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ORANI-F AND MONASH: GENERAL EQUILIBRIUM MODELS OF THE AUSTRALIAN ECONOMY FOR MEDIUM-RUN FORECASTING

by

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The Centre of Policy Studies (COPS) is a research centre at Monash University devoted to quantitative analysis of issues relevant to Australian economic policy. The Impact Project is a cooperative venture between the Australian Federal Government and Monash University, La Trobe University, and the Australian National University. During the three years January 1993 to December 1995 COPS and Impact will operate as a single unit at Monash University with the task of constructing a new economy-wide policy model to be known as *MONASH*. This initiative is supported by the Industry Commission on behalf of the Commonwealth Government, and by several other sponsors. The views expressed herein do not necessarily represent those of any sponsor or government.

ABSTRACT

Since the mid-1980s ORANI-F has been the main vehicle used by the research team now located at the Centre of Policy Studies (CoPS) for forecasting the average annual growth rates of macroeconomic and structural variables over the medium-run periods (six years, say). The model contains enough dynamics to accumulate variables such as capital stocks and foreign debt over the medium term but not enough to give convincing year-to-year time paths for the variables. In this paper we describe a 22-sector version of ORANI-F which is available to users outside the CoPS research team in a fully documented PC version.

The CoPS team is in the process of moving to a new model, called *MONASH* , with enough dynamics to allow sectorally disaggregated annual forecasts which track externally projected business-cycle phenomena. We compare forecasts from *MONASH* and ORANI-F for the period 1990-91 to 1996-97.

from the ORANI-F simulation using the corrected growth rate for investment are reported in the last column of Table 3 (see row 10 for the corrected investment growth rate).

By comparing the last column of Table 3 with the seventh column (i.e., the accumulated MONASH-style projections), we see that while reconciling the differences between the two models in their projections of capital growth and technical change, the correction to the investment growth rate creates other discrepancies. The main problem is that our ORANI-F projections of GDP growth, which are driven by projections for the expenditure-side aggregates, depend on the end point of the investment path, not on accumulated investment. By reducing the smooth growth rate of investment, we have lowered this end point and reduced our ORANI-F projection of GDP growth (row 7 of Table 3). We have also reduced projected import growth (row 11) and increased the rate at which the trade balance is projected to improve.

5. Conclusion

Starting with the 22-sector version of ORANI-F described by Horridge, Parmenter and Pearson (1993), we create a MONASH-style model by replacing the ORANI-F investment specification with the specification described by Adams, Dixon, McDonald, Meagher and Parmenter (1993, section II.3).

We show that when all computations are performed *via* single-step Johansen procedures ORANI-F gives projections of six-year movements in economic variables which are somewhat different from those obtained by accumulating annual projections obtained from a MONASH-style model. Differences between the two sets of projections are explained by two factors: the greater numerical accuracy of the MONASH-style computations and fundamental problems flowing from the smooth-growth assumptions used to simplify the dynamics of ORANI-F.

The first of these sources of difference can easily be eliminated by using multi-step computing procedures for the six-year ORANI-F simulation and for each of the six one-year MONASH-style simulations. The second is the unavoidable cost of the simplifying assumptions which were adopted for the ORANI-F dynamics. The symptoms of the problem can emerge in a number of different variables but, without complicating the model's dynamics, it is not in general possible to obtain projections from ORANI-F which are consistent for all variables simultaneously with projections obtained from the MONASH style model.

References

ABARE, (1992) *Agricultural and Resources Quarterly*, Volume 4(4), December.

Adams, P.D., P.B. Dixon, D. McDonald, G.A. Meagher and B.R. Parmenter, (1993) "Forecasting for the Australian Economy Using the MONASH Model", *mimeo*, Centre of Policy Studies, Monash University, May, 30pp.

Dixon, P.B. and D. McDonald, (1992) "Creating 1990-91 Input-Output Tables for Australia by ORANI Simulation", *mimeo*, Centre of Policy Studies, Monash University, December, 40 pp.

Dixon, P. B. , B. R. Parmenter, J. Sutton and D. P. Vincent, (1982) *ORANI: A Multisectoral Model of the Australian Economy*, North Holland Publishing Co., Amsterdam.

Horridge, J.M., B.R. Parmenter and K.R. Pearson (1993) "ORANI-F: A General Equilibrium Model of the Australian Economy", *Economic and Financial Computing*, Volume 3, Number 2, Summer, pp. 71-140.

Johansen, L ,(1960) *A Multisectoral Model of Economic Growth*, North Holland Publishing Company, Amsterdam (2nd edition 1974)

Peter, M. W., (1993) "Immigration and the Current Account Deficit", *mimeo*, Centre of Policy Studies, Monash University.

Syntec Economic Services (1993) *Five Year Forecasts*, Volume 10(4), May.

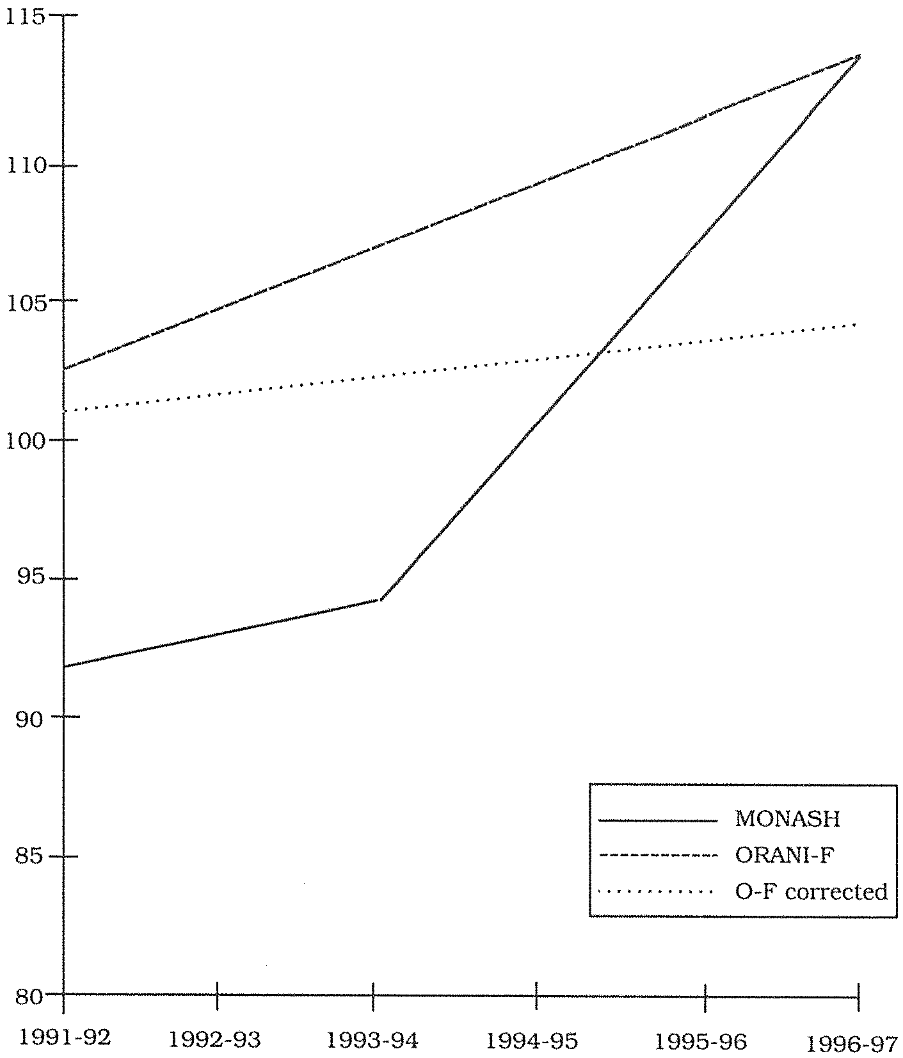

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Table 3: ***Projections of six-year percentage changes from ORANI-F and of annual and six-year percentage changes from MONASH: 1990-91 to 1996-97***[(a)]

Variable	MONASH (multi-step):							ORANI-F	ORANI-F
	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	Six-year change	(multi-step)	(multi-step. corrected)
Macroeconomic variables:									
1. Net foreign debt/GDP, 1996-97	36.32	34.62	33.20	31.11	28.81	26.13		24.16	23.03
2. Change in BT/GDP ratio	0.91	-0.43	-0.00	0.20	0.40	0.35	1.41	1.99	2.53
3. Percentage real devaluation	1.27	2.02	1.63	0.94	1.19	0.37	7.64	7.72	7.57
Six-year percentage changes									
4. Employment (hours)	-1.60	0.20	1.80	2.70	1.80	2.00	7.04	7.04	7.04
5. Labour saving technical change	2.37	2.85	1.04	2.43	3.00	0.63	11.55	9.33	10.95
6. Capital stock	3.95	1.84	1.71	1.76	2.65	3.96	16.92	24.01	16.92
7. Real GDP	1.84	2.61	2.45	3.86	4.09	3.10	19.33	19.77	18.61
8. Real private consumption	2.50	2.00	1.80	3.00	3.20	1.60	14.94	14.94	14.94
9. Real public consumption	4.80	2.80	3.40	3.00	2.70	2.60	20.90	20.90	20.90
10. Real investment	-8.00	1.30	1.80	6.90	7.00	5.90	14.92	14.92	6.74
11. Import volumes	-0.16	1.83	2.44	5.86	7.32	4.29	23.40	20.42	16.91
12. Export volumes	9.10	4.90	4.50	6.60	7.30	5.50	44.32	44.32	44.32
13. Consumer price index	2.30	1.70	3.40	3.70	4.40	4.40	21.59	21.59	21.59
14. GDP price deflator	1.64	0.75	2.86	3.29	4.03	4.77	18.59	20.19	18.52
15. Investment price deflator	1.29	1.84	3.14	3.05	2.96	4.98	18.51	21.85	18.47

(a) In accumulating foreign debt, we assume that the average real rate of interest is four per cent.

results by recomputing the simulation in a multi-step procedure. The results for macroeconomic variables are reported in the third column of Table 2. To clean up the comparisons still further, we recomputed the MONASH-style simulation, using a multi-step procedure for each of the annual computations. Results are in the fourth column of Table 2.

The first thing to notice about the recomputations is that moving to a multi-step procedure had very little effect on the MONASH-style results, i.e., the second and fourth columns of Table 2 are very similar. As we would expect, linearisation errors in the six-year MONASH-style results are small even when each of the underlying annual computations is performed using a single-step procedure. Differences between the first and third columns of the table indicate, however, that there are more significant linearisation errors in the one-step ORANI-F projections, especially for the trade-balance/GDP ratio (row 2), the real exchange rate (row 3) and technical change (row 5). For the first two of these variables, removing the linearisation errors pushes the ORANI-F projections much closer to the MONASH-style projections. Removing linearisation error reduces sharply the ORANI-F projection of the rate of technical change. Hence, the multi-step ORANI-F projection is for significantly less technical change than is in the MONASH-style projections. As we argued above, we should expect this in view of the fact that the rate of capital growth projected by ORANI-F is significantly stronger than that projected by the MONASH-style model.

This brings us to the second move required to reconcile the ORANI-F and the MONASH-style projections. As implied above and as can be seen by comparing the last two columns of Table 2, removing linearisation errors does not remove all the differences between the ORANI-F and the MONASH-style projections. In particular, ORANI-F continues to project a higher rate of growth of the capital stock than does the MONASH-style model. This reflects a fundamental difficulty with the ORANI-F method which is elucidated by Table 3. In the first six columns of the table, we report, for some macroeconomic variables, the annual MONASH-style projections, all computed by multi-step procedures. In the seventh and eighth columns are the accumulated, six-year MONASH-style projections (also reported in the last column of Table 2) and the multi-step ORANI-F projections (also in the third column of Table 2). With the solid line in Figure 4 we have plotted the path of an index of investment (1990-91 = 100, cf. row 10 of Table 3) in the MONASH-style simulation. The dashed line plots the time path implied by our smooth-growth assumption in the ORANI-F simulation. Since capital growth relates to the areas under the investment paths, not to their end points, it is clear that we have imposed too much capital growth in the ORANI-F simulation compared to the MONASH-style simulation.

If we have the complete time path of investment, as we have in Table 1, then it is easy to correct for this error in setting up the ORANI-F simulation. All that is required is that we calculate the smooth path of investment which would accumulate, by the end of the projection period, the same amount of capital as is accumulated by the actual path. This corrected path is plotted as the dotted line in Figure 4[4]. It involves total six-year growth rate of investment of 6.74 per cent, not the 14.94 per cent imposed in the original ORANI-F simulation. Results

4 The reader might initially expect that the areas under the MONASH and corrected ORANI-F paths in Figure 4 should be equal. This would be the case were the depreciation rate zero.

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1. Introduction

Since the mid 1980s, we have been using computable general equilibrium (CGE) models for medium-run forecasting as well as for comparative-static policy analysis. Until quite recently we used ORANI-F, a model capable of projecting only the average annual growth rates of variables over medium-run periods (six years, say), not year-to-year time paths. Now we are using a new model (MONASH) with enough dynamics to allow sectorally disaggregated annual forecasts which track externally projected business-cycle phenomena.

Horridge, Parmenter and Pearson (1993) provide full documentation of a 22-sector PC version of ORANI-F which is available to users outside the CoPS research team. We summarise that documentation in section 2 of this paper, focussing in particular on the dynamic equations which were added to facilitate applications to forecasting. In section 3 we explain the additional dynamics which were added for MONASH. We have replaced the ORANI-F dynamics with the MONASH dynamics in the 22-sector model and conducted forecasting simulations with the two versions of the model for the period 1990-91 to 1996-97. The simulations are described in section 4. They are designed to show whether, in forecasts typical of those which we have been conducting, differences in the dynamics between ORANI-F and MONASH have any significant effects on projections of average annual movements in variables for the period as a whole.

2. ORANI-F

2.1. Static equations

Apart from its investment specification and the addition of equations to account for the accumulation of foreign debt, ORANI-F is similar to the well-known static ORANI model described by Dixon, Parmenter, Sutton and Vincent (1982). The basic structure of the static component of the model is revealed by its input-output database. For the 22-sector version documented by Horridge, Parmenter and Pearson (1993), this is shown schematically in Figure 1.

It reveals the basic structure of the model. The columns in the main part of the figure (an absorption matrix) identify the following agents:

Figure 1: ***The ORANI-F Input-Output Database***

		Absorption Matrix					
		1	2	3	4	5	6
		Producers	Investors	Household	Export	Other	Change in Inventories
	Size	I	I	1	1	1	1
Basic Flows	C×S	V1BAS	V2BAS	V3BAS	V4BAS	V5BAS	V6BAS
Margins	C×S×M	V1MAR	V2MAR	V3MAR	V4MAR	V5MAR	na
Taxes	C×S	V1TAX	V2TAX	V3TAX	V4TAX	V5TAX	na
Labour	O	V1LAB					
Capital	1	V1CAP					
Land	1	V1LND					
Other Costs	1	V1OCT					

C = Number of Commodities (23)

I = Number of Industries (22)

S = Number of sources (2: domestic, imported)

O = Number of Occupations Types (2)

M = Number of Commodities used as Margins (2)

Size	Joint Production Matrix
	I
C	Make

Size	Import Duty
	1
C	V0TAR

Table 2: ***Projections of six-year percentage changes from ORANI-F and MONASH: 1990-91 to 1996-97(a)***

Variable	ORANI-F (one-step)	MONASH (one-step)	ORANI-F (multi-step)	MONASH (multi-step)
Macroeconomic variables:				
1. Net foreign debt/GDP, 1996-97	22.31	25.55	24.16	26.13
2. Change in BT/GDP ratio	2.59	1.51	1.99	1.41
3. Percentage real devaluation	10.13	7.92	7.72	7.64
Six-year percentage changes				
4. Employment (hours)	7.04	7.04	7.04	7.04
5. Labour saving technical change	11.30	11.90	9.33	11.55
6. Capital stocks	23.80	16.83	24.01	16.92
7. Real GDP	19.97	19.33	19.77	19.33
8. Real private consumption	14.94	14.94	14.94	14.94
9. Real public consumption	20.90	20.90	20.90	20.90
10. Real investment	14.92	14.92	14.92	14.92
11. Import volumes	19.65	23.22	20.42	
12. Export volumes	44.32	44.32	44.32	44.32
13. Consumer price index	21.59	21.59	21.59	21.59
14. GDP price deflator	20.15	18.54	20.19	18.59
15. Investment price deflator	22.07	18.47	21.85	18.51

(a) In accumulating foreign debt, we assume that the average real rate of interest is four per cent.

Table 1 (continued):

	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	Total change	Comments
Shifts in foreign currency export prices								
Cereals	14.6	0.9	-3.4	-0.6	5.8	2.9	20.88	
Broadacre rural	7.9	-17.5	-7.9	3.2	4.8	3.1	-8.58	
Mining, export	-4.1	-6.2	-1.5	7.4	9.4	5.9	10.25	
Food and fibre, export	-2.9	-7.8	4.6	-0.4	5.8	3.0	1.64	
Non-traditional exports	3.4	2.8	3.0	3.3	3.3	3.1	20.45	
Traditional export volumes								
Cereals	-26.2	15.0	10.3	14.0	-3.7	0.7	3.49	
Broadacre rural	35.8	-11.7	-5.3	14.0	-3.7	0.7	25.54	
Mining, export	8.5	1.3	0.4	3.6	4.1	4.5	24.37	
Food and fibre, export	8.4	9.3	-7.9	14.0	-3.7	0.7	20.63	
Production								
Broadacre rural	-6.0	-1.3	-7.6	3.0	2.1	2.3	-7.77	

(1) domestic producers divided into 22 industries;

(2) investors divided into 22 industries;

(3) a single representative household;

(4) an aggregate foreign purchaser of exports;

(5) an 'other' demand category, broadly corresponding to government; and

(6) a holder of inventories of domestically produced commodities.

The rows show the structure of the purchases made by each of the agents identified in the columns. Each of the 23 commodity types identified in the model can be obtained locally or imported from overseas. The source-specific commodities are used by industries as inputs to current production and capital formation, are consumed by households and governments, are exported and are added to or subtracted from inventories. Two of the domestically produced goods are used as margins services (wholesale and retail trade, and transport); these are required to transfer commodities from their sources to their users. Commodity taxes are payable on the purchases. As well as intermediate inputs, current production requires inputs of three categories of primary factors: labour (divided into 2 occupations), fixed capital, and agricultural land. The 'other costs' category covers various miscellaneous industry expenses.

In principle, each industry is capable of producing any of the 23 commodity types. The MAKE matrix at the bottom of Figure 1 shows the value of output of each commodity by each industry. Finally, import taxes are assumed to be levied at rates which vary by commodity but not by user. The revenue obtained is represented by the tariff vector V0TAR.

In the levels of its variables, the model is non-linear — agents respond to relative prices, for example. However, following Johansen (1960), the model is solved in a linearised form in the percentage growth rates of the variables.

The key behavioural and institutional assumptions adopted for static part of the model are as follows.

(i) Producers

Producers are assumed to be price takers in the markets both for their outputs and for their inputs. The multi-input, multi-output production system in which each industry can produce several commodities is kept manageable by the assumption of input-output separability. Under this assumption, an industry's generalised production function:

$$F(\text{inputs},\text{outputs}) = 0 \qquad (1)$$

can be written as:

$$G(\text{inputs}) = Z = H(\text{outputs})\ , \qquad (2)$$

where Z is an index of the industry's activity level.

Under (2), producers are assumed to choose their output mixes to maximise revenue subject to the function H which is specified as CRETH. They are assumed to choose their inputs to minimise costs subject to the function G which is specified as constant-returns-to-scale with a series of Leontief/CES nests. The G function allows no substitution between inputs of different commodity categories or between produced inputs, primary factors and "other costs". Substitution is allowed: between alternative sources (i.e., domestic production and international imports) of produced inputs of a given commodity category; between aggregate labour (a CES combination of labour of the 8 occupations), capital and agricultural land; and between occupations. Hence, input demands are functions of activity variables and of the relative prices of substitutable inputs. For example, the demand for aggregate labour in an industry is a function of the industry's activity level and of the prices of aggregate labour, capital and agricultural land.

(ii) Investors

In constructing units of capital, investors are assumed to be price takers and to choose inputs of produced investment goods to minimise costs subject to capital production functions which allow substitution between alternative sources of each commodity but not between commodity categories. Hence, input demands are functions of industries' investment levels and of the source specific prices of the relevant commodities. The determination of industries' investment levels is described in section 2.2.

(iii) Households

Aggregate consumption spending per household can be determined in a number of ways, eg., set exogenously or implied by a balance-of-trade constraint. Some versions of the model include a Keynesian consumption function which relates per-household consumption to per-household disposable income. Households are assumed to choose the consumption of composites of domestically produced and imported commodities to maximise a Stone-Geary utility function subject to the aggregate-spending constraint. The composite commodities are defined as CES combinations of source-specific commodities, as for intermediate inputs and inputs to investment. Hence, household demands for composite commodities are functions of the aggregate expenditure level and of the relative prices of the commodities. If households are to maximise utility, subject to the expenditure constraint, they must minimise the cost of obtaining any given quantity of a composite commodity, subject to the CES functions which define the composites. Hence, household demands for source-specific commodities are functions of the demands for the relevant composites and of source-specific commodity prices.

(iv) International exports

To model export demands, commodities in ORANI-F are divided into two groups: the traditional exports, mostly primary products, which comprise the bulk of exports; and the remaining, non-traditional exports. Exports account for large shares of total output for most commodities in the traditional-export category but for only small shares in total output for non-traditional-export commodities.

Downward-sloping foreign demand schedules for traditional exports are specified. That is, export volumes are declining functions of their prices in foreign currency,

Table 1 (continued)

	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	Total change	Comments
Tariffs								
Mining, export	-0.2	-0.2	-0.2	-0.2	-0.2	0.0	-1.00	
Food and fibre, export	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	-0.50	
Food, other	-0.4	-0.4	-0.4	-0.4	-0.4	0.0	-1.98	
Textiles, clothing and footwear	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-13.03	
Wood related products	-0.9	-0.9	-0.9	-0.9	-0.9	0.0	-4.42	
Chemicals and oil products	-0.5	-0.5	-0.5	-0.5	-0.5	0.0	-2.47	
Non-metallic mineral products	-0.7	-0.7	-0.7	-0.7	-0.7	0.0	-3.45	
Metal products	-1.5	-1.5	-1.5	-1.5	-1.5	0.0	-7.28	
Transport equipment	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-9.22	
Other machinery	-0.9	-0.9	-0.9	-0.9	-0.9	0.0	-4.42	
Other manufacturing	-1.7	-1.7	-1.7	-1.7	-1.7	0.0	-8.21	
Shifts to Labour-saving technical change by industry								
Broadacre rural	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-10.87	
Intensive rural	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-10.87	
Mining, export	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-5.85	
Mining, other	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-4.70	
Food and fibre, export	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-9.22	
Food, other	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-9.22	
Textiles, clothing and footwear	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-9.22	
Wood related products	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-9.22	
Chemical and oil products	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-9.22	
Non-metallic mineral products	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-9.22	
Metal products	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-9.22	
Transport equipment	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-9.22	
Other machinery	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-9.22	
Other manufacturing	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-9.22	
Utilities	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-8.11	
Construction	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-4.70	
Retail and wholesale trade	0.2	0.2	0.2	0.2	0.2	0.2	1.21	
Transport	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5	-19.24	
Banking and finance	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-4.70	
Ownership of dwellings	0.0	0.0	0.0	0.0	0.0	0.0	0.00	
Public services	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-4.71	
Private services	2.5	2.5	2.5	2.5	2.5	2.5	15.97	

Continued ....

Historically, non-traditional exports have been small and volatile, pre-cluding the estimation of individual export demand elasticities. However, in recent years aggregate non-traditional exports have experienced rapid growth. In ORANI-F the commodity composition of aggregate non-traditional exports is exogenised by treating non-traditional exports as a Leontief aggregate. Total demand is related to the average price *via* a constant-elasticity demand curve, similar to those for traditional exports.

(v) *Government consumption and changes in inventories*

Government consumption and changes in inventories are essentially exogenous. The default assumption for government consumption is that it moves at the same rate as aggregate household consumption.

(vi) *Margins*

Margins services, required to facilitate flows of commodities from their producers or importers to their users, are provided by two sectors in the 22-sector version of ORANI-F (18, *Wholesale and Retail Trade*) and (19, *Transport*). We assume that margins are required in fixed proportions to the commodity flows with which they are associated. Together with commodity taxes, these margins account for the differences between basic-values and purchasers' prices.

(vii) *Prices*

Basic-value prices are set *via* the competitive assumption that no pure profits can be earned from current production, investment or importing. Combined with the assumption of constant returns to scale in the model's production functions for current production and capital formation, this implies that the basic-value prices of commodities and the supply prices of units of capital are functions just of the relevant input prices. The basic-value prices of international imports in the domestic economy are the domestic-currency equivalents of the foreign-currency, cif prices inclusive of the tariff.

Purchasers' prices for each of six classes of purchaser (producers; investors; households; international exports; government and inventory holders) are the sums of basic values, sales taxes and margins. Commodity taxes are treated as *ad valorem* on basic-values. In the case of an international export, the purchasers' price is defined as the price at the port of exit. We set these purchasers' prices equal to the domestic-currency equivalent of the world price (net of the costs of transferring the exports from their ports of exit to their foreign destinations). This is equivalent to assuming that no pure profits can be earned from exporting.

(viii) *Market clearing*

The model includes market-clearing constraints for domestically produced commodities. International imports are assumed to be elastically supplied at exogenous world prices. Hence, import volumes are determined by the demand for imports in the domestic economy.

Also included are equations which compute the aggregate demand for labour by occupation and an index of aggregate employment using wage-bill weights. Labour supply is exogenous. The main options in conducting simulations with the model are to set wage rates exogenously and have employment demand

Table 1: ***Assumptions***

Exogenous variable:	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	Total change	Comments
Real GDP and its components								
1. Private consumption	2.5	2.0	1.8	3.0	3.2	1.6	14.94	Exogenised by endog-enising economy-wide labour-saving technical change .
2. Public consumption	4.8	2.8	3.4	3.0	2.7	2.6	20.90	Shifter on public consumption is already exogenous.
3. Total investment	-8.0	1.3	1.8	6.9	7.0	5.9	14.92	Exogenised by endogen-ising the general shifter in the investment equations.
4. Private dwelling construction (including real estate transfer fees)	1.8	9.8	3.7	1.2	-3.9	3.2	16.33	Investment in ownership of dwelling treated as an exogenous variable.
5. Dwelling and non-dwelling construction	-6.1	3.0	2.3	3.4	0.5	3.8	6.72	Output of construction set exogenously by endogen-ising stocks.
6. Public investment	-0.6	0.0	0.8	6.0	9.9	7.4	25.34	Investment in public services treated as exogenous variable.
7. Exports	9.1	4.9	4.5	6.6	7.3	5.5	44.32	Exogenised by endogenising BT/GDP.
Other macroeconomic variables								
8. Consumer prices	2.3	1.7	3.4	3.7	4.4	4.4	21.59	The numeraire.
9. Foreign currency import prices (Consumer Price inflation for OECD)	3.4	2.8	3.0	3.3	3.3	3.1	20.45	Already exogenous.
10. Employment (people)	-1.6	0.2	1.8	2.7	1.8	2.0	7.04	Already exogenous.
11. Population	1.4	1.3	1.4	1.4	1.4	1.4	8.59	Already exogenous.

Continued ....

determined, or to set employment exogenously and allow the model to set wage rates consistent with that level of employment

As well as equations describing the agents' demands for commodities and primary factors, price formation and market clearing, all of which follow from the assumptions described in points *(i)* to *(viii)*, the model includes a series of identities describing: gross national product and its expenditure- and income-side components; a range of aggregate price indexes; and the international trade balance.

2.2. Capital and investment

(i) Rates of return

The rate of return on capital (net of depreciation) in industry j (R_j) is defined as the ratio of the rental price of capital (Q_j) to the supply price (Π_j) *minus* the rate of depreciation. In percentage growth rates of the variables this can be written as[1]:

$$r_j = \Theta_j \, (q_j - \pi_j) \, . \qquad (3)$$

where the parameter Θ_j is the ratio of the gross to the net rate of return.

The percentage growth rate of the net rate of return in the industry (relative to the economy-wide rate, R) is assumed to be a positive function of the growth rate of the industry's capital stock, k_j (relative to the economy wide stock, k), i.e.,

$$r_j - r = \beta_j \, (k_j - k) + f_j. \qquad (4)$$

This is to be interpreted as a risk-related relationship with relatively fast- (slow-) growing industries requiring premia (accepting discounts) on their rates of return. The parameter β_j specifies the strength of this relationship. The variable f_j allows exogenous shifts in the industry's rate of return.

(ii) Capital accumulation

The basic capital-accumulation relation in ORANI-F is:

$$K_j(t) = K_j(t-1)D_j + Y_j(t-1) \, , \qquad (5)$$

where $K_j(t)$ is the capital stock operational at time t, $Y_j(t)$ is investment at time t, and D_j is the depreciation factor (one minus the depreciation rate). Notice that capital is assumed to take one period to install. Suppose that we are interested in forecasting over the period 0 to T, then $K_j(T)$, the capital stock at T will be given by:

$$K_j(T) = K_j(0) \, D_j^{T} + \sum_{t=0}^{T-1} Y_j(t) \, D_j^{T-t-1} \, . \qquad (6)$$

We also assume that investment over the time span 0–T follows a linear path:

1 We use the usual ORANI convention that lower-case characters denote percentage changes or percentage growth rates in variables denoted by the corresponding upper-case characters.

exogenous variables are listed in Table 1[3]. The annual growth rates given in the first six columns of numbers in the table are the shocks for our MONASH-style computations. In the last column of numbers are the corresponding accumulated six-year growth rates. These are the shocks for our ORANI-F computations.

By including components of the expenditure side of the national accounts, our exogenous shocks determine the growth rate of the GDP from the demand side. *Via* the models' accumulation relationships (9) and (12), capital input is determined by the exogenous setting of investment. Employment growth is also exogenous. Hence, the average rate of technical progress (modelled as labour-saving) must be endogenous to reconcile the supply-side and demand-side shocks. The sectoral pattern of technical change is set exogenously by the shifts listed on page 13.

Selected results of the comparative simulations are reported in Tables 2 and 3. Table 2 covers macroeconomic variables, reporting only their six-year growth rates. As we have explained, variables in ORANI-F appear in this form. For the MONASH-style computations, we have accumulated the annual growth rates which are produced in this mode. Until very recently, the standard way in which we obtained solutions to ORANI-based models (including MONASH) was by one-step solutions of the linear system. The first two columns of Table 2 contain results computed in this way. For ORANI-F, one six-year computation was required, using the shocks listed in the final column of numbers in Table 1. For the MONASH-style model, six annual computations are required (see Figure 2), each using shocks from one of the first six columns of numbers in Table 1.

Comparing the first two columns of Table 2 and recalling that the variables in rows 4, 8, 9, 10, 12 and 13 are all exogenous, we see that there are marked differences between the two sets of projections for most endogenous variables. The difference is especially marked for the capital stock (row 6). In view of this, it is surprising that there is not more difference for technical change (row 5). The two projections for GDP growth are quite close, which is not surprising given that GDP growth is determined largely by our exogenous settings of its expenditure-side components. Employment growth is exogenous and identical in both sets of projections but ORANI-F projects much more capital growth than does the MONASH-style model. Hence, we should expect that it would project much less technical change as being necessary to reconcile the growth of factor inputs with GDP growth.

Our first move in attempting to reconcile the ORANI-F and MONASH-style results in the first two columns of Table 2 is to recognise that the ORANI-F results are likely to exhibit more linearisation error than the MONASH-style results. The MONASH-style procedure of making six annual computations with intervening data updates, as described by Figure 2, and accumulating the results is similar to a six-step ORANI-F calculation (see Horridge, Parmenter and Pearson, 1993, section 3). The only difference is that in making a six-step ORANI-F calculation to reduce linearisation error we would usually split the six-year shocks in a more regular way than that represented by the first six columns of numbers in Table 1. To remove this source of difference between the ORANI-F and MONASH-style results, we removed the linearisation error from the ORANI-F

3 Forecasts for macroeconomic variables in Table 1 are based of Syntec (1993). Tariff shocks represent the Federal government's current industry plans. Forecasts for the export prices, volumes and production levels are based on ABARE (1992).

Finally, we make the simplifying assumption that:

$$E(R_j(t+1)) = R_j(t) \quad . \tag{14}$$

Another possibility to be investigated in future work is the rational-expectations assumption that:

$$E(R_j(t+1)) = R_j(t+1) \quad .$$

Under (14), we can rewrite (13) as:

$$k_j(t) = \frac{\beta_j}{RN_j} R_j(t-1) + \frac{\beta_j}{RN_j} \Delta R_j(t) + trend_j(t) + f \tag{15}$$

where, from (11) we have:

$$\Delta R_j(t) = \frac{Q_j(t-1)}{\Pi_j(t-1)} (q(t) - \pi(t)) \quad . \tag{16}$$

$q(t)$ and $\pi(t)$ are the growth rates in $Q(t)$ and $\Pi(t)$ between years t–1 and t. From equations (15) and (12), we see that initial conditions play a crucial role in our investment specification. In equation (15), the rate of return in year t–1 is an important determinant of $k_j(t)$ and in equation (12), the investment capital ratio for year t–1 is critical in translating the capital growth rate for year t into an investment growth rate for year t.

With these investment/capital dynamics, the first of the MONASH simulations depicted in Figure 2 projects growth in the endogenous variables for the year 1990-91 to 1991-92. These projections, together with the exogenous growth rates, allow updating of the model's data, yielding an input-output data base for 1991-92 and 1991-92 initial conditions for the dynamic equations. The updated data and forecasts of growth in the exogenous variables for the year 1991-92 to 1992-93 are then used in a second annual MONASH simulation. Further data updates and further annual simulations follow, eventually yielding a complete set of annual projections for the period 1990-91 to 1996-97 and estimates of input-output structure of the economy in each of the years 1991-92 to 1996-97.

4. A Comparison of Forecasts from ORANI-F and MONASH

We have computed forecasts for the period 1990-91 to 1996-97, first using ORANI-F and then in the style of MONASH. The version of ORANI-F which we used is the version described in Horridge, Parmenter and Pearson (1993), implemented on a 22-sector aggregation of the 1990-91 input-output database prepared by Dixon and McDonald (1992). Variables in this model are interpreted as six-year growth rates for the period 1990-91 to 1996-97. For the MONASH-style computations, we replaced the capital-investment dynamics in this version of ORANI-F (see section 2) with the MONASH equations described in section 3. Variables from the model which includes the MONASH investment specification are interpreted as annual growth rates. Our purpose is to explain any differences which emerge between the ORANI-F projections of the six-year movements in the variables and the projections implied by the MONASH-style computations.

As is the case in the six-year forecasts which we have produced recently using MONASH (Adams, Dixon, McDonald, Meagher and Parmenter, 1993), most of the macroeconomics in our comparative simulations is exogenous. Shocks for the

$$Y_j(t) = \{(T-t)/T\}Y_j(0) + \{t/T\}Y_j(T) \quad . \tag{7}$$

Thus

$$K_j(T) = K_j(0)\, D_j^{\,T} + \sum_{t=0}^{T-1} [\{(T-t)/T\}Y_j(0) + \{t/T\}Y_j(T)]D_j^{\,T-t-1} \, . \tag{8}$$

The assumption that investment grows smoothly allows us to simplify dramatically the dynamics of the model. It avoids the necessity of explicitly including in (8) any variables relating to periods between 0 and T. Notice that $K_j(T)$ is linearly related to $Y_j(T)$, and to the predetermined values $K_j(0)$ and $Y_j(0)$.

In growth rates of the variables, (8) leads to accumulation equations of the form

$$y_j(t) = A_j + B_j\, k_j(t) \tag{9}$$

where $y_j(t)$ and $k_j(t)$ are the growth rates of investment and capital over the entire span 0 to T. The coefficients A_j and B_j are functions of the ratios of investment to capital in period 0, i.e., the higher is the initial investment/capital ratio, the lower will be the rate of growth of investment required to support any given rate of growth of the capital stock.

3. Dynamics in MONASH[2]

MONASH is a dynamic model in the sense that it projects the annual time paths of the variables. Figure 2 elaborates the projection procedure taking the example of annual projections for the six-year period 1990-91 to 1996-97 such as are discussed in section 4. The crucial dynamic part of the model is its specification of investment. This specification is explained by reference to Figure 3.

We assume that the capital stock available for use in production in industry j in year t is $K_j(t-1)$, i.e., output in industry j is a function of the capital stock in place at the beginning of the year. The rate of return in year t on this capital stock is:

$$R_j(t) = \frac{Q_j(t)/(1+i) - \Pi_j(t-1) + \Pi_j(t)(1-D_j)/(1+i)}{\Pi_j(t-1)} \, , \tag{10}$$

where

- i is the rate of interest,
- D_j is the depreciation rate on industry j's capital stock;
- $Q_j(t)$ is the rental on capital in industry j in year t; and
- $\Pi_j(t)$ is the construction cost of a unit of capital at the beginning of year t+1.

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2 This section is extracted from Adams, Dixon, McDonald, Meagher and Parmenter (1993).

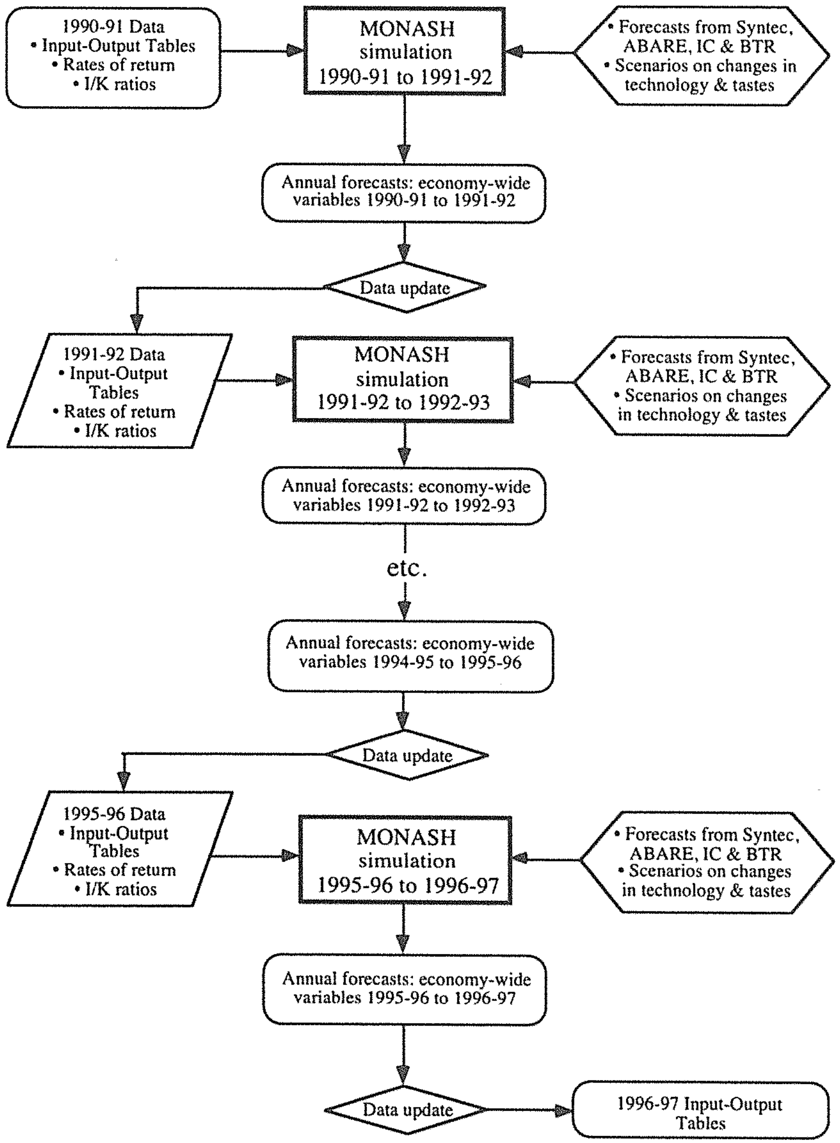

Figure 2: ***Annual Forecasting with MONASH***

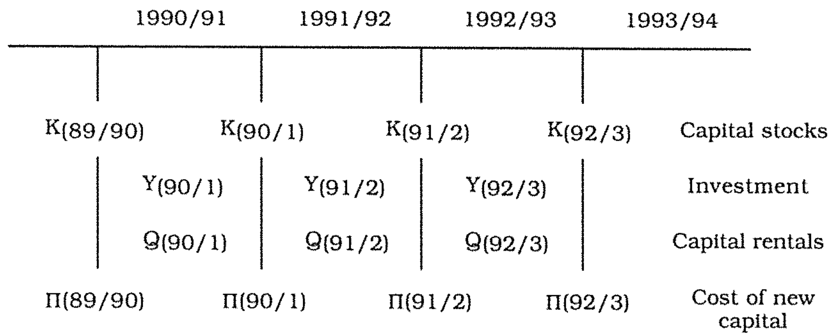

Figure 3: ***Investment Variables and Timing***

For convenience, we approximate formula (10) as:

$$R_j(t) = \frac{Q_j(t)}{\Pi_j(t)} - D_j \,. \qquad (11)$$

where we assume that:

$$\frac{\Pi(t)}{\Pi_j(t-1)} \simeq 1+i \,.$$

Investment in year t determines capital growth over year t according to (5), i.e.,

$$\frac{K_j(t) - K_j(t-1)}{K_j(t-1)} = \frac{Y_j(t-1)}{K_j(t-1)} \left(\left\{ \frac{Y_j(t) - Y_j(t-1)}{Y_j(t-1)} \right\} + 1 \right) - D_j \,,$$

or, in growth rates

$$k_j(t) = \frac{Y_j(t-1)}{K_j(t-1)} \left[y_j(t) + 1 \right] - D_j \,. \qquad (12)$$

Next, we assume that capital growth over year t is motivated by the expected rate of return in year t+1:

$$k_j(t) = \frac{\beta_j}{RN_j} E\left(R_j(t+1)\right) + trend_j(t) + f \,, \qquad (13)$$

where

RN_j	is an estimate of the normal rate of return for industry j,
$trend_j(t)$	is the long-run trend rate of growth of capital in industry j,
β_j	is a positive parameter, and
f	is a shift variable allowing (4) to be compatible with a forecast of aggregate investment from outside MONASH (e.g., from Syntec).