^e, the percentage change in the rental value (or profit) per unit of capital in the exporting sector;
- ℓ^e, the percentage change in employment in the exporting sector;
- x^e, the percentage change in the volume of output of sector e, and
- r^e, the percentage change in primary factor income in the sector.

The parameters are:

- S^e_ℓ, S^e_k and S^e_i, the shares of the costs of production in the exporting sector represented by payments to labor, rentals on capital and purchases of other inputs;
- V^e_ℓ and V^e_k, the shares of labor and capital in value added, and
- σ^e, the elasticity of substitution between capital and labor.

S^e_ℓ, S^e_k and S^e_i sum to unity as do V^e_ℓ and V^e_k.

$$V^e_\ell = S^e_\ell/(1 - S^e_i) \text{ and } V^e_k = S^e_k/(1 - S^e_i) \quad .$$

The pricing equation (1) is a zero pure profits condition. Notice that we have assumed that the price per unit of inputs other than labor and capital moves with the CPI. The labor-demand equation (2) and the relationship (3) between output and labor input are implications of the short-run profit maximizing problem of choosing output and labor input to maximize profits subject to a CES production function and a fixed stock of capital.[9] Equation (4) defines the percentage change in real income (returns to labor and capital) in the exporting sector, assuming that the employment of capital is fixed. The variables that can be thought of as endogenous to the exporting sector are q^e, ℓ^e, x^e and r^e. The exogenous treatment of p^e is only an approximation to the treatment in ORANI where high (but not infinite) values are adopted for export demand elasticities (DPSV [1982, p.196]).

For the sector producing the non-exported commodity (sector n), we adopt equations analogous to (1) to (4):

$$(5) \qquad p^n = S^n_\ell(w + \xi) + S^n_k q^n + S^n_o p^o + S^n_e p^e + S^n_m p^n_m + S^n_i \xi ,$$

$$(6) \qquad \ell^n = \sigma^n(q^n - w - \xi) ,$$

$$(7) \qquad x^n = V^n_\ell \ell^n ,$$

and

$$(8) \qquad r^n = V^n_\ell(\ell^n + w) + V^n_k(q^n - \xi) .$$

Only (5) needs further explanation. Compared with (1), (5) provides a more detailed breakdown of other inputs. S^n_o, S^n_e and S^n_m are the shares of costs in sector n represented by inputs of oil, inputs of the exportable commodity and imports. p^o and p^n_m are the percentage changes in the domestic prices of

oil and imported inputs. S^n_i is the share of miscellaneous costs, e.g., the costs of holding working capital. We assume that miscellaneous costs per unit of output move with the CPI. The cost shares S^n_ℓ, S^n_k, S^n_o, S^n_e, S^n_m and S^n_i sum to one. In (5) we have netted out sector n's intermediate usage of its own output.

Next we define percentage changes in the CPI by:

$$(9) \qquad \xi = W_n p^n + W_m p^c_m + W_o p^o + W_e p^e ,$$

where W_n, W_m, W_o and W_e are the weights in the CPI of non-exportable commodities, imports, oil and exportables. p^c_m is the percentage change in the domestic price of imported consumer goods. It may differ from p^n_m. In fact, we assume

$$(10) \qquad p^c_m = 0.219t^c ,$$

and

$$(11) \qquad p^n_m = 0.160t^n ,$$

where t^c and t^n are the percentage changes in the ad valorem tariff rates applying to consumer goods and intermediate inputs respectively. Equations (10) and (11) are justified by our assumptions that the foreign currency prices of imports are exogenous and that the nominal exchange rate is fixed. The coefficients on the RHS's of (10) and (11) are $T^c/(1 + T^c)$ and $T^n/(1 + T^n)$ where T^c and T^n are the average tariff rates applying to consumption goods and intermediate inputs. In the ORANI data base, $T^c = 0.28$ and $T^n = 0.19$.

Finally, we introduce a demand function for non-exportables. (No explicit demand function is required for exportables since p^e is exogenous). We assume that the demand for non-exportables is described by: