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Managing Editor: Dr. H. Motamen-Scobie

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Aims and Scope

Economic and Financial Computing aims to provide a forum to present recent advances on the measurement aspects of economic and financial problems. The Journal covers both the methodological and practical facets of quantitative and computational techniques as applied to economic and financial issues. It is intended that the Journal will bring to the fore high quality research in the areas, demonstrate applications of such techniques and capture the fast growth in this field.
Economic and Financial Computing is also designed to identify gaps in the current literature pertaining to quantitative methods in economics, finance and forecasting. It is anticipated that, by highlighting the demand for further in-depth analysis to overcome the existing deficiencies, the Journal will promote new directions for research in the field.
It is within the scope of the Journal to publish the latest research in software developments as well as some of the advances in hardware relevant to the disciplines of economics and finance.
Other features include book reviews, conference announcements, conference reports, and software reviews.

Volume 3 Number 2 Summer 1993

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Conference Announcement

CALL FOR PAPERS

INTERNATIONAL SYMPOSIUM ON ECONOMIC MODELLING

THE WORLD BANK, WASHINGTON, D.C., USA,

22 - 24 JUNE 1994

Organised jointly by the International Trade Division, the World Bank, Washington, D.C., USA, and the European Economics and Financial Centre, London, UK.

The symposium is designed to have a fairly broad theme and will present recent advances in all aspects of economic modelling. It is intended that the Symposium would act as a forum for new developments in different aspects of economic modelling - covering national macroeconomic models and related topics, general equilibrium, methodological aspects of model building, models of international trade in areas such as regional trade arrangements, trade and environment impact of Uruguay Round; and/or reports in areas including finance, agriculture, natural resources, dynamic games and rational and adaptive expectations. It is also one of the aims of this Symposium to bring closer the work of economic modellers to that of non-modellers. Thus, papers are invited from the non-technical economists as well as the practitioners.

SUBMISSION OF PAPERS

All participants interested in presenting papers should send a brief abstract (in triplicate) to Dr. H. M. Scobie, Director, European Economics and Financial Centre, P.O. Box 2498, London W2 4LE, UK. (Tel: 071- 229 0402; Fax: 071-221 5118). The closing date for submissions is 1 November, 1993.

LANGUAGE

The language in which all the papers are presented is English.

ACCOMMODATION

A number of hotels are available in the vicinity of the World Bank, Washington,.D.C. at reduced rates.

Further details are available from the Secretary, the European Economics and Financial Centre, P.O. Box 2498, London W2 4LE, UK
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ORANI-F: A General Equilibrium Model of the Australian Economy

J.M. Horridge, B.R. Parmenter and K.R. Pearson
Centre of Policy Studies and Impact Project, Monash University, Australia

Abstract: *ORANI is an applied general equilibrium (AGE) model of the Australian economy which is widely used by academics and by economists in the government and private sectors. We describe a recent version of the model, ORANI-F, which contains dynamic elements arising from stock/flow accumulation relations: between capital stocks and investment, and between foreign debt and trade deficits. ORANI-F has been applied in making medium-term forecasts for the Australian economy.*

Our description of the model's equations and database is closely integrated with an explanation of how the model is solved using the GEMPACK system. The intention is to provide a convenient starting-point for those wishing to construct their own AGE model. A companion disk is available, which contains a complete model specification and an executable model solution program.

We conclude with a detailed analysis of some typical simulation results.

Revised April 1993

We thank Philip Adams, Kwanjai Arun-Smit, Michael Malakellis and Jayant Menon for assistance in the preparation of this article and for comments on earlier drafts.

1. Introduction

ORANI is an applied general equilibrium (AGE) model of the Australian economy which was first developed in the late 1970s as part of the government-sponsored IMPACT project (Powell, 1977; Dixon, Parmenter, Ryland and Sutton, 1977; Dixon, Parmenter, Sutton and Vincent (DPSV), 1982). The model has been widely used in Australia as a tool for practical policy analysis by academics, and by economists employed in government departments and in the private sector (Parmenter and Meagher, 1985; Powell and Lawson, 1989, Powell, 1991; Vincent, 1989). Initial versions of the model were static, with applications confined to comparative-static analysis. More recently, we have developed a version of the model (ORANI-F) containing dynamic elements, arising from stock/flow accumulation relations: between capital stocks and investment, and between foreign debt and trade deficits. ORANI-F has been applied in making medium-term forecasts for the Australian economy (e.g., Dixon and Parmenter, 1988; Adams, Dixon, Parmenter and Peter, 1991).

In this volume, we describe a generic version of ORANI-F. It has the AGE structure of the original comparative-static ORANI model and the minimal dynamics which were added for the forecasting version. The version of ORANI-F described by Parmenter (1988) included a detailed national- and government-accounts module. This has been omitted from the generic version described here.

GEMPACK is a flexible system for solving AGE models which is used to formulate and solve ORANI-F (Codsi and Pearson, 1988). GEMPACK automates the process of translating the model specification into a model solution program. The GEMPACK user needs no programming skills. Instead, he/she creates a text file, listing the equations of the model. The syntax of this file resembles ordinary algebraic notation. The GEMPACK program TABLO then translates this text file into a model-specific FORTRAN program, which, when executed, solves the model.

Powell A (1977) *The IMPACT Project: an Overview—First Progress Report of the IMPACT Project*, Vol 1,Canberra:Australian Government Publishing Service.

Dixon PB, Parmenter BR, Ryland GJ and Sutton JM (1977) *ORANI, A General Equilibrium Model of the Australian Economy: Current Specification and Illustrations of Use for Policy Analysis—First Progress Report of the IMPACT Project*, Vol 2, Canberra:Australian Government Publishing Service.

Dixon PB, Parmenter BR, Sutton JM and Vincent DP (1982) *ORANI: A Multisectoral Model of the Australian Economy*, Amsterdam:North-Holland,*hereafter DPSV*.

Parmenter BR and Meagher GA (1985) Policy Analysis Using a Computable General Equilibrium Model: a Review of Experience at the IMPACT Project, *Australian Economic Review*, No. 1'85, pp.3-15.

Powell A and Lawson A (1989) A decade of applied general equilibrium modelling for policy work, pp. 241-290 in Bergman L, Jorgenson D and Zalai E (eds), *General Equilibrium Modeling and Economic Policy Analysis*, New York:Blackwell

Powell A (1991) A Brief Account of Activities 1988 to 1990, *IMPACT Project Report* No. R-08, February, 50pp.

Vincent DP (1989) Applied General Equilibrium Modelling in the Australian Industries Assistance Commission: Perspectives of a Policy Analyst, pp. 291-350 in Bergman L, Jorgenson D and Zalai E (eds), *General Equilibrium Modeling and Economic Policy Analysis*, New York: Blackwell

Dixon PB and Parmenter BR (1988) Recent Developments in Forecasting with the ORANI Model, *Australian Economic Papers*, 27, supp., June pp. 92-104.

Adams PD, Dixon PB, Parmenter BR and Peter MW (1991) Prospects for the Australian Economy 1988–89 to 2029-30: ORANI-F Projections for the Ecologically Sustainable Development Working Groups, 112 pp in *Economic Modelling*. ESD Working Groups, Canberra, December

Parmenter BR (1988) ORANI-F User's Manual, *IAESR Working Paper* No. 7/1988, Melbourne, August,.59 pp.

Codsi G and Pearson KR (1988) GEMPACK: general-purpose software for applied general equilibrium and other economic modellers, *Computer Science in Economics and Management*, Vol 1, 1988, pp 189-207

The documentation in this volume is designed to serve as a template for researchers who may wish to construct a model like ORANI-F using the GEMPACK software. It consists of:

- an outline of the structure of the model and of the appropriate interpretations of the results of comparative-static and forecasting simulations;
- a description of the solution procedure;
- a brief description of the data, emphasising the general features of the data structure required for such a model;
- a complete description of the theoretical specification of the model framed around the TABLO Input file which implements the model in GEMPACK;
- a guide to the GEMPACK system, covering PC and mainframe versions; and
- an illustrative application.

A computer diskette complements this document. It may be obtained at small cost—see Appendix B. The diskette contains the 22-sector ORANI-F TABLO Input file and an executable version of the model. It allows solution of the model presented here, but does not contain the full GEMPACK system which would be required to implement changes to the model. To order the full GEMPACK, see Appendix C.

2. Model Structure and Interpretation of Results

ORANI, which is the core of ORANI-F, has a theoretical structure which is typical of an AGE model. It consists of equations describing, for some time period:

- producers' demands for produced inputs and primary factors;
- producers' supplies of commodities;
- demands for inputs to capital formation;
- household demands;
- export demands;
- government demands;
- the relationship of basic values to production costs and to purchasers' prices;
- market-clearing conditions for commodities and primary factors; and
- numerous macroeconomic variables and price indices.

Demand and supply equations for private-sector agents are derived from the solutions to the optimisation problems (cost minimisation, utility maximisation, etc.) which are assumed to underlie the behaviour of the agents in conventional neoclassical microeconomics. The agents are assumed to be price takers, with producers operating in competitive markets which prevent the earning of pure profits.

In addition to this static core, ORANI-F includes several accumulation relationships which link the values of stocks (capital by industry and net foreign debt) over time, relating them to initial conditions and to the values of the relevant accumulating flows (investment and depreciation by industry, and foreign borrowing).

2.1. A comparative-static interpretation of model results

Like the majority of AGE models, ORANI was designed originally for comparative-static simulations. Its equations and variables, which are described in detail in Section 4, all refer implicitly to the economy at some future time period.

This interpretation is illustrated by Figure 1, which graphs the values of some variable, say employment, against time. A is the level of employment in the base period (period 0) and B is the level which it would attain in T years time if some policy—say a tariff change—were *not* implemented. With the tariff change, employment would reach C, all other things being equal. In a comparative-static simulation, ORANI might generate the percentage change in employment 100(C-B)/B, showing how employment *in period T* would be affected by the tariff change alone.

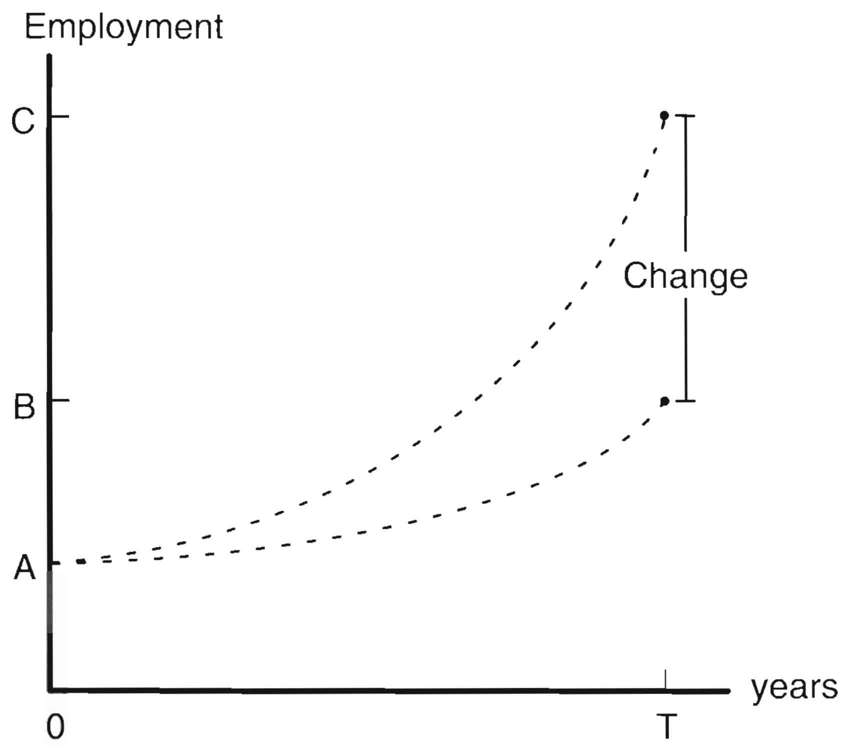

Figure 1. Comparative-static interpretation of results

Cooper R, McLaren K and Powell A (1985) Macroeconomic Closure in Applied General Equilibrium Modelling: Experience from ORANI and Agenda for Further Research, in J. Piggot and J. Whalley (eds), *New Developments in Applied General Equilibrium Analysis*, New York: Cambridge University Press.

Many comparative-static ORANI simulations have analysed the short-run effects of policy changes. For these simulations, capital stocks have usually been held at their pre-shock levels. Econometric evidence suggests that a short-run equilibrium will be reached in about two years, i.e., T=2 (Cooper, McLaren and Powell, 1985). Other simulations have adopted the long-run assumption that capital stocks will have adjusted to restore (exogenous) rates of return—this might take 10 or 20 years, i.e., T=10 or 20. In either case, only the choice of closure and the interpretation of results bear on the timing of changes: the model itself is atemporal. Consequently it tells us nothing of adjustment paths, shown as dotted lines in Figure 1.

2.2. *A forecasting interpretation of model results*

The comparative-static interpretation of ORANI results lends itself to policy analysis. Business and government planners, however, require forecasts of industry outputs, prices and other variables to inform their investment decisions. The forecasting interpretation of ORANI results is shown in Figure 2. As before, the model generates percentage changes in its variables but in this case they are interpreted as 100(D-A)/A, comparing the values of the variables at two different time periods—period 0 and period T. In contrast to comparative static simulations, which usually show the effect of one or a few exogenous changes, forecasting simulations normally show the effects of *all* exogenous changes assumed to occur over the simulation period 0 to T.

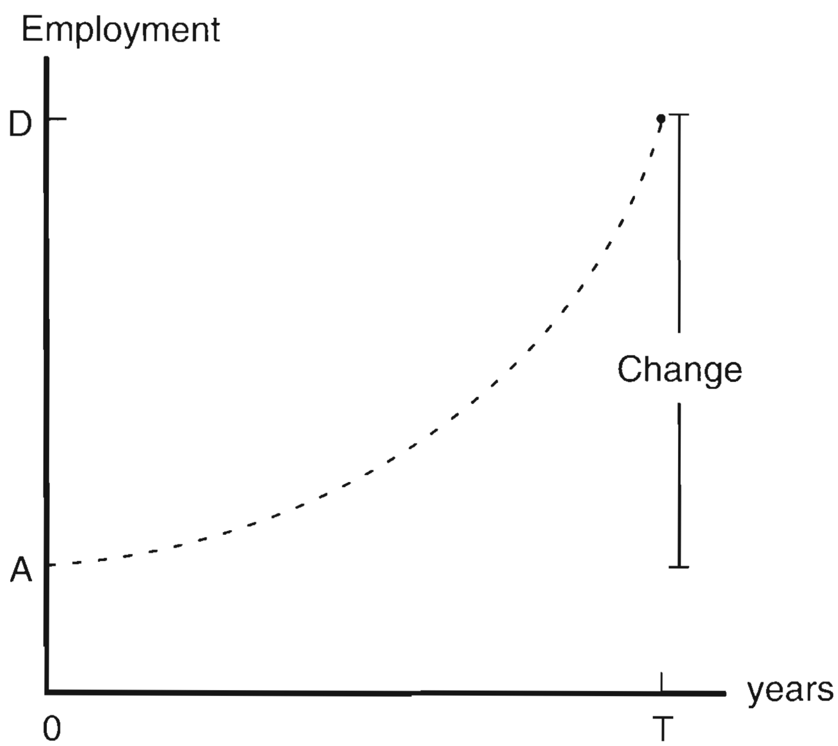

Figure 2. Forecasting interpretation of results

3. The Percentage-Change Approach to Model Solution

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

Many of the ORANI-F equations are non-linear—demands depend on price ratios, for example. However, following Johansen (1960), the model is solved by representing it as a series of linear equations relating percentage changes in model variables. This section explains how the linearised form can be used to generate exact solutions of the underlying, non-linear, equations, as well as to compute linear approximations to those solutions.

A typical AGE model can be represented in the levels as:

$$\mathbf{F}(\mathbf{Y},\mathbf{X}) = \mathbf{0}, \tag{1}$$

where $\mathbf{Y}$ is a vector of endogenous variables, $\mathbf{X}$ is a vector of exogenous variables and $\mathbf{F}$ is a system of non-linear functions. The problem is to compute $\mathbf{Y}$, given $\mathbf{X}$. Normally we cannot write $\mathbf{Y}$ as an explicit function of $\mathbf{X}$.

Several techniques have been devised for computing $\mathbf{Y}$. The linearised approach starts by assuming that we already possess some solution to the system, $\{\mathbf{Y}^0,\mathbf{X}^0\}$, i.e.,

$$\mathbf{F}(\mathbf{Y}^0,\mathbf{X}^0) = \mathbf{0}. \tag{2}$$

Normally the initial solution $\{\mathbf{Y}^0,\mathbf{X}^0\}$ is drawn from historical data—we assume that our equation system was true for some point in the past. With conventional assumptions about the form of the $\mathbf{F}$ function it will be true that for small changes $\mathbf{dY}$ and $\mathbf{dX}$:

$$\mathbf{F}_Y(\mathbf{Y},\mathbf{X})\mathbf{dY} + \mathbf{F}_X(\mathbf{Y},\mathbf{X})\mathbf{dX} = \mathbf{0}, \tag{3}$$

where $\mathbf{F}_Y$ and $\mathbf{F}_X$ are matrices of the derivatives of $\mathbf{F}$ with respect to $\mathbf{Y}$ and $\mathbf{X}$, evaluated at $\{\mathbf{Y}^0,\mathbf{X}^0\}$. For reasons explained below, we find it more convenient to express $\mathbf{dY}$ and $\mathbf{dX}$ as small percentage changes $\mathbf{y}$ and $\mathbf{x}$. Thus y and x, some typical elements of $\mathbf{y}$ and $\mathbf{x}$, are given by:

$$y = 100dY/Y \quad \text{and} \quad x = 100dX/X. \tag{4}$$

Correspondingly, we define:

$$G_Y(\mathbf{Y},\mathbf{X}) = F_Y(\mathbf{Y},\mathbf{X})\hat{\mathbf{Y}} \quad \text{and} \quad G_X(\mathbf{Y},\mathbf{X}) = F_X(\mathbf{Y},\mathbf{X})\hat{\mathbf{X}}, \tag{5}$$

where $\hat{\mathbf{Y}}$ and $\hat{\mathbf{X}}$ are diagonal matrices. Hence the linearised system becomes:

$$\mathbf{G}_Y(\mathbf{Y},\mathbf{X})\mathbf{y} + \mathbf{G}_X(\mathbf{Y},\mathbf{X})\mathbf{x} = \mathbf{0}. \tag{6}$$

Such systems are easy for computers to solve, using standard techniques of linear algebra. But they are accurate only for small changes in $\mathbf{Y}$ and $\mathbf{X}$. Otherwise, linearisation error may occur. The error is illustrated by Figure 3, which shows how some endogenous variable Y changes as an exogenous variable X moves from X^0 to X^F. The true, non-linear relation between X and Y is shown as a curve. The linear, or first-order, approximation:

$$y = -\mathbf{G}_Y(\mathbf{Y},\mathbf{X})^{-1}\mathbf{G}_X(\mathbf{Y},\mathbf{X})x \tag{7}$$

leads to the Johansen estimate Y^J—an approximation to the true answer, Y^{exact}.

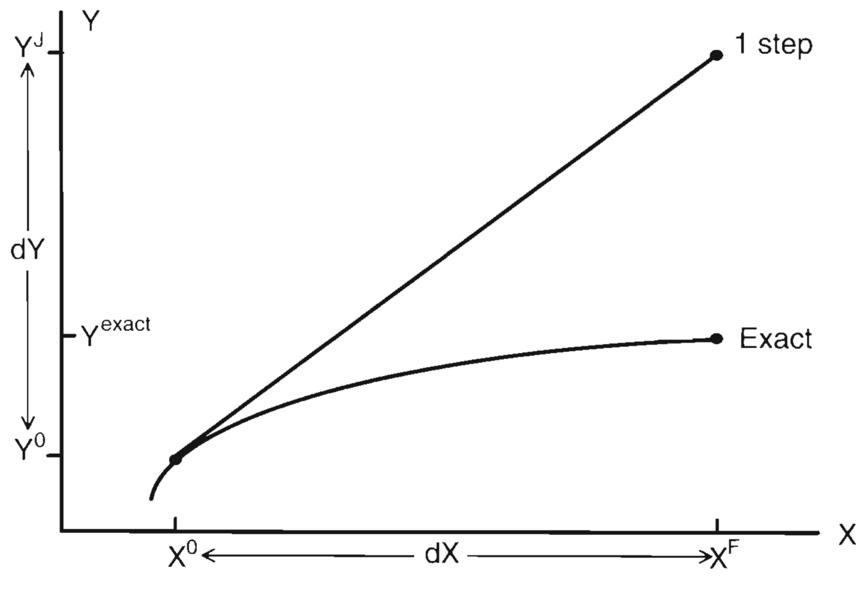

Figure 3. Linearisation error

Figure 3 suggests that, the larger is x, the greater is the proportional error in y. This observation leads to the idea of breaking large changes in X into a number of steps, as shown in Figure 4. For each sub-change in X, we use the linear approximation to derive the consequent sub-change in Y. Then, using the new values of X and Y, we recompute the coefficient matrices $\mathbf{G}_Y$ and $\mathbf{G}_X$. The process is repeated for each step. If we use 3 steps (see Figure 4), the final value of Y, Y^3, is closer to Y^{exact} than was the Johansen estimate Y^J. We can show, in fact, that given sensible restrictions on the derivatives of $\mathbf{F}(\mathbf{Y},\mathbf{X})$, we can obtain a solution as accurate as we like by dividing the process into sufficiently many steps.

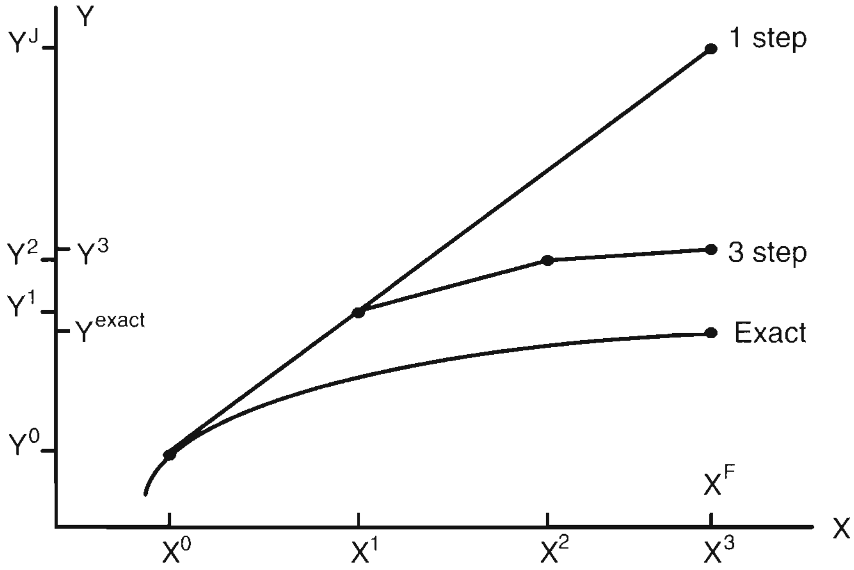

Figure 4. Multistep process to reduce linearisation error

The technique illustrated in Figure 4, known as the Euler method, is the simplest of several related techniques of numerical integration—the process of using differential equations (change formulae) to move from one solution to another. GEMPACK offers the choice of several such techniques. Each requires the user to supply an initial solution $\{\mathbf{Y}^0,\mathbf{X}^0\}$, formulae for the derivative matrices $\mathbf{G}_Y$ and $\mathbf{G}_X$, and the total percentage change in the exogenous variables, $\mathbf{x}$. The levels functional form, $\mathbf{F}(\mathbf{Y},\mathbf{X})$, need not be specified, although it underlies $\mathbf{G}_Y$ and $\mathbf{G}_X$.

The accuracy of multistep solution techniques can be improved by extrapolation. Suppose the same experiment were repeated using 4-step, 8-step and 16-step Euler computations, yielding the following estimates for the total percentage change in some endogenous variable Y:

y(4-step) = 4.5%,
y(8-step) = 4.3% (0.2% less), and
y(16-step) = 4.2% (0.1% less).

Extrapolation suggests that the 32-step solution would be:

y(32-step) = 4.15% (0.05% less),

and that the exact solution would be:

y(∞-step) = 4.1%.

The extrapolated result requires 28 (=4+8+16) steps to compute but would normally be more accurate than that given by a single 28-step computation. Alternatively, extrapolation enables us to obtain given accuracy with fewer steps. As we noted above, each step of a multi-step solution requires: computation from data of the percentage-change derivative matrices $\mathbf{G_Y}$ and $\mathbf{G_X}$; solution of the linear system (6); and use of that solution to update the data $(\mathbf{X},\mathbf{Y})$.

For a detailed treatment of the linearised approach to AGE modelling, see:

Dixon PB, Parmenter BR, Powell AA and Wilcoxen PJ (1992) *Notes and Problems in Applied General Equilibrium Economics*, Amsterdam:North-Holland.

Chapter 3 contains information about Euler's method and multistep computations.

In practice, for typical AGE models, it is unnecessary, during a multistep computation, to record values for every element in $\mathbf{X}$ and $\mathbf{Y}$. Instead, we can define a set of *data coefficients* $\mathbf{V}$, which are functions of $\mathbf{X}$ and $\mathbf{Y}$, i.e., $\mathbf{V} = \mathbf{H}(\mathbf{X},\mathbf{Y})$. Most elements of $\mathbf{V}$ are simple cost or expenditure flows such as appear in input-output tables. $\mathbf{G_Y}$ and $\mathbf{G_X}$ turn out to be simple functions of $\mathbf{V}$; often indeed identical to elements of $\mathbf{V}$. After each small change, $\mathbf{V}$ is updated using the formula $\mathbf{v} = \mathbf{H_Y}(\mathbf{X},\mathbf{Y})\mathbf{y} + \mathbf{H_X}(\mathbf{X},\mathbf{Y})\mathbf{x}$. The advantages of storing $\mathbf{V}$, rather than $\mathbf{X}$ and $\mathbf{Y}$, are twofold:

- the expressions for $\mathbf{G_Y}$ and $\mathbf{G_X}$ in terms of $\mathbf{V}$ tend to be simple, often far simpler than the original $\mathbf{F}$ functions; and
- there are fewer elements in $\mathbf{V}$ than in $\mathbf{X}$ and $\mathbf{Y}$ (e.g., instead of storing prices and quantities separately, we store merely their products, the values of commodity or factor flows).

3.1. Levels and linearised systems compared: a small example

For a comparison of the levels and linearised approaches to solving AGE models see Hertel TW, Horridge JM and Pearson KR (1992) Mending the Family Tree, *Economic Modelling*, October, pp 385-407.

To illustrate the convenience of the linear approach, we consider a very small equation system: the CES input demand equations for a producer who makes output Z from N inputs X_k, k=1-N, with prices P_k. In the levels the equations are (see Appendix A):

$$X_k = Z\,\delta_k^{1/(\rho+1)}\left[\frac{P_k}{P_{ave}}\right]^{-1/(\rho+1)}, \qquad k=1,N \quad (8)$$

where $$P_{ave} = \left(\sum_{i=1}^{N} \delta_i^{1/(\rho+1)} P_i^{\rho/(\rho+1)}\right)^{-(\rho+1)/\rho}. \quad (9)$$

The δ_k and ρ are behavioural parameters. To solve the model in the levels, the values of the δ_k are normally found from historical flows data, $V_k=P_kX_k$, presumed consistent with the equation system and with some externally given value for ρ. This process is called calibration. To fix the X_k, it is usual to assign arbitrary values to the P_k, say 1. This merely sets convenient units for the X_k (base-period-dollars-worth). ρ is normally given by econometric estimates of the elasticity of substitution, σ (=1/(ρ+1)). With the P_k, X_k, Z and ρ known, the δ_k can be deduced.

In the solution phase of the levels model, δ_k and ρ are fixed at their calibrated values. The solution algorithm attempts to find P_k, X_k and Z consistent with the levels equations and with other exogenous restrictions. Typically this will involve repeated evaluation of both (8) and (9)—corresponding to $\mathbf{F}(\mathbf{Y},\mathbf{X})$—and of derivatives which come from these equations—corresponding to $\mathbf{F_Y}$ and $\mathbf{F_X}$.

The percentage-change approach is far simpler. Corresponding to (8) and (9), the linearised equations are (see Appendices A and E):

$$x_k = z - \sigma\left(p_k - p_{ave}\right), \qquad k=1,N \quad (10)$$

and $$p_{ave}\sum_{i=1}^{N} V_i = \sum_{i=1}^{N} V_i p_i, \quad (11)$$

Since percentage changes have no units, the calibration phase—which amounts to an arbitrary choice of units—is not required. For the same reason the δ_k parameters do not appear. However, the flows data V_k again form the starting point. After each change they are updated by:

$$V_{k,new} = V_{k,old} + V_{k,old}(x_k + p_k)/100 \tag{12}$$

GEMPACK is designed to make the linear solution process as easy as possible. The user specifies the linear équations (10) and (11) and the update formulae (12) in the TABLO language—which resembles algebraic notation. Then GEMPACK repeatedly:

- evaluates $\mathbf{G}_Y$ and $\mathbf{G}_X$ at given values of $\mathbf{V}$;
- solves the linear system to find $\mathbf{y}$, taking advantage of the sparsity of $\mathbf{G}_Y$ and $\mathbf{G}_X$; and
- updates the data coefficients $\mathbf{V}$.

The housekeeping details of multistep and extrapolated solutions are hidden from the user.

Apart from its simplicity, the linearised approach has two further advantages.

- It allows free choice of which variables are to be exogenous or endogenous. Many levels algorithms do not allow this flexibility.
- To reduce AGE models to manageable size, it is often necessary to use model equations to substitute out matrix variables of large dimensions. In a linear system, we can always make any variable the subject of any equation in which it appears. Hence, substitution is a simple mechanical process. In fact, because GEMPACK performs this routine algebra for the user, the model can be specified in terms of its original behavioural equations, rather than in a reduced form. This reduces the potential for error and makes model equations easier to check.

3.2. The Initial Solution

Our discussion of the solution procedure has so far assumed that we possess an initial solution of the model—$\{\mathbf{Y}^0,\mathbf{X}^0\}$ or the equivalent $\mathbf{V}^0$—and that results show percentage deviations from this initial state. However, this assumption raises two difficulties.

The first difficulty relates to comparative-static simulations—see Figure 1. In practice, the ORANI database does not, like B, show the expected state of the economy at a future date. Instead the most recently available historical data, A, are used. At best, these refer to the present-day economy. Note that, for the atemporal static model, A provides a solution for period T. In the static model, setting all exogenous variables at their base-period levels would leave all the endogenous variables at their base-period levels. Nevertheless, A may not be an empirically plausible control state for the economy at period T and the question therefore arises: are estimates of the B-to-C percentage changes much affected by starting from A rather than B? For example, would the percentage effects of a tariff cut inflicted in 1988 differ much from those caused by a 1993 cut? Probably not. First, balanced growth, i.e., a proportional enlargement of the model database, just scales equation coefficents equally; it does not affect ORANI results. Second, compositional changes, which do alter percentage-change effects, happen quite slowly. So for short- and medium-run simulations A is a reasonable proxy for B.

The second difficulty associated with the need for an initial solution arises in forecasting simulations with the dynamic model, ORANI-F (see section 2.2 and Figure 2). We compute the through-time changes which are the subject of our forecasting simulations *as if* they were comparative static changes occurring at time T, the last year of our forecast period. This requires values of the variables for time T which, together with the initial conditions (V^0), provide a solution for the dynamic system. However, the base-period data (A in Figure 2) do not in general provide model-consistent values for the variables at any future period. That is, setting the exogenous variables in the future period T at their base-period values will not in general be consistent with the endogenous variables remaining in period T at their base-period values. For example, unless the base data depict a steady state, capital stocks will change through time even if investment remains unchanged. To overcome the lack of control values of the variables for period T, we augment the model's dynamic equations with slack variables F in such a way that, when the levels values of the slack variables are unity, the equations are unaffected (see sections 4.21 and 4.23). Then, we generate a control solution by allowing the slacks to take values, usually non-unity, which render $\{V^0, V^T{=}V^0, F\}$ a solution to the augmented model. Finally, we apply through-time shocks to the exogenous variables *as if* they were comparative-static shocks at period T and include shocks to the slack variables to return them to unity, i.e., to reinstate the unaugmented dynamic equations.

A by-product of the GEMPACK solution process is an updated database $\mathbf{V}^T$ that is consistent with the percentage-change results. Thus, a forecasting simulation can produce a $\mathbf{V}^T$ database that is our best estimate of the (future) state of affairs at T. By using such a database as a starting point for comparative-static simulations, we can overcome the first difficulty mentioned in this subsection.

4. The Equations of ORANI-F

In this section we provide a formal description of the linear form of the model used to generate the simulations reported in Section 7. Our description is organised around the TABLO file which implements the model in GEMPACK. We present the complete text of the TABLO Input file divided into a sequence of excerpts and supplemented by tables, figures and explanatory text.

The TABLO language in which the file is written is essentially conventional algebra, with names for variables and coefficients chosen to be suggestive of their economic interpretations. Some practice is required for readers to become familiar with the TABLO notation but it is no more complex than alternative means of setting out the model—the sort of notation employed in DPSV (1982), for example. Acquiring the familiarity allows ready access to the GEMPACK programs used to conduct simulations with the model and to convert the results to human-readable form. Both the input and the output of these programs employ the TABLO notation. Moreover, familiarity with the TABLO format is essential for users who may wish to make modifications to the model's structure.

Another compelling reason for using the TABLO Input file to document the model is that it ensures that our description is complete and accurate: complete because the only other data needed by the GEMPACK solution process is numerical (the model's database and the exogenous inputs to particular forecasts or policy experiments); and accurate because GEMPACK is nothing more than an equation solving system, incorporating no economic assumptions of its own.

We continue this section with a short introduction to the TABLO language—other details may be picked up later, as they are encountered. Then we describe the input-output database which underlies the model. This structures our subsequent presentation.

4.1. The TABLO language

The TABLO model description defines the percentage-change equations of the model. For example, the CES demand equations, (10) and (11), would appear as:

```
Equation E_x # input demands #
     (All, f, FAC)  x(f) = z - SIGMA{p(f) - p_f};
Equation E_p_f # input cost index #
     V_F*p_f = Sum(f,FAC,V(f)*p(f));
```

The first word, 'Equation', is a keyword which defines the statement type. Then follows the identifier for the equation, which must be unique. The descriptive text between '#' symbols is optional—it appears in certain report files. The expression '(All, f, FAC)' signifies that the equation is a matrix equation, containing one scalar equation for each element of the set FAC.

Within the equation, the convention is followed of using lower-case letters for the percentage-change variables (x, z, p and p_f), and upper case for the coefficients (SIGMA, V and V_F). Since GEMPACK ignores case, this practice assists only the human reader. An implication is that we cannot use the same sequence of characters, distinguished only by case, to define a variable and a coefficient. The '(f)' suffix indicates that variables and coefficients are vectors, with elements corresponding to the set FAC. A semicolon signals the end of the TABLO statement.

To facilitate portability between computing environments, the TABLO character set is quite restricted—only alphanumerics and a few punctuation marks may be used. The use of Greek letters and subscripts is precluded, and the asterisk, '*', must replace the multiplication symbol '×'.

Sets, coefficients and variables must be explicitly declared, *via* statements such as:

```
Set FAC # inputs # (capital, labour, energy);
Coefficient    (All, f, FAC)  V(f)     # cost of inputs #;
                              V_F      # total cost #;
                              SIGMA    # substitution elasticity #;
Variable       (All, f, FAC)  p(f)     # price of inputs  #;
               (All, f, FAC)  x(f)     # demand for inputs  #;
                              z        # output #;
                              p_f      # input cost index #;
```

As the last two statements in the 'Coefficient' block and the last three in the 'Variable' block illustrate, initial keywords (such as 'Coefficient' and 'Variable') may be omitted if the previous statement was of the same type.

Coefficients must be assigned values, either by reading from file:

```
Read V from file FLOWDATA;
Read SIGMA from file PARAMS;
```

or in terms of other coefficients, using formulae:

```
Formula V_F = Sum(f, FAC, V(f)); ! used in cost index equation !
```

The right hand side of the last statement employs the TABLO summation notation, equivalent to the Σ notation used in standard algebra. It defines the sum over an index f running over the set FAC of the input-cost coefficients, V(f). The statement also contains a comment, i.e., the text between exclamation marks (!). TABLO ignores comments.

Some of the coefficients will be updated during multistep computations. This requires the inclusion of statements such as:

```
Update (All, f, FAC) V(f) = x(f)*p(f);
```

which is the default update statement, causing V(f) to be increased after each step by [x(f) + p(f)]%, where x(f) and p(f) are the percentage changes computed at the previous step.

The sample statements listed above introduce most of the types of statement required for the model. But since all sets, variables and coefficients must be defined before they are used, and since coefficients must be assigned values before appearing in equations, it is necessary for the order of the TABLO statements to be almost the reverse of the order in which they appear above. The ORANI-F TABLO Input file is ordered as follows:

- definition of sets;
- declarations of variables;
- declarations of often-used coefficients which are read from files, with associated Read and Update statements;
- declarations of other often-used coefficients which are computed from the data, using associated Formulae; and
- groups of topically-related equations, with some of the groups including statements defining coefficients which are used only within that group.

4.2. The model's data base

Figure 5 is a schematic representation of the model's input-output database. It reveals the basic structure of the model. The columns in the main part of the figure (an absorption matrix) identify the following agents:

(1) domestic producers divided into I industries;
(2) investors divided into I industries;
(3) a single representative household;
(4) an aggregate foreign purchaser of exports;
(5) an 'other' demand category, broadly corresponding to government; and
(6) changes in inventories of domestically produced goods.

The rows show the structure of the purchases made by each of the agents identified in the columns. Each of the C 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, or are added to or subtracted from inventories. Only domestically produced goods appear in the export and inventory columns. M of the domestically produced goods are used as margins services (wholesale and retail trade, and transport) which 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 O occupations), fixed capital, and agricultural land. The 'other costs' category covers various miscellaneous industry expenses.

Each cell in the absorption matrix contains the name of the corresponding matrix of the values (in some base year) of flows of commodities, indirect taxes or primary factors to a group of users. For example, V2MAR is a 4-dimensional array showing the cost of M margins services on the flows of C goods, both domestically produced and imported (S), to I investors.

In principle, each industry is capable of producing any of the C commodity types. The MAKE matrix at the bottom of Figure 5 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.

		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	n/a
Taxes	↑ C×S ↓	V1TAX	V2TAX	V3TAX	V4TAX	V5TAX	n/a
Labour	↑ O ↓	V1LAB					
Capital	↑ 1 ↓	V1CAP					
Land	↑ 1 ↓	V1LND					
Other Costs	↑ 1 ↓	V1OCT					

C = Number of Commodities

I = Number of Industries

S = 2: Domestic,Imported,

O = Number of Occupation Types

M = Number of Commodities used as Margins

	Joint Production Matrix
Size	← I →
↑ C ↓	MAKE

	Import Duty
Size	← 1 →
↑ C ↓	V0TAR

Figure 5. The ORANI-F Flows Database

4.3. Dimensions of the model

Excerpt 1 of the TABLO Input file defines sets of descriptors for the components of vector variables. Set names appear in upper-case characters. For example, the first statement is to be read as defining a set named 'COM' which contains commodity descriptors C1 to C23.

Excerpt 1 of TABLO Input file: Definitions of sets

```
Set                                                                 ! Suffix !
 COM       # Commodities #                 (C1 - C23);                 ! c !
 SRC       # Source of Commodities #       (dom,imp);                  ! s !
 IND       # Industries #                  (I1 - I22);                 ! i !
 OCC       # Occupation Types #            (skilled, unskilled);       ! o !
 MAR       # Margin Commodities #          (C18, C19);                 ! m !
 NONMAR    # Non-Margin Commodities #      (C1 - C17, C20 - C23);      ! n !
Subset
 MAR       is subset of COM;
 NONMAR    is subset of COM;
```

The commodity, industry, and occupational classifications are aggregates of the classifications used in the original version of ORANI-F, which has over 100 industries and commodities, and 8 labour occupations.

The industry and commodity classifications are different. Both are listed in Table 1. In this aggregated version of the model, multiproduction is confined to the first two industries, which produce the first three commodities. Each of the remaining industries produces a unique commodity. Three categories of primary factors (labour, capital and land) are distinguished in the model, with the last used only in the first two, rural, industries. Labour is disaggregated into 2 occupational categories, based on the Australian Standard Classification of Occupations.

Table 1 Commodity and Industry Classification

	Commodities		Industries
1	Cereals		
2	Broadacre rural	1	Broadacre rural
3	Intensive rural	2	Intensive rural
4	Mining, export	3	Mining, export
5	Mining, other	4	Mining, other
6	Food & fibre, export	5	Food & fibre, export
7	Food, other	6	Food, other
8	Textiles, clothing & footwear	7	Textiles, clothing & footwear
9	Wood related products	8	Wood related products
10	Chemicals & oil products	9	Chemicals & oil products
11	Non-metallic mineral products	10	Non-metallic mineral products
12	Metal products	11	Metal products
13	Transport equipment	12	Transport equipment
14	Other machinery	13	Other machinery
15	Other manufacturing	14	Other manufacturing
16	Utilities	15	Utilities
17	Construction	16	Construction
18	Retail & wholesale trade	17	Retail & wholesale trade
19	Transport	18	Transport
20	Banking & finance	19	Banking & finance
21	Ownership of dwellings	20	Ownership of dwellings
22	Public services	21	Public services
23	Private services	22	Private services

Commodities C18 and C19 are margins commodities, i.e., they are required to facilitate the flows of other commodities from producers (or importers) to users. Hence, the costs of margins services, together with indirect taxes, account for differences between *basic* prices (received by producers or importers) and *purchasers'* prices (paid by users).

TABLO does not prevent two elements of different sets from sharing the same name; nor, in such a case, does it infer any connection between the two elements. The 'Subset' statements which conclude Excerpt 1 are required for TABLO to realize that the two elements of MAR, 'C18' and 'C19' are the same as the 18th and 19th elements of the set COM.

4.4. Model variables

The names of model's variables are listed in the next five excerpts of the TABLO Input file. Unless otherwise stated, all variables are percentage changes—to indicate this, their names appear in lower-case letters. Preceding the names of the variables are their dimensions, indicated using the sets defined in Excerpt 1. For example, the first variable statement in Excerpt 2 defines a matrix variable x1 (indexed by commodity, source, and using industry) the elements of which are percentage changes in the direct demands by producers for source-specific intermediate inputs.

The last variable in the first group in Excerpt 2, delx6, is preceded by the 'Change' qualifier to indicate that it is an ordinary (rather than percentage) change, since changes in inventories may be either positive or negative. Our multistep solution procedure requires that large changes be broken into a sequence of small changes. However, no sequence of small *percentage* changes allows a (levels) variable to change sign—at least one change must exceed -100%. Thus, for variables that may, in the levels, change sign, we prefer to use ordinary changes.

The reader will notice that there is a pattern to the names given to the variables and to the coefficients which appear later. Although GEMPACK does not require that names conform to any pattern, we find that systematic naming reduces the burden on (human) memory. As far as possible, names for variables and coefficients conform to a system in which each name consists of 2 or more parts, as follows:

first, a letter or letters indicating the type of variable, for example,

a	technical change
del	ordinary (rather than percentage) change
f	shift variable
H	indexing parameter
p	price, \$A
pf	price, foreign currency
S	input share
SIGMA	elasticity of substitution
t	tax
V	levels value, \$A
w	percentage-change value, \$A
x	input quantity;

second, one of the digits 0 to 6 indicating user, that is,

1	current production
2	investment
3	consumption

4	export
5	'other' (Government)
6	inventories
0	all users, or user distinction irrelevant;

third (optional), three or more letters giving further information, for example,

bas	(often omitted) basic—not including margins or taxes
cap	capital
cif	imports at border prices
imp	imports (duty paid)
lab	labour
lnd	land
lux	linear expenditure system (supernumerary part)
mar	margins
oct	other cost tickets
prim	all primary factors (land, labour or capital)
pur	at purchasers' prices
sub	linear expenditure system (subsistence part)
tar	tariffs
tax	indirect taxes
tot	total or average over all inputs for some user;

fourth (optional), an underscore character, indicating that this variable is an aggregate or average, with subsequent letters showing over which sets the underlying variable has been summed, for example,

_i	sum over IND (industries),
_c	sum over COM (commodities),
_io	sum over IND and OCC (skills).

Although GEMPACK does not distinguish between upper and lower case, we use:

lower case for variable names and set indices;
upper case for set and coefficient names; and
initial letter upper case for TABLO keywords.

The variables in Excerpt 2 are grouped to show their relation to the data base depicted in Figure 5. The first group of variables contains the quantities associated with row 1 (basic flows) of the data base, i.e., the flow matrices V1BAS, V2BAS, and so on. All these quantities are valued at basic prices, p0, which are listed next. Then follow technical-change variables (akin to shifts in input-output coefficients) for the first 3 user types, and a shift variable for 'other' demands.

The next group of variables contains the quantities associated with row 2 (margins) of Figure 5, i.e., the flow matrices V1MAR, V2MAR, and so on. These are the quantities of retail and wholesale services or transport needed to deliver each basic flow to the user. All these quantities are valued at basic prices, p0, already listed. Again, technical-change variables follow, this time for the first 5 user types.

The next group of variables contains the quantities associated with row 3 (taxes) of Figure 5, i.e., the flow matrices V1TAX, V2TAX, and so on. These variables are powers of the taxes on the basic flows. (The power of a tax is one plus the *ad valorem* rate.)

The last group of variables in this block contains the purchasers' prices which include basic, margin and tax components.

```
Variable
! Basic Demands for commodities (excluding margin demands) !
(All,c,COM)(All,s,SRC)(All,i,IND)      x1(c,s,i)  # Intermediate #;
(All,c,COM)(All,s,SRC)(All,i,IND)      x2(c,s,i)  # Investment #;
(All,c,COM)(All,s,SRC)                 x3(c,s)    # Household #;
(All,c,COM)                            x4(c)      # Export #;
(All,c,COM)(All,s,SRC)                 x5(c,s)    # Other #;
(Change) (All,c,COM)                   delx6(c)   # Inventories #;

(All,c,COM)(All,s,SRC)        p0(c,s)    # basic price of commodity c, source s #;

! Technical or Taste Change Variables affecting Basic Demands !
(All,c,COM)(All,s,SRC)(All,i,IND)      a1(c,s,i)  # Intermediate #;
(All,c,COM)(All,s,SRC)(All,i,IND)      a2(c,s,i)  # Investment #;
(All,c,COM)(All,s,SRC)                 a3(c,s)    # Household #;
(All,c,COM)(All,s,SRC)                 f5(c,s)    # Other Demand Shift #;

! Margin Usage on Basic Flows !
(All,c,COM)(All,s,SRC)(All,i,IND)(All,m,MAR)   x1mar(c,s,i,m)# Intermediate #;
(All,c,COM)(All,s,SRC)(All,i,IND)(All,m,MAR)   x2mar(c,s,i,m)# Investment #;
(All,c,COM)(All,s,SRC)(All,m,MAR)              x3mar(c,s,m)    # Household #;
(All,c,COM)(All,m,MAR)                         x4mar(c,m)      # Export #;
(All,c,COM)(All,s,SRC)(All,m,MAR)              x5mar(c,s,m)    # Other #;

! Technical Change in Margins Usage !
(All,c,COM)(All,s,SRC)(All,i,IND)(All,m,MAR)   a1mar(c,s,i,m)  # Intermediate #;
(All,c,COM)(All,s,SRC)(All,i,IND)(All,m,MAR)   a2mar(c,s,i,m)  # Investment #;
(All,c,COM)(All,s,SRC)(All,m,MAR)              a3mar(c,s,m)    # Household #;
(All,c,COM)(All,m,MAR)                         a4mar(c,m)      # Export #;
(All,c,COM)(All,s,SRC)(All,m,MAR)              a5mar(c,s,m)    # Other #;

! Powers of Commodity Taxes on Basic Flows !
(All,c,COM)(All,s,SRC)(All,i,IND)      t1(c,s,i)  # Intermediate #;
(All,c,COM)(All,s,SRC)(All,i,IND)      t2(c,s,i)  # Investment #;
(All,c,COM)(All,s,SRC)                 t3(c,s)    # Household #;
(All,c,COM)                            t4(c)      # Export #;
(All,c,COM)(All,s,SRC)                 t5(c,s)    # Other #;

! Purchaser's Prices (including margins and taxes) !
(All,c,COM)(All,s,SRC)(All,i,IND)      p1(c,s,i)  # Intermediate #;
(All,c,COM)(All,s,SRC)(All,i,IND)      p2(c,s,i)  # Investment #;
(All,c,COM)(All,s,SRC)                 p3(c,s)    # Household #;
(All,c,COM)                            p4(c)      # Exports $A #;
(All,c,COM)(All,s,SRC)                 p5(c,s)    # Other #;
```

Excerpt 2 of TABLO Input file: Variables relating to commodity flows

Excerpt 3 of the TABLO Input file corresponds to the remaining rows of Figure 5. The first group of variables relates to industry demands for labour (V1LAB in Figure 5). First appear percentage changes in the quantities and wages, then the labour-saving technical-change variable. The variable 'f1lab' is a shift variable which can be used to shock independently the wage rate for each labour type.

The next 3 groups of variables relate to industry demands for capital, land and 'other costs' (V1CAP, V1LND and V1OCT in Figure 5). The last parts of the flows database, the MAKE matrix and the duty vector, are represented by the variable q1, output by commodity and industry, and t0imp, the powers of the tariffs.

```
! Variables relating to usage of labour, occupation o, in industry i !
(All,i,IND)(All,o,OCC)  x1lab(i,o)    # Employment #;
(All,i,IND)(All,o,OCC)  p1lab(i,o)    # Wage #;
(All,i,IND)             a1lab_o(i)    # Labor Augmenting Technical Change #;
(All,i,IND)(All,o,OCC)  f1lab(i,o)    # Wage shift variable #;

! Variables relating to usage of fixed capital in industry i !
(All,i,IND)   x1cap(i)  # Current Capital Stock #;
(All,i,IND)   p1cap(i)  # Rental Price of Capital #;
(All,i,IND)   a1cap(i)  # Capital Augmenting Technical Change #;
(All,i,IND)   r1cap(i)  # Net Rates of Return on Fixed Capital #;

! Variables relating to usage of land !
(All,i,IND)   x1lnd(i)  # Use of Land #;
(All,i,IND)   p1lnd(i)  # Rental Price of Land #;
(All,i,IND)   a1lnd(i)  # Land Augmenting Technical Change #;

! Variables relating to "Other Costs" !
(All,i,IND)   x1oct(i)  # Demand for "Other Cost" Tickets #;
(All,i,IND)   p1oct(i)  # Price of "Other Cost" Tickets #;
(All,i,IND)   a1oct(i)  # "Other Cost" Ticket Augmenting Techncal Change#;
(All,i,IND)   f1oct(i)  # Shifts in Price of "Other Cost" Tickets #;

! Variables relating to commodity supplies and import duties !
(All,c,COM)(All,i,IND)  q1(c,i)    # Output of commodity c by industry i #;
(All,c,COM)             t0imp(c)   # Power of Tariffs #;
```

Excerpt 3 of TABLO Input file: Variables relating to primary-factor flows, commodity supplies and import duties

Excerpt 4 contains variables defining quantities and prices for commodity composites of imports and domestic products, and the associated technical- and taste-change variables. The roles of these composites will be explained in our discussion of the model's equations.

```
! Demands for import/domestic commodity composites !
(All,c,COM)(All,i,IND)  x1_s(c,i)    # Intermediate #;
(All,c,COM)(All,i,IND)  x2_s(c,i)    # Investment #;
(All,c,COM)             x3_s(c)      # Household #;
(All,c,COM)             x3lux(c)     # Household - Supernumerary Demands #;
(All,c,COM)             x3sub(c)     # Household - Subsistence Demands #;

! Effective Prices of import/domestic commodity composites !
(All,c,COM)(All,i,IND)  p1_s(c,i)    # Intermediate #;
(All,c,COM)(All,i,IND)  p2_s(c,i)    # Investment #;
(All,c,COM)             p3_s(c)      # Household #;

! Technical or Taste Change Variables for import/domestic composites !
(All,c,COM)(All,i,IND)  a1_s(c,i)    # Intermediate #;
(All,c,COM)(All,i,IND)  a2_s(c,i)    # Investment #;
(All,c,COM)             a3_s(c)      # All Household Usage of Good c #;
(All,c,COM)             a3lux(c)     # Household - Supernumerary Demands #;
(All,c,COM)             a3sub(c)     # Household - Subsistence Demands #;
```

Excerpt 4 of TABLO Input file: Variables describing composite commodities

Excerpt 5 of the TABLO Input file specifies the model's remaining vector variables. These are mainly shift variables and aggregations of variables which appeared in the earlier excerpts. Their roles will be described as they occur in the equations.

```
Variable
(All,c,COM)   f0tax_s(c)    # General Sales Tax Shifter #;
(All,c,COM)   f4p(c)        # Price (upward) Shift in Export Demand Schedule#;
(All,c,COM)   f4q(c)        # Quantity (right) Shift in Export Demands #;
(All,c,COM)   pf0cif(c)     # C.I.F. Foreign Currency Import Prices #;
(All,c,COM)   x0dom(c)      # Total Supplies of Domestic Goods #;
(All,c,COM)   x0imp(c)      # Total Supplies of Imported Goods #;
(All,i,IND)   a1prim(i)     # All Factor Augmenting Technical Change #;
(All,i,IND)   a1tot(i)      # All Input Augmenting Technical Change #;
(All,i,IND)   a2tot(i)      # Neutral Technical Change - Investment #;
(All,i,IND)   employ(i)     # Employment by Industry #;
(All,i,IND)   f1lab_o(i)    # Industry-Specific Wage Shifter #;
(All,i,IND)   f_accum(i)    # Capital Accumulation Shifter #;
(All,i,IND)   f1ret(i)      # Rate of Return Shifter #;
(All,i,IND)   p1lab_o(i)    # Price of Labour Composite #;
(All,i,IND)   p1prim(i)     # Effective Price of Primary Factor Composite #;
(All,i,IND)   p1tot(i)      # Average Input/Output Price #;
(All,i,IND)   p2tot(i)      # Costs of Units of Capital #;
(All,i,IND)   x1lab_o(i)    # Effective Labour Input #;
(All,i,IND)   x1prim(i)     # Primary Factor Composite #;
(All,i,IND)   x1tot(i)      # Activity Level or Value-Added #;
(All,i,IND)   x2tot(i)      # Investment by Using Industry #;
(All,o,OCC)   f1lab_i(o)    # Occupation-Specific Wage Shifter #;
(All,o,OCC)   x1lab_i(o)    # Employment by Occupation #;
```

Excerpt 5 of TABLO Input file:
Miscellaneous vector variables

Excerpt 6 of the TABLO Input file completes the listing of the model's variables by specifying a number of macroeconomic aggregates and price indexes. As with the variables listed in Excerpt 5, most of these are aggregates or averages of variables defined earlier. Note that the first few variables are ordinary changes. These variables may (in the levels) equal zero or change sign.

```
Variable
(Change) delB              # (Balance of Trade)/GDP #;
(Change) delDebt           # Ordinary Change in Real Foreign Debt #;
(Change) delDebt_Ratio     # Ordinary Change in Debt/GDP ratio #;
(Change) delBT             # Ordinary Change in Real Trade Deficit #;
(Change) delFudge          # "Fudge Factor": set to Unity for Dynamic Simulation #;
(Change) delUnity          # Dummy Variable, Always Exogenously Set to Unity #;
(Change) levDebt_Ratio     # Levels Debt/GDP ratio #;
employ_i       # Aggregate Employment- Wage Bill Weights #;
f1lab_io       # Overall Wage Shifter #;
f1tax_csi      # Uniform % Change in Powers of Taxes on Intermediate Usage #;
f2tax_csi      # Uniform % Change in Powers of Taxes on Investment #;
f3tax_cs       # Uniform % Change in Powers of Taxes on Household Usage #;
f4_ntrad       # Demand Shift, Non-Traditional Export Aggregate #;
f4tax_ntrad    # Uniform % Change in Powers of Taxes on Non-Tradit'nal Exports #;
f4tax_trad     # Uniform % Change in Powers of Taxes on Traditional Exports #;
f5tax_cs       # Uniform % Change in Powers of Taxes on "Other" Usage #;
f5tot          # Overall Shift Term For "Other" Demands #;
f5tot2         # Ratio between f5tot and x3tot #;
p0cif_c        # Imports Price Index, CIF, A$ #;
p0gdpexp       # GDP Price Index, Expenditure Side #;
p0imp_c        # Duty-paid Imports Price Index,A$ #;
p0realdev      # Real Devaluation #;
p0toft         # Terms of Trade #;
p1cap_i        # Average Capital Rental #;
p2tot_ii       # Aggregate Investment Price Index #;
p3tot          # Consumer Price Index #;
p4_ntrad       # Price, Non-Traditional Export Aggregate #;
p4tot          # Exports Price Index #;
p5tot          # "Other" Demands Price Index #;
```

Excerpt 6 of TABLO Input file:
Scalar or macro variables

```
p6tot          # Inventories Price Index #;
phi            # Exchange Rate #;
q              # Number of Households #;
r1cap_i        # Average Rate of Return #;
utility        # Utility per Household #;
w0cif_c        # CIF A$ Value of Imports #;
w0gdpexp       # Nominal GDP from Expenditure Side #;
w0gdpinc       # Nominal GDP from Income Side #;
w0imp_c        # Value of Imports plus Duty #;
w0tar_c        # Aggregate Tariff Revenue #;
w0tax_csi      # Aggregate Revenue from All Indirect Taxes #;
w1cap_i        # Aggregate Payments to Capital #;
w1lab_io       # Aggregate Payments to Labour #;
w1lnd_i        # Aggregate Payments to Land #;
w1oct_i        # Aggregate Other Cost Ticket Payments #;
w1tax_csi      # Aggregate Revenue from Indirect Taxes on Intermediate #;
w2tax_csi      # Aggregate Revenue from Indirect Taxes on Investment #;
w2tot_i        # Aggregate Nominal Investment #;
w3lux          # Total Nominal Supernumerary Household Expenditure #;
w3tax_cs       # Aggregate Revenue from Indirect Taxes on Households #;
w3tot          # Nominal Total Household Consumption #;
w4tax_c        # Aggregate Revenue from Indirect Taxes on Exports #;
w4tot          # A$ Border Value of exports #;
w5tax_cs       # Aggregate Revenue from Indirect Taxes on "Other" Demands#;
w5tot          # Aggregate Nominal Value of "Other" Demands #;
w6tot          # Aggregate Nominal Value of Inventories #;
x0cif_c        # Import Volume Index, CIF Weights #;
x0gdpexp       # Real GDP from Expenditure Side #;
x0imp_c        # Import Volume Index, Duty-Paid Weights #;
x1cap_i        # Aggregate Capital Stock, Rental Weights #;
x1prim_i       # Aggregate Output: Value-Added Weights #;
x2tot_i        # Aggregate Real Investment Expenditure #;
x3tot          # Real Household Consumption #;
x4_ntrad       # Quantity, Non-Traditional Export Aggregate #;
x4tot          # Export Volume Index #;
x5tot          # Aggregate Real "Other" Demands #;
x6tot          # Aggregate Real Inventories #;
```

Excerpt 6 of TABLO Input file (cont.): Scalar or macro variables

The next section of the TABLO file (Excerpts 7-10) contains statements indicating data to be read from file. The data items defined in these statements appear as coefficients in the model's equations. The statements define coefficient names (which all appear in upper-case characters), the locations from which the data are to be read and, where appropriate, formulae for the data updates which are necessary in computing multi-step solutions to the model (see Section 3).

The section begins in Excerpt 7 by defining a logical name for the file (MDATA) where data are stored. The rest of Excerpts 7 to 10 of the file contain data statements for the input-output data (Figure 5).

Excerpt 7 contains the basic commodity flows corresponding to rows 1 (direct flows) and 2 (margins flows) of Figure 5. Each of these is the product of a price and a quantity. For example, the first 'Coefficient' statement in Excerpt 7 defines a data item V1BAS(c,s,i) which is the basic value (indicated by 'BAS') of a flow of intermediate inputs (indicated by '1') of commodity c from source s to user industry i. The first 'Read' statement indicates that this data item is stored on file MDATA with header '1BAS'. (A GEMPACK data file consists of a number of data items such as arrays of real numbers. Each data item is identified by a unique key or 'header').

```
File MDATA # Data File #;

Coefficient    ! Basic Flows of Commodities!
 (All,c,COM)(All,s,SRC)(All,i,IND)     V1BAS(c,s,i)     # Intermediate #;
 (All,c,COM)(All,s,SRC)(All,i,IND)     V2BAS(c,s,i)     # Investment #;
 (All,c,COM)(All,s,SRC)                V3BAS(c,s)       # Households #;
 (All,c,COM)                           V4BAS(c)         # Export #;
 (All,c,COM)(All,s,SRC)                V5BAS(c,s)       # Other Demand #;
 (All,c,COM)                           V6BAS(c)         # Inventories #;
Read
 V1BAS From File MDATA Header "1BAS";
 V2BAS From File MDATA Header "2BAS";
 V3BAS From File MDATA Header "3BAS";
 V4BAS From File MDATA Header "4BAS";
 V5BAS From File MDATA Header "5BAS";
 V6BAS From File MDATA Header "6BAS";
Update
 (All,c,COM)(All,s,SRC)(All,i,IND)     V1BAS(c,s,i)  = p0(c,s)*x1(c,s,i);
 (All,c,COM)(All,s,SRC)(All,i,IND)     V2BAS(c,s,i)  = p0(c,s)*x2(c,s,i);
 (All,c,COM)(All,s,SRC)                V3BAS(c,s)    = p0(c,s)*x3(c,s);
 (All,c,COM)                           V4BAS(c)      = p0(c,"dom")*x4(c);
 (All,c,COM)(All,s,SRC)                V5BAS(c,s)    = p0(c,s)*x5(c,s);

Coefficient        (All,c,COM) P0DOM(c) # levels domestic basic prices #;
Formula (Initial)  (All,c,COM) P0DOM(c) = 1; ! arbitrary initial setting !
Update             (All,c,COM) P0DOM(c) = p0(c,"dom");
 (Change)          (All,c,COM) V6BAS(c) =
                        V6BAS(c)*p0(c,"dom")/100 + P0DOM(c)*delx6(c);

Coefficient    ! Margin Flows!
 (All,c,COM)(All,s,SRC)(All,i,IND)(All,m,MAR)   V1MAR(c,s,i,m)   # Intermediate #;
 (All,c,COM)(All,s,SRC)(All,i,IND)(All,m,MAR)   V2MAR(c,s,i,m)   # Investment #;
 (All,c,COM)(All,s,SRC)(All,m,MAR)              V3MAR(c,s,m)     # Households #;
 (All,c,COM)(All,m,MAR)                         V4MAR(c,m)       # Export #;
 (All,c,COM)(All,s,SRC)(All,m,MAR)              V5MAR(c,s,m)     # Other #;
Read
 V1MAR From File MDATA Header "1MAR";
 V2MAR From File MDATA Header "2MAR";
 V3MAR From File MDATA Header "3MAR";
 V4MAR From File MDATA Header "4MAR";
 V5MAR From File MDATA Header "5MAR";
Update
 (All,c,COM)(All,s,SRC)(All,i,IND)(All,m,MAR)
     V1MAR(c,s,i,m)    = p0(m,"dom")*x1mar(c,s,i,m);
 (All,c,COM)(All,s,SRC)(All,i,IND)(All,m,MAR)
     V2MAR(c,s,i,m)    = p0(m,"dom")*x2mar(c,s,i,m);
 (All,c,COM)(All,s,SRC)(All,m,MAR)
     V3MAR(c,s,m)      = p0(m,"dom")*x3mar(c,s,m);
 (All,c,COM)(All,m,MAR)
     V4MAR(c,m)        = p0(m,"dom")*x4mar(c,m);
 (All,c,COM)(All,s,SRC)(All,m,MAR)
     V5MAR(c,s,m)      = p0(m,"dom")*x5mar(c,s,m);
```

Excerpt 7 of TABLO Input file: Data coefficients relating to basic commodity flows

The first 'Update' statement indicates that the flow V1BAS(c,s,i) should be updated using the default update formula, which is used for a data item which is a product of two (or more) of the model's variables. For an item of the form V = PX, the formula for the updated value V^U is:

$$V^U = V^0 + \Delta(PX) = V^0 + X^0\Delta P + P^0\Delta X$$

$$= V^0 + P^0X^0\left(\frac{\Delta P}{P^0} + \frac{\Delta X}{X^0}\right) = V^0 + V^0\left(\frac{p}{100} + \frac{x}{100}\right) \qquad (13)$$

where V^0, P^0 and X^0 are the pre-update values, and p and x are the percentage changes of the variables P and X. For the data item V1BAS(c,s,i) the relevant percentage-change variables are p0(c,s) (the basic-value price of commodity c from source s) and x1(c,s,i) (the demand by user industry i for intermediate inputs of commodity c from source s).

Not all of the model's data items are amenable to update *via* default Updates. For some items, including the inventories flows, V6BAS, explicit formulae must be given in the Update statements. In these cases, the word 'Change' appears in parentheses in the first line of the Update statement. The Update statement then contains an explicit formula for the ordinary change in the data item. The Update statement for V6BAS reflects our decision to represent these flows by an ordinary-change variable, delx6, rather than a percentage change. The Update formula (13) then becomes:

$$V^U = V^0 + P^0X^0\left(\frac{\Delta P}{P^0} + \frac{\Delta X}{X^0}\right) = V^0 + V^0\frac{p}{100} + P^0\Delta X. \qquad (14)$$

Notice that we are now required to define and update the levels price, P^0, i.e., we are obliged to specify units of measurement for quantities. In the TABLO code P0DOM is the relevant price vector. The initial values of its elements are set (arbitrarily) to 1 *via* the 'Formula (Initial)' statement in Excerpt 7.

Excerpt 8 relates to the commodity taxes in the third row of Figure 5. The tax flows again require explicit Update formulae. We will explain these in Section 4.16, after we have set out the corresponding tax equations.

```
Coefficient    ! Taxes on Basic Flows!
 (All,c,COM)(All,s,SRC)(All,i,IND)      V1TAX(c,s,i);
 (All,c,COM)(All,s,SRC)(All,i,IND)      V2TAX(c,s,i);
 (All,c,COM)(All,s,SRC)                 V3TAX(c,s);
 (All,c,COM)                            V4TAX(c);
 (All,c,COM)(All,s,SRC)                 V5TAX(c,s);
Read
 V1TAX From File MDATA Header "1TAX";
 V2TAX From File MDATA Header "2TAX";
 V3TAX From File MDATA Header "3TAX";
 V4TAX From File MDATA Header "4TAX";
 V5TAX From File MDATA Header "5TAX";
Update (Change) (All,c,COM)(All,s,SRC)(All,i,IND)
     V1TAX(c,s,i) = V1TAX(c,s,i)* {x1(c,s,i) + p0(c,s)}/100 +
          {V1BAS(c,s,i)+V1TAX(c,s,i)}*t1(c,s,i)/100;
Update (Change) (All,c,COM)(All,s,SRC)(All,i,IND)
     V2TAX(c,s,i) = V2TAX(c,s,i)* {x2(c,s,i) + p0(c,s)}/100 +
          {V2BAS(c,s,i)+V2TAX(c,s,i)}*t2(c,s,i)/100;
Update (Change) (All,c,COM)(All,s,SRC)
     V3TAX(c,s) = V3TAX(c,s)* {x3(c,s) + p0(c,s)}/100 +
          {V3BAS(c,s)+V3TAX(c,s)}*t3(c,s)/100;
Update (Change) (All,c,COM)
     V4TAX(c) = V4TAX(c)* {x4(c) + p0(c,"dom")}/100 +
          {V4BAS(c)+V4TAX(c)}*t4(c)/100;
Update (Change) (All,c,COM)(All,s,SRC)
     V5TAX(c,s) = V5TAX(c,s)*{x5(c,s) + p0(c,s)}/100 +
          {V5BAS(c,s)+V5TAX(c,s)}*t5(c,s)/100;
```

Excerpt 8 of TABLO Input file: Data coefficients relating to commodity taxes

Excerpt 9 relates to the primary-input flows in rows 4-7 of Figure 5. Like the commodity flows in Excerpt 7, these are the products of prices and quantities. Hence, they can be updated *via* default Update statements.

Excerpt 9 of TABLO Input file: Data coefficients relating to primary-factor flows

```
Coefficient    ! Primary Factor and Other Industry costs!
 (All,i,IND)                V1CAP(i)      # capital rentals #;
 (All,i,IND)(All,o,OCC)  V1LAB(i,o)    # wage bill matrix #;
 (All,i,IND)                V1LND(i)      # land rentals #;
 (All,i,IND)                V1OCT(i)      # other cost tickets #;
Read
 V1CAP From File MDATA Header "1CAP";
 V1LAB From File MDATA Header "1LAB";
 V1LND From File MDATA Header "1LND";
 V1OCT From File MDATA Header "1OCT";
Update
 (All,i,IND)                V1CAP(i)      = p1cap(i)*x1cap(i);
 (All,i,IND)(All,o,OCC)  V1LAB(i,o)    = p1lab(i,o)*x1lab(i,o);
 (All,i,IND)                V1LND(i)      = p1lnd(i)*x1lnd(i);
 (All,i,IND)                V1OCT(i)      = p1oct(i)*x1oct(i);
```

Excerpt 10 covers the last two items of Figure 5 (MAKE and V0TAR). The V0TAR Update formula resembles those for the tax terms in Excerpt 8.

Excerpt 10 of TABLO Input file: Data coefficients relating to commodity outputs and import duties

```
Coefficient (All,c,COM)(All,i,IND) MAKE(c,i)
# production of commodity c by industry i #;
Read MAKE From File MDATA Header "MAKE";
Update (All,c,COM)(All,i,IND) MAKE(c,i)= p0(c,"dom")*q1(c,i);

Coefficient (All,c,COM) V0TAR(c)# tariff revenue #;
Read V0TAR From File MDATA Header "0TAR";
Coefficient (All,c,COM) V0IMP(c) # Total basic-value imports of good c #;
! V0IMP(c) is needed to update V0TAR: it is declared now and defined later !
Update (Change)   (All,c,COM)
     V0TAR(c) = V0TAR(c)*{x0imp(c)+pf0cif(c)+phi}/100 + V0IMP(c)*t0imp(c)/100;
```

4.5. Aggregations of data items

Excerpts 11 to 14 of the TABLO file define various flows which are aggregates of data items and which will be used as coefficients in the model's equations. The first part of Excerpt 11 defines the values at purchasers' prices of the commodity flows identified in Figure 5.

The definitions employ the TABLO summation notation, explained in Section 4.1. For example, the first formula in Excerpt 11 contains the term:

SUM(m,MAR,V1MAR(c,s,i,m))

This defines the sum, over an index m running over the set of margins commodities (MAR), of the input-output data flows V1MAR(c,s,i,m). This sum is the total value of margins commodities required to facilitate the flow of intermediate inputs of commodity c from source s to user industry i. Adding this sum to the basic value of the intermediate-input flow and the associated indirect tax, gives the purchaser's-price value of the flow.

The second part of Excerpt 11 computes the import/domestic shares for usage of each composite commodity by users 1 to 3. These shares appear in subsequent demand equations. Where a user uses none of some commodity—either domestic or imported—such shares would be undefined. The 'Zerodivide' statement provides that they are then assigned the arbitrary value 0.5. This device avoids a numerical error in computing, without any other substantive consequence.

```
Coefficient ! Flows at Purchasers prices !
 (All,c,COM)(All,s,SRC)(All,i,IND) V1PUR(c,s,i)  # Intermediate #;
 (All,c,COM)(All,s,SRC)(All,i,IND) V2PUR(c,s,i)  # Investment  #;
 (All,c,COM)(All,s,SRC)            V3PUR(c,s)    # Households #;
 (All,c,COM)                       V4PUR(c)      # Export #;
 (All,c,COM)(All,s,SRC)            V5PUR(c,s)    # Other Demand #;
Formula
 (All,c,COM)(All,s,SRC)(All,i,IND)
      V1PUR(c,s,i)  = V1BAS(c,s,i) + V1TAX(c,s,i) + Sum(m,MAR,V1MAR(c,s,i,m));
 (All,c,COM)(All,s,SRC)(All,i,IND)
      V2PUR(c,s,i)  = V2BAS(c,s,i) + V2TAX(c,s,i) + Sum(m,MAR,V2MAR(c,s,i,m));
 (All,c,COM)(All,s,SRC)
      V3PUR(c,s)    = V3BAS(c,s)   + V3TAX(c,s)   + Sum(m,MAR,V3MAR(c,s,m));
 (All,c,COM)
      V4PUR(c)      = V4BAS(c)     + V4TAX(c)     + Sum(m,MAR,V4MAR(c,m));
 (All,c,COM)(All,s,SRC)
      V5PUR(c,s)    = V5BAS(c,s)   + V5TAX(c,s)   + Sum(m,MAR,V5MAR(c,s,m));

Coefficient ! Flows at Purchaser's prices: Domestic + Imported Totals !
 (All,c,COM)(All,i,IND)  V1PUR_S(c,i);
 (All,c,COM)(All,i,IND)  V2PUR_S(c,i);
 (All,c,COM)             V3PUR_S(c);
Formula
 (All,c,COM)(All,i,IND)  V1PUR_S(c,i)= Sum(s,SRC,V1PUR(c,s,i));
 (All,c,COM)(All,i,IND)  V2PUR_S(c,i)= Sum(s,SRC,V2PUR(c,s,i));
 (All,c,COM)             V3PUR_S(c)  = Sum(s,SRC,V3PUR(c,s));

Coefficient ! Source Shares in Flows at Purchaser's prices !
 (All,c,COM)(All,s,SRC)(All,i,IND) S1(c,s,i);
 (All,c,COM)(All,s,SRC)(All,i,IND) S2(c,s,i);
 (All,c,COM)(All,s,SRC)            S3(c,s);
Zerodivide Default 0.5;
Formula
 (All,c,COM)(All,s,SRC)(All,i,IND)  S1(c,s,i)  = V1PUR(c,s,i) / V1PUR_S(c,i);
 (All,c,COM)(All,s,SRC)(All,i,IND)  S2(c,s,i)  = V2PUR(c,s,i) / V2PUR_S(c,i);
 (All,c,COM)(All,s,SRC)             S3(c,s)    = V3PUR(c,s)   / V3PUR_S(c);
Zerodivide Off;
```

Excerpt 11 of TABLO Input file: Aggregates and shares of flows at purchasers' prices

Excerpt 12 covers the computation of some useful cost and usage aggregates.

```
Coefficient     ! Industry-Specific Cost Totals !
 (All,i,IND)    V1LAB_O(i)   # total labour bill in industry i #;
 (All,i,IND)    V1PRIM(i)    # total factor input to industry i#;
 (All,i,IND)    V1TOT(i)     # total cost in each industry #;
 (All,i,IND)    V2TOT(i)     # total capital created for each industry #;
 (All,o,OCC)    V1LAB_I(o)   # total wages, occupation o #;
Formula
 (All,i,IND)    V1LAB_O(i)   = Sum(o,OCC, V1LAB(i,o));
 (All,i,IND)    V1PRIM(i)    = V1LAB_O(i) + V1CAP(i) + V1LND(i);
 (All,i,IND)    V1TOT(i)     = Sum(c,COM, V1PUR_S(c,i)) + V1PRIM(i) + V1OCT(i);
 (All,i,IND)    V2TOT(i)     = Sum(c,COM, V2PUR_S(c,i));
 (All,o,OCC)    V1LAB_I(o)   = Sum(i,IND, V1LAB(i,o));

Coefficient (All,c,COM) V0MAR_CSI(c) # Total usage for margins purposes #;
Formula (All,m,MAR) V0MAR_CSI(m) =
     Sum(c,COM, V4MAR(c,m) +
          Sum(s,SRC, V3MAR(c,s,m) + V5MAR(c,s,m) +
               Sum(i,IND, V1MAR(c,s,i,m) + V2MAR(c,s,i,m) ) ) );
Formula (All,n,NONMAR) V0MAR_CSI(n) = 0.0;

Coefficient (All,c,COM) SALES(c)      # Total sales of domestic commodity c #;
Formula (All,c,COM) SALES(c) =
     Sum(i,IND,V1BAS(c,"dom",i) + V2BAS(c,"dom",i)) + V3BAS(c,"dom")
          + V4BAS(c) + V5BAS(c,"dom") + V6BAS(c,) + V0MAR_CSI(c);
```

Excerpt 12 of TABLO Input file: Cost and usage aggregates

```
! Coefficient (All,c,COM) V0IMP(c)      # Total basic-value imports of good c #; !
! above had to be declared prior to V0TAR update statement!
Formula (All,c,COM) V0IMP(c) =
     Sum(i,IND,V1BAS(c,"imp",i) + V2BAS(c,"imp",i))
     + V3BAS(c,"imp") + V5BAS(c,"imp");
```

Excerpt 12 of TABLO Input file (cont.): Cost and usage aggregates

```
Coefficient (All,c,COM) V0CIF(c)        # Total ex-duty imports of good c #;
Formula (All,c,COM) V0CIF(c) = V0IMP(c) - V0TAR(c);
```

Excerpt 13 covers the computation of GDP from the income side.

```
Coefficient ! Aggregate Revenue, indirect taxes on ....     !
 V1TAX_CSI  # Intermediate #;
 V2TAX_CSI  # Investment #;
 V3TAX_CS   # Households #;
 V4TAX_C    # Export #;
 V5TAX_CS   # Other Demand #;
 V0TAR_C    # Aggregate Tariff Revenue #;
 V0TAX_CSI  # Aggregate Indirect Tax Revenue #;
Formula
 V1TAX_CSI= Sum(c,COM,Sum(s,SRC,Sum(i,IND, V1TAX(c,s,i))));
 V2TAX_CSI= Sum(c,COM,Sum(s,SRC,Sum(i,IND, V2TAX(c,s,i))));
 V3TAX_CS = Sum(c,COM,Sum(s,SRC,           V3TAX(c,s)));
 V4TAX_C  = Sum(c,COM,                     V4TAX(c));
 V5TAX_CS = Sum(c,COM,Sum(s,SRC,           V5TAX(c,s)));
 V0TAR_C  = Sum(c,COM,                     V0TAR(c));
 V0TAX_CSI= V1TAX_CSI + V2TAX_CSI + V3TAX_CS
            + V4TAX_C + V5TAX_CS + V0TAR_C;

Coefficient ! All-Industry Factor Cost Aggregates !
     V1CAP_I      # total payments to capital #;
     V1LAB_IO     # total payments to labour #;
     V1LND_I      # total payments to land #;
     V1OCT_I      # total other cost ticket payments #;
     V1PRIM_I     # total primary factor payments#;
     V0GDPINC     # nominal gdp from income side #;
Formula
     V1CAP_I      = Sum(i,IND,V1CAP(i));
     V1LAB_IO     = Sum(i,IND,V1LAB_O(i));
     V1LND_I      = Sum(i,IND,V1LND(i));
     V1OCT_I      = Sum(i,IND,V1OCT(i));
     V1PRIM_I     = V1LAB_IO + V1CAP_I + V1LND_I;
     V0GDPINC     = V1PRIM_I + V1OCT_I + V0TAX_CSI;
```

Excerpt 13 of TABLO Input file: Income-side components of GDP

Excerpt 14 covers the computation of GDP from the expenditure side.

```
Coefficient ! Expenditure Aggregates at Purchaser's Prices !
 V0CIF_C    # Total A$ import costs, excluding tariffs #;
 V0IMP_C    # Total basic-value imports (includes tariffs) #;
 V2TOT_I    # Total Investment Usage #;
 V3TOT      # Total purchases by households #;
 V4TOT      # Total Export earnings #;
 V5TOT      # total value of other demands #;
 V6TOT      # total value of inventories #;
 V0GDPEXP # Nominal GDP from expenditure side #;
Formula
 V0CIF_C    = Sum(c,COM, V0CIF(c));
 V0IMP_C    = Sum(c,COM, V0IMP(c));
 V2TOT_I    = Sum(i,IND,   V2TOT(i));
 V3TOT      = Sum(c,COM, V3PUR_S(c));
 V4TOT      = Sum(c,COM, V4PUR(c));
 V5TOT      = Sum(c,COM,Sum(s,SRC, V5PUR(c,s)));
 V6TOT      = Sum(c,COM, V6BAS(c));
 V0GDPEXP= V3TOT + V2TOT_I + V5TOT + V6TOT + V4TOT - V0CIF_C;
```

Excerpt 14 of TABLO Input file: Expenditure-side components of GDP

4.6. The equation system

The rest of the TABLO Input file is an algebraic specification of the linear form of the model, with the equations organised into a number of blocks. Each Equation statement begins with a name and description. Generally, these refer to the left-hand-side variable. Except where indicated, the variables are percentage changes. Variables are in lower-case characters and coefficients in upper case. Variables have been defined in the variable lists in Excerpts 2-6 of the TABLO file. Most of the coefficients have been defined in Excerpts 7-14. Readers who have followed the TABLO file so far should have no difficulty in reading the equations in the TABLO notation. We provide some commentary on the theory underlying each of the equation blocks.

4.7. Structure of production

ORANI-F allows each industry to produce several commodities, using as inputs domestic and imported commodities, labour of several types, land, capital and 'other costs'. The multi-input, multi-output production specification is kept manageable by a series of separability assumptions, illustrated by the nesting shown in Figure 6. For example, the assumption of *input-output separability* implies that the generalised production function for some industry:

$$F(\text{inputs,outputs}) = 0 \qquad (15)$$

may be written as:

$$G(\text{inputs}) = \text{X1TOT} = H(\text{outputs}) \qquad (16)$$

where X1TOT is an index of industry activity. Assumptions of this type reduce the number of estimated parameters required by the model. Figure 6 shows that the H function in (16) is derived from a CET (constant elasticity of transformation) aggregation function, while the G function is broken into a sequence of nests. At the top level, commodity composites, a primary-factor composite and 'other costs' are combined using a Leontief production function. Consequently, they are all demanded in direct proportion to X1TOT. Each commodity composite is a CES (constant elasticity of substitution) function of a domestic good and the imported equivalent. The primary-factor composite is a CES aggregation of land, capital and composite labour. Composite labour is a CES aggregation of occupational labour types. Although all industries share this common production structure, input proportions and behavioural parameters may vary between industries.

The nested structure is mirrored in the TABLO equations—each nest requiring 2 sets of equations. We begin at the bottom of Figure 6 and work upwards.

4.8. Demands for primary factors

Excerpt 15 shows the equations determining the occupational composition of labour demand in each industry. For each industry i, the equations are derived from the following optimisation problem.

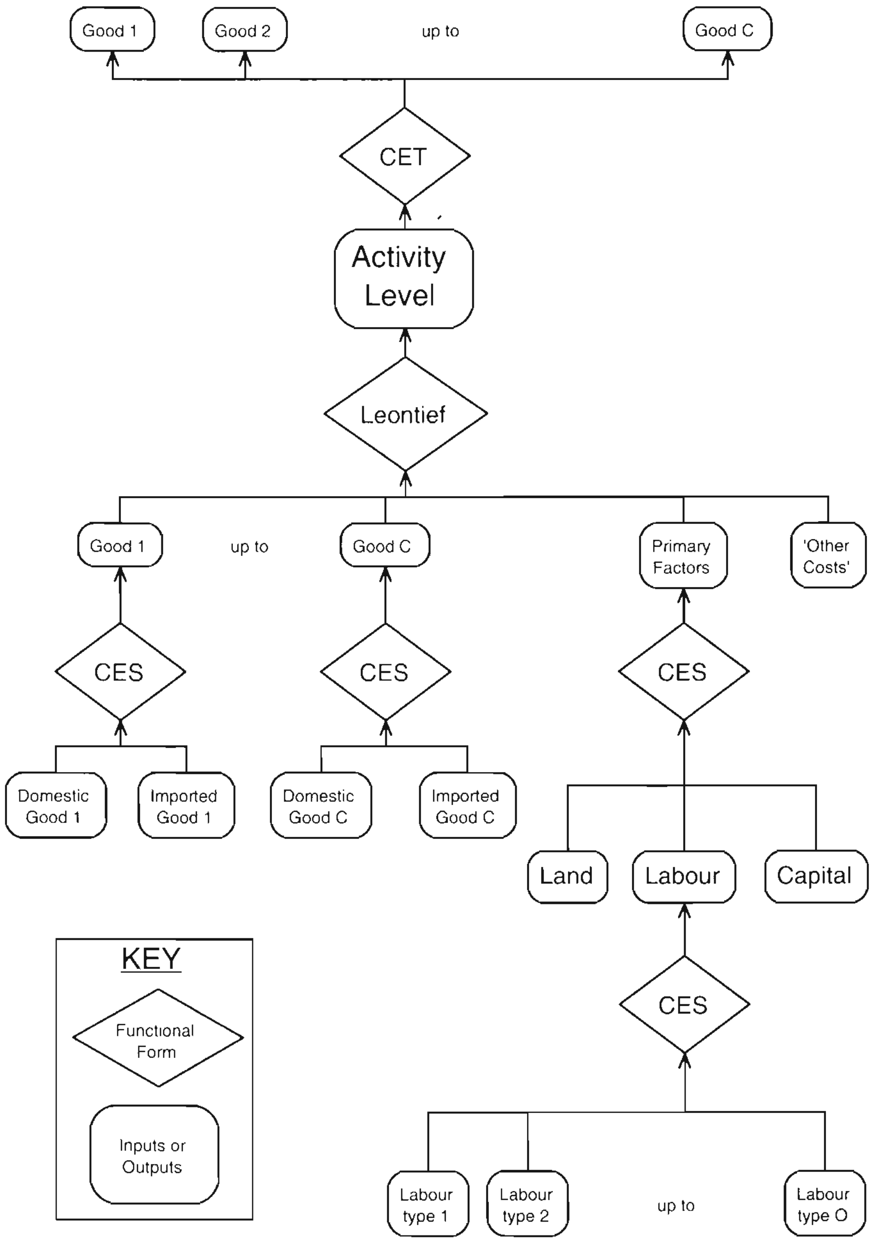

Figure 6. Structure of Production

Choose inputs of occupation-specific labour,
    X1LAB(i,o),
to minimize total labour cost,
    Sum(o,OCC, P1LAB(i,o)*X1LAB(i,o)),
where
    X1LAB_O(i) = CES[All,o,OCC: X1LAB(i,o)],
regarding as exogenous to the problem
    P1LAB(i,o) and X1LAB_O(i).

Note that the problem is formulated in the levels of the variables. Hence, we have written the variable names in upper case. The notation CES[ ] represents a CES function defined over the set of variables enclosed in the square brackets.

The solution of this problem, in percentage-change form, is given by equations E_x1lab and E_p1lab_o (see Appendix A for derivation). The first of the equations indicates that demand for labour type o is proportional to overall labour demand, X1LAB_O, and to a price term. In change form, the price term is composed of an elasticity of substitution, SIGMA1LAB(i), multiplied by the percentage change in a price ratio [p1lab(i,o)-p1lab_o(i)] representing the wage of occupation o relative to the average wage for labour in industry i. Changes in the relative prices of the occupations induce substitution in favour of relatively cheapening occupations. The percentage change in the average wage, p1lab_o(i), is given by the second of the equations. This could be rewritten:

p1lab_o(i) = Sum(o,OCC, S1LAB(i,o)*p1lab(i,o)),

if S1LAB(i,o) were the value share of occupation o in the total wage bill of industry i. In other words, p1lab_o(i) is a Divisia index of the p1lab(i,o).

It is worth noting that if the individual equations of E_x1lab were multiplied by corresponding elements of S1LAB(i,o), and then summed together, all price terms would disappear, giving:

x1lab_o(i) = Sum(o,OCC, S1LAB(i,o)*x1lab(i,o)).

This is the percentage-change form of the CES aggregation function for labour.

Excerpt 15 of TABLO Input file: Equations for occupational composition of labour demand

```
Coefficient (All,i,IND) SIGMA1LAB(i) # CES substitution between skill types #;
Read SIGMA1LAB From File MDATA Header "SLAB";

Equation E_x1lab  # Demand for labour by industry and skill group #
(All,i,IND)(All,o,OCC)
 x1lab(i,o) = x1lab_o(i) - SIGMA1LAB(i)*[p1lab(i,o) - p1lab_o(i)];

Equation E_p1lab_o     # Price to each industry of labour composite #
(All,i,IND)
 V1LAB_O(i)*p1lab_o(i) = Sum(o,OCC,V1LAB(i,o)*p1lab(i,o));
```

Excerpt 16 contains equations determing the composition of demand for primary factors. Their derivation follows a pattern similar to that underlying the previous nest. In this case, total primary factor costs are minimised subject to the production function:

$$\mathrm{X1PRIM(i)} = \mathrm{CES}\left[\frac{\mathrm{X1LAB\_O(i)}}{\mathrm{A1LAB\_O(i)}}, \frac{\mathrm{X1CAP(i)}}{\mathrm{A1CAP(i)}}, \frac{\mathrm{X1LND(i)}}{\mathrm{A1LND(i)}}\right].$$

Because we may wish to introduce factor-saving technical changes, we include explicitly the coefficients A1LAB_O(i), A1CAP(i), and A1LND(i).

The solution to this problem, in percentage-change form, is given by equations E_x1lab_o, E_x1cap and E_x1lnd, and E_p1prim. Ignoring the technical-change terms, we see that demand for each factor is proportional to overall factor demand, X1PRIM, and to a price term. In change form the price term is an elasticity of substitution, SIGMA1PRIM(i), multiplied by the percentage change in a price ratio representing the unit cost of the factor relative to the overall, effective cost of primary factor inputs to industry i. Changes in the relative prices of the primary factors induce substitution in favour of relatively cheapening factors. The percentage change in the average effective cost, p1prim(i), given by equation E_p1prim, is again a cost-weighted Divisia index of individual prices and technical changes.

Appendix A contains a formal derivation of CES demand equations with technical-change terms. The technical-change terms appear in a predictable pattern. Imagine that the percentage-change equations lacked these terms, as in the previous, occupational-demand, block. We could add them in by:

replacing each quantity (x) variable by (x-a);
replacing each price (p) variable by (p+a); and
rearranging terms.

Excerpt 16 of TABLO Input file: Equations for primary factor proportions

```
Coefficient (All,i,IND) SIGMA1PRIM(i) # CES substitution, primary factors #;
Read SIGMA1PRIM From File MDATA Header "P028";

Equation E_x1lab_o     # Industry demands for effective labour #
(All,i,IND)     x1lab_o(i) - a1lab_o(i) =
    x1prim(i) - SIGMA1PRIM(i)*[p1lab_o(i) + a1lab_o(i) - p1prim(i)];

Equation E_x1cap # Industry demands for capital #
(All,i,IND)     x1cap(i) - a1cap(i) =
    x1prim(i) - SIGMA1PRIM(i)*[p1cap(i) + a1cap(i) - p1prim(i)];

Equation E_p1lnd # Industry demands for land #
(All,i,IND)     x1lnd(i) - a1lnd(i) =
    x1prim(i) - SIGMA1PRIM(i)*[p1lnd(i) + a1lnd(i) - p1prim(i)];

Equation E_p1prim     # Effective price term for factor demand equations #
(All,i,IND)     V1PRIM(i)*p1prim(i) = V1LAB_O(i)*{p1lab_o(i) + a1lab_o(i)}
           + V1CAP(i)*{p1cap(i) + a1cap(i)} + V1LND(i)*{p1lnd(i) + a1lnd(i)};
```

4.9. Demands for intermediate inputs

Armington PS (1969) The Geographic Pattern of Trade and the Effects of Price Changes, *IMF Staff Papers*, XVI, July, pp 176-199.

— (1970) Adjustment of Trade Balances: Some Experiments with a Model of Trade Among Many Countries, *IMF Staff Papers*, XVII, November, pp 488-523.

We adopt the Armington (1969; 1970) assumption that imports are imperfect substitutes for domestic supplies. Excerpt 17 shows equations determining the import/domestic composition of intermediate commodity demands. They follow a pattern similar to the previous nest. Here, the total cost of imported and domestic good i are minimised subject to the production function:

$$X1\_S(c,i) = CES\left[All,s,SRC: \frac{X1(c,s,i)}{A1(c,s,i)}\right], \tag{17}$$

Commodity demand from each source is proportional to demand for the composite, X1_S(c,i), and to a price term. The change form of the price term is an elasticity of substitution, SIGMA1(i), multiplied by the percentage change in a price ratio representing the price from the source relative to the effective cost of the import/domestic composite. Lowering of a source-specific price, relative to the average, induces substitution in favour of that source. The percentage change in the average effective cost, p1_s(i), is again a cost-weighted Divisia index of individual prices and technical changes.

Following the pattern established for factor demands, we could have written Equation E_p1_s as:

V1PUR_S(c,i)*p1_s(c,i)=Sum(s,SRC,V1PUR(c,s,i)*[p1(c,s,i)+a1(c,s,i)]);

using aggregates defined in Excerpt 11. However, this equation would have left p1_s(c,i) undefined when V1PUR_S(c,i) is zero—not all industries use all commodities. In computing the share:

S1(c,s,i) =V1PUR(c,s,i)/V1PUR_S(c,i),

(see again Excerpt 11) we used the Zerodivide statement to instruct GEMPACK to set import and domestic shares (arbitrarily) to 0.5 in such cases.

```
Coefficient (All,c,COM) SIGMA1(c) # Armington elasticities: Intermediate #;
Read SIGMA1 From File MDATA Header "1ARM";
```

Excerpt 17 of TABLO Input file: Equations for import/domestic composition of intermediate demands

```
Equation E_x1      # Source-Specific Commodity Demands #
(All,c,COM)(All,s,SRC)(All,i,IND)
x1(c,s,i)-a1(c,s,i) = x1_s(c,i) - SIGMA1(c)*[p1(c,s,i)+a1(c,s,i) - p1_s(c,i)];

Equation E_p1_s  # Effective Price of Commodity Composite #
(All,c,COM)(All,i,IND)
p1_s(c,i) = Sum(s,SRC, S1(c,s,i)*[p1(c,s,i) + a1(c,s,i)]);
```

Excerpt 18 covers the topmost input-demand nest of Figure 6. Commodity composites, the primary-factor composite and 'other costs' are combined using a Leontief production function, given by:

$$X1TOT(i) = \frac{1}{A1TOT(i)} \times$$
$$MIN\left[All,c,COM: \frac{X1\_S(c,i)}{A1\_S(c,i)}, \frac{X1PRIM(i)}{A1PRIM(i)}, \frac{X1OCT(i)}{A1OCT(i)}\right]. \qquad (18)$$

Consequently, each of these three categories of inputs identified at the top level is demanded in direct proportion to X1TOT(i).

The Leontief production function is equivalent to a CES production function with the substitution elasticity set to zero. Hence, the demand equations resemble those derived from the CES case but lack price (substitution) terms. The a1tot(i) are Hicks-neutral technical-change terms, affecting all inputs equally. Although it is not required in the top-level input demand equations, we include in Excerpt 18 equations which define p1tot(i), the percentage change in the effective price per unit of activity (X1TOT) in industry i, as a cost-share-weighted average of percentage changes in the input prices. Given the constant returns to scale which characterise the model's production technology, these cost-share-weighted averages define percentage changes in average costs. Setting output (activity) prices equal to average costs imposes the competitive *Zero Pure Profits* condition.

Excerpt 18 of TABLO Input file: Equations for the top nest of industry input demands

```
Equation E_x1_s  # Demands for Commodity Composites #
(All,c,COM)(All,i,IND)    x1_s(c,i) - {a1_s(c,i) + a1tot(i)} = x1tot(i);

Equation E_x1prim# Demands for primary factor composite #
(All,i,IND)       x1prim(i) - {a1prim(i) + a1tot(i)} = x1tot(i);

Equation E_x1oct  # Demands for other cost tickets #
(All,i,IND)       x1oct(i) - {a1oct(i) + a1tot(i)} = x1tot(i);

Equation E_p1tot  # Zero pure profits in production #
(All,i,IND)
V1TOT(i)*{p1tot(i)-a1tot(i)} = Sum(c,COM, V1PUR_S(c,i)*{p1_s(c,i) + a1_s(c,i)})
                 + V1PRIM(i)*{p1prim(i) + a1prim(i)} + V1OCT(i)*{p1oct(i) + a1oct(i)};
```

The two equations of Excerpt 19 determine the commodity composition of industry output—the final nest of Figure 6. Here, the total revenue from all outputs is *maximised* subject to the production function:

$$X1TOT(i) = CET[\ All,c,COM: Q1(c,i)]. \qquad (19)$$

The CET (constant elasticity of transformation) aggregation function is identical to CES, except that the transformation parameter in the CET function has the opposite sign to the substitution parameter in the CES function. Here then, an increase in a commodity price, relative to the average, induces transformation in favour of that output. The symbol, p1tot, referring to average unit revenue, is the same as that used in the previous equation group to refer to the effective price of a unit of activity. This confirms our interpretation of equation E_p1tot as a *Zero Pure Profits* condition.

Excerpt 19 of TABLO Input file: Equations for industries' output mixes

```
Coefficient (All,i,IND) SIGMA1OUT(i) # CET transformation elasticities #;
Read SIGMA1OUT From File MDATA Header "SCET";

Equation E_q1     # Supplies of commodities by industries #
(all,c,COM)(all,i,IND)
q1(c,i) = x1tot(i) + SIGMA1OUT(i)*(p0(c,"dom") - p1tot(i));

Coefficient (All,i,IND) MAKE_C(i) # all production by industry i #;
Formula (All,i,IND) MAKE_C(i) = Sum(c,COM,MAKE(c,i));

Equation E_x1tot # Average price received by industries #
(All,i,IND) MAKE_C(i)*p1tot(i) = Sum(c,COM,MAKE(c,i)*p0(c,"dom"));
```

4.10. Demands for investment goods

Figure 7 shows the nesting structure for the production of new units of fixed capital. Capital is assumed to be produced with inputs of domestically produced and imported commodities. The production function has the same nested structure as that which governs intermediate inputs to current production. No primary factors are used directly as inputs to capital formation.

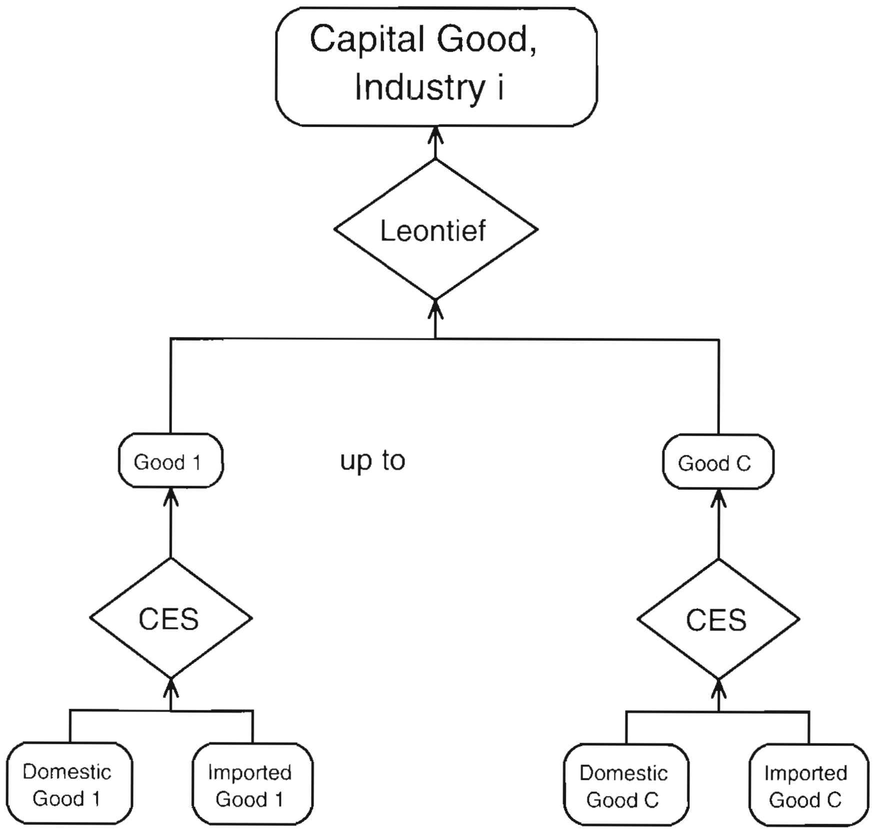

Figure 7. Structure of Investment Demand

The investment demand equations (see Excerpt 20) are derived from the solutions to the investor's two-part cost-minimisation problem. At the bottom level, the total cost of imported and domestic good i is minimised subject to the CES production function:

$$\text{X2\_S}(c, i) = \text{CES}[\text{All},s,\text{SRC}: \frac{\text{X2}(c,s,i)}{\text{A2}(c,s,i)}], \qquad (20)$$

while at the top level the total cost of commodity composites is minimised subject to the Leontief production function:

$$\text{X2TOT}(i) = \frac{1}{\text{A2TOT}(i)} \text{MIN}[\text{All},c,\text{COM}: \frac{\text{X2\_S}(c,i)}{\text{A2\_S}(c,i)}], \qquad (21)$$

where the total amount of investment in each industry, X2TOT(i), is exogenous to the cost-minimisation problem and determined by other equations, covered in Excerpt 35 below. The equations in Excerpt 20 describing the demand for source-specific inputs (E_x2 and E_p2_s) and for composites (E_x2_s) are thus very similar to the corresponding intermediate demand equations in Excerpts 17 and 18. The source-specific demand equation (E_x2) requires an elasticity of substitution, SIGMA2(i). Also included is an equation which determines the price of new units of capital as the average cost of producing the unit—a *Zero Pure Profits* condition.

```
Coefficient (All,c,COM) SIGMA2(c) # Armington Elasticities: Investment #;
Read SIGMA2 From File MDATA Header "2ARM";

Equation E_x2      # Source-Specific Commodity Demands #
(All,c,COM)(All,s,SRC)(All,i,IND)
x2(c,s,i)-a2(c,s,i) = x2_s(c,i) - SIGMA2(c)*{p2(c,s,i)+a2(c,s,i) - p2_s(c,i)};

Equation E_p2_s  # Effective Price of Commodity Composite #
(All,c,COM)(All,i,IND)
p2_s(c,i) = Sum(s,SRC, S2(c,s,i)*[p2(c,s,i)+a2(c,s,i)]);

! Investment top nest !

Equation E_x2_s  # Demands for Commodity Composites #
(All,c,COM)(All,i,IND)   x2_s(c,i) - {a2_s(c,i) + a2tot(i)} = x2tot(i);

Equation E_p2tot  # Zero pure profits in investment #
(All,i,IND) V2TOT(i)*{p2tot(i) - a2tot(i)} =
          Sum(c,COM,  V2PUR_S(c,i) *{p2_s(c,i)+a2_s(c,i)});
```

Excerpt 20 of TABLO Input file: Equations for investment demands

4.11. Household demands

As Figure 8 shows, the nesting structure for household demand is nearly identical to that for investment demand. The only difference is that commodity composites are aggregated by a Stone-Geary, rather than a Leontief, function, leading to the linear expenditure system (LES).

The equations for the lower nest (see Excerpt 21) are similar to the corresponding equations for intermediate and investment demands.

```
Coefficient (All,c,COM) SIGMA3(c) # Armington elasticities: Households #;
Read SIGMA3 From File MDATA Header "3ARM";

Equation E_x3      # Source-Specific Commodity Demands #
(All,c,COM)(All,s,SRC)
x3(c,s)-a3(c,s) = x3_s(c) - SIGMA3(c)*{ p3(c,s)+a3(c,s) - p3_s(c) };

Equation E_p3_s  # Effective Price of Commodity Composite #
(All,c,COM) p3_s(c) = Sum(s,SRC, S3(c,s)*[p3(c,s)+a3(c,s)]);
```

Excerpt 21 of TABLO Input file: Equations for the import/domestic composition of household demands

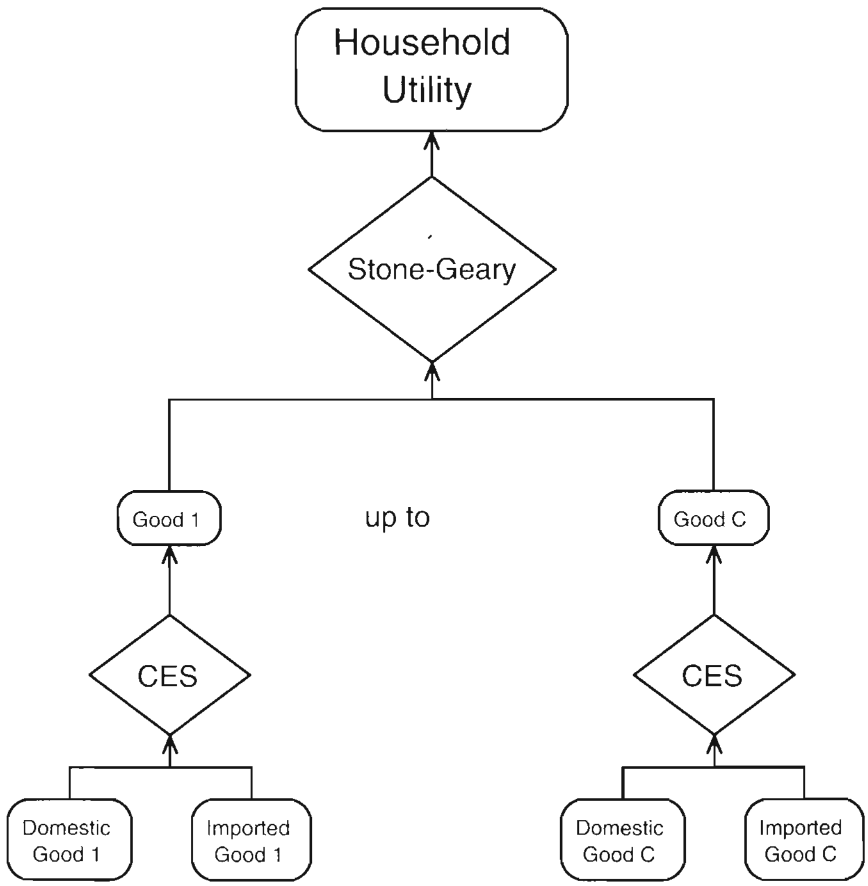

Figure 8. Structure of Consumer Demand

The equations determining the commodity composition of household demand, which is determined by the Stone-Geary nest of the structure, are given in Excerpt 23. The necessary coefficients are first defined in Excerpt 22 and derived from the econometrically estimated values FRISCH (total/supernumerary expenditure) and S3LUX (marginal budget shares).

Excerpt 22 of TABLO Input file: Data and formulae for coefficients used in household demand equations

```
Coefficient             FRISCH  # the Frisch 'parameter' #;
Read                    FRISCH From File MDATA Header "P021";
Update (Change)         FRISCH = FRISCH*[w3lux - w3tot]/100.0;

Coefficient             ALPHA # share of supernumerary in total expenditure #;
Formula                 ALPHA = -1/FRISCH;

Coefficient (All,c,COM) S3LUX(c) # Marginal household budget shares #;
Read                    S3LUX From File MDATA Header "P044";
Update (All,c,COM)      S3LUX(c) = a3lux(c);

Zerodivide Default 0.0;
Coefficient (All,c,COM) S3_S(c) # shares in total household expenditure #;
Formula (All,c,COM)     S3_S(c) = V3PUR_S(c)/V3TOT;
Zerodivide Off;

Coefficient (All,c,COM) EPS(c) # Household expenditure elasticities #;
Zerodivide Default 1.0;
Formula (All,c,COM)     EPS(c) = S3LUX(c)/S3_S(c); ! marg/ave budget shares !
Zerodivide Off;

Coefficient (All,c,COM) B3LUX(c)
 # supernumerary expenditure commodity c/total expenditure commodity c #;
Formula (All,c,COM)     B3LUX(c) = ALPHA*EPS(c);
```

The equations in Excerpt 23 differ from the CES pattern established in previous excerpts. (The reader may need to consult Appendix E to see how some percentage-change forms arise.) To analyse the Stone-Geary utility function, it is helpful to divide total consumption of each commodity composite, X3_S(c), into two components: a luxury (or supernumerary) part, X3LUX(c), and a subsistence (or minimum) part, X3SUB(c).

$$X3\_S(c) = X3LUX(c) + X3SUB(c), \qquad (22)$$

giving Equation E_x3_s in Excerpt 23. The subsistence component is proportional to the number of households, Q, and to a taste-change variable, A3SUB(c)—see Equation E_x3sub.

Only the luxury components enter into the per-household utility function, which has the well-known Cobb-Douglas form:

$$\text{Utility} = \frac{1}{Q}\sum_c X3LUX(c)^{S3LUX(c)}, \text{ where } \sum_c S3LUX(c) = 1. \qquad (23)$$

Because the Cobb-Douglas form gives rises to exogenous budget shares for spending on luxuries:

$$X3LUX(c)*P3\_S(c) = S3LUX(c)*V3LUX\_C, \qquad (24)$$

S3LUX(i) may be interpreted as the marginal budget share of total spending on luxuries, V3LUX_C. This gives Equation E_x3lux in Excerpt 23. The taste-change variable a3lux(i) is the change in S3LUX(i). Equation E_utility is the percentage-change form of the utility function.

Equations E_a3sub and E_a3lux provide default settings for the taste-change variables, a3sub and a3lux, which allow the average budget shares to be shocked, *via* the a3_s, in a way that preserves the pattern of expenditure elasticities.

The equations just described determine the composition of household demands but do not determine total consumption. That could be done in a variety of ways, for example *via* a balance of trade constraint.

```
Equation E_x3sub      # Subsistence Demand for composite commodities #
 (All,c,COM)  x3sub(c) = q + a3sub(c);

Equation E_x3lux      # Luxury Demand for composite commodities #
(All,c,COM)  x3lux(c) + p3_s(c) = w3lux + a3lux(c);

Equation E_x3_s       # Total Household demand for composite commodities #
(All,c,COM)  x3_s(c) = B3LUX(c)*x3lux(c) + [1-B3LUX(c)]*x3sub(c);

Equation E_utility    # Change in utility disregarding taste change terms #
             utility + q = Sum(c,COM, S3LUX(c)*x3lux(c));

Equation E_a3lux      # default setting for luxury taste shifter #
(All,c,COM)  a3lux(c) = a3sub(c) - Sum(k,COM, S3LUX(k)*a3sub(k));

Equation E_a3sub      # default setting for subsistence taste shifter #
(All,c,COM)  a3sub(c) = a3_s(c) - Sum(k,COM, S3_S(k)*a3_s(k));
```

Excerpt 23 of TABLO Input file: Equations for the commodity composition of household demand

4.12. Export and other final demands

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.

Equation E_x4_a in Excerpt 24 specifies downward-sloping foreign demand schedules for traditional exports. In the levels, the equation would read:

$$X4(c) = F4Q(c)\left[\frac{P4(c)}{PHI*F4P(c)}\right]^{EXP\_ELAST(c)}, \tag{25}$$

where EXP_ELAST(c) is a negative parameter—the constant elasticity of demand. That is, export volumes, X4(c), are declining functions of their prices in foreign currency, (P4(c)/PHI). The exchange rate PHI converts local to foreign currency units. The variables F4Q(i) and F4P(i) allow for horizontal (quantity) and vertical (price) shifts in the demand schedules.

Historically, non-traditional exports have been small and volatile, precluding 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 (see equation E_x4_b in Excerpt 24). Total demand is related to the average price *via* a constant-elasticity demand curve, similar to those for traditional exports (see equation E_x4_ntrad).

```
Set
 TRADEXP    # Traditional Export Commodities #         (C1, C2, C4, C6);
 NTRADEXP   # Non-Traditional Export Commodities #     (C3, C5, C7 - C23);
Subset
 TRADEXP    is subset of COM;
 NTRADEXP   is subset of COM;

Coefficient ! Export Aggregates !
 V4TRADEXP       # Total Traditional Export earnings #;
 V4NTRADEXP      # Total Non-Traditional Export earnings #;
Formula
 V4TRADEXP       = Sum(c, TRADEXP,   V4PUR(c));
 V4NTRADEXP      = Sum(c, NTRADEXP,  V4PUR(c));

Coefficient (All,c,COM) EXP_ELAST(c)    # Export Demand Elasticities #;
Read EXP_ELAST From File MDATA Header "P018";

Equation E_x4_A          # Traditional export demand functions #
     (All,c,TRADEXP)  x4(c) - f4q(c) = EXP_ELAST(c)*[p4(c) - phi - f4p(c)];

Equation E_x4_B          # Non-Traditional export demand functions #
     (All,c,NTRADEXP) x4(c) = x4_ntrad;

Equation E_p4_ntrad      # Average Price of Non-Traditional exports #
     V4NTRADEXP*p4_ntrad = Sum(c,NTRADEXP, V4PUR(c)*p4(c));

Coefficient EXP_ELAST_NT # Non-Traditional Export Demand Elasticity #;
Read EXP_ELAST_NT From File MDATA Header "EXNT";

Equation E_x4_ntrad      # Demand for Non-Traditional export aggregate #
     x4_ntrad = EXP_ELAST_NT*[p4_ntrad - phi - f4_ntrad];

Equation E_x5            # "Other" demands #
     (All,c,COM)(All,s,SRC)  x5(c,s) = f5(c,s) + f5tot;

Equation E_f5tot         # Overall "Other" demands shift #
     f5tot = x3tot + f5tot2;
```

Excerpt 24 of TABLO Input file: Equations for exports and other final demands

Equations E_x5 and E_f5tot determine government usage. With both of the shift variables f5 and f5tot exogenous, the level and composition of government consumption is exogenously determined. Then equation E_f5tot merely determines the value of the endogenous variable f5tot2, which appears nowhere else. Alternatively, many ORANI applications have assumed that, in the absence of shocks to the shift variables, aggregate government consumption moves with real aggregate household consumption, x3tot. This is achieved by *endogenising* f5tot and *exogenising* f5tot2. The trick of changing behavioural specifications by switching the exogenous/endogenous status of shift variables is used frequently in applying ORANI. It helps to avoid proliferation of model variants, allowing the same TABLO Input file to contain different versions of some equations. The choice of which shift variables are exogenous determines at run time which version is operative in the rest of the model.

4.13. Demands for margins

The equations in Excerpt 25 indicate that, in the absence of technical change, demands for margins are proportional to the commodity flows with which the margins are associated. The 'a' variables allow for technical change in margins usage.

Excerpt 25 of TABLO Input file: Equations for margin demands

```
Equation E_x1mar # Margins to producers #
(All,c,COM)(All,s,SRC)(All,i,IND)(All,m,MAR)
    x1mar(c,s,i,m)  = x1(c,s,i) + a1mar(c,s,i,m);
Equation E_x2mar # Margins to capital creators #
(All,c,COM)(All,s,SRC)(All,i,IND)(All,m,MAR)
    x2mar(c,s,i,m)  = x2(c,s,i) + a2mar(c,s,i,m);
Equation E_x3mar # Margins to households #
(All,c,COM)(All,s,SRC)(All,m,MAR)
    x3mar(c,s,m)    = x3(c,s) + a3mar(c,s,m);
Equation E_x4mar # Margins to exports #
(All,c,COM)(All,m,MAR)
    x4mar(c,m)      = x4(c) + a4mar(c,m);
Equation E_x5mar # Margins to "Other" users #
(All,c,COM)(All,s,SRC)(All,m,MAR)
    x5mar(c,s,m)    = x5(c,s) + a5mar(c,s,m);
```

4.14. Purchasers' prices

The equations in Excerpt 26 define purchasers' prices for each of the first five user groups: producers; investors; households; exports; and government. Purchasers' prices (in levels) are the sums of basic values, sales taxes and margins. Sales taxes are treated as *ad valorem* on basic values, with the sales-tax variables t in the linearised model being percentage changes in the powers of taxes. For example, equation E_p3 is derived from the levels form:

$$X3(c,s)*P3(c,s) = X3(c,s)*P0(c,s)*T3(c,s) \\ + Sum(m,MAR, X3MAR(c,s,m)*P0(m,"dom")).$$

In percentage-change form this is:

$$V3PUR(c,s)*\{x3(c,s) + p3(c,s)\} = \\ \{V3TAX(c,s)+V3BAS(c,s)\}*\{x3(c,s)+p0(c,s)+t3(c,s)\} \\ + \quad Sum(m, MAR, V3MAR(c,s,m)*\{x3mar(c,s,m)+p0(m,"dom")\}).$$

By using Equation E_x3mar from Excerpt 25 to eliminate x3mar(c,s,m), we can cancel out the x3(c,s) terms to obtain:

V3PUR(c,s)*p3(c.s) =
[V3BAS(c,s)+V3TAX(c,s)]*[p0(c,s)+ t3(c,s)]
+ Sum(m,MAR, V3MAR(c,s,m)*{p0(m,"dom")+a3mar(c,s,m)}).

For a commodity which is not used by households, V3PUR(c,s) and its constituents would all be zero, leaving p3(i,s) undefined. To finesse this problem, the TABLO file adds the coefficient TINY (set to some small number) to the left hand side. With V3PUR(c,s) zero, equation E_p3 becomes:

p3(c,s) = 0.

The same procedure is used for the purchasers'-price equations referring to intermediate, investment, export and government users in Excerpt 26.

The final equation in the excerpt, E_p0_A, relates the domestic-currency prices of imports (c.i.f., duty-paid) to their foreign-currency prices. It is derived from the levels form:

P0IMP(c) = PF0CIF(c)*PHI*T0IMP(c). (26)

Excerpt 26 of TABLO Input file: Equations describing the price system

```
Coefficient TINY;
Formula TINY = 0.000000000001;

Equation E_p1 # Purchasers prices - producers #
(All,c,COM)(All,s,SRC)(All,i,IND)
[V1PUR(c,s,i)+TINY]*p1(c,s,i) =
    [V1BAS(c,s,i)+V1TAX(c,s,i)]*[p0(c,s)+ t1(c,s,i)]
+ Sum(m,MAR,V1MAR(c,s,i,m)*{p0(m,"dom")+a1mar(c,s,i,m)});

Equation E_p2 # Purchasers prices - capital creators #
(All,c,COM)(All,s,SRC)(All,i,IND)
[V2PUR(c,s,i)+TINY]*p2(c,s,i) =
    [V2BAS(c,s,i)+V2TAX(c,s,i)]*[p0(c,s)+ t2(c,s,i)]
+ Sum(m,MAR,V2MAR(c,s,i,m)*{p0(m,"dom")+a2mar(c,s,i,m)});

Equation E_p3 # Purchasers prices - households #
(All,c,COM)(All,s,SRC)
[V3PUR(c,s)+TINY]*p3(c,s) =
    [V3BAS(c,s)+V3TAX(c,s)]*[p0(c,s)+ t3(c,s)]
+ Sum(m,MAR,V3MAR(c,s,m)*{p0(m,"dom")+a3mar(c,s,m)});

Equation E_p4 # Zero pure profits in exporting #
(All,c,COM)
[V4PUR(c)+TINY]*p4(c) =
    [V4BAS(c)+V4TAX(c)]*[p0(c,"dom")+ t4(c)]
+ Sum(m,MAR,V4MAR(c,m)*{p0(m,"dom")+a4mar(c,m)});

Equation E_p5 # Zero pure profits in distribution of other #
(All,c,COM)(All,s,SRC)
[V5PUR(c,s)+TINY]*p5(c,s) =
    [V5BAS(c,s)+V5TAX(c,s)]*[p0(c,s)+ t5(c,s)]
+ Sum(m,MAR,V5MAR(c,s,m)*{p0(m,"dom")+a5mar(c,s,m)});

Equation E_p0_A # Zero pure profits in importing #
(All,c,COM) p0(c,"imp") = pf0cif(c) + phi + t0imp(c);
```

4.15. Market-clearing equations

Excerpt 27 includes market-clearing equations for domestic commodities, and equations which compute percentage changes in the aggregate demand for imports and for labour.

Equation E_x0dom computes percentage changes in the aggregate supply of domestic commodities. The next two equations (E_p0_B and E_p0_C) equate percentage changes in supply and aggregate demand, for margins and non-margins commodities respectively. Note that on the RHS of E_p0_B we include changes in inventories (delx6(n)). The inventory-change variables are included in the model to allow exogenous changes in inventories (see Section 7)—we include no theory of inventory investment. Because the inventory variable is included as an ordinary (not percentage) change, the last term on the RHS of E_p0_B shows clearly that the RHS terms are 100 times the values of the changes in the components of demand.

Equation E_x0imp computes the percentage changes in the aggregate usage of imported commodities. By exogenously setting the world price of imports, pf0cif(c), we assume infinite elasticity of the supply of imports.

Excerpt 27 of TABLO Input file: Market-clearing equations

```
Coefficient (All,c,COM) MAKE_I(c) # total production of commodity c #;
Formula (All,c,COM)     MAKE_I(c)    = Sum(i,IND, MAKE(c,i));

Equation E_x0dom# Total output of domestic commodities #
(all,c,COM)   MAKE_I(c)*x0dom(c)   = Sum(i,IND, MAKE(c,i)*q1(c,i));

Equation E_p0_B  # Demand equals supply for non margin commodities #
(All,n,NONMAR)
     SALES(n)*x0dom(n) =
     Sum(i, IND, V1BAS(n,"dom",i)*x1(n,"dom",i) + V2BAS(n,"dom",i)*x2(n,"dom",i))
              + V3BAS(n,"dom")*x3(n,"dom")
              + V4BAS(n)*x4(n)
              + V5BAS(n,"dom")*x5(n,"dom")
              + 100*P0DOM(n)*delx6(n);

Equation E_p0_C # Demand equals supply for margin commodities #
(All,m,MAR)
     SALES(m)*x0dom(m) =                    ! basic part first !
     Sum(i,IND, V1BAS(m,"dom",i)*x1(m,"dom",i)+V2BAS(m,"dom",i)*x2(m,"dom",i))
              + V3BAS(m,"dom")*x3(m,"dom")
              + V4BAS(m)*x4(m)
              + V5BAS(m,"dom")*x5(m,"dom")
              + 100*P0DOM(m)*delx6(m)      ! now margin part !
 + Sum(c,COM,V4MAR(c,m)*x4mar(c,m)
 + Sum(s,SRC, V3MAR(c,s,m)*x3mar(c,s,m)+V5MAR(c,s,m)*x5mar(c,s,m)
 + Sum(i,IND,  V1MAR(c,s,i,m)*x1mar(c,s,i,m)+V2MAR(c,s,i,m)*x2mar(c,s,i,m))));
! note nesting of Sum parentheses !

Equation E_x0imp # Import volumes #
(All,c,COM)
     V0IMP(c)*x0imp(c) =
       Sum(i,IND, V1BAS(c,"imp",i)*x1(c,"imp",i) + V2BAS(c,"imp",i)*x2(c,"imp",i))
                + V3BAS(c,"imp")*x3(c,"imp")   + V5BAS(c,"imp")*x5(c,"imp");

Equation E_x1lab_i # Demand equals supply for labour of each skill #
(All,o,OCC) V1LAB_I(o)*x1lab_i(o) = Sum(i,IND, V1LAB(i,o)*x1lab(i,o));
```

Equation E_x1lab calculates the percentage change in the aggregate demand for occupation-specific labour. Users of the model have the option of setting aggregate employment exogenously, with market-clearing wage rates determined endogenously, or setting wage rates exogenously, allowing employment to be demand determined (see Section 4.20). In view of Australia's centralised wage-fixing mechanisms, the latter assumption has often been adopted in ORANI applications with short-run foci (e.g., Dixon, Powell and Parmenter, 1979).

Dixon PB, Powell A and Parmenter BR (1979) *Structural Adaptation in an Ailing Macro-economy*, Melbourne University Press.

4.16. Indirect taxes

Excerpt 28 contains default rules for setting sales-tax rates for producers, investors, households, and government. Sales taxes are treated as *ad valorem* on basic values, with the sales-tax variables in the linearised model being percentage changes in the powers of the taxes. Each equation allows the changes in the relevant tax rates to be commodity-specific or user-specific. To simulate more complex patterns of tax changes, we would omit or modify these equations.

Excerpt 28 of TABLO Input file: Tax rate equations

```
Equation
E_t1     # power of tax on sales to intermediate #
  (All,c,COM)(All,s,SRC)(All,i,IND) t1(c,s,i) = f0tax_s(c) + f1tax_csi;
E_t2     # power of tax on sales to investment #
  (All,c,COM)(All,s,SRC)(All,i,IND) t2(c,s,i) = f0tax_s(c) + f2tax_csi;
E_t3     # power of tax on sales to households #
  (All,c,COM)(All,s,SRC)            t3(c,s)   = f0tax_s(c) + f3tax_cs;
E_t4_A # power of tax on sales to traditional exports #
  (All,c,TRADEXP)                   t4(c)     = f0tax_s(c) + f4tax_trad;
E_t4_B # power of tax on sales to non-traditional exports #
  (All,c,NTRADEXP)                  t4(c)     = f0tax_s(c) + f4tax_ntrad;
E_t5     # power of tax on sales to other #
  (All,c,COM)(All,s,SRC)            t5(c,s)   = f0tax_s(c) + f5tax_cs;
```

The equations of Excerpt 29 compute percentages changes in aggregate revenue raised from indirect taxes. In explaining them we can also explain the Update statements for the tax coefficients which were introduced in Excerpt 8. The bases for the sales taxes are the basic values of the corresponding commodity flows, and the tax-rate variables appearing in the model are powers of the sales-tax rates. Hence, for any component of sales tax, we can express revenue (VTAX), in levels, as the product of the base (VBAS) and the power of the tax (T) minus one, i.e.,

$$VTAX = VBAS(T-1). \tag{27}$$

Hence: $\Delta VTAX = \Delta VBAS(T-1) + VBAS\Delta T$,

$$= VBAS(T-1)\frac{\Delta VBAS}{VBAS} + VBAS*T\frac{\Delta T}{T},$$

$$= VBAS(T-1)wbas/100 + VBAS*T*t/100,$$

$$= VTAX*wbas/100 + (VBAS+VTAX)t/100,$$

where wbas and t are percentage changes in VBAS and T. VBAS is in turn a product of a quantity (X) and a basic price (P), so its percentage change wbas can be written as (x + p). Hence:

$$\Delta VTAX = VTAX(x+p)/100 + (VBAS+VTAX)t/100 \tag{28}$$

which has the form of the tax Update statements in Excerpt 8.

```
Equation
E_w1tax_csi # revenue from indirect taxes on flows to intermediate #
    V1TAX_CSI*w1tax_csi = Sum(c,COM, Sum(s,SRC, Sum(i,IND,
    V1TAX(c,s,i)*{p0(c,s)+x1(c,s,i)}+(V1TAX(c,s,i)+V1BAS(c,s,i))*t1(c,s,i))));
E_w2tax_csi # revenue from indirect taxes on flows to investment #
    V2TAX_CSI*w2tax_csi = Sum(c,COM, Sum(s,SRC, Sum(i,IND,
    V2TAX(c,s,i)*{p0(c,s)+x2(c,s,i)}+(V2TAX(c,s,i)+V2BAS(c,s,i))*t2(c,s,i))));
E_w3tax_cs # revenue from indirect taxes on flows to households #
    V3TAX_CS*w3tax_cs = Sum(c,COM, Sum(s,SRC,
    V3TAX(c,s)*{p0(c,s)+ x3(c,s)} + (V3TAX(c,s)+V3BAS(c,s))*t3(c,s)));
E_w4tax_c # revenue from indirect taxes on exports #
    V4TAX_C*w4tax_c = Sum(c,COM,
    V4TAX(c)*{p0(c,"dom") + x4(c)} + (V4TAX(c)+ V4BAS(c))*t4(c));
E_w5tax_cs # revenue from indirect taxes on flows to "Other" #
    V5TAX_CS*w5tax_cs = Sum(c,COM, Sum(s,SRC,
    V5TAX(c,s)*{p0(c,s)+ x5(c,s)} + (V5TAX(c,s)+V5BAS(c,s))*t5(c,s)));
E_w0tar_c # tariff revenue #
    V0TAR_C*w0tar_c = Sum(c,COM,
    V0TAR(c)*{pf0cif(c) + phi + x0imp(c)} + V0IMP(c)*t0imp(c));
```

Excerpt 29 of TABLO Input file: Indirect tax revenue

The left-hand side of each equation in Excerpt 29 is the product of a levels tax flow and the corresponding percentage change. Each product shows 100 times the ordinary change in aggregate tax revenue for some user group. Since the aggregate change is just the sum of many individual changes, the right hand sides consist of summations of terms such as (28) above—multiplied by 100.

4.17. GDP from the income and expenditure sides

Excerpt 30 defines the nominal aggregates which make up GDP from the income side. These include totals of factor payments, the value of other costs, and the total yield from commodity taxes. Their derivation is straightforward. Equation, E_w1lnd_i, for example, is derived as follows. Excerpt 13 contained the formula for total land revenue:

V1LND_I = Sum(i,IND, V1LND(i)),

which is equivalent to:

V1LND_I = Sum(i,IND, X1LND(i)*P1LND(i)).

Hence, in percentage-change form:

V1LND_I*w1lnd_i = Sum(i,IND,V1LND(i)*{x1lnd(i)+p1lnd(i)}).

Because TABLO does not distinguish upper and lower case, we cannot use 'v1lnd_i' to refer to the change in V1LND_I—instead we use 'w1lnd_i'. This conflict arises only for aggregate flows, since only these flows appear simultaneously as variables and coefficients.

```
Equation
E_w1lnd_i     # aggregate payments to land #
     V1LND_I*w1lnd_i = Sum(i,IND,V1LND(i)*{x1lnd(i)+p1lnd(i)});
E_w1lab_io    # aggregate payments to labour #
     V1LAB_IO*w1lab_io =
Sum(i,IND,Sum(o,OCC,V1LAB(i,o)*{x1lab(i,o)+p1lab(i,o)}));
E_w1cap_i     # aggregate payments to capital #
     V1CAP_I*w1cap_i = Sum(i,IND,V1CAP(i)*{x1cap(i)+p1cap(i)});
E_w1oct_i     # aggregate other cost ticket payments #
     V1OCT_I*w1oct_i = Sum(i,IND,V1OCT(i)*{x1oct(i)+p1oct(i)});
E_w0tax_csi   # aggregate value of indirect taxes #
     V0TAX_CSI*w0tax_csi = V1TAX_CSI*w1tax_csi + V2TAX_CSI*w2tax_csi
     + V3TAX_CS*w3tax_cs + V4TAX_C*w4tax_c
     + V5TAX_CS*w5tax_cs + V0TAR_C*w0tar_c;
E_w0gdpinc    # aggregate nominal GDP from income side #
     V0GDPINC*w0gdpinc =
          V1LND_I*w1lnd_i + V1CAP_I*w1cap_i + V1LAB_IO*w1lab_io
     +    V1OCT_I*w1oct_i + V0TAX_CSI*w0tax_csi;
```

Excerpt 30 of TABLO Input file: Equations for factor incomes and GDP

Excerpt 31 defines the aggregates which make up GDP from the expenditure side. We could have computed percentage changes in the nominal aggregates as in the previous section. For example, in equation E_w2tot_i, total nominal investment could have been written as:

V2TOT_I*w2tot_i = Sum(i,IND,V2TOT(i)*{x2tot(i)+p2tot(i)}).

We choose to decompose this change into price and quantity components—see equations E_p2tot_i and E_x2tot_i. The nominal change is the sum of these two Divisia indices.

Superficially, price and quantity components such as p2tot_i and x2tot_i resemble the price and quantity indices which arise from the nested production functions of agents. Those Divisia indices arise from homothetic functional forms. However, the model contains no analogous function to aggregate investment quantities across industries. Similarly, our definition of real consumption is not derived from the household utility function. We use these price-quantity decompositions only as convenient summary measures.

For investment, and for each other expenditure component of GDP, we define a quantity index and a price index which add to the (percentage change in the) nominal value of the aggregate. We weight these together to form expenditure-side measures of real GDP, the GDP deflator and nominal GDP.

```
E_x2tot_i      # total real investment #
     V2TOT_I*x2tot_i = Sum(i,IND,V2TOT(i)*x2tot(i));
E_p2tot_i      # investment price index #
     V2TOT_I*p2tot_i = Sum(i,IND,V2TOT(i)*p2tot(i));
E_w2tot_i      # total nominal investment #
     w2tot_i = x2tot_i + p2tot_i;

E_x3tot        # real consumption #
     V3TOT*x3tot = Sum(c,COM, Sum(s,SRC, V3PUR(c,s)*x3(c,s) ));
E_p3tot        # consumer price index #
     V3TOT*p3tot = Sum(c,COM,Sum(s,SRC,V3PUR(c,s)*p3(c,s)));
E_w3tot        # household budget constraint #
     w3tot = x3tot + p3tot;
```

Excerpt 31 of TABLO Input file: Equations for expenditure aggregates and GDP

```
E_x4tot        # export volume index #
    V4TOT*x4tot = Sum(c,COM,V4PUR(c)*x4(c));
E_p4tot        # exports price index, $A #
    V4TOT*p4tot = Sum(c,COM,V4PUR(c)*p4(c));
E_w4tot        # A$ Border value of exports #
    w4tot = x4tot + p4tot;

E_x5tot        # aggregate real "Other" demands #
    V5TOT*x5tot = Sum(c,COM,Sum(s,SRC,V5PUR(c,s)*x5(c,s) ));
E_p5tot        # 'other' demands price index #
    V5TOT*p5tot = Sum(c,COM,Sum(s,SRC,V5PUR(c,s)*p5(c,s)));
E_w5tot        # aggregate nominal value of "Other" demands #
    w5tot = x5tot + p5tot;

E_x6tot        # inventories volume index: base period dollars #
    V6TOT*x6tot = 100*Sum(c,COM, P0DOM(c)*delx6(c));
E_p6tot        # inventories price index #
    V6TOT*p6tot = Sum(c,COM,V6BAS(c)*p0(c,"dom"));
E_w6tot        # aggregate nominal value of inventories #
    w6tot = x6tot + p6tot;

E_x0cif_c      # CIF Import volume index, CIF weights #
    V0CIF_C*x0cif_c = Sum(c,COM,V0CIF(c)*x0imp(c));
E_p0cif_c      # A$ CIF imports price index #
    V0CIF_C*p0cif_c = Sum(c,COM,V0CIF(c)*{phi+pf0cif(c)});
E_w0cif_c      # A$ CIF value of imports #
    w0cif_c = x0cif_c + p0cif_c;

E_x0gdpexp  # real GDP,expenditure side #
    V0GDPEXP*x0gdpexp = V3TOT*x3tot + V2TOT_I*x2tot_i
                 + V5TOT*x5tot + V6TOT*x6tot + V4TOT*x4tot - V0CIF_C*x0cif_c;
E_p0gdpexp  # price index for GDP,expenditure side #
    V0GDPEXP*p0gdpexp = V3TOT*p3tot + V2TOT_I*p2tot_i
                 + V5TOT*p5tot + V6TOT*p6tot + V4TOT*p4tot - V0CIF_C*p0cif_c;
E_w0gdpexp  # nominal GDP from expenditure side #
    w0gdpexp = x0gdpexp + p0gdpexp;

Display V0GDPINC;     ! Display for checking purposes !
Display V0GDPEXP;     ! Two should always be the same !
```

Excerpt 31 of TABLO Input file: (cont.) Equations for expenditure aggregates and GDP

It is an accounting identity that GDP from the expenditure and income sides must be equal, both in the levels and in percentage changes. That is:

$$\text{V0GDPEXP} \equiv \text{V0GDPINC}, \quad \text{and} \quad \text{w0gdpexp} \equiv \text{w0gdpinc}. \tag{29}$$

Nonetheless, we find it useful to compute and print these values separately as a check on the model's accounting relations.

4.18. The trade balance and other aggregates

Because zero is a plausible base-period value, the balance of trade is computed in the first equation in Excerpt 32 as an ordinary change, not a percentage change. We avoid choosing units by expressing this change as a fraction of GDP.

The next three equations in Excerpt 32 measure percentage changes in imports at tariff-inclusive prices. The next four define percentage changes in indexes of the aggregate employment of capital, the average rental price of capital, employment by industry and the aggregate employment of labour. In computing the aggregate employment measures, we use rental or wage-bill weights, reflecting the relative marginal products of the components. Hence, the aggregates indicate the aggregate productive capacities of the relevant factors. Finally, the excerpt contains measures of percentage changes in the aggregate volume of output, the terms of trade and the real exchange rate.

```
Equation
E_delB        # (balance of trade)/(GDP) #
    100*V0GDPEXP*delB = V4TOT*w4tot - V0CIF_C*w0cif_c
              -(V4TOT-V0CIF_C)*w0gdpexp;

E_x0imp_c     # import volume index, duty paid weights #
    V0IMP_C*x0imp_c = Sum(c,COM,V0IMP(c)*x0imp(c));
E_p0imp_c     # duty paid imports price index #
    V0IMP_C*p0imp_c = Sum(c,COM,V0IMP(c)*p0(c,"imp"));
E_w0imp_c     # value of imports (duty paid) #
    w0imp_c = x0imp_c + p0imp_c;

E_x1cap_i     # aggregate usage of capital,rental weights #
    V1CAP_I*x1cap_i = Sum(i,IND,V1CAP(i)*x1cap(i));
E_p1cap_i     # average capital rental #
    V1CAP_I*p1cap_i = Sum(i,IND,V1CAP(i)*p1cap(i));

E_employ      # employment by industry #
(All,i,IND)   V1LAB_O(i)*employ(i) = Sum(o,OCC,V1LAB(i,o)*x1lab(i,o));

E_employ_i    # aggregate employment,wage bill weights #
    V1LAB_IO*employ_i= Sum(i,IND,V1LAB_O(i)*employ(i));

E_x1prim_i    # aggregate output: value-added weights #
    V1PRIM_I*x1prim_i = Sum(i,IND,V1PRIM(i)*x1tot(i));

E_p0toft      # terms of trade #
    p0toft = p4tot - p0cif_c;

E_p0realdev   # real exchange rate #
    p0realdev = p0cif_c - p0gdpexp;
```

Excerpt 32 of TABLO Input file: Equations for the trade balance and other aggregates

4.19. Rates of return

Equation E_p1cap in Excerpt 33 defines the percentage change in the rate of return on capital (net of depreciation) in industry i. In levels this is the ratio of the rental price of capital (P1CAP) to the supply price (P2TOT), *minus* the rate of depreciation. Hence, the coefficient QCOEF is the ratio of the gross to the net rate of return.

The second equation makes the change in the net rate of return in an industry (relative to the economy-wide rate) a positive function of the change in the industry's capital stock (relative to the economy-wide stock). It 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 BETA_R specifies the strength of this relationship. The variable f1ret(i) allows exogenous shifts in the industry's rate of return.

```
Coefficient (All,i,IND) QCOEF(i) # ratio, gross to net rate of return #;
Read QCOEF From File MDATA Header "P027";
Update (Change)  (All,i,IND)
    QCOEF(i) = QCOEF(i)*[1.0 - QCOEF(i)]*[p1cap(i) - p2tot(i)]/100;

Equation E_p1cap # definition of net rates of return to capital #
(All,i,IND) r1cap(i) = QCOEF(i)*(p1cap(i) - p2tot(i));

Coefficient (all,i,IND) BETA_R(i);
Read BETA_R From File MDATA Header "BETR";

Equation E_r1cap  # capital growth rates related to rates of return #
(All,i,IND)
 (r1cap(i) - r1cap_i) = BETA_R(i)*[x1cap(i) - x1cap_i] + f1ret(i);
```

Excerpt 33 of TABLO Input file: Rate-of-return equations

4.20. Indexation

Equations E_p1lab and E_p1oct in Excerpt 34 allow for indexation of nominal wages and of the unit price of 'other costs' to the CPI. The 'f1lab' variables allow for deviations in the growth of wages relative to the growth of the CPI. The variable f1oct(i) can be interpreted as the percentage change in the real price of 'other costs' to industry i.

Excerpt 34 of TABLO Input file: Indexing equations

```
Equation E_p1lab        # flexible setting of money wages #
(All,i,IND)(All,o,OCC)  p1lab(i,o)= p3tot + f1lab_io + f1lab_o(i) + f1lab_i(o) + f1lab(i,o);
Equation E_p1oct        # Indexing of prices of "Other Cost" tickets #
(All,i,IND)             p1oct(i) = p3tot + f1oct(i);   ! assumes full indexation !
```

4.21. Investment-capital accumulation equations

The equations described thus far follow closely the original version of ORANI, described in DPSV (1982). The main differences are that (a) a number of new macro aggregates—such as the tax revenue variables—have been defined and (b) the order and format of the equations has been altered for presentational purposes.

ORANI-F is a superset of ORANI. The remaining excerpts of the TABLO Input file describe the additional equations which are included in ORANI-F. These describe two stock-flow accumulation equations: between investment and capital, and between trade deficits and foreign debt.

To derive the investment-capital accumulation equations, we will start by using conventional algebraic notation, and ignoring industry subscripts. We make the transposition to TABLO notation at a later stage. The underlying accumulation relation is:

$$K_t = K_{t-1}D + Y_{t-1}, \tag{30}$$

where K_t is the capital stock operational at time t, Y_t is investment at time t, and D is the depreciation factor (one minus the depreciation rate). Notice that capital is assumed to take one period to install. Suppose that the forecasting simulation is comparing the current situation, t = 0, with that T years later. Then K_T, the capital stock at T, will be given by:

$$K_T = K_0D^T + \sum_{t=0}^{T-1} Y_tD^{T-t-1}. \tag{31}$$

We also assume that investment in the time span 0-T follows a straight line path:

$$Y_t = Y_0 + \frac{1}{T}(Y_T - Y_0)t. \tag{32}$$

Thus $$K_T = K_0D^T + \sum_{t=0}^{T-1} [Y_0 + \frac{1}{T}(Y_T - Y_0)t]D^{T-t-1}. \tag{33}$$

The assumption that investment grows smoothly allows us to simplify dramatically the dynamics of our model. It avoids the necessity of explicitly including in (33) any variables relating to periods between 0 and T. We can write (33) as:

$$K_T - K_0 = K_0(D^T-1) + Y_0N + (Y_T - Y_0)M, \tag{34}$$

where $$M = \sum_{t=0}^{T-1} \frac{t}{T} D^{T-t-1} = \sum_{t=1}^{T} \frac{t-1}{T} D^{T-t} \tag{35}$$

and $$N = \sum_{t=0}^{T-1} D^{T-t-1} = \sum_{t=1}^{T} D^{T-t}. \tag{36}$$

Notice that K_T is linearly related to Y_T, and to the predetermined values K_0 and Y_0. We treat K_T and Y_T as variables, and K_0, Y_0 and D as parameters. As explained in Section 3, our initial 'solution' for $\{K_T,Y_T\}$ is $\{K_0,Y_0\}$. Unless, by coincidence:

$$K_0(D^T-1) + Y_0N = 0, \tag{37}$$

these values for K_T and Y_T will not satisfy (34) We solve this problem by the purely technical device of augmenting equation (34) with an additional variable F as follows:

$$K_T - K_0 = [K_0(D^T-1) + Y_0N]F + (Y_T - Y_0)M. \tag{38}$$

Zangwill WI and Garcia CB (1981), *Pathways to Solutions, Fixed Points, and Equilibria*, Prentice Hall.

We choose the initial value of F to be 0, so that (38) is satisfied when $K_T = K_0$ and $Y_T = Y_0$. We refer to F as a 'fudge factor'—others call it a 'homotopy parameter' (Zangwill and Garcia, 1981). In forecasting simulations we shock F to 1 ($\Delta F=1$). Then (38) is equivalent to (34) and our percentage-change results are consistent with equations (31) to (34), as desired.

Taking ordinary changes in F, and percentage changes in K_T and Y_T, (38) becomes:

$$k_TK_T = 100[K_0(D^T-1) + Y_0N]\Delta F + y_TY_TM$$

or $$k_T = \frac{100}{Z}[D^T-1 + R_0N]\Delta F + M*R_Ty_T, \tag{39}$$

where $R_0 = Y_0/K_0$ (a parameter),

$R_T = Y_T/K_T$ (an updatable coefficient, initially equal to R_0),

and $Z = K_T/K_0$ (an updatable coefficient, initially equal to 1).

Excerpt 35 sets up equation (39) in the TABLO notation. It starts by defining and reading in the data coefficients DEP and R_T (D and R_T in (39)). The previously defined TABLO variables x1cap and x2tot, which appear in the Update statements for Z and R_T, correspond to k_T and y_T in (39). T, the number of years in the simulation period, is specified by the user at runtime. The user also provides values for the coefficient vector ORD, i.e., the integers 1 to T which are needed for the evaluation of the constants:

$$\text{M\_TERM} = \sum_{t=1}^{T} \frac{t-1}{T} D^{T-t} \quad \text{and} \quad \text{N\_TERM} = \sum_{t=1}^{T} D^{T-t}, \tag{40}$$

corresponding to M and N in (39) above. The obvious expression for N:

N_TERM(i) = Sum(y,YEARS, DEP(i) ^{NYEARS -y});

is not legal in the strongly-typed TABLO language, since y is not an integer running from 1 to T—it refers instead to the first T members of the set YEARS, whatever they may be.

Excerpt 35 of TABLO Input file: Investment/capital accumulation equations

```
Coefficient (All,i,IND) DEP(i) # depreciation factors #;
Read DEP From File MDATA Header "DPRC";  ! numbers like 0.95 !

Coefficient (All,i,IND) R_T(i) # investment/capital ratio, Y(T)/K(T) #;
Read R_T From File MDATA Header "YBYK";  ! numbers like 0.07 !
Update (Change)  (All,i,IND)
 R_T(i) = R_T(i)*[x2tot(i)-x1cap(i)]/100;

Coefficient (INTEGER) T # number of years covered by simulation #;
Read T From Terminal;  ! entered by user at run-time  !

Set YEARS MAXIMUM SIZE 100 SIZE T;

Coefficient (all,y,YEARS) ORD(y) # = y for y = 1 to T #;
Read ORD From Terminal;  ! entered by user at run-time  !

Coefficient (All,i,IND) Z(i) # K(T)/K(0) #;
Formula (Initial) (All,i,IND) Z(i) = 1;
Update (All,i,IND) Z(i) = x1cap(i);

Coefficient (All,i,IND) R_0(i) # Y(0)/K(0) #;
Formula (Initial) (All,i,IND) R_0(i) = R_T(i);

Coefficient (All,i,IND) DEP_T(i) # DEP to the power of T #;
Formula (Initial) (All,i,IND) DEP_T(i) = DEP(i)^T;

Coefficient (All,i,IND) N_TERM(i) # useful constant #;
Formula (Initial) (All,i,IND) N_TERM(i) =
     Sum(y,YEARS, DEP(i)^{T - ORD(y)} ); ! note y takes values 1 to T !

Coefficient (All,i,IND) M_TERM(i) # useful constant #;
Formula (Initial) (All,i,IND) M_TERM(i) =
     Sum(y,YEARS,([ORD(y)-1]/T)*DEP(i)^{T - ORD(y)} );

Coefficient (All,i,IND) K_TERM(i) # delFudge coefficient  #;
Formula (All,i,IND) K_TERM(i) = 100 *[DEP_T(i) - 1 + R_0(i)*N_TERM(i)] /Z(i);

Equation E_x2tot # investment/capital accumulation #
(All,i,IND)
 x1cap(i) = K_TERM(i)*delFudge + M_TERM(i)*R_T(i)*x2tot(i) + f_accum(i);
```

Formulae with the 'Initial' qualifier are evaluated only once—at the first step of a multistep computation. Such statements are used in two ways in Excerpt 35: firstly, to set the initial value of the levels variable Z (the ratio K_T/K_0) which is updated at subsequent steps, and secondly, to define the values of the parameters R_0, DEP_T, N_TERM and M_TERM which are not altered at subsequent steps.

All these coefficients are combined in equation E_x2tot, which corresponds to (39). We have added the shift variable f_accum, which is normally exogenous and zero. It could be endogenized to switch off equation E_x2tot. For example, we could replicate the traditional ORANI short-run environment by exogenising the x1cap instead of the f_accum.

4.22. *Capital accumulation in comparative-static simulations*

As mentioned towards the end of Section 3, a by-product of a forecasting simulation is an updated database that is consistent with the final, cumulated percentage-change results. We can use such a database as a control solution for comparative-static simulations which enforce the levels accumulation equation (34) *without* moving forward in time. Since we can assume that (34) is true in the pre-shock equilibrium, there is no need for any 'fudge factor' shock, ΔF. Thus the percentage-change equation (39) becomes:

$$k_T = M*R_T y_T \tag{41}$$

Notice that the coefficients of this equation do *not* depend on the initial (time 0) Y/K ratios, nor indeed on any time 0 variable. This is a convenient corollary of our assumption that investment followed a straight-line path during the period 0 to T.

4.23. Debt accumulation equations

Excerpt 36 contains equations modelling the nation's foreign debt. They relate the debt to accumulated balance-of-trade deficits. It is convenient to reuse the algebraic derivations of the previous section. Analogous to equation (31) above, we may write:

$$DEBT_T = DEBT_0(R\_WORLD)^T + \sum_{t=0}^{T-1} B_t(R\_WORLD)^{T-t-1}, \quad (42)$$

where $DEBT_t$ is the debt at year t and B_t is the trade deficit in year t. R_WORLD is the interest rate factor—one plus the world real interest rate, which we treat as a parameter.

Since R_WORLD is a (fixed) real foreign interest rate, it is clear that $DEBT_t$ and B_t are denominated in base-period foreign-currency units. However, they must be related to other variables—such as the values of exports and imports—which are measured in year-t Australian dollars ($A). The coefficient P_GLOBAL, defined at the start of Excerpt 36, is used to convert current $A values into base-period foreign dollars. It is given in percentage change form as p0cif_c (see Excerpt 31). For example, the second group of statements in Excerpt 36 define the coefficient BT as:

$$BT = (V0CIF\_C - V4TOT)/P\_GLOBAL \quad (43)$$

where, as previously defined, V0CIF_C and V4TOT are $A values of imports and exports. The change in BT (delBT) is a variable of the model. Equation E_delBT relates it to percentage changes in export receipts and the import bill, i.e., it puts (43) into change form.

The current debt value is stored on file as a debt/GDP ratio, defined as:

$$DEBT\_RATIO = DEBT / (V0GDPEXP/P\_GLOBAL). \quad (44)$$

A Formula derived from (44) calculates DEBT from DEBT_RATIO, V0GDPEXP and P_GLOBAL. Equation E_delDebt_Ratio expresses (44) in change form.

The next few statements define coefficients needed for the debt accumulation equation E_delDebt. That equation is akin to (38) above—as before we used the straight line assumption to interpolate values for B between 0 and T. We eschew percentage changes in Equation E_delDebt because both DEBT and BT may assume zero values, or change sign.

Finally, with Equation E_levDebt_Ratio we trick TABLO into generating a *levels* variable result for the Debt/GDP ratio. To express a levels variable X solely in terms of changes, we might start by writing:

$$X = X^0 + \Delta X. \quad (45)$$

Although constant terms such as X^0 are forbidden in TABLO equations, we can achieve the same effect by writing:

$$X = X^0 \Delta U + \Delta X \quad (46)$$

where ΔU is an exogenous variable that is always set to 1. delUnity is a variable of this type.

```
Coefficient P_GLOBAL        # Converts $A Values into 'Real' Terms #;
Formula (Initial) P_GLOBAL = 1; ! original value arbitrary !
Update P_GLOBAL = p0cif_c;

Coefficient BT              # Real trade deficit #;
Formula BT = (V0CIF_C - V4TOT)/P_GLOBAL;

Equation E_delBT            # Ordinary Change in Real Trade Deficit #
100*P_GLOBAL*delBT = V0CIF_C*(w0cif_c-p0cif_c) - V4TOT*(w4tot-p0cif_c);

Coefficient DEBT_RATIO      # Debt/GDP ratio #;
Read DEBT_RATIO From File MDATA Header "DGDP";
Update (Change)  DEBT_RATIO = delDebt_Ratio;

Coefficient DEBT            # Real Foreign Debt #;
Formula DEBT = DEBT_RATIO*V0GDPEXP/P_GLOBAL;

Equation E_delDebt_Ratio    # Change in Debt/GDP ratio #
delDebt_Ratio = (DEBT_RATIO / DEBT)*delDebt
                         - (DEBT_RATIO / 100)*(w0gdpexp-p0cif_c);

Coefficient DEBT0           # Original Real Foreign Debt #;
Formula (Initial) DEBT0 = DEBT;

Coefficient R_WORLD         # World Interest Rate: number like 1.04 (4% rate) #;
Read R_WORLD From File MDATA Header "RWLD";

Coefficient N_DEBT          # Useful Constant #;
Formula (Initial) N_DEBT = Sum(y,YEARS, R_WORLD^{T - ORD(y)} );

Coefficient M_DEBT          # Useful Constant #;
Formula (Initial)
 M_DEBT = Sum(y,YEARS,([ORD(y)-1]/T)*R_WORLD^{T - ORD(y)} );

Coefficient B0              # Original Real Trade Deficit #;
Formula (Initial) B0 = BT;

Equation E_delDebt          # change in foreign debt #
delDebt = {DEBT0*(R_WORLD^T - 1) + B0*N_DEBT}*delFudge + M_DEBT*delBT;

Coefficient DEBT_RATIO_0 # Original Debt/GDP ratio #;
Formula (Initial) DEBT_RATIO_0 = DEBT_RATIO;

Equation E_levDebt_Ratio    # Levels Debt/GDP ratio #
levDebt_Ratio = DEBT_RATIO_0*delUnity + delDebt_Ratio;
```

Excerpt 36 of TABLO Input file: Debt Accumulation Equations

5. Closing the Model

The model specified in Section 4 has more variables than equations. To close the model, we choose which variables are to be exogenous and which endogenous. The number of endogenous variables must equal the number of equations. For a complex AGE model, it may be surprisingly difficult to find a sensible closure which satisfies this accounting restriction.

Table 2 allows us to attack the task systematically. It arranges the model's 103 equations and 150 variables according to their dimensions. Equations broken into parts, such as E_x4_A (covering traditional export commodities) and E_x4_B (covering non-traditional exports) are treated as one equation block for this purpose. The first column lists the various combinations of set indices that occur in the model. The second column shows how many variables have these combinations. For example, 8 variables are dimensioned by COM, SRC and IND. The third column counts equations in the same way. For example, there are 51 macro, i.e., scalar, equations.

In most straightforward closures of the model, the correspondence between equations and endogenous variables applies for each row of the table, as well as in total. The fourth column shows the difference between the preceding two, i.e, it shows how many variables of that size would normally be exogenous.

Table 2 Tally of Variables and Equations

1 Dimension	2 Variable Count	3 Equation Count	4 Exogenous Count	5 Unexplained Variables
MACRO	66	51	15	delFudge delUnity f0tax_s *f1lab_io* f4_ntrad f4tax_ntrad *f5tot2* *phi* q r1cap_i *w3lux* f1taxWcsi f2tax_csi f3tax_cs f5tax_cs
COM	18	11	7	t0imp a3_s f4p f4q pf0cif f4tax_trad delx6
COM*IND	7	5	2	a1_s a2_s
COM*MAR	2	1	1	a4mar
COM*SRC	9	7	2	f5 a3
COM*SRC*IND	8	6	2	a1 a2
COM*SRC*IND*MAR	4	2	2	a1mar a2mar
COM*SRC*MAR	4	2	2	a3mar a5mar
IND	27	15	12	a1cap a1lab_o a1lnd a1oct a1prim a1tot f1lab_o f1oct f1ret f_accum x1lnd a2tot
IND*OCC	3	2	1	f1lab
OCC	2	1	1	f1lab_i
TOTAL	150	103	47	

In constructing the TABLO Input file, we chose to name each equation after the variable it seemed to explain or determine. Some variables had no equation named after them—they appear in the fifth column. Those variables are promising candidates for exogeneity. They include:

- technical change variables, mostly beginning with the letter 'a';
- tax rate variables, mostly beginning with 't';
- shift variables, mostly beginning with 'f';
- land endowments x1lnd, and the number of households q;
- foreign prices, pf0cif, and the average rate of return r1cap_i;
- inventory changes, delx6;
- the exchange rate phi, which could serve as numeraire;
- w3lux (household above-subsistence expenditure); and
- the artificial variables delFudge and delUnity.

Although Column 5 contains a perfectly valid exogenous set for the model, we chose, for the simulations reported in Section 7, to adopt a slightly different closure. (That closure is explained in Section 7.1.) The macro variables italicised in Column 5 were replaced as follows.

- Aggregate employment, employ_i, took the place of the real wage shifter, f1lab_io.
- The CPI, p3tot, replaced the exchange rate phi as numeraire.
- We exogenized f5tot instead of f5tot2, so disconnecting government from household consumption.
- The exogenous trade balance delB determined household consumption, rather than w3lux.

With its 23 commodities, 22 industries, 2 sources, 2 margin goods and 2 occupations, our version of ORANI-F has 21,818 scalar variable elements and 13,926 scalar equations. Full-size ORANI-F has 114 commodities, 113 industries, 2 sources, 9 margin goods and 8 occupations, leading to 1.25 million variables and 0.7 million equations. In its raw form, it would be far too big to solve. The next section explains how GEMPACK can condense a model to manageable size.

6. Using GEMPACK to Solve the Model

Figure 9 shows, in simplified form, the main stages in the GEMPACK process. The first and largest task, the specification of the model's equations using the TABLO language, has been described at length in the previous sections. This material is contained in the ORANIF.TAB file (at top left of the figure).

The model as described so far has too many equations and variables for efficient solution. Their numbers are reduced by instructing the TABLO program to:

- omit specified variables from the system. This option is useful for variables which will be exogenous and unshocked (zero percentage change). Normally it allows us to dispense with the bulk of the technical change terms. Of course, the particular selection of omitted variables will alter in accordance with the model simulations to be undertaken.
- substitute out specified variables using specified equations. This results in fewer but more complex equations. Typically we use this method to eliminate multi-dimensional matrix variables which are defined by simple equations. For example, the equation:

  ```
  Equation E_x1_s   # Demands for Commodity Composites #
  (All,c,COM)(All,i,IND)    x1_s(c,i) - {a1_s(c,i) + a1tot(i)} = x1tot(i);
  ```

  which appears in Excerpt 18 of the TABLO Input file in Section 4.9, can be used to substitute out variable x1_s. In fact the names of the ORANI-F equations are chosen to suggest which variable each equation could eliminate.

The variables for omission and the equation-variable pairs for substitution are listed in a second, instruction, file: ORANIF.STI.

The TABLO program converts the TAB and STI files into a FORTRAN source file, ORANIF.FOR, which contains the model-specific code needed for a solution program.

The compilation and linking phase combines ORANIF.FOR with other, general-purpose, code to produce the executable program ORANIF.EXE, which can be used to solve the model specified by the user in the TAB and STI files.

Simulations are conducted using ORANIF.EXE. Its inputs are:

- a data file, containing input-output data and behavioural parameters. This data file contains all necessary information about the initial equilibrium.
- user input, from the terminal, of the number of years , T, and the values of the coefficient ORD (see Section 4.21).

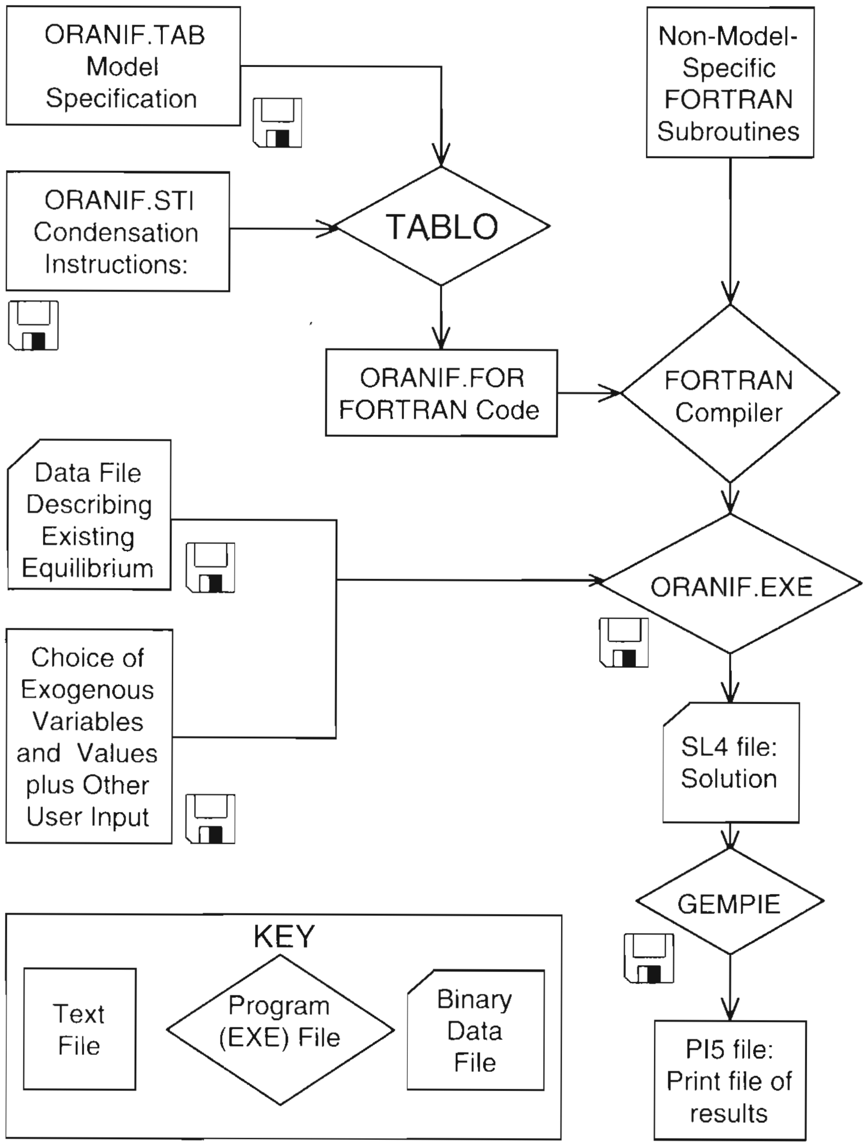

Figure 9. Stages in the GEMPACK process

- user input, from the terminal or from a text file, which specifies:
  (a) which variables are to be exogenous, and their values; and
  (b) into how many steps the computation is divided, and other details of the solution process.

Each simulation produces an SL4 (Solution) file. The file is often rather large. The non-model-specific program GEMPIE is used to select and print parts of it.

The disk which is companion to this article (see Appendix B) contains the files marked  in Figure 9. They enable the user to perform any simulation using the ORANI-F model which does not involve either changing model equations, or altering values in the initial database. Both of these changes would require the full GEMPACK system. The model-specification files at top left of the figure are included partly for reference and partly as a resource for those who wish to build their own general equilibrium model using the full GEMPACK system—they might well start by editing the ORANIF.TAB file to alter the dimensions and equations of the model to suit their own needs.

7. An Illustrative Application: Medium-Term Prospects for the Australian Economy, 1989-90 to 1995-96

We based these simulations on forecasts using the full-size version of ORANI-F which are reported in:

Adams PD, Dixon PB and Parmenter BR (1992) Medium-term Prospects for the Australian Economy: 1989-90 to 2000-01, *Australian Bulletin of Labour*, Vol.18, No. 4.

The database for the model underlying the simulations combines structural information from the 1986-87 Australian input-output tables and 1989-90 initial conditions for the capital- and debt-accumulation equations.

In this section we report an application in which ORANI-F is used to project developments in the Australian economy over the six-year period 1989-90 to 1995-96. 1989-90 is the base year for the current version of the model. The model projects just the aggregate changes in the variables over the whole period, not their detailed year-to-year growth paths.

The ratio of Australia's net foreign debt to its GDP is about 40 per cent and continues to rise. Until very recently, the trade balance has been substantially in deficit. Underlying our projections is the view that, despite current problems associated with management of recovery from the recession, the economy's medium-term prospects will be dominated by attempts to improve the foreign accounts. We assume that macroeconomic policy is adjusted to ensure modest improvements in the trade balance, reducing the rate of increase of the net-debt/GDP ratio.

We begin by compiling a scenario about developments through the projection period in variables which are exogenous for the simulations. Conditional upon the scenario for the exogenous variables, the model is solved to yield projections for the endogenous variables. At the time of writing, the first two years of the projection were already in place. In our scenario for the changes in the exogenous variables over the period 1989-90 to 1995-96, we included data through to 1991-92, together with assumptions about likely developments from 1991-92 to 1995-96. That is, we calculated six-year percentage changes (g^T) in the exogenous variables according to the formula:

$$(1 + \frac{g^T}{100}) = (1 + \frac{g^1}{100})(1 + \frac{g^2}{100}),$$

where g^1 is the observed percentage change for the period 1989-90 to 1991-92 and g^2 is the assumed change for the period 1991-92 to 1995-96.

7.1 Exogenous scenario

The choice of exogenous variables (i.e., the closure of the model) imposes some important assumptions on the simulations, particularly concerning the macroeconomic environment. In Table 3 we report our numerical assumptions for the main exogenous variables. We include notes explaining our assumptions. A complete listing of the exogenous shocks, with explanatory notes, is given in Appendix F.

A stylised representation of the macroeconomic closure underlying our projections is given in Figure 10. In this figure, exogenous variables are identified by rectangles and endogenous variables by ovals. Arrows indicate prime causal linkages in the model.

The required rate of return on capital is exogenous, reflecting the assumption that Australia faces an elastic supply of capital from the world capital market. That is, the domestic rate of return is assumed to be determined by world interest rates which are assumed to remain constant through the projection period. *Via* the factor-price frontier, fixing the rate of return determines the real wage rate per effective labour unit and the capital/labour ratio. We set employment growth exogenously, assuming growth of almost

Table 3 Main Exogenous Assumptions Underlying the Projections:1989-90 to 1995-96

Variable	Ordinary changes 1989-90 to 1995-96	Comment
Total change in balance of trade (percentage of GDP) (delB)	1.80	The BT/GDP ratio is assumed to remain at its 1991-92 value (approximately zero) through to 1995-96.
Changes in inventories (percentage of GDP) (delx6)	-4.1	Initially high stocks, especially of wool and commercial buildings, are run down over the simulation period.
Variable	**Percentage changes 1989-90 to 1995-96**	**Comment**
Average required rate of return on investment (r1cap_i)	0	Assumed to be set by world interest rates.
Consumer price index (p3tot)	34.0	*Numeraire* -- makes no difference to real growth rates. Equivalent to an average annual inflation rate of 5 per cent.
Exogenous component of the terms of trade (pf0cif, f4p, f4ntrad)	-6.7	Based on Australian Bureau of Agriculture (ABARE) forecasts (see Note 2 to Table F2).
Aggregate employment (employ_i)	6.1	Allows for recovery in employment growth after 1991-92.
Labour-saving technical change (-a1lab_o)	5.5	Industry-specific rates set at average performance of last decade. This ignores possible impact of microeconomic reform.
Public consumption (f5tot)	12.6	We assume growth at about the same rate as GDP growth.
Rates of tariff protection (t0imp)	Government plans	Our assumptions are consistent with Government plans for tariff reductions announced in the March 1991 economic statement.

Note: Full details of shock values are given in Appendix F

2 per cent per annum from 1991-92 to 1995-96, after a fall of 1.6 per cent in employment over the period 1989-90 to 1991-92. With employment growth, the rate of labour-saving technical change and the capital/labour ratio all set, the rates of growth of the aggregate capital stock and of real GDP are determined. On the expenditure side, setting capital growth determines real investment growth *via* the model's capital-accumulation relationships. Real public consumption and the trade balance are both exogenous. Real private consumption is then implied from the GDP identity. The real exchange rate adjusts to enforce the exogenous setting of the trade balance.

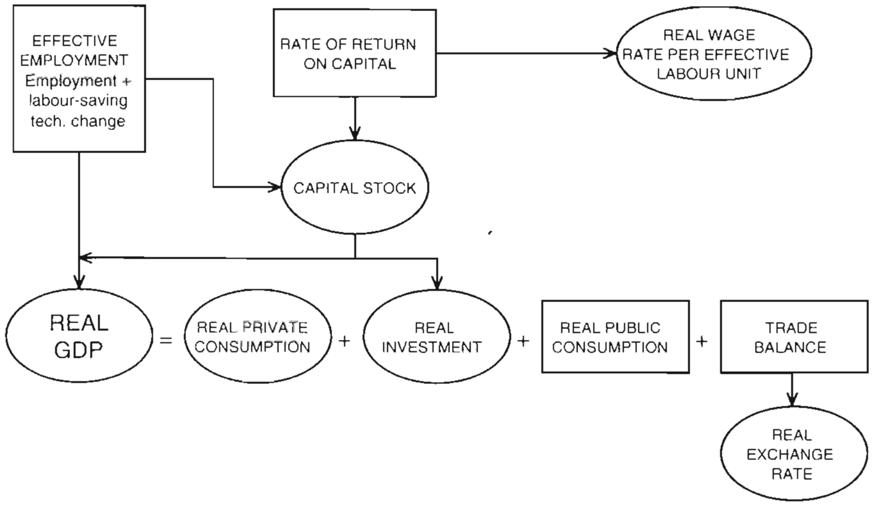

Figure 10. Macroeconomic closure underlying projections

7.2 Simulations results: final projections

Our final projections, including the effects of all the shocks, are given in columns VIII and IX of Table 4 (macroeconomic variables) and of Table 5 (sectoral output changes). Columns I–VII in these tables decompose the projections in column VIII to show the separate effects of each of the assumptions listed in Table 3.

The results in columns I to VIII were computed *via* a one-step (Johansen) procedure (see Section 3). They are, therefore, accurate only to first order but they have the advantage that the total effect (column VIII) is simply the sum of its parts (columns I to VII). The results in the final column, IX, which includes the effects of all shocks as does column VIII, were calculated by a multistep solution procedure. They are extrapolated from the results of 8, 10 and 12 step Gragg (Modified Midpoint) computations, and may be regarded as an exact solution of the levels model. Nevertheless, they differ little from the Johansen results of column VIII. Bearing in mind the uncertainty that must be attached to model specification, data sources and projections of future exogenous variable values, only a brave economist could assert that the column IX results represent a substantially better forecast than do those of column VIII.

Gragg's method is an elaboration of the Euler method described in Section 3. It is the most rapidly converging of the different computational methods offered by GEMPACK. On a 486/33 IBM-compatible desktop, column IX took 151 seconds to compute. For further information see:

Pearson KR (1991) Solving Nonlinear Economic Models Accurately Via a Linear Representation, *Impact Preliminary Working Paper* No. IP-55, July, 39 pp.

In this section we concentrate on explaining the projections in column VIII of Tables 4 and 5, with only occasional references to the decomposition. Details of the decomposition are given in the next section.

Row 1 of column VIII of Table 4 shows that the net-foreign-debt/GDP ratio reaches 51.5 per cent by 1995-96, 15.2 percentage points above its value in 1989-90 (36.3 per cent). However, the projected rise in the debt/GDP ratio would have been greater than this had the trade-balance/GDP ratio (row 2) remained at its base-period value (a 1.8% deficit).

Generation of the trade-balance improvement requires growth of real domestic absorption (rows 8, 9, 10 and 11) to be slower than growth in real GDP (row 7). In our projections, real GDP is projected to grow by 13.3 per cent over the six-year period. This is slightly faster than growth in effective employment (row 5) because of relatively rapid growth in capital usage (row 6). Around 30 per cent of the capital stock is housing. The rest comprises stocks of business equipment and non-residential buildings. Demand for

Table 4 Decomposed Projections from ORANI-F: 1989-90 to 1995-96: Macroeconomic Variables

Variable	I Momentum	II Employ-ment growth	III Labour-saving technical change	IV Decline in terms of trade	V Growth in public con-sumption	VI Annual change in BT/GDP ratio	VII Reductions in protection	VIII Base projection (sum of I to VIII)	IX Base projection (exact solution)
1. Net Foreign debt/GDP, 1995-96 (levDebt_Ratio)*	55.08	-1.07	-1.69	2.41	0.11	-3.76	0.45	51.52	49.47
2. Change in BT/GDP ratio (delB)	0.0	0.0	0.0	0.0	0.0	1.80	0.0	1.80	1.80
3. Percentage real devaluation (p0realdev)	-4.26	2.09	-0.58	7.43	-0.53	2.86	1.67	8.68	6.50
Six-year percentage changes									
4. Real hourly wage rate, CPI deflated (f1lab_io)	-0.19	-0.59	5.16	-1.92	0.42	-0.62	1.84	4.11	5.09
5. Effective employment (employ_i - a1lab_o)	0.00	6.15	5.50	0.00	0.00	0.00	0.00	11.65	11.65
6. Capital stock (x1cap_i)	12.07	4.39	3.88	-0.73	-2.10	-0.72	0.57	17.38	18.14
7. Real GDP (x0gdpexp)	4.12	5.47	4.77	-0.19	-0.88	-0.26	0.25	13.28	14.05
8. Real private consumption (x3tot)	21.95	0.99	0.88	-1.07	-2.23	-2.48	-0.88	17.17	17.49
9. Real public consumption (x5tot)	0.00	0.00	0.00	0.00	12.62	0.00	0.00	12.62	12.62
10. Real investment (x2tot_i)	-20.52	20.85	18.28	-4.39	-8.44	-3.47	2.90	5.22	6.88
11. Change in stocks (% of GDP)	-4.10	0.00	0.00	0.00	0.00	0.00	0.00	-4.10	-3.37
12. Import volumes (x0cif_c)	-1.85	8.00	7.28	-3.18	-2.76	-1.82	4.28	9.96	12.29
13. Export volumes (x4tot)	-2.74	9.41	8.34	6.07	-3.34	11.22	5.45	34.42	37.62
14. Consumer Price Index (p3tot)	34.01	0.00	0.00	0.00	0.00	0.00	0.00	34.01	34.01
15. GDP price deflator (p0gdpexp)	32.47	0.10	-0.07	-1.30	0.19	-0.09	0.05	31.34	31.32
16. Investment price deflator (p2tot_i)	28.80	1.31	0.22	1.09	-0.10	0.57	-0.24	31.66	30.96
17. Terms of trade (p0toft)	-0.31	-0.86	-0.83	-8.73	0.30	-1.05	-0.51	-11.99	-8.75

* In accumulating foreign debt, we assume that the average real rate of interest (R_WORLD) is 4 per cent (its average rate in 1989-90).

housing rises strongly over the projection period, due to quite strong growth in private consumption (row 8) and a high expenditure elasticity for housing services. The strength of growth in demand for business capital relative to the demand for labour is due partly to a small decrease in the cost of capital relative to the cost of labour which leads to the adoption of more capital-intensive production techniques and partly to compositional effects favouring capital-intensive sectors.

The projected rate of growth of capital requires only a small increase in investment (row 10). This is explained by the very strong level of investment recorded in the base year (1989-90). Even if investment were to remain constant at that level, quite rapid growth in capital would occur. The slowness of investment growth, combined with a rundown of stocks, especially of wool and commercial buildings (row 11), allows relatively strong growth in real private consumption (row 8) despite the need to restrict absorption growth to a rate below the rate of growth of GDP.

The slow growth in investment, which is import intensive, contributes directly to the required improvement in the trade-account balance. In addition, an improvement in Australia's international competitiveness (i.e., a real devaluation) is necessary to switch expenditure from foreign to domestically produced goods. Our projections show that to improve the trade account by 1.8 per cent of GDP, real devaluation of 8.68 per cent is necessary (row 3). This restricts growth of import volumes (row 12) to a rate below the growth rate of GDP (row 7) and stimulates growth in export volumes (row 13). Note that our assumption that the terms of trade will decline has a large effect on the extent of the required depreciation (row 3, column IV of Table 4).

The final four rows of Table 4 contain projections for various price deflators. Growth in the CPI (row 14) is assumed to be 34 per cent. Due mainly to the decline in the terms of trade (row 17), the GDP deflator (row 15), which includes exports but not imports, rises by less than the CPI, which includes imports but not exports. Part of the terms-of-trade decline is imposed exogenously (6.7 per cent, see Table 3). The rest is due to the expansion in export volumes (row 13) and the consequent movement down foreign demand curves. The investment deflator (row 16) falls slightly relative to the CPI. The depressed level of activity in the non-dwelling construction sector, generated by our recognition of an excess supply of commercial buildings, offsets the rise in the price of imported investment goods which is generated by real devaluation.

The terms-of-trade decline explains why the real wage rate (row 4) grows by only 4.11 per cent despite our assumption that average labour-saving technological change is 5.5 per cent. The CPI-deflated real wage rate per effective labour unit falls by 1.35 per cent (4.11-5.46). To understand this, first note that the growth in the market-price GDP deflator reported in row 15 can be calculated in two ways, both yielding the same result. It can be calculated either as a weighted average of growth in the domestic-absorption deflator and in the terms of trade, or as a weighted average of the growth in the wage rate (per effective labour unit), in average capital and land rental rates and in indirect tax rates. In our projections, the terms-of-trade decline reduces growth in the GDP deflator to below that of the absorption deflator (in which the CPI has the dominant weight). The average rental on capital rises slightly faster than the GDP deflator (rows 15 and 16), as do rentals on agricultural land and indirect tax rates (not reported in Table 4). Hence, declines in the nominal wage rate per effective labour unit relative to the GDP deflator and to the CPI are implied.

We turn now to the projections for sectoral output changes reported in Table 5. To help in understanding these, we provide Table 6, which gives the main characteristics of the sectors and brief comments on their prospects in the the forecasts.

The growth prospects of export-oriented industries are enhanced by real devaluation. Real devaluation increases domestic-currency prices of exports relative to production costs. *Mining, export* (sector 3) is a good example. Agriculture is also export-oriented. However, the growth prospects of *Broadacre rural* (sector 1) and of the processor *Food & fibre, export* (sector 5) are held back by a number of special factors exogenously imposed in our

Table 5 Decomposed Projections from ORANI-F: 1989-90 to 1995-96: Percentage Changes in Output by Sector

	I	II	III	IV	V	VI	VII	VIII	IX
Sector	Momentum	Employ-ment growth	Labour-saving technical change	Decline in terms of trade	Growth in public con-sumption	Annual change in BT/GDP ratio	Reductions in protection	Base projection (sum of I to VII)	Base projection (exact solution)
1. Broadacre rural	-7.56	2.89	2.92	-18.57	-1.07	2.43	0.58	-18.39	-21.36
2. Intensive rural	7.74	4.13	3.51	-4.48	-0.76	2.80	1.02	13.96	14.75
3. Mining, export	1.30	8.07	4.74	3.20	-3.06	4.80	2.74	21.80	20.91
4. Mining, other	5.96	6.78	4.24	6.88	-2.66	2.52	2.13	25.85	25.95
5. Food & fibre, export	1.97	5.88	4.01	-28.95	-2.32	5.32	1.40	-12.69	-13.58
6. Food, other	11.32	2.20	2.36	4.79	-1.54	0.89	0.18	20.20	21.21
7. Textiles, clothing & footwear	7.21	3.43	2.61	5.02	-1.25	1.22	-7.08	11.16	9.58
8. Wood related products	0.71	6.82	6.17	2.13	-1.87	-0.15	-0.20	13.61	14.49
9. Chemicals & oil products	5.57	5.39	5.00	3.69	-1.90	1.28	0.18	19.21	20.26
10. Non-metallic mineral products	-22.39	14.83	13.41	-1.32	-5.44	-2.58	1.09	-2.41	-0.89
11. Metal products	-14.91	13.54	12.25	4.16	-4.80	0.40	0.03	10.67	12.28
12. Transport equipment	-12.99	12.10	10.15	10.22	-4.45	3.60	-6.15	12.48	11.76
13. Other machinery	-14.46	15.20	13.20	4.28	-5.65	0.95	1.26	14.78	15.93
14. Other manufacturing	-0.65	7.76	6.83	6.10	-2.67	1.85	-3.18	16.05	16.26
15. Utilities	10.44	4.06	3.64	-0.03	-1.15	-0.61	-0.17	16.17	16.62
16. Construction	-30.44	17.36	15.71	-4.25	-6.32	-4.27	1.73	-10.48	-8.62
17. Retail & wholesale trade	7.97	4.66	4.10	-0.59	-2.22	-0.58	0.27	13.61	14.19
18. Transport	5.93	5.91	6.99	5.62	-2.12	2.12	1.26	25.71	27.89
19.Banking & finance	6.33	5.76	5.13	0.70	-1.74	-0.58	0.11	15.72	16.52
20.Ownership of dwellings	19.19	3.18	3.01	-0.98	-2.53	-1.78	-0.24	19.85	20.47
21.Public services	6.53	0.71	0.66	0.06	8.02	-0.66	-0.40	14.92	15.04
22.Private services	22.07	1.75	-1.75	-0.76	-1.64	-2.69	-1.23	15.74	15.54

projections. These include: poor world-price prospects for some agricultural commodities and the need to reduce Australia's stockpile of wool. Sectors 1, 3 and 5 are the traditional export sectors, producing commodities for which we specify separate foreign demand schedules. We handle exports from other sectors *via* a dummy non-traditional-export sector (see Section 4.12). We specify a single foreign demand schedule for aggregate non-traditional exports. The aggregate volume of non-traditional exports is free to respond to movements in the real exchange rate but its commodity composition is exogenous. Sectors whose prospects are significantly affected by expansion in their non-traditional exports include *Mining, other* (sector 4) and *Transport* (sector 18).

Sectors facing import competition also benefit from the real devaluation. Examples are *Textiles, clothing & footwear* (sector 7), *Wood related products* (8), *Chemicals & oil products* (9), and *Transport equipment* (12). For some of the import-competing sectors, such as *Textiles, clothing & footwear* and *Transport equipment*, the benefits of devaluation are offset by tariff cuts (column VII of Table 5).

Table 6 Major Characteristics of the Sectors

Sector	Trade category[a]	Major source of final domestic demand[b]	Comments
1. Broadacre rural	E	*	Poor world-price prospects. Excess stocks.
2. Intensive rural	ER/IC	*	Most of output sold as inputs to processing sectors. Includes fishing and forestry which face biological and environmental constraints.
3. Mining, export	E	*	Elastic foreign demand.
4. Mining, other	ER/IC	*	Significant export share. Includes crude oil which is also imported.
5. Food & fibre, export	E	C	Poor world-price prospects.
6. Food, other	IC	C	Prospects dominated by consumption. Faces some import competition.
7. Textiles, clothing & footwear	IC	C	Tariff protected.
8. Wood related products	IC	C/IR	Some trade exposure. Prospects dominated by consumption and construction.
9. Chemicals & oil products	IC/ER	C	Significant shares of exports and imports.
10. Non-metallic mineral products	IC	IR	Some trade exposure. Very close linkage with the construction sector.
11. Metal products	IC	IR	Moderately dependent on investment.
12. Transport equipment	IC	C/I	Tariff protected.
13. Other machinery	IC	I/C	Considerable trade-exposure. Most sales are to investment.
14. Other manufacturing	IC	C	Moderate trade exposure.
15. Utilities	NT	C	Prospects roughly in line with GDP.
16. Construction	NT	I	Dominated by investment in housing and non-residential buildings. Excess stocks of non-residential buildings.
17. Retail & wholesale trade	NT	C	Margins industry. Prospects roughly in line with GDP.
18. Transport	ER/IC	C	Margins industry. Strong direct and indirect connections to exports.
19. Banking & finance	NT	C	Prospects roughly in line with GDP.
20. Ownership of dwellings	NT	C	Output sold entirely to consumption with a high expenditure elasticity.
21. Public services	NT	G	Prospects dominated by public consumption.
22. Private services	NT	C	Slow technical progress.

(a) The following notation has been used: IC, import competing; NT, non-traded; ER, export-related; E, exporting.
(b) In this column: *, no significant sales to domestic final demand; C, private consumption; I, investment; IR, investment-related; G, government consumption.

Prospects for most of the remaining sectors are dominated by what happens to domestic demand. Sectors selling mainly to private and public consumption have good growth prospects due to the increase in aggregate consumption. This is especially so for sectors producing goods which have high consumption expenditure elasticities, such as *Ownership of dwellings* (20). By contrast, because growth of aggregate investment spending is low, the prospects of most investment-oriented sectors are poor. *Construction* (sector 16) and the supplier of many of its inputs, *Non-metallic mineral products* (sector 10), are especially depressed because of our assumption that, following the construction boom of the late 1980s, there are excess stocks of non-residential buildings.

7.3 Simulation results: decomposition

In this section we explain in detail the decomposition of our projection results which appear in columns I-VII of Tables 4 and 5. Column I (Momentum) accounts for the fact that, given the dynamic equations of the model, endogenous variables will be changing even if we impose no shocks on the exogenous variables. For example, given the level of investment in the base year, the capital stock will continue to expand even if investment remains constant or, if the capital stock is to remain constant, then investment must fall. Similarly, given the base-period levels of the foreign debt, world interest rates and the balance of trade, the foreign debt/GDP ratio will continue to increase. Each of columns II-VII of the decomposition shows the additional effects of imposing just a subset of our exogenous assumptions while holding all the other exogenous variables constant. For example, column II shows the effects of increasing aggregate employment, with no changes in technology, the terms of trade, etc. Details of the exogenous shocks corresponding to the columns of the decomposition are given in Table 7.

Table 7 Shocks corresponding to columns I to VII

	Column	Shocked Variables
I	Momentum	delFudge, delUnity, q, p3tot,delx6
II	Employment growth	employ_i
III	Labour-saving technical change	a1lab_o
IV	Decline in terms of trade	pf0cif, f4p, f4ntrad
V	Growth in public consumption	f5tot
VI	Annual change in BT/GDP ratio	delB
VII	Reductions in protection	t0imp

Note: Full details of shock values are given in Appendix F.

The decomposition shows the sensitivity of our results to our assumptions and can be used to construct alternatives to our final forecasts in column VIII of the tables. For example, to see how our projection for real GDP would be affected over the period 1989-90 to 1995-96 by slower employment growth we go to column II of Table 4. If employment growth were to be 3 per cent over the six-year period instead of 6.15 per cent, then our revised forecast for the percentage change in real GDP over the entire period would be

$$13.28 - 5.47(1.0 - 3/6.15) = 10.48$$

(i.e., (row 7, column VIII) *minus* (row 7, column II) *times* (1.0 - 3/6.15)).

Momentum (column I)

The main effects captured in column I of Tables 4 and 5 arise from three factors:

- changes in investment and the foreign debt/GDP ratio implied by the state of the economy in the base year;
- an exogenously-imposed rundown in stocks existing in the base year, especially of wool and commercial buildings; and
- the *numeraire* shock to the CPI.

The key to understanding column I is that in the absence of shocks to the exogenous variables (especially with no growth in employment and no technical change) there is no initial stimulus to capital growth. Hence, given the high initial level of investment, investment must fall (row 10, Table 4). The requirement that investment falls and the reduction in stocks (row 11), with the balance of trade and public consumption remaining unchanged, allows an increase in private consumption (row 8). The increase in consumption generates capital growth (row 6), particularly in the housing component. This moderates the fall in real investment (row 10). It also increases real GDP (row 7) .

Because investment is more import-intensive than consumption, the reallocation of domestic demand puts downward pressure on import volumes. At the same time, exports of wool are stimulated by the need to reduce stocks. Thus, the real exchange rate (row 3) must appreciate to keep the trade-account balance unchanged (row 2). The real appreciation encourages imports (row 12) and restricts non-wool exports. The increase in wool exports forces down the world price of wool, reducing the terms of trade (row 17). The terms-of-trade deterioration reduces the real wage rate (row 4) .

The foreign debt/GDP ratio at the end of the period (row 1) is almost 19 percentage points above its value in 1989-90. This results from six consecutive years of trade-account deficits at the base-year level and from the accrual of interest payments. These dominate the negative valuation effect of real appreciation and the effect of increased GDP.

Column I of Table 5 gives sectoral output changes consistent with the macroeconomic projections in column I of Table 4. Because aggregate investment spending is projected to decline, investment-related sectors (see Table 6) have poor growth prospects. Another negative influence on the trade-exposed members of this group is the real appreciation of the exchange rate. Increased aggregate consumption implies relatively good growth prospects for consumption-oriented sectors in column I.

Employment growth (column II)

Because technology is held constant, the 6.15 per cent growth in employment translates directly into growth of effective employment (row 5). The main effect of employment growth is to increase the demand for capital (row 6). However, capital expands at a slower rate than effective employment because of an employment-favouring change in relative factor prices (compare row 4 with row 16). The increase in capital generates increases in investment (row 10) and (together with the increase in employment) in real

GDP (row 7). Despite the additional real investment, the increased production allows a small rise in real consumption (row 8).

The increase in domestic demand (especially investment) increases the demand for imports (row 12). To stop the trade-account balance (row 2) from deteriorating, real devaluation (row 3) is necessary. This moderates the increase in imports and encourages exports (row 13). The latter accounts for the decline in the terms of trade (row 17). Due to the expansion in construction and to the real devaluation, the investment price deflator (row 16) rises strongly. Because rates of return are exogenous, this causes the average rental on capital to increase and, along with the terms-of-trade decline, reduces the real wage rate (row 4).

The final effect of employment growth is to reduce the foreign debt/GDP ratio (row 1). The projected growth of GDP, which outweighs the valuation effects of the real devaluation, explains this reduction.

At the sectoral level (column II of Table 5), we find relatively good growth prospects for investment-related sectors. In addition, most of these sectors benefit from the real devaluation. Real devaluation also assists other import-competing and export-oriented sectors. By contrast, consumption-oriented sectors not exposed to trade face relatively poor growth prospects.

Labour-saving technical change (column III)

Labour-saving technical progress is equivalent to an increase in effective employment (row 5). Thus, after adjusting for the different aggregate sizes of the shocks, the effects in column III are similar to those in column II. The extent to which there are differences is a consequence of the industrial profile of the technical change.

The pattern of technical progress imposed in column III favours industries in the traded-goods sector as opposed to industries producing non-traded goods—see the a1lab_o column of Table F2 in Appendix F. Thus, to maintain a fixed balance of trade, real *appreciation* (row 3) is required in column III, rather than real *depreciation* as in column II. The appreciation leads to the larger fall in the debt/GDP ratio (row 1). It also leads to the smaller increase in the investment price deflator (row 16) and to a smaller decrease in the real wage rate per effective unit of labour.

Differences between the sector-level results in columns III and II of Table 5 are readily traced to the sectoral bias in technical change. One example is provided by *Mining, export* (3), which has significantly worse prospects in column III than in column II because it is assumed to experience less rapid technical improvements than are other export sectors. Other examples are *Transport* (sector 18), which performs relatively well in column III because of relatively rapid technical progress, and *Private services* (sector 22), which performs badly because of a decline in its labour productivity.

Decline in terms of trade (column IV)

The terms-of-trade decline reduces export revenues. To keep the trade balance (row 2) unchanged, real devaluation (row 3) is required. This encourages import replacement (row 12) and restores the profitability of exporting (row 13).

Another direct effect of the terms-of-trade decline is to reduce the GDP deflator (row 15) relative to the CPI (row 14). With the investment price deflator (and the rental rate on capital) (row 16) rising because of the real devaluation, the real wage rate (row 4) falls. The consequent change in relative factor prices helps to explain the reductions in demand for capital (row 6), and hence in investment (row 10) and real GDP (row 7).

The final macroeconomic effect of the terms-of-trade decline is to increase the debt/GDP ratio (row 1). The valuation effect of the real devaluation explains this increase.

At the sectoral level (column IV of Table 5), the traditional export sectors *Broadacre rural* (row 1) and *Food & fibre, export* (row 5) are shown to be adversely affected by the terms-of-trade decline, while mining sectors benefit (rows 3 and 4). This reflects the commodity profile of the terms-of-trade shock. According to the ABARE forecasts, most of the overall decline in the terms of trade occurs through falls in world agricultural commodity prices, particularly the price of wool (see Appendix F). Thus, despite real devaluation, in column IV producers of raw and processed agricultural commodities experience declines in output. Other sectors adversely effected by the terms-of-trade decline are the investment-related sectors (10 and 16), which suffer from the decline in aggregate investment spending, and the producers of non-traded consumption goods (20 and 22), which suffer from the decline in real household spending.

Growth in public consumption (column V)

Public consumption is the most labour-intensive component of domestic absorption. Thus the immediate effect of an increase in public consumption is to increase the average labour intensity of the economy. This is manifested in our projections as a reduction in the capital stock (row 6) and hence in real GDP (row 7). Because of the fall in capital, real investment (row 10) declines. However, this decline is not sufficient to accommodate the growth in public consumption, hence private consumption (row 8) must also fall, leading to further declines in capital usage. Along with the fall in investment is a reduction in imports, requiring real appreciation (row 3) to maintain a fixed trade balance (row 2). Real appreciation encourages imports (row 12), discourages exports (row 13), causes a small improvement in the terms of trade (row 17), reduces the investment price deflator (row 16) and increases in the real wage rate (row 4).

As would be expected from the macroeconomic effects, an increase in public consumption crowds out activity in most sectors (column V of Table 5). The only sector projected to benefit is *Public services* (21), the direct beneficiary of increased public demand.

Annual change in BT/GDP ratio (column VI)

A trade-account improvement requires a fall in the share of production absorbed domestically. In our projections, some of this fall occurs *via* a reduction in consumption (row 8). Because consumption is relatively capital intensive, the demand for capital declines (row 6) leading to falls in GDP (row 7) and in investment (row 10). The reduction in investment assists in reducing the demand for imports.

An improvement in the trade account also requires real devaluation (row 3). The real devaluation increases the prices of tradeable products relative to the prices of non-tradeables. This encourages import replacement (row 12) and export expansion (row 13). With the increase in exports comes a reduction in the terms of trade (row 17). The consequent decline in the GDP deflator relative to the CPI, combined with increases in rents to agricultural land and capital, explains the reduction in the real hourly wage rate (row 4). The effects of the improvement in the trade balance in reducing the foreign-debt/GDP ratio (row 1) is weakened by the offsetting valuation effects of the real devaluation and the decline in GDP.

The growth prospects of traded-goods sectors are considerably improved by the real devaluation (see column VI of Table 5). However, sectors which are not trade-exposed contract due to the decrease in aggregate domestic expenditure

Reductions in protection (column VII.)

Columns VII of Tables 4 and 5 show the effects of reductions in rates of protection against imports in line with the plans most recently announced by the Australian Government (see Appendix F).

At the macroeconomic level (Table 4), the effects are small. Imports (row 12) increase, requiring real devaluation (row 3) to keep the trade-account balance unchanged. As a consequence, exports (row 13) expand and the terms of trade (row 17) deteriorate. The cuts in protection allow room for an increase in the real wage rate (row 4) (although, to replace lost tariff revenue, increases in income taxes might be required). The increase in the wage rate encourages the demand for capital (row 6), leading to increases in GDP (row 7) and in investment (row 10). Because of the relatively large increase in investment, consumption (row 8) falls. The valuation effects of the real devaluation explain the increases in the debt/GDP ratio (row 1).

Column VII of Table 5 shows that cuts in tariff protection have a negative impact on the highly-protected *Textiles, clothing & footwear* (7), *Transport equipment* (12) and *Other manufacturing* (14) sectors. Sectors reliant on consumption demand also suffer from the tariff cuts. On the other hand, non-protected, trade-exposed sectors such as those in agriculture and mining experience good growth prospects due to real devaluation.

8. Conclusion

Our experience has been that AGE models can be fruitful and flexible vehicles for practical policy analysis. In Australia, versions of the ORANI model, which have been available since the late 1970s, have been used widely by economists in the public, private and academic sectors. The key ingredients in the process of making the model accessible to such a wide range of users have been:

- comprehensive documentation of all aspects of the model—theoretical structure, data, computational procedures and illustrative applications;
- user friendly, readily transportable and low-cost computer software—GEMPACK; and
- establishment of a pool of potential users who have acquired the necessary training as employees or graduate students within the development team, on the job in organisations (especially the Australian Industry Commission) committed to routine use of the model, or in special training courses.

This document is designed to extend the accessibility of ORANI-style models within the international community. It provides comprehensive documentation of a recent version of the model (ORANI-F). ORANI-F can be used for making medium-run forecasts of the development of the Australian economy as well as for comparative-static policy analysis. It includes enough dynamics to accumulate variables such as capital stocks and foreign debt over medium-run periods (six years, say) but not enough to give convincing year-to-year time paths for the variables.

A distinctive feature of the document is that its account of the theoretical structure and data of the model is framed around the precise representation which is required as input to the GEMPACK computer system. This tight integration of economic and computational aspects of the modelling is intended to allow readers to acquire a hands-on familiarity with the model. The companion diskette, described in Appendix B, contains enough of the GEMPACK system to allow readers to reproduce the illustrative projections reported in Section 7 and to conduct their own simulations with the version of ORANI-F described in the rest of the document.

We hope that some readers will be stimulated to go beyond conducting simulations with the model described here. Our documentation could also be used as a template for the construction of models which are similar but which use different data (perhaps referring to different countries), have different dimensions or incorporate modifications to the theoretical structure. To make these steps, more of the GEMPACK system than is included on the companion diskette is required. Appendix C explains how the necessary software can be obtained.

Appendix A: Percentage-Change Equations of a CES Nest

Problem: Choose inputs X_i (i = 1 to N), to minimise the cost $\sum_i P_i X_i$ of producing given output Z, subject to the CES production function:

$$Z = \left(\sum_i \delta_i X_i^{-\rho}\right)^{-1/\rho}. \tag{A1}$$

The associated first order conditions are:

$$P_k = \Lambda \frac{\partial Z}{\partial X_k} = \Lambda \delta_k X_k^{-(1+\rho)} \left(\sum_i \delta_i X_i^{-\rho}\right)^{-(1+\rho)/\rho}. \tag{A2}$$

Hence $$\frac{P_k}{P_i} = \frac{\delta_k}{\delta_i}\left(\frac{X_i}{X_k}\right)^{1+\rho}, \tag{A3}$$

or $$X_i^{-\rho} = \left(\frac{\delta_i P_k}{\delta_k P_i}\right)^{-\rho/(\rho+1)} X_k^{-\rho}. \tag{A4}$$

Substituting the above expression back into the production function we obtain:

$$Z = X_k \left(\sum_i \delta_i \left[\frac{\delta_k P_i}{\delta_i P_k}\right]^{\rho/(\rho+1)}\right)^{-1/\rho}. \tag{A5}$$

This gives the input demand functions:

$$X_k = Z \left(\sum_i \delta_i \left[\frac{\delta_k P_i}{\delta_i P_k}\right]^{\rho/(\rho+1)}\right)^{1/\rho}, \tag{A6}$$

or $$X_k = Z\,\delta_k^{1/(\rho+1)}\left[\frac{P_k}{P_{ave}}\right]^{-1/(\rho+1)}, \tag{A7}$$

where $$P_{ave} = \left(\sum_i \delta_i^{1/(\rho+1)} P_i^{\rho/(\rho+1)}\right)^{-(\rho+1)/\rho}. \tag{A8}$$

Transforming to percentage changes (see Appendix E) we get:

$$x_k = z - \sigma\left(p_k - p_{ave}\right), \tag{A9}$$

and $$p_{ave} = \sum_i S_i p_i, \tag{A10}$$

where $$\sigma = \frac{1}{\rho+1} \text{ and } S_i = \delta_i^{1/(\rho+1)} P_i^{\rho/(\rho+1)} \Big/ \sum_k \delta_k^{1/(\rho+1)} P_k^{\rho/(\rho+1)}. \tag{A11}$$

Multiplying both sides of (A7) by P_k we get:

$$P_k X_k = Z\,\delta_k^{1/(\rho+1)} P_k^{\rho/(\rho+1)} P_{ave}^{1/(\rho+1)}. \tag{A12}$$

Hence $$\frac{P_k X_k}{\sum_i P_i X_i} = \delta_k^{1/(\rho+1)} P_k^{\rho/(\rho+1)} \Big/ \sum_i \delta_i^{1/(\rho+1)} P_i^{\rho/(\rho+1)} = S_i, \tag{A13}$$

i.e., the S_i of (A11) turn out to be cost shares.

With technical change terms, we must choose inputs X_i so as to:

minimise $\sum_i P_i X_i$ subject to: $$Z = \left(\sum_i \delta_i \left[\frac{X_i}{A_i}\right]^{-\rho}\right)^{-1/\rho}. \tag{A14}$$

Setting $\tilde{X}_i = \frac{X_i}{A_i}$ and $\tilde{P}_i = P_i A_i$ we get: (A15)

minimise $\sum_i \tilde{P}_i \tilde{X}_i$ subject to: $$Z = \left(\sum_i \delta_i \tilde{X}_i^{-\rho}\right)^{-1/\rho}, \tag{A16}$$

which has the same form as problem (A1). Hence the percentage-change form of the demand equations is:

$$\tilde{x}_k = z - \sigma\left(\tilde{p}_k - \tilde{p}_{ave}\right), \tag{A17}$$

and $$\tilde{p}_{ave} = \sum_i S_i \tilde{p}_i. \tag{A18}$$

But from (A15), $\tilde{x}_k = x_i - a_i$, and $\tilde{p}_i = p_i + a_i$, giving:

$$x_k - a_k = z - \sigma\left(p_k + a_k - \tilde{p}_{ave}\right). \tag{A19}$$

and $$\tilde{p}_{ave} = \sum_i S_i\,(p_i + a_i). \tag{A20}$$

When technical change terms are included, we call z and $\tilde{p}_{ave}$ *effective* indices of input quantities and prices.

Appendix B: How to Obtain and Use the Sample Disk

The sample disk containing the ORANI-F model, together with instructions on using it, may be obtained by sending 10 Australian dollars to the address below. (If sending from overseas, this must be in the form of a **bank draft in Australian dollars which is payable on an Australian bank**. You can obtain such a draft from your local bank.)

GEMPACK Manager,
C/- Dr. K.R. Pearson,
Impact Project, 11th Floor Menzies Building,
Monash University, Wellington Road,
Clayton VIC 3168
AUSTRALIA
Telephone (03) 565 5112 (from overseas: 61 3 565 5112)
FAX (03) 565 5486 (from overseas; 61 3 565 5486)

Only one format is available: 1.44Mbyte MSDOS. Please note that the sample disk does not contain the entire GEMPACK system.

It contains programs, data and text files for carrying out simulations with ORANI-F, namely:

- a program ORANIF.EXE which allows one to perform any simulation using the ORANIF model which does not involve either changing model equations or altering values in the original database. (Such changes would require the full GEMPACK system.):
- a special version of the GEMPACK program GEMPIE which is used to view or print simulation results;
- the data file ORANIF.DAT which contains the 23-sector data base (based on Australian input-output data) which was used as the starting point for the forecasts reported in Section 7;
- text files for setting up the closure and shocks for the simulations reported in Section 7; and
- a file READ.ME giving information about running ORANI.EXE and changing closure, shocks and/or solution method.

You can use these to reproduce the results in Tables 4 and 5 of Section 7, and to see how different exogenous assumptions would affect these results.

The disk also contains material needed to alter or regenerate the ORANI-F model, namely:

- the file ORANIF.TAB listed (by excerpts) in Section 4; and
- the batch file input to TABLO used to create the ORANI-F model.

These files are of use only in conjunction with the complete GEMPACK system.

Most of the files on the disk are in compressed form. The utility program for uncompressing them onto your hard disk is included on the disk. Brief written instructions for moving the files onto your hard disk and for accessing them will be sent with the disk.

To run ORANIF.EXE, you need an IBM compatible computer with a 386SX or better processor, a numeric coprocessor, 4Mbytes total RAM, a hard disk with at least 5Mbytes free and DOS Version 3.3. or higher.

Appendix C: Hardware and Software Requirements for Using GEMPACK

GEMPACK can be used on most mainframe and minicomputers: wherever an ANSI-standard FORTRAN is available. Customized installation kits are available for VAX-VMS, UNIX, Macintosh and DOS machines. The DOS system requirements are:

- a 386 or 386SX machine with math coprocessor, or a 486DX machine;
- DOS version 3.3 or higher;
- at least 4 Mbytes total RAM: 112-sector ORANI requires 16 Mbytes;
- at least 15 Mb free hard disk space; and
- an ANSI-compatible FORTRAN. The only DOS FORTRAN recommended and supported by GEMPACK is the Lahey F77L-EM/32 compiler. This must be purchased separately from GEMPACK.

At the time of writing, the cost of GEMPACK is between 2000 and 4000 Australian dollars; the Lahey compiler costs about $US1000. Current details may be obtained from the address listed in Appendix B.

Appendix D: Main differences between full-size ORANI-F and the version described here

Our version follows ORANI-F very closely. The main departures from the full-size version of ORANI-F described by Parmenter (1988) and DPSV (1982) are as follows.

- The model is more aggregated: there are only 23 commodities, 22 industries and 2 occupations (down from 114, 112 and 8).
- CRESH primary factor aggregators have been replaced by CES forms.
- The Leontief-CRESH double nest which, in ORANI, defines the commodity composition of output by joint-product industries is simplified to a single CET nest.
- Many percentage-change equations have been re-arranged—normally to avoid unnecessary computation of shares.
- The large version of ORANI-F contains a full specification of the Australian government accounts—omitted here to save space.

Appendix E: Deriving Percentage-Change Forms

Using first principles, a levels equation, for example,

$$Y = X^2 + Z,$$

is turned into percentage-change form by first taking total differentials:

$$dY = 2XdX + dZ.$$

Percentage changes x, y, and z are defined *via*:

$$y = 100\frac{dY}{Y} \quad \text{or} \quad dY = \frac{Yy}{100}, \quad \text{similarly} \quad dX = \frac{Xx}{100} \quad \text{and} \quad dZ = \frac{Zz}{100}.$$

Thus our sample equation becomes:

$$\frac{Yy}{100} = 2X\frac{Xx}{100} + \frac{Zz}{100}, \quad \text{or} \quad Yy = 2X^2x + Zz.$$

In practice such formal derivations are often unnecessary. Most percentage-change equations follow standard patterns which the modeller soon recognizes. Some of these are shown in Table E1.

Table E1 Examples of Percentage-Change Forms

Example	Original or Levels Form	Percentage-Change Form
1	$Y = 4$	$y = 0$
2	$Y = X$	$y = x$
3	$Y = 3X$	$y = x$
4	$Y = XZ$	$y = x + z$
5	$Y = X/Z$	$y = x - z$ *or* $100(Z)\Delta Y = Xx - Xz$
6	$X_1 = M/4P_1$	$x_1 = m - p_1$
7	$Y = X^3$	$y = 3x$
8	$Y = X^{\alpha}$	$y = \alpha x$ (α assumed constant)
9	$Y = X + Z$	$Yy = Xx + Zz$ *or* $y = S_x x + S_z z$ where $S_x = X/Y$, etc
10	$Y = X - Z$	$Yy = Xx - Zz$ *or* $y = S_x x - S_z z$ where $S_x = X/Y$, etc, *or* $100(\Delta Y) = Xx - Zz$
11	$PY = PX + PZ$	$PYy = PXx + PZz$ *or* $y = S_x x + S_z z$ where $S_x = PX/PY$, etc
12	$Z = \sum X_i$	$Zz = \sum X_i x_i$
13	$XP = \sum X_i P_i$	$XP(x+p) = \sum X_i P_i (x_i + p_i)$

The third alternate form for example 10 shows how ordinary and percentage changes may be mixed. It is based on the identity $Yy \equiv 100\Delta Y$. See also example 5.

Variables can only be added or subtracted (as in examples 9 and 12) where they share the same units. In adding quantities, we can normally identify a common price (often the basic price). By multiplying through additive expressions by a common price, we can express the coefficients of percentage-change equations as functions of flows, rather than quantities, so obviating the need to define physical units (compare examples 9 and 11).

Appendix F: Complete List of Shocks to Exogenous Variables for Simulations Reported in Section 7

Table F1 Scalar Shocks

Variable	Shock	Comment
delFudge	1.0	Ensures satisfaction of capital-accumulation relationships—see Section 4.21
delUnity	1.0	Allows computation of debt/GDP ratio in levels—see Section 4.23
q	8.06	Demographic variable—the number of households—required for household demand equations—see Section 4.2.1
p3tot	34.01	Numeraire
employ_i	6.15	Aggregate employment
f4ntrad	23.64	Vertical shift in foreign demand curve for non-traditional exports—part of the terms of trade shock—see note 2 below.
f5tot	12.61	Government consumption
delB	0.018	Trade balance improvement

Table F2 Vector Shocks

	a1lab_o[1]	f4p[2]	pf0cif[2]	delx6[3]	t0imp[4]
Agricultural Sectors					
Commodity: Cereals	n/a	10.82	23.64	173.0	0
Industry: Broadacre rural	-10.68	n/a	n/a	n/a	n/a
Commodity: Broadacre rural	n/a	-15.81	23.64	-1568.1	0
Industry: Intensive rural	-10.68	n/a	n/a	n/a	n/a
Commodity: Intensive rural	n/a	0	23.64	0	0
Single Product Industries					
Mining, export	-5.88	19.68	23.64	-290.2	-1.17
Mining, other	-4.79	0	23.64	0	0
Food & fibre, export	-9.09	1.63	23.64	-875.5	-0.77
Food, other	-9.09	0	23.64	0	-2.64
Textiles, clothing & footwear	-9.09	0	23.64	0	-12.81
Wood related products	-9.09	0	23.64	0	-5.56
Chemicals & oil products	-9.09	0	23.64	0	-2.91
Non-metallic mineral products	-9.09	0	23.64	0	-4.17
Metal products	-9.09	0	23.64	0	-8.8
Transport equipment	-9.09	0	23.64	0	-9.12
Other machinery	-9.09	0	23.64	0	-5.32
Other manufacturing	-9.09	0	23.64	0	-9.63
Utilities	-7.97	0	23.64	0	0
Construction	-4.79	0	23.64	-8263.2	0
Retail & wholesale trade	1.23	0	23.64	0	0
Transport	-19.37	0	23.64	0	0
Banking & finance	-4.79	0	23.64	0	0
Ownership of dwellings	0	0	23.64	0	0
Public services	-4.79	0	23.64	0	0
Private services	15.67	0	23.64	0	0

1. Labour-saving technical change by industry—averages -5.5 across industries (see Table 3).
2. Together, the shocks to f4p, pf0cif and f4ntrad reduce the exogenous component of the terms of trade by 6.7%.
3. The first 4 of these shocks implement stock changes for agricultural and mining commodities—component 2 is Wool. The units are base-period-dollars-worth. The shock to component 17 (Construction) reflects the excess supply of commercial buildings in the base period.
4. These tariff changes reflect the government's announced plans for trade liberalization

Appendix G: Creating your own AGE model from ORANI-F

In conjunction with the full GEMPACK system, the ORANI-F.TAB file which appears in Excerpts 1-36 forms an excellent starting-point for constructing your own AGE model. This file is supplied on the companion disk (see Appendix B). The best plan is to start from something that works (ORANI-F) and modify it in small steps until it suits your needs.

The most minimal change is to attach a different data file, appropriate to another country. Use the GEMPACK program MODHAR to turn data in text files into GEMPACK's binary format. Table G1 lists the data matrices that will be needed.

Table G1 Contents of ORANI-F Data File

Header	Array Dimensions	Description
1BAS	23x2x22	Intermediate Basic
2BAS	23x2x22	Investment Basic
3BAS	23x2	Households Basic
4BAS	23	Exports Basic
5BAS	23x2	Government Basic
6BAS	23	Inventory Changes
1MAR	23x2x22x2	Intermediate Margins
2MAR	23x2x22x2	Investment Margins
3MAR	23x2x2	Households Margins
4MAR	23x2	Exports Margins
5MAR	23x2x2	Government Margins
1TAX	23x2x22	Intermediate Tax
2TAX	23x2x22	Investment Tax
3TAX	23x2	Households Tax
4TAX	23	Exports Tax
5TAX	23x2	Government Tax
1CAP	22	Capital
1LAB	22x2	Labour
1LND	22	Land
1OCT	22	Other Costs
MAKE	23x22	Multiproduct Matrix
0TAR	23	Tariff Revenue
P027	22	Gross/Net Rate of Return
P021	1	Frisch Parameter
P044	23	Marginal Budget Shares
YBYK	22	Investment/Capital Ratios
P018	23	Traditional Export Elasticities
EXNT	1	Non-Traditional Export Elasticities
SLAB	22	Labour Sigma
P028	22	Primary Factor Sigma
SCET	22	Output Sigma
1ARM	23	Intermediate Armington
2ARM	23	Investment Armington
3ARM	23	Households Armington
BETR	22	Investment Parameter
DPRC	22	Depreciation Factors
DGDP	1	Debt/GDP ratio
RWLD	1	World Interest Rate Factor

To alter the dimensions of the model (e.g., the number of sectors) simply edit the 'Set' statements which appear in Excerpts 1 and 24.

Your own national input-output tables may not support the ORANI-F level of detail. For example, you may be unable to distinguish land as a third primary factor. Rather than deleting all mention of land from the equations, achieve the same effect by supplying a data vector of land rentals (header '1LND' in Table G1) which is filled with tiny non-zero numbers. Again, if you cannot gather margins data, you may restrict the set of margins commodities (in Excerpt 1) to a single commodity, and fill all margins matrices with tiny numbers. Define one occupational labour category only, if need be. A diagonal MAKE matrix is equivalent to removing multi-production. All these techniques are less error-prone than altering the equations.

You may remove the dynamic relationships which are distinctive to ORANI-F, to create a very conventional AGE model with reduced data needs. Simply delete Excerpts 35 and 36 and remove the variables delFudge, f_accum, delUnity, delBT, delDebt, delDebt_Ratio and levDebt_Ratio from Excerpts 5 and 6. This removes all reference to foreign debt and breaks the link between capital stocks and investment. Consequently, the investment by industry variable, x2tot, must be added to the exogenous list. The headers YBYK, DPRC, DGDP and RWLD in Table G1 will not now be needed.

As your confidence grows, you may wish to change or extend the equation system. For example, you could easily add a consumption function. More ambitiously, you could alter the production nesting system of Figure 6 to allow intermediate usage of energy to be substitutable with primary factors.

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