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# ORANI-G: A General Equilibrium Model of the Australian Economy

by

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# ORANI-G: A General Equilibrium Model of the Australian Economy

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*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 generic version of the model, ORANI-G, designed for expository purposes.*

*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. Computer files are available, which contain a complete model specification and database.*

*Bibliographical Note: this document has its origin in the article"ORANI-F: A General Equilibrium Model of the Australian Economy", by J.M.. Horridge, B.R. Parmenter and K.R. Pearson (all of the Centre of Policy Studies), which appeared in the journal Economic and Financial Computing (vol.3,no.2,Summer 1993). Subsequently Horridge has progressively altered the article for teaching purposes, removing contributions by the other authors. This version was originally prepared for the Course in Practical GE Modelling run at Monash University in June 1998.*

*Note to the 1998 revision*

*It is pleasing to see how far the original aims of the ORANI-G model, to aid in teaching GE modelling; and to serve as a spring-board for new models, have been realized. It forms the basis of an annual modelling course, and has been adapted to build models of South Africa, Pakistan, Sri Lanka, Fiji, South Korea, Denmark, Vietnam, Thailand, Indonesia, Philippines and both Chinas. Most of the additions and revisions made for this version have arisen through interactions with colleagues in those countries. We thank them for their contribution.*

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# 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[1]. 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[2].

Initial versions of ORANI were static, with applications confined to comparative-static analysis. More recent versions (ORANI-F and MONASH) have contained dynamic elements, arising from stock/flow accumulation relations: between capital stocks and investment, and between foreign debt and trade deficits. Other extensions to the basic model have included systems of government accounts, and regional breakdowns of model results.

These extensions are omitted from the version of ORANI described here: ORANI-G. It resembles very closely the original ORANI specification, and is designed both as an introduction to the ORANI methodology, and as a launching pad for developing new models. Indeed, it has already served as the basis for models of South Africa, Vietnam, Indonesia, South Korea, Thailand, the Philippines, Pakistan, Denmark, both Chinas and Fiji.

GEMPACK, a flexible system for solving AGE models, is used to formulate and solve ORANI-G (Harrison and Pearson, 1994). 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 program which solves the model.

The documentation in this volume is designed to serve as a template for researchers who may wish to construct a model like ORANI-G 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 set of computer files complements this document. It may be obtained from the World Wide Web—see Appendix B. The files contain ORANI-G TABLO Input file and a 22-sector database. Some version of GEMPACK is required to solve the model. To order GEMPACK, see Appendix C.

---

[1] See: Powell, 1977; Dixon, Parmenter, Ryland and Sutton, 1977; Dixon, Parmenter, Sutton and Vincent (DPSV/Green Book), 1982.

[2] See: Parmenter and Meagher, 1985; Powell and Lawson, 1989, Powell, 1991; Vincent, 1989.

## 2. Model Structure and Interpretation of Results

ORANI-G has a theoretical structure which is typical of a static 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.

### *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.

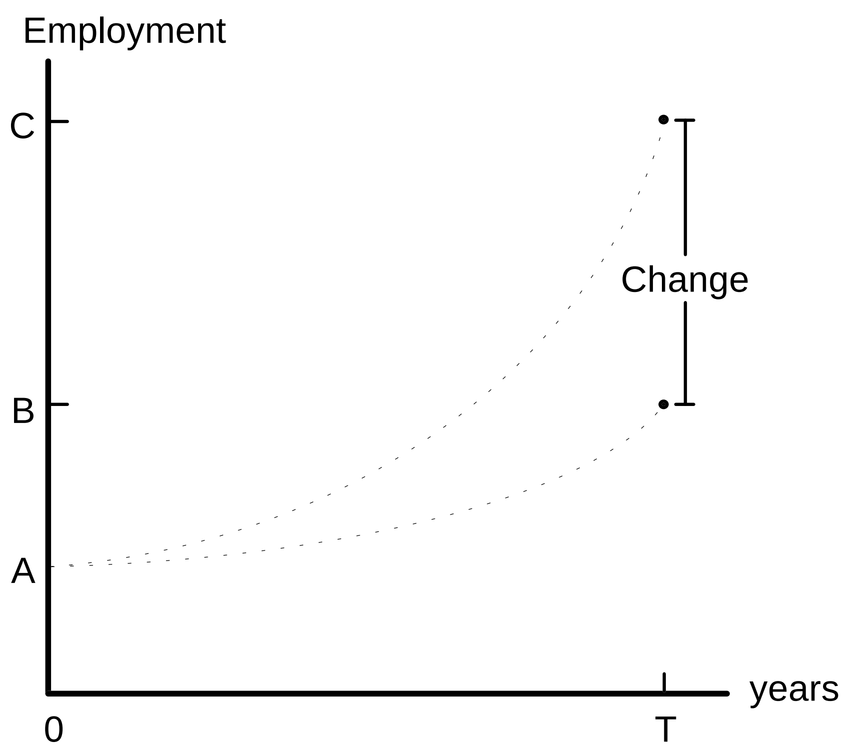


**Figure 1. Comparative-static interpretation of results**

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.

There are also various dynamic versions of ORANI, to which this document refers only in passing. Results from the dynamic versions are also reported in percentage change form. Here, however, the changes compare two different instants in time. For example, in terms of Figure 1, results from a base forecast might refer to the change from A to B. Another set of results, incorporating the changed tariff, would refer to the change from A to C.

The dynamic versions of ORANI generally incorporate investment-capital accumulation relations which explicitly mention the length of the period T. A more important practical difference between dynamic and comparative-static applications is that dynamic models require far more information about changes in exogenous variables. Comparative-static simulation of the change from B to C requires, in addition to the initial database, only the value of the exogenous tariff change. For a dynamic simulation we must specify changes in *all* exogenous variables. Thus we would need to forecast changes in foreign prices, in all sorts of tax rates, in technology and in tastes.

MONASH is the current flagship of the ORANI line. It is a large dynamic model for which T is usually set to 1. A sequence of MONASH solutions are linked together, so that a complete MONASH forecast consists of a series of year-on-year changes for all of its many thousands of variables. By computing annual solutions, we are able to be fairly explicit about adjustment processes. The disadvantage, as mentioned above, is that the modeller is forced to postulate the future time-path of very many exogenous variables.

## 3. The Percentage-Change Approach to Model Solution

Many of the ORANI-G 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[3].

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:

---

[3] For a detailed treatment of the linearised approach to AGE modelling, see the Black Book. Chapter 3 contains information about Euler's method and multistep computations.

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

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 **Y** and **X**. Otherwise, linearisation error may occur. The error is illustrated by Figure 2, 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, $Y^{exact}$.

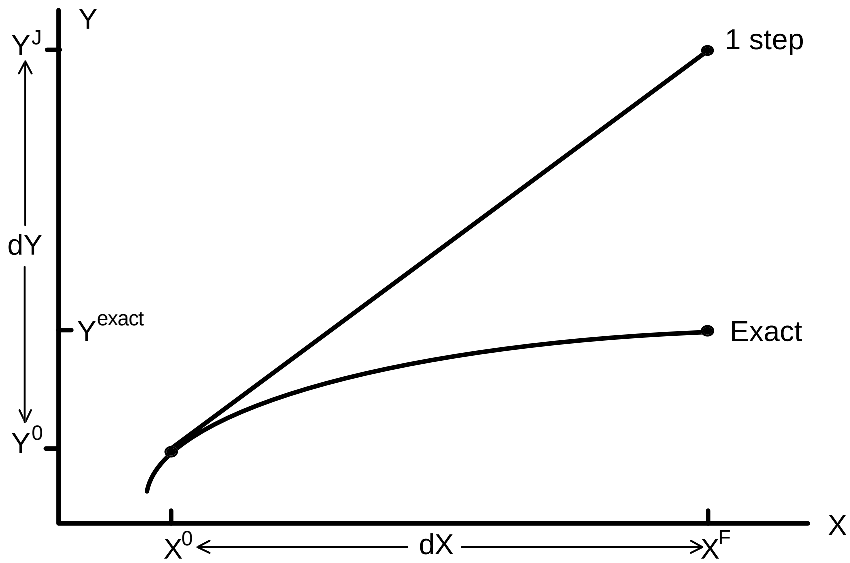


**Figure 2. Linearisation error**

Figure 2 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 3. 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 3), 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.

The technique illustrated in Figure 3, 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, **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%.

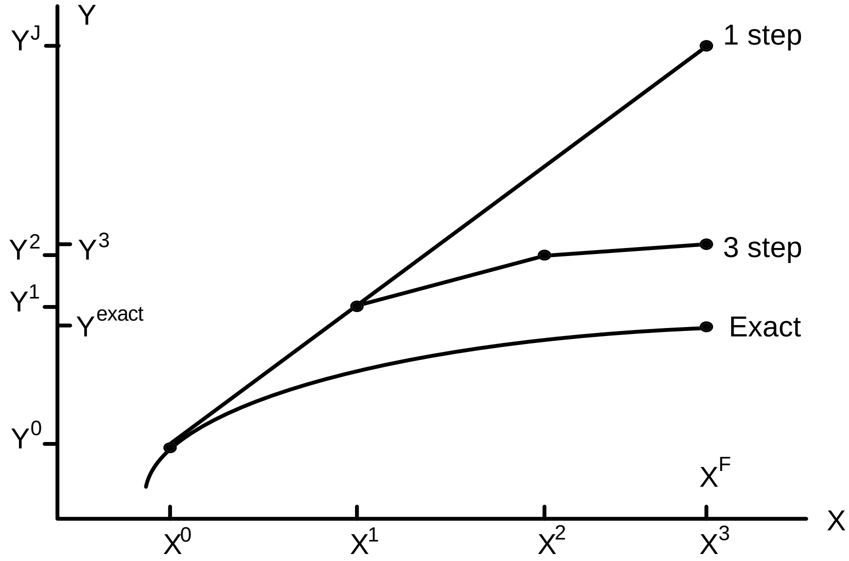


**Figure 3. Multistep process to reduce linearisation error**

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 ($\mathbf{X}$,$\mathbf{Y}$).

In practice, for typical AGE models, it is unnecessary, during a multistep computation, to record values for every element in **X** and **Y**. Instead, we can define a set of *data coefficients* **V**, which are functions of **X** and **Y**, i.e., $\mathbf{V} = \mathbf{H}(\mathbf{X},\mathbf{Y})$. Most elements of **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 **V**; often indeed identical to elements of **V**. After each small change, **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 **V**, rather than **X** and **Y**, are twofold:

- the expressions for $\mathbf{G}_Y$ and $\mathbf{G}_X$ in terms of **V** tend to be simple, often far simpler than the original **F** functions; and
- there are fewer elements in **V** than in **X** and **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*

To illustrate the convenience of the linear approach[4], 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):

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

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

The $\delta_k$ and $\rho$ are behavioural parameters. To solve the model in the levels, the values of the $\delta_k$ 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 $\rho$. 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). $\rho$ is normally given by econometric estimates of the elasticity of substitution, $\sigma$ (=1/($\rho$+1)). With the $P_k$, $X_k$, Z and $\rho$ known, the $\delta_k$ can be deduced.

In the solution phase of the levels model, $\delta_k$ and $\rho$ 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

[4] For a comparison of the levels and linearised approaches to solving AGE models see Hertel, Horridge & Pearson (1992).

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):

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

and $$p_{ave} = \sum_{i=1}^{N} S_i p_i, \qquad \text{where the } S_i \text{ are cost shares, eg, } S_i = V_i \Big/ \sum_{k=1}^{N} V_k \qquad (11)$$

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 $\delta_k$ parameters do not appear. However, the flows data $V_k$ again form the starting point. After each change they are updated by:

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

GEMPACK is designed to make the linear solution process as easy as possible. The user specifies the linear equations (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.

In practice, the ORANI database does not, like B in Figure 1, 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 coefficients 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, (Dixon, Parmenter and Rimmer, 1986).[5]

[5] We claim here that, for example, the estimate that a reduction in the textile tariff would reduce textile employment 5 years hence by, say, 7%, is not too sensitive to the fact that our simulation started from today's database rather than a database representing the economy in 5 years time. Nevertheless, the social implications of a 7% employment loss depend closely on whether textile employment is projected to grow in the absence of any tariff cut. To examine this question we need a forecasting model, such as MONASH. If a MONASH control scenario had textile employment grow annually by 1.5%, the 7% reduction could be absorbed without actually firing any textile workers.

## 4. The Equations of ORANI-G

In this section we provide a formal description of the linear form of the model. 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 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 simulations); 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.[6]

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 '×'.

---

[6] For equation E_x we could have written: (all, j, FAC)  x(j) = z - SIGMA*[p(j) - p_f], without affecting simulation results. Our convention that the index, (f), be the same as the initial letter of the set it ranges over, aids comprehension but is not enforced by GEMPACK. By contrast, GAMS (a competing software package) enforces consistent usage of set indices by rigidly connecting indices with the corresponding sets.

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-G 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 4 is a schematic representation of the model's input-output database. It reveals the basic structure of the model. The column headings in the main part of the figure (an absorption matrix) identify the following demanders:

(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.

| | | 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 4. The ORANI-G Flows Database**

The entries in each column show the structure of the purchases made by the agents identified in the column heading. 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 column. 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 illustrative absorption matrix in Figure 4 contains the name of the corresponding data matrix. 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 4 shows the value of output of each commodity by each industry. Finally, tariffs on imports 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.

### *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.

```
! Excerpt 1 of TABLO input file: !
! Definitions of sets !

Set                                                                  ! Subscript !
 COM         # Commodities #
 ( C1Cereals, C2Broadacre, C3Intensive, C4MiningEx, C5MiningOth,
   C6FoodFibre, C7FoodOther, C8TCF, C9Wood, C10Chem, C11NonMetal,
   C12MetalP, C13TrnspEq, C14OthMach, C15OthManu, C16Utilities,
   C17Constr, C18W_RTrade, C19Transport, C20Finance, C21Dwellings,
   C22PublServ, C23PrivServ );                                         ! c !
 SRC         # Source of commodities #   (dom,imp);                    ! s !
 IND         # Industries #
  ( I1Broadacre, I2Intensive, I3MiningEx, I4MiningOth,
   I5FoodFibre, I6FoodOther, I7TCF, I8Wood, I9Chem, I10NonMetal,
   I11MetalP, I12TrnspEq, I13OthMach, I14OthManu, I15Utilities,
   I16Constr, I17W_RTrade, I18Transport, I19Finance, I20Dwellings,
   I21PublServ, I22PrivServ );                                         ! i !
 OCC         # Occupation types #        (skilled,unskilled);          ! o !
 MAR         # Margin commodities #      (C18W_RTrade,C19Transport); ! m !

Subset MAR is subset of COM;
Set NONMAR # Non-margin commodities # = COM - MAR;                     ! n !

Set TRADEXP # Traditional export commodities #
  ( C1Cereals, C2Broadacre, C4MiningEx, C6FoodFibre);
Subset TRADEXP is subset of COM;
Set NTRADEXP # Nontraditional Export Commodities # = COM - TRADEXP;

Set EXOGINV # 'exogenous' investment industries # ( I21PublServ, I22PrivServ );
Subset EXOGINV is Subset of IND;
Set ENDOGINV # 'endogenous' investment industries # = IND - EXOGINV;
```

The commodity, industry, and occupational classifications are aggregates of the classifications used in the original version of ORANI, 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.

Commodities 18 and 19 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 follows the list of MAR elements is required for TABLO to realize that the two elements of MAR, 'C18W_RTrade' and 'C19Transport' are the same as the 18th and 19th elements of the set COM.

The subset TRADEXP allows us to single out certain commodities for special treatment in the export demand equations, described later. Similarly, we shall see below that investment in a group of industries, EXOGINV, is treated differently.

The statements for NONMAR, NTRADEXP, and ENDOGINV define those sets as complements. That is, NONMAR consists of all those elements of COM which are not in MAR. In this case TABLO is able to deduce that NONMAR must be a subset of COM.

**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 |

### *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. 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 or averaged, for example,

| | |
|---|---|
| _i | over IND (industries), |
| _c | over COM (commodities), |
| _io | 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 4. 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[7]. 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 4, 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 4, 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.

[7] Exports (V4BAS) are valued with price vector pe. Unless we activate the optional CET transformation between goods destined for export and those for local use, the pe are identical to the domestic part of p0. See Excerpt 19.

```
! Excerpt 2 of TABLO input file: !
! Variables relating to commodity flows !

Variable
! Basic Demands for commodities (excluding margin demands) !
(all,c,COM)(all,s,SRC)(all,i,IND)  x1(c,s,i)  # Intermediate basic demands #;
(all,c,COM)(all,s,SRC)(all,i,IND)  x2(c,s,i)  # Investment basic demands #;
(all,c,COM)(all,s,SRC)             x3(c,s)    # Household basic demands #;
(all,c,COM)                        x4(c)      # Export basic demands #;
(all,c,COM)(all,s,SRC)             x5(c,s)    # Government basic demands #;
(change) (all,c,COM)(all,s,SRC)    delx6(c,s) # Inventories demands #;

(all,c,COM)(all,s,SRC)  p0(c,s)     # Basic prices by commodity and source #;

! Technical or Taste Change Variables affecting Basic Demands !
(all,c,COM)(all,s,SRC)(all,i,IND)  a1(c,s,i) # Intermediate basic tech change #;
(all,c,COM)(all,s,SRC)(all,i,IND)  a2(c,s,i) # Investment basic tech change #;
(all,c,COM)(all,s,SRC)             a3(c,s)   # Household basic taste change #;
(all,c,COM)(all,s,SRC)             f5(c,s)   # Government 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 margin demands #;
(all,c,COM)(all,s,SRC)(all,i,IND)(all,m,MAR)
                                  x2mar(c,s,i,m)# Investment margin demands #;
(all,c,COM)(all,s,SRC)(all,m,MAR) x3mar(c,s,m)  # Household margin demands #;
(all,c,COM)(all,m,MAR)            x4mar(c,m)    # Export margin demands #;
(all,c,COM)(all,s,SRC)(all,m,MAR) x5mar(c,s,m)  # Government margin demands #;

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

! Powers of Commodity Taxes on Basic Flows !
(all,c,COM)(all,s,SRC)(all,i,IND)  t1(c,s,i)  # Power of tax on intermediate #;
(all,c,COM)(all,s,SRC)(all,i,IND)  t2(c,s,i)  # Power of tax on investment #;
(all,c,COM)(all,s,SRC)             t3(c,s)    # Power of tax on household #;
(all,c,COM)                        t4(c)      # Power of tax on export #;
(all,c,COM)(all,s,SRC)             t5(c,s)    # Power of tax on government #;

! Purchaser's Prices (including margins and taxes) !
(all,c,COM)(all,s,SRC)(all,i,IND) p1(c,s,i)# Purchaser's price, intermediate #;
(all,c,COM)(all,s,SRC)(all,i,IND) p2(c,s,i)# Purchaser's price, investment #;
(all,c,COM)(all,s,SRC)            p3(c,s)  # Purchaser's price, household #;
(all,c,COM)                       p4(c)    # Purchaser's price, exports $A #;
(all,c,COM)(all,s,SRC)            p5(c,s)  # Purchaser's price, government #;
```

Excerpt 3 of the TABLO Input file corresponds to the remaining rows of Figure 4. The first group of variables relates to industry demands for labour (V1LAB in Figure 4). 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 4). 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.

```
! Excerpt 3 of TABLO input file: !
!  Variables for primary-factor flows, commodity supplies and import duties !

! Variables relating to usage of labour, occupation o, in industry i !
(all,i,IND)(all,o,OCC)   x1lab(i,o)  # Employment by industry and occupation #;
(all,i,IND)(all,o,OCC)   p1lab(i,o)  # Wages by industry and occupation #;
(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 #;

! 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)        # Shift in price of "other cost" tickets #;

! Variables relating to commodity supplies, import duties and stocks !
(all,c,COM)(all,i,IND)  q1(c,i)     # Output by commodity and industry #;
(all,c,COM)             t0imp(c)    # Power of tariff #;
(all,c,COM)(all,s,SRC)  fx6(c,s)    # Shifter on rule for stocks #;
```

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.

```
! Excerpt 4 of TABLO input file: !
! Variables describing composite commodities !

! Demands for import/domestic commodity composites !
(all,c,COM)(all,i,IND)  x1_s(c,i)  # Intermediate use of imp/dom composite #;
(all,c,COM)(all,i,IND)  x2_s(c,i)  # Investment use of imp/dom composite #;
(all,c,COM)             x3_s(c)    # Household use of imp/dom composite #;
(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)  # Price, intermediate imp/dom composite #;
(all,c,COM)(all,i,IND)  p2_s(c,i)  # Price, investment imp/dom composite #;
(all,c,COM)             p3_s(c)    # Price, household imp/dom composite #;

! Technical or Taste Change Variables for import/domestic composites !
(all,c,COM)(all,i,IND)  a1_s(c,i) # Tech change, int'mdiate imp/dom composite #;
(all,c,COM)(all,i,IND)  a2_s(c,i) # Tech change, investment imp/dom composite #;
(all,c,COM)             a3_s(c)   # Taste change, household imp/dom composite #;
(all,c,COM)             a3lux(c)  # Taste change, supernumerary demands #;
(all,c,COM)             a3sub(c)  # Taste change, subsistence demands #;
```

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.

```
! Excerpt 5 of TABLO input file: !
! Miscellaneous vector variables !

Variable
(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,c,COM)  f0tax_s(c)     # General sales tax shifter #;
(all,o,OCC)  f1lab_i(o)     # Occupation-specific wage shifter #;
(all,i,IND)  f1lab_o(i)     # Industry-specific wage 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)  p0com(c)       # Output price of locally-produced commodity #;
(all,c,COM)  p0dom(c)       # Basic price of domestic goods = p0(c,"dom") #;
(all,c,COM)  p0imp(c)       # Basic price of imported goods = p0(c,"imp") #;
(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)       # Cost of unit of capital #;
(All,c,COM)  pe(c)          # Basic price of export commodity #;
(all,c,COM)  pf0cif(c)      # C.I.F. foreign currency import prices #;
(all,c,COM)  x0com(c)       # Output of commodities #;
(all,c,COM)  x0dom(c)       # Output of commodities for local market #;
(all,c,COM)  x0imp(c)       # Total supplies of imported goods #;
(all,o,OCC)  x1lab_i(o)     # Employment by occupation #;
(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 #;
```

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 variable in this excerpt is an ordinary change. This variable may (in the levels) equal zero or change sign.

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 4).

Excerpt 7 contains the basic commodity flows corresponding to rows 1 (direct flows) and 2 (margins flows) of Figure 4. 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').

```
! Excerpt 6 of TABLO input file: !
! Scalar or macro variables !

Variable
(change) delB    # (Balance of trade)/GDP #;
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 #;
f3tot            # Ratio, consumption/GDP #;
f4p_ntrad        # Upward demand shift, non-traditional export aggregate #;
f4q_ntrad        # Right demand shift, non-traditional export aggregate #;
f4tax_ntrad      # Uniform % change in powers of taxes on nontradtnl exports #;
f4tax_trad       # Uniform % change in powers of taxes on tradtnl exports #;
f5tax_cs         # Uniform % change in powers of taxes on government usage #;
f5tot            # Overall shift term for government demands #;
f5tot2           # Ratio between f5tot and x3tot #;
p0cif_c          # Imports price index, C.I.F., $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 #;
p1lab_io         # Average nominal wage #;
p2tot_i          # Aggregate investment price index #;
p3tot            # Consumer price index #;
p4_ntrad         # Price, non-traditional export aggregate #;
p4tot            # Exports price index #;
p5tot            # Government price index #;
p6tot            # Inventories price index #;
phi              # Exchange rate, $A/$world #;
q                # Number of households #;
realwage         # Average real wage #;
utility          # Utility per household #;
w0cif_c          # C.I.F. $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 export #;
w4tot            # $A border value of exports #;
w5tax_cs         # Aggregate revenue from indirect taxes on government #;
w5tot            # Aggregate nominal value of government demands #;
w6tot            # Aggregate nominal value of inventories #;
x0cif_c          # Import volume index, C.I.F. 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 government demands #;
x6tot            # Aggregate real inventories #;
```

```
! Excerpt 7 of TABLO input file: !
! Data coefficients relating to basic commodity flows !

File  MDATA  # Data file #;

Coefficient  ! Basic Flows of Commodities!
 (all,c,COM)(all,s,SRC)(all,i,IND)  V1BAS(c,s,i)  # Intermediate basic flows #;
 (all,c,COM)(all,s,SRC)(all,i,IND)  V2BAS(c,s,i)  # Investment basic flows #;
 (all,c,COM)(all,s,SRC)             V3BAS(c,s)    # Household basic flows #;
 (all,c,COM)                        V4BAS(c)      # Export basic flows #;
 (all,c,COM)(all,s,SRC)             V5BAS(c,s)    # Government basic flows #;
 (all,c,COM)(all,s,SRC)             V6BAS(c,s)    # Inventories basic flows #;
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)      = pe(c)*x4(c);
 (all,c,COM)(all,s,SRC)             V5BAS(c,s)    = p0(c,s)*x5(c,s);

Coefficient (all,c,COM)(all,s,SRC) LEVP0(c,s) # Levels basic prices #;
Formula (Initial) (all,c,COM)(all,s,SRC) LEVP0(c,s) = 1; ! arbitrary setting !
Update   (all,c,COM)(all,s,SRC) LEVP0(c,s) = p0(c,s);
(change) (all,c,COM)(all,s,SRC)
        V6BAS(c,s) = V6BAS(c,s)*p0(c,s)/100 + LEVP0(c,s)*delx6(c,s);

Coefficient  ! Margin Flows!
 (all,c,COM)(all,s,SRC)(all,i,IND)(all,m,MAR)
                                    V1MAR(c,s,i,m)  # Intermediate margins #;
 (all,c,COM)(all,s,SRC)(all,i,IND)(all,m,MAR)
                                    V2MAR(c,s,i,m)  # Investment margins #;
 (all,c,COM)(all,s,SRC)(all,m,MAR)  V3MAR(c,s,m)    # Households margins #;
 (all,c,COM)(all,m,MAR)             V4MAR(c,m)      # Export margins #;
 (all,c,COM)(all,s,SRC)(all,m,MAR)  V5MAR(c,s,m)    # Government margins #;
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)  = p0dom(m)*x1mar(c,s,i,m);
 (all,c,COM)(all,s,SRC)(all,i,IND)(all,m,MAR)
                V2MAR(c,s,i,m)  = p0dom(m)*x2mar(c,s,i,m);
 (all,c,COM)(all,s,SRC)(all,m,MAR)
                V3MAR(c,s,m)    = p0dom(m)*x3mar(c,s,m);
 (all,c,COM)(all,m,MAR)
                V4MAR(c,m)      = p0dom(m)*x4mar(c,m);
 (all,c,COM)(all,s,SRC)(all,m,MAR)
                V5MAR(c,s,m)    = p0dom(m)*x5mar(c,s,m);
```

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:

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

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 4. 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.

```
! Excerpt 8 of TABLO input file: !
! Data coefficients relating to commodity taxes !

Coefficient  ! Taxes on Basic Flows!
 (all,c,COM)(all,s,SRC)(all,i,IND)  V1TAX(c,s,i) # Taxes on intermediate #;
 (all,c,COM)(all,s,SRC)(all,i,IND)  V2TAX(c,s,i) # Taxes on investment #;
 (all,c,COM)(all,s,SRC)             V3TAX(c,s)   # Taxes on households #;
 (all,c,COM)                        V4TAX(c)     # Taxes on export #;
 (all,c,COM)(all,s,SRC)             V5TAX(c,s)   # Taxes on government #;
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) + pe(c)]/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 9 relates to the primary-input flows in rows 4-7 of Figure 4. 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 4 (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) # Multiproduction matrix #;
Read MAKE from file MDATA header "MAKE";
Update (all,c,COM)(all,i,IND) MAKE(c,i)= p0com(c)*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 4.

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 composite commodities 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.

```
! Excerpt 11 of TABLO input file: !
! Aggregates and shares of flows at purchasers' prices !

Coefficient ! Flows at Purchasers prices !
 (all,c,COM)(all,s,SRC)(all,i,IND)  V1PUR(c,s,i)  # Intermediate purch. value #;
 (all,c,COM)(all,s,SRC)(all,i,IND)  V2PUR(c,s,i)  # Investment purch. value #;
 (all,c,COM)(all,s,SRC)             V3PUR(c,s)    # Households purch. value #;
 (all,c,COM)                        V4PUR(c)      # Export purch. value #;
 (all,c,COM)(all,s,SRC)             V5PUR(c,s)    # Government purch. value #;
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) # Dom+imp intermediate purch. value #;
 (all,c,COM)(all,i,IND)     V2PUR_S(c,i) # Dom+imp investment purch. value #;
 (all,c,COM)                V1PUR_SI(c)  # Dom+imp intermediate purch. value #;
 (all,c,COM)                V2PUR_SI(c)  # Dom+imp investment purch. value #;
 (all,c,COM)                V3PUR_S(c)   # Dom+imp households purch. value #;
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)                V1PUR_SI(c)   = sum{i,IND, V1PUR_S(c,i) };
 (all,c,COM)                V2PUR_SI(c)   = sum{i,IND, V2PUR_S(c,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) # Intermediate source shares #;
 (all,c,COM)(all,s,SRC)(all,i,IND)  S2(c,s,i) # Investment source shares #;
 (all,c,COM)(all,s,SRC)             S3(c,s)   # Households source shares #;
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 12 covers the computation of some useful cost and usage aggregates.

```
! Excerpt 12 of TABLO input file: !
! 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 of industry i #;
 (all,i,IND)  V2TOT(i)    # Total capital created for industry i #;
 (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)    = V1PRIM(i) + V1OCT(i) + sum{c,COM,  V1PUR_S(c,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) MARSALES(c) # Total usage for margins purposes #;
Formula (all,m,MAR) MARSALES(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) MARSALES(n) = 0.0;

Coefficient (all,c,COM) DOMSALES(c) # Total sales to local market #;
Formula (all,c,COM)
   DOMSALES(c) = sum{i,IND, V1BAS(c,"dom",i) + V2BAS(c,"dom",i) }
    + V3BAS(c,"dom") + V5BAS(c,"dom") + V6BAS(c,"dom") + MARSALES(c);

Coefficient (all,c,COM) SALES(c) # Total sales of domestic commodities #;
Formula (all,c,COM) SALES(c) = DOMSALES(c) + V4BAS(c);

! 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")+ V6BAS(c,"imp");

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.

```
! Excerpt 13 of TABLO input file: !
! Income-Side Components of GDP !

Coefficient ! Total indirect tax revenues !
 V1TAX_CSI  # Total intermediate tax revenue #;
 V2TAX_CSI  # Total investment tax revenue #;
 V3TAX_CS   # Total households tax revenue #;
 V4TAX_C    # Total export tax revenue #;
 V5TAX_CS   # Total government tax revenue #;
 V0TAR_C    # Total tariff revenue #;
 V0TAX_CSI  # Total 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 14 covers the computation of GDP from the expenditure side.

```
! Excerpt 14 of TABLO input file: !
! Expenditure-side components of GDP !

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 government 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, sum{s,SRC, V6BAS(c,s) }};
 V0GDPEXP  = V3TOT + V2TOT_I + V5TOT + V6TOT + V4TOT - V0CIF_C;

Coefficient TINY # Small number to prevent singular matrix #;
Formula TINY = 0.000000000001;
```

The last coefficient in Excerpt 14, TINY, will be used extensively in later sections. Note for now that it is several orders of magnitude smaller than typical database flows.

### *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-G allows each industry to produce several commodities, using as inputs domestic and imported commodities, labour of several types, land, capital and 'other costs'. In addition, commodities destined for export are distinguished from those for local use. The multi-input, multi-output production specification is kept manageable by a series of separability assumptions, illustrated by the nesting shown in Figure 5. For example, the assumption of *input-output separability* implies that the generalised production function for some industry:

F(inputs, outputs) = 0 (15)

may be written as:

G(inputs) = X1TOT = H(outputs) (16)

where X1TOT is an index of industry activity. Assumptions of this type reduce the number of estimated parameters required by the model. Figure 5 shows that the H function in (16) is derived from two nested CET (constant elasticity of transformation) aggregation functions, 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 5 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.

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.

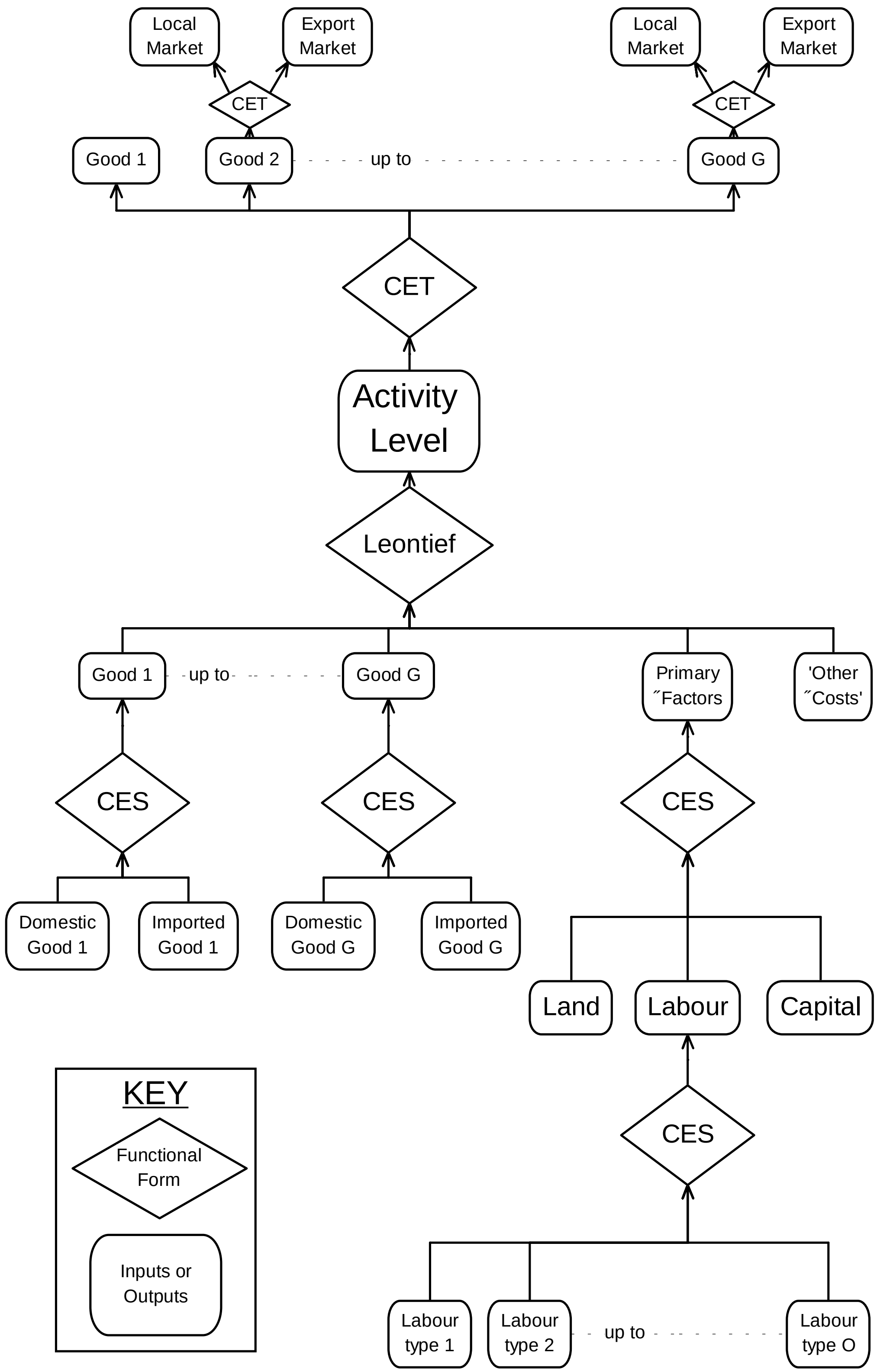


**Figure 5. Structure of Production**

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.

For an industry which does not use labour (housing services is a common example), V1LAB(i,o) would contain only zeros so that p1lab_o(i) would be undefined. To prevent this, we add the coefficient TINY (set to some very small number) to the left hand side of equation E_p1lab_o. With V1LAB_O(i) zero, equation E_p1lab_o becomes:

p1lab_o(i) = 0.

The same procedure is used extensively in later equations.

```
! Excerpt 15 of TABLO input file: !
! Occupational composition of labour demand !
!$  Problem: for each industry i, minimize labour cost    !
!$          sum{o,OCC, P1LAB(i,o)*X1LAB(i,o) }            !
!$   such that  X1LAB_O(i) = CES( All,o,OCC: X1LAB(i,o) ) !

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)
 [TINY+V1LAB_O(i)]*p1lab_o(i) = sum{o,OCC, V1LAB(i,o)*p1lab(i,o) };
```

Excerpt 16 contains equations determining 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:

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

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 cost of an effective unit 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.

```
! Excerpt 16 of TABLO input file: !
! Primary factor proportions !
!$  X1PRIM(i) =                !
!$    CES( X1LAB_O(i)/A1LAB_O(i), X1CAP(i)/A1CAP(i), X1LND(i)/A1LND(i) ) !

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_p1cap  # 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)];
```

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.

*4.9. Demands for intermediate inputs*

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:

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

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 effective 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.

```
! Excerpt 17 of TABLO input file: !
! Import/domestic composition of intermediate demands !
!$  X1_S(c,i) = CES( All,s,SRC: X1(c,s,i)/A1(c,s,i) ) !

Coefficient (all,c,COM) SIGMA1(c) # Armington elasticities: intermediate #;
Read SIGMA1 from file MDATA header "1ARM";

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 5. Commodity composites, the primary-factor composite and 'other costs' are combined using a Leontief production function, given by:

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

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: !
! Top nest of industry input demands !
!$  X1TOT(i) = MIN( All,c,COM: X1_S(c,i)/[A1_S(c,s,i)*A1TOT(i)],  !
!$                             X1PRIM(i)/[A1PRIM(i)*A1TOT(i)],     !
!$                             X1OCT(i)/[A1OCT(i)*A1TOT(i)] )   !

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)];
```

ORANI-G allows for each industry to produce a mixture of all the commodities. For each industry, the mix varies, according to the relative prices of commodities. The first two equations of Excerpt 19A determine the commodity composition of industry output—the final nest of Figure 5. Here, the total revenue from all outputs is *maximised* subject to the production function:

$$\mathrm{X1TOT(i)} = \mathrm{CET[\ All,c,COM: Q1(c,i)]}. \tag{19}$$

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. In equation E_q1, an increase in a commodity price, relative to the average, induces transformation in favour of that output. The symbol, p1tot, defined in E_x1tot as 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.

Note that all industries that produce, say, Cereals, receive the same unit price, p0com("Cereals"). Cereals produced by different industries are deemed to be perfect substitutes. Equation E_x0com simply adds up all industries' output of each commodity to get the total supply, x0com.

Most non-Australian applications of the ORANI-G framework enforce a one-to-one correspondence between industries and commodities[8]. This is implied whenever all off-diagonal elements of the MAKE matrix are zero. In this case, the equations of Excerpt 19A just equate corresponding elements of p0com and p1tot. Similarly, x1tot and x0com become, in effect, the same variable. The computational overhead of including Excerpt 19A is very slight.

```
! Excerpt 19A of TABLO input file: !
! Output mix of commodities !

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)*[p0com(c) - p1tot(i)];

Coefficient
 (all,i,IND) MAKE_C(i) # All production by industry i #;
 (all,c,COM) MAKE_I(c) # Total production of commodities #;
Formula
 (all,i,IND) MAKE_C(i) = sum{c,COM, MAKE(c,i) };
 (all,c,COM) MAKE_I(c) = sum{i,IND, 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)*p0com(c) };

Equation E_x0com # Total output of commodities #
(all,c,COM) MAKE_I(c)*x0com(c) = sum{i,IND, MAKE(c,i)*q1(c,i) };
```

Excerpt 19B allows for the possibility that goods destined for export are not the same as those for local use[9]. Conversion of an undifferentiated commodity into goods for both destinations is governed by a CET transformation frontier. Conceptually, the system is the same as Excerpt 19A, but it is expressed a little differently; partly because there are only two outputs; and partly to facilitate switching the system off. This is achieved by setting TAU to zero, so that p0com, p0dom and pe are all equal.

The names of the prices, quantities and flows in the two CET nests of Excerpt 19 are shown below:

| | Joint Production CET Nest | | | | |
|---|---|---|---|---|---|
| Type of Variable | Industry Output | Commodity Outputs | Undifferentiated Commodity | Local Destination | Export Destination |
| %Δ quantity | x1tot(i) | q1(c,i) | x0com(c) | x0dom(c) | x4(c) |
| %Δ price | p1tot(i) | p0com(c) | p0com(c) | p0dom(c) = p0(c,"dom") | pe(c) |
| Value of flow | V1TOT(i) | MAKE(c,i) | SALES(c) | DOMSALES(c) | V4BAS(c) |
| | | | Export/Domestic CET nest | | |

[8] Multiproduction can be useful even where each industry produces just one commodity. For example we could split electricity generation into 2 parts: oil-fired and nuclear, each producing the same commodity, electricity.
[9] This feature is not part of the ORANI tradition, but appears in some other applied GE models.

```
! Excerpt 19B of TABLO input file: !
! CET between outputs for local and export markets !

Coefficient
 (all, c,COM) EXPSHR(c) # share going to exports #;
 (all, c,COM) TAU(c) # 1/elast. of transformation, exportable/locally used #;
Zerodivide Default 0.5;
Formula
 (all,c,COM) EXPSHR(c) = V4BAS(c)/SALES(c);
 (all,c,COM) TAU(c) = 0.0; ! if zero, p0dom = pe, and CET is nullified !
Zerodivide Off;

Equation E_x0dom  # supply of commodities to export market #
 (all,c,COM) TAU(c)*[x0dom(c) - x4(c)] = p0dom(c) - pe(c);

Equation E_pe     # supply of commodities to domestic market #
 (all,c,COM) x0com(c) = [1.0-EXPSHR(c)]*x0dom(c) + EXPSHR(c)*x4(c);

Equation E_p0com  # Zero pure profits in transformation #
 (all,c,COM) p0com(c) = [1.0-EXPSHR(c)]*p0dom(c) + EXPSHR(c)*pe(c);

! Map between vector and matrix forms of basic price variables !

Equation E_p0dom  # Basic price of domestic goods = p0(c,"dom") #
 (all,c,COM) p0dom(c) = p0(c,"dom");

Equation E_p0imp  # Basic price of imported goods = p0(c,"imp") #
 (all,c,COM) p0imp(c) = p0(c,"imp");
```

### *4.10. Demands for investment goods*

Figure 6 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.

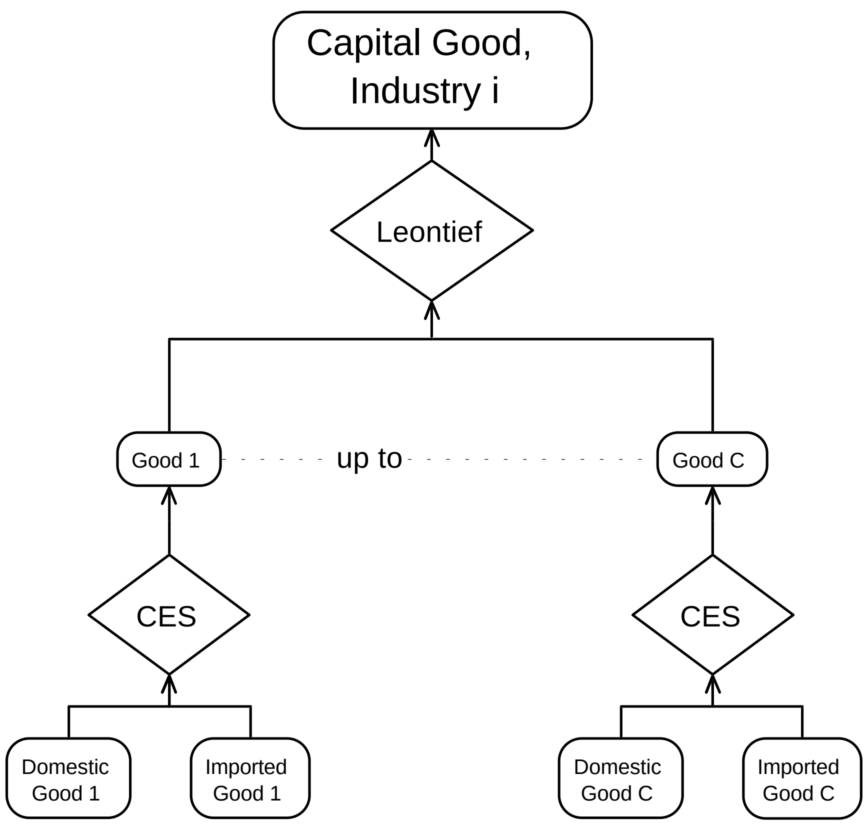


**Figure 6. Structure of Investment Demand**

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:

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

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

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

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.

```
! Excerpt 20 of TABLO input file: !
! Investment demands !
!$  X2_S(c,i) = CES( All,s,SRC: X2(c,s,i)/A2(c,s,i) ) !

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 !
!$  X2TOT(i) = MIN( All,c,COM: X2_S(c,i)/[A2_S(c,s,i)*A2TOT(i)] ) !

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)] };
```

### *4.11. Household demands*

As Figure 7 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 Klein-Rubin, rather than a Leontief, function, leading to the linear expenditure system (LES).

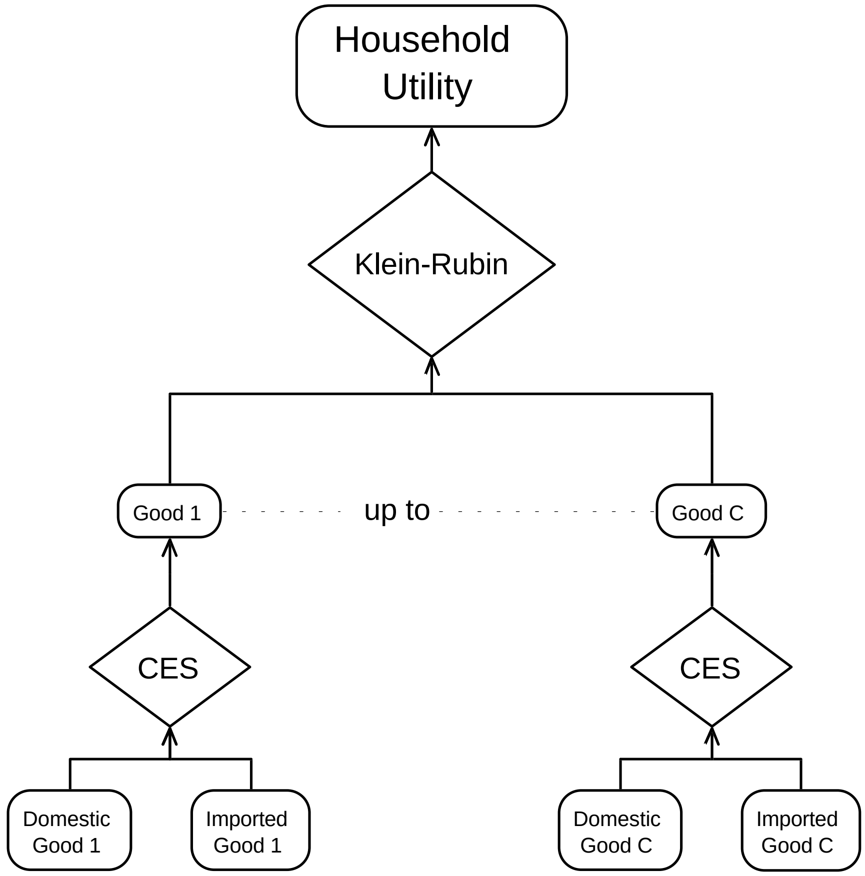


**Figure 7. Structure of Consumer Demand**

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

```
! Excerpt 21 of TABLO input file: !
! Import/domestic composition of household demands !

!$ X3_S(c,i) = CES( All,s,SRC: X3(c,s)/A3(c,s) ) !

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)] };
```

Excerpts 22 and 23 of the TABLO input file determine the allocation of household expenditure between commodity composites. They are derived from the Klein-Rubin utility function:

$$\text{Utility per household} = \frac{1}{Q}\prod_{c} \{X3\_S(c) - X3SUB(c)\}^{S3LUX(c)}, \tag{22}$$

The X3SUB and S3LUX are behavioural coefficients—the S3LUX must sum to unity. Q is the number of households. The demand equations that arise from this utility function are:

$$X3\_S(c) = X3SUB(c) + S3LUX(c)*V3LUX\_C/P3\_S(c), \tag{23}$$

where:

$$V3LUX\_C = V3TOT - \sum X3SUB(c)*P3\_S(c) \tag{24}$$

The name of the linear expenditure system derives from its property that expenditure on each good is a linear function of prices (P3_S) and expenditure (V3TOT). The form of the demand equations gives rise to the following interpretation. The X3SUB are said to be the 'subsistence' requirements of each good—these quantities are purchased regardless of price. V3LUX_C is what remains of the consumer budget after subsistence expenditures are deducted—we call this 'luxury' or 'supernumerary' expenditure. The S3LUX are the shares of this remnant allocated to each good—the marginal budget shares. Such an interpretation facilitates our transition to percentage change form, which begins from the levels equations:

$$X3\_S(c) = X3SUB(c) + X3LUX(c) \tag{25}$$

$$X3LUX(c)*P3\_S(c) = S3LUX(c)*V3LUX\_C \tag{26}$$

$$X3SUB(c) = Q*A3SUB(c) \tag{27}$$

As equation (25) makes plain, the X3LUX are luxury usages, or the difference between the subsistence quantities and total demands. Equation (26) states that luxury expenditures follow the marginal budget shares S3LUX. Together, equations (25) and (26) are equivalent to (23). Equation (27) is necessary because our demand system applies to aggregate instead of to individual households. It states that total subsistence demand for each good c is proportional to the number of households, Q, and to the individual household subsistence demands, A3SUB(c). The percentage change forms of equations (27), (26) and (25) appear as the first three items in Excerpt 23 of the Tablo Input File. Note that a3lux(c) is the percentage change in S3LUX(c).

Equation E_utility is the percentage-change form of the utility function (22). 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. See Appendix F for further details.

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.

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

Coefficient FRISCH # Frisch LES 'parameter'= - (total/luxury) #;
Read  FRISCH from file MDATA header "P021";
Update (change) FRISCH = FRISCH*[w3tot - w3lux]/100.0;

Coefficient (all,c,COM) EPS(c) # Household expenditure elasticities #;
Read  EPS from file MDATA header "XPEL";
Update (change)
(all,c,COM) EPS(c) = EPS(c)*[x3lux(c)-x3_s(c)+w3tot-w3lux]/100.0;

Coefficient (all,c,COM) S3_S(c) # Household average budget shares #;
Formula     (all,c,COM) S3_S(c) = V3PUR_S(c)/V3TOT;

Coefficient (all,c,COM) B3LUX(c)
 # Ratio, (supernumerary expenditure/total expenditure), by commodity #;
Formula (all,c,COM) B3LUX(c) = -EPS(c)/FRISCH;

Coefficient (all,c,COM) S3LUX(c) # Marginal household budget shares #;
Formula     (all,c,COM) S3LUX(c) = EPS(c)*S3_S(c);
```

The reader may wonder why there is no equation based on (24) which would determine the variable w3lux. The reason is that (24) can be deduced from (23) and the definition of V3TOT:

$$V3TOT = \sum X3\_S(c)*P3\_S(c) \tag{28}$$

The percentage change form of (28) in fact appears as equation E_w3tot later in the Tablo Input File (see Excerpt 31). Hence any additional equation defining w3lux would be redundant.

```
! Excerpt 23 of TABLO input file: !
! Commodity composition of household demand !

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) };
```

### *4.12. Export and other final demands*

To model export demands, commodities in ORANI-G 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:

$$X4(c) = F4Q(c)\left[\frac{P4(c)}{PHI*F4P(c)}\right]^{EXP\_ELAST(c)}, \qquad (29)$$

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-G 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). Demand for the aggregate is related to its average price *via* a constant-elasticity demand curve, similar to those for traditional exports (see equation E_x4_ntrad).

```
! Excerpt 24 of TABLO input file: !
! Export and government demands !

Coefficient V4NTRADEXP # Total non-traditional export earnings #;
Formula     V4NTRADEXP = sum{c,NTRADEXP, V4PUR(c)};

Coefficient (all,c,COM) EXP_ELAST(c)
  # Export demand elasticities: typical value -20.0 #;
Read EXP_ELAST from file MDATA header "P018";

Equation E_x4A  # Traditional export demand functions #
(all,c,TRADEXP) x4(c) - f4q(c) = EXP_ELAST(c)*[p4(c) - phi - f4p(c)];

Equation E_x4B  # 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 - f4q_ntrad   = EXP_ELAST_NT*[p4_ntrad - phi - f4p_ntrad];

Equation E_x5  # Government demands #
(all,c,COM)(all,s,SRC) x5(c,s) = f5(c,s) + f5tot;

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

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: !
! 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 government 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:

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

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)}

+ 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 to V3PUR(c,s) so that if it is 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:

P0(c,"imp") = PF0CIF(c)∗PHI∗T0IMP(c). (30)

```
! Excerpt 26 of TABLO input file: !
! The price system !

Coefficient TINY # Small number to prevent singular matrix #;
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)*[p0dom(m)+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)*[p0dom(m)+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)*[p0dom(m)+a3mar(c,s,m)] };

Equation E_p4 # Zero pure profits in exporting #
(all,c,COM)
[V4PUR(c)+TINY]*p4(c) =
  [V4BAS(c)+V4TAX(c)]*[pe(c)+ t4(c)]
+ sum{m,MAR, V4MAR(c,m)*[p0dom(m)+a4mar(c,m)] };
! note that we refer to export taxes,not subsidies !

Equation E_p5 # Zero pure profits in distribution of government #
(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)*[p0dom(m)+a5mar(c,s,m)] };

Equation E_p0A # 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_x0com 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—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 !

Equation E_p0B # Demand equals supply for non margin commodities #
(all,n,NONMAR)
  DOMSALES(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")
  +            V5BAS(n,"dom")*x5(n,"dom")   ! note exports omitted !
  +            100*LEVP0(n,"dom")*delx6(n,"dom");

Equation E_p0C # Demand equals supply for margin commodities #
(all,m,MAR)
  DOMSALES(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")
  +              V5BAS(m,"dom")*x5(m,"dom")   ! note exports omitted !
  +              100*LEVP0(m,"dom")*delx6(m,"dom")   ! now margin part !
  +  sum{c,COM,  V4MAR(c,m)*x4mar(c,m)   ! note nesting of sum parentheses !
  +  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) }}};

Equation E_x0imp # Import volumes #
(all,c,COM)
   [TINY + 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")
 +             100*LEVP0(c,"imp")*delx6(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).

*4.16. Indirect taxes*

ORANI-G allows for great flexibility in the treatment of indirect taxes. However, it is cumbersome to shock 3-dimensional variables such as t1 and t2 directly, because they have so many elements. Besides, most projected changes to tax rates have a fairly simple structure. For example, an increase in the tax on petrol might raise the price to all users by 10%. To simulate a tax change like this, it helps to include equations which implement the tax regime to be simulated. The effect is to replace multi-dimensional exogenous tax variables with vectors that are easier to shock.

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.[10]

```
! 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_t4A # Power of tax on sales to traditional exports #
  (all,c,TRADEXP)                    t4(c)      = f0tax_s(c) + f4tax_trad;
E_t4B # 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 government #
  (all,c,COM)(all,s,SRC)             t5(c,s)    = f0tax_s(c) + f5tax_cs;
```

The equations of Excerpt 29 compute percentage 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.,

$$\mathrm{VTAX} = \mathrm{VBAS(T\text{-}1)}. \qquad (31)$$

Hence: $\Delta\mathrm{VTAX} = \Delta\mathrm{VBAS(T\text{-}1)} + \mathrm{VBAS}\Delta\mathrm{T}$,

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

$$= \mathrm{VBAS(T\text{-}1)wbas/100 + VBAS{*}T{*}t/100},$$

$$= \mathrm{VTAX{*}wbas/100 + (VBAS+VTAX)t/100},$$

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:

$$\Delta\mathrm{VTAX} = \mathrm{VTAX(x+p)/100 + (VBAS+VTAX)t/100} \qquad (32)$$

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

---

[10] The same problem, that exogenous variables have too many dimensions, sometimes arises when we wish to simulate technical change. Suppose we wished to shock the variable a1 (which varies by commodity, source and industry). It might be simplest to write a new equation, like the equations of Excerpt 28, that related a1 to one or more new vector variables. The modeller is expected to add these equations and variables as required, since their form is experiment-specific.

```
! Excerpt 29 of TABLO input file: !
! Indirect tax revenue !

Equation
E_w1tax_csi # Revenue from indirect taxes on flows to intermediate #
  [TINY + 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 #
  [TINY + 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 #
  [TINY + 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 #
  [TINY + V4TAX_C]*w4tax_c = sum{c,COM,
    V4TAX(c)*[pe(c) + x4(c)] + [V4TAX(c)+ V4BAS(c)]*t4(c) };

E_w5tax_cs # Revenue from indirect taxes on flows to government #
  [TINY + 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 #
  [TINY+V0TAR_C]*w0tar_c = sum{c,COM,
    V0TAR(c)*[pf0cif(c) + phi + x0imp(c)] + V0IMP(c)*t0imp(c) };
```

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)) = 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)}).

```
! Excerpt 30 of TABLO input file: !
! Factor incomes and GDP !

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;
```

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.

```
! Excerpt 31 of TABLO input file: !
! GDP expenditure aggregates !

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;

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 government demands #
  V5TOT*x5tot = sum{c,COM, sum{s,SRC, V5PUR(c,s)*x5(c,s) }};
E_p5tot    # Government price index #
  V5TOT*p5tot = sum{c,COM, sum{s,SRC, V5PUR(c,s)*p5(c,s) }};
E_w5tot    # Aggregate nominal value of government demands #
  w5tot = x5tot + p5tot;

E_x6tot    # Inventories volume index #
  V6TOT*x6tot = 100*sum{c,COM, sum{s,SRC, LEVP0(c,s)*delx6(c,s) }};
E_p6tot    # Inventories price index #
  [TINY+V6TOT]*p6tot = sum{c,COM, sum{s,SRC, V6BAS(c,s)*p0(c,s) }};
E_w6tot    # Aggregate nominal value of inventories #
  w6tot = x6tot + p6tot;

E_x0cif_c  # Import volume index, C.I.F. weights #
  V0CIF_C*x0cif_c = sum{c,COM, V0CIF(c)*x0imp(c) };
E_p0cif_c  # Imports price index, $A C.I.F. #
  V0CIF_C*p0cif_c = sum{c,COM, V0CIF(c)*[phi+pf0cif(c)] };
E_w0cif_c  # Value of imports, $A C.I.F. #
  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;
```

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 percentage change is the sum of percentage changes in 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[11].

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 percentage changes in real GDP, the GDP deflator and nominal 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:

$$\text{V0GDPEXP} \equiv \text{V0GDPINC}, \text{ and } \text{w0gdpexp} \equiv \text{w0gdpinc}. \qquad (33)$$

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.

```
! Excerpt 32 of TABLO input file: !
! Trade balance and other aggregates !

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) };

Equation E_employ # Employment by industry #
(all,i,IND) V1LAB_O(i)*employ(i) = sum{o,OCC, V1LAB(i,o)*x1lab(i,o) };
```

[11] There is indeed no levels equation corresponding to our change definition of, say, the investment price index. A levels formulation could use either initial or final weights; our formula uses weights that vary continuously between these two values. Because our formula for p2tot_i can only be written in change form, results for that variable suffer from path-dependence: they depend slightly on details of the solution algorithm that should be irrelevant. The effect however is normally very small, and rarely propagates through to other equations.

```
E_employ_i  # Aggregate employment,wage bill weights #
  V1LAB_IO*employ_i= sum{i,IND, V1LAB_O(i)*employ(i) };

E_p1lab_io  # Average nominal wage #
  V1LAB_IO*p1lab_io = sum{i,IND, sum{o,OCC, V1LAB(i,o)*p1lab(i,o) }};

E_realwage  # Average real wage #
  realwage = p1lab_io - p3tot;

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 devaluation #
  p0realdev =  p0cif_c - p0gdpexp;
```

### *4.19. Rates of return and investment*

In this section we relate the creation of new capital stock in each industry to profitability in that industry. In recent years, ORANI has evolved into a dynamic model (MONASH) and the specification of investment behaviour has been in a state of flux. The implementation given here follows the original ORANI computer model. For a fuller explanation, the reader is referred to DPSV, Section 19.

Equation E_r1cap 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.

```
! Excerpt 33 of TABLO input file: !
! Investment equations !

!  Follows Section 19 of DPSV - warts and all.  In particular, the
ratios Q and G are treated as parameters, just as in the original
ORANI implementation.  Attempts to improve the theory by updating
these parameters have been found to occasionally lead to perversely
signed coefficients !

Variable
(all,i,IND)  finv(i)   # Investment shifter #;
(all,i,IND)  r1cap(i)  # Current rates of return on fixed capital #;
               omega   # Economy-wide "rate of return" #;

Equation E_r1cap # Definition of rates of return to capital #
(all,i,IND) r1cap(i) = 2.0*(p1cap(i) - p2tot(i));
! Note: above equation comes from DPSV equation 19.7.  The value 2.0
  corresponds to the DPSV ratio Q (= ratio, gross to net rate of
  return) and is a typical value of this ratio.  !

Equation E_x2totA # Investment rule #
(all,i,ENDOGINV)
x2tot(i) - x1cap(i) = finv(i) + 0.33*[r1cap(i) - omega];
! Note: above equation comes from substituting together DPSV
  equations 19.8-9. The value 0.33 corresponds to the DPSV ratio
  [1/G.Beta] and is a typical value of this ratio.  !

Equation E_x2totB # Investment in exogenous industries #
(all,i,EXOGINV) x2tot(i)=x2tot_i + finv(i);
```

Equation E_x2totA relates, for selected industries, the investment/capital ratio to the net rate of return (relative to the economy-wide rate, omega). 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 variable finv(i) allows exogenous shifts in investment. Equation E_x2totB gives a simple rule to determine investment in those industries for which the preceding theory is deemed inappropriate. These might be industries where investment is determined by government policy.

The DPSV theory of investment is directed at a short-run simulation with aggregate investment exogenous. This is made possible by leaving the variable omega endogenous. The same equations have been adapted to long-run simulations. Here, the r1cap and omega are held exogenous at zero change. Industry capital stocks and aggregate investment are endogenous. The effect is that investment in each industry moves in proportion to that industry's capital stock.

### *4.20. Indexation and other equations*

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.

Equation E_f3tot implements a simple, optional, consumption function. If f3tot is exogenous, the equation links household spending to nominal GDP. Otherwise, there is no effect on the rest of the system, since the variable f3tot appears nowhere else.

Equation E_delx6 shows one way that delx6, the change in the volume of goods going to inventories, might be endogenized. It states that the percentage change in the volume of each commodity, domestic or imported, going to inventories, is the same as the percentage change in domestic production of that commodity. Like the previous equation, E_delx6 can be insulated from the rest of the equation system—by leaving fx6 endogenous. A chief purpose for this equation is to facilitate the *real homogeneity test* described in Appendix I.

```
! Excerpt 34 of TABLO input file: !
! Indexing and other 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 !

Equation E_f3tot # Consumption function #
 w3tot = w0gdpexp + f3tot;

E_delx6 # possible rule for stocks #
(all,c,COM)(all,s,SRC) 100*LEVP0(c,s)*delx6(c,s)=V6BAS(c,s)*x0com(c)+fx6(c,s);
```

The equations described above 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. The remainder of the TABLO input file, described below, is supplementary material which does not directly affect simulation results.

### *4.21. Adding variables for explaining results*

Part of the ORANI tradition is that simulation results, although voluminous, must all be capable of verbal explanation based on model equations and data. It is customary to examine and present results in great detail. The aim is to dispel any tendency to treat the model as a black box. These detailed analyses sometimes yield theoretical insights; for example, we may find that some mechanism which we thought to be of minor significance exerts a dominant force in certain sectors. More often we discover errors: either in the data or in the model equations. Inappropriate theory may also lead to implausible results.

Results analysis, then, is an indispensable (but laborious) part of quality control for an economic model. To make it less painful, we often add equations and variables merely to help explain results. Excerpt 35 contains a useful example of this type of addition.

Suppose our simulation predicts an increase in domestic production of Textiles. This could be due to three causes:

- the local market effect: an increase in local usage of Textiles, whether domestically-produced or imported;
- the export effect: an increase in exports of Textiles; or
- the import share effect: a shift in local usage of Textiles, from imported to domestically-produced.

Very often these 3 effects will work in different directions; for example, a increase in foreign demand might pull local producers up the supply curve, so increasing the domestic price and facilitating import penetration. The decomposition of Fan[12], implemented in Excerpt 35, aims to show the relative magnitude of these 3 contributions to output change.

Suppose we have a variable X which is the sum of 2 parts:

$$X = A + B \qquad \text{or} \qquad PX = PA + PB \tag{34}$$

then, for small percentage changes, we can write:

$$x = \text{conta} + \text{contb} \qquad \text{where conta} = (PA/PX)a \quad \text{and} \quad \text{contb} = (PB/PX)b \tag{35}$$

We call conta and contb the *contributions* of A and B to the percentage change in X.
For larger changes, which require a multistep computation, equation (35) would result in values for conta and contb which did not quite add up to the total percentage change in X[13]. To avoid this, it is useful to specify both conta and contb as ordinary change variables and to define a new ordinary change variable, q, in such a way that the final result for q (after results for several computational steps have been accumulated) is identical to that for x. This leads to the small change equation:

$$X^0q = Xx \qquad \text{where } X^0 \text{ is the initial value of X,} \tag{36}$$

and to the revised decomposition:

$$q = \text{conta} + \text{contb} \tag{37}$$

$$\text{where} \quad \text{conta} = (PA/PX^0)a \quad \text{and} \quad \text{contb} = (PB/PX^0)b \tag{38}$$

Excerpt 35 starts by defining x0loc, the percentage change in local sales from both sources. Equation E_fandecompA says that this percentage, weighted by the value of local domestic sales, is the local market component of the percentage change in local production. Similarly, equation E_fandecompB defines the export component. In these equations INITSALES corresponds to the term $PX^0$ in equation (38): it is the initial value of sales, updated only by the change in price. Equation E_fandecompC corresponds to equation (37)—it defines the import share component as a residual[14]. Finally, equation E_fandecompD corresponds to equation (36).

---

[12] Named after Fan Ming-Tai of the Academy of Social Sciences, Beijing; their PRCGEM is one of the most elaborate versions of ORANI-G.

[13] The reason is that during a multistep computation percentage changes are compounded, whilst ordinary changes are added.

[14] No interactive term is concealed in the residual. Because these decompositions are specified in small change terms, the changes due to each part add up to the change in the whole. To convince yourself, retrace the example starting at equation (34) with the multiplicative form X = AB, leading to $X^0q = Xa + Xb$, with contribution terms $(X/X^0)a$ and $(X/X^0)b$. However, the cumulative results of these contributions can be defined only as a path integral of the contribution terms computed at each solution step. Hence they are not (quite) invariant to the details of our solution procedure. See also footnote 7.

```
! Excerpt 35 of TABLO input file: !
! Decomposition of Fan !

Set FANCAT # parts of Fan decomposition #
  (LocalMarket, ImportShare, Export, Total);

Variable
(all,c,COM) x0loc(c)  # real percent change in LOCSALES (dom+imp)  #;
(change)(all,c,COM)(all,f,FANCAT) fandecomp(c,f) # Fan decomposition #;

Coefficient
 (all,c,COM) LOCSALES(c)  # Total local sales of dom + imp commodity c #;
 (all,c,COM) INITSALES(c) # Initial volume of SALES at final prices #;
Formula
 (all,c,COM) LOCSALES(c) = DOMSALES(c) + V0IMP(c);
 (initial) (all,c,COM) INITSALES(c) = SALES(c);
Update
  (all,c,COM) INITSALES(c) = p0com(c);

Equation E_x0loc # %growth in local market #
(all,c,COM) LOCSALES(c)*x0loc(c) =
 DOMSALES(c)*x0dom(c) + V0IMP(c)*x0imp(c);

Equation E_fandecompA # growth in local market effect #
(all,c,COM)  INITSALES(c)*fandecomp(c,"LocalMarket") = DOMSALES(c)*x0loc(c);
! The local market effect is the % change in output that would have occurred
if local sales of the domestic product had followed dom+imp sales (x0loc) !

Equation E_fandecompB # export effect #
(all,c,COM) INITSALES(c)*fandecomp(c,"Export") = V4BAS(c)*x4(c);

Equation E_fandecompC # import leakage effect - via residual #
(all,c,COM) fandecomp(c,"Total") =
fandecomp(c,"LocalMarket") + fandecomp(c,"ImportShare") + fandecomp(c,"Export");

Equation E_fandecompD # Fan total = x0com #
(all,c,COM) INITSALES(c)*fandecomp(c,"Total") = SALES(c)*x0com(c);
```

*4.22. Checking the data*

A model rendered in the TABLO language is a type of computer program, and like other computer programs tends to contain errors. We employ a number of strategies to prevent errors and to make errors apparent. One strategy is to check all conditions which the initial data must satisfy. This is done in Excerpt 36. The conditions are:

- The row sums of the MAKE matrix must equal the row sums of the BAS and MAR rows of Figure 4. That is, the output of domestically produced commodities must equal the total of the demands for them.
- The column sums of the MAKE matrix must equal the sum of the first, producers', column of Figure 4. That is, the value of output by each industry must equal the total of production costs.
- The average value of the household expenditure elasticities, EPS, should be one. The average should be computed using the expenditure weights, V3PUR_S.

To check these conditions, the items PURE_PROFITS, LOST_GOODS, and EPSTOT are stored on a file of summary data. The modeller should examine this file to ensure that their values are near to zero (or one, for EPSTOT).

It should be emphasized that the validity of percentage change equations depends on the validity of the data from which the equation coefficients are calculated. The GEMPACK solution method must start from a database which is consistent, in the levels, with all the equations.

There are other formal tests which can reveal errors in model formulation. These are set out in Appendix I.

```
! Excerpt 36 of TABLO input file: !
! Data for Checking Identities !

File (new) SUMMARY  # Summary and checking data #;

Coefficient                     ! coefficients for checking !
 (all,i,IND) PURE_PROFITS(i) # COSTS-MAKE_C : should be zero #;
 (all,c,COM) LOST_GOODS(c)   # SALES-MAKE_I : should be zero #;
             EPSTOT          # Average Engel elasticity: should = 1 #;
Formula
 (all,i,IND) PURE_PROFITS(i) = V1TOT(i) - MAKE_C(i);
 (all,c,COM) LOST_GOODS(c)   = SALES(c) - MAKE_I(c);
             EPSTOT          = sum{c,COM, S3_S(c)*EPS(c)};
Write
PURE_PROFITS to file SUMMARY header "PURE" longname "COSTS-MAKE_C: should = 0";
LOST_GOODS to file SUMMARY header "LOST" longname "SALES-MAKE_I: should = 0";
EPSTOT to file SUMMARY header "ETOT" longname "Average Engel elast: should = 1";
```

### *4.23. Summarizing the data*

The next few Excerpts collect together various summaries of the data and store these on file in a form that is convenient for later viewing. These summaries are useful for checking the plausibility of data and for explaining simulation results. Excerpt 37 groups into vectors the various components of, first, GDP from the expenditure side; second, GDP from the income side; and third, the components of total indirect taxes[15].

```
! Excerpt 37 of TABLO input file: !
! Components of GDP from income and expenditure sides !

Set EXPMAC # Expenditure Aggregates #
 (Consumption, Investment, Government, Stocks, Exports, Imports);
Coefficient (all,e,EXPMAC)  EXPGDP(e) # Expenditure Aggregates #;
Formula
 EXPGDP("Consumption") = V3TOT;
 EXPGDP("Investment")  = V2TOT_I;
 EXPGDP("Government")  = V5TOT;
 EXPGDP("Stocks")      = V6TOT;
 EXPGDP("Exports")     = V4TOT;
 EXPGDP("Imports")     = -V0CIF_C;
Write EXPGDP to file SUMMARY header "EMAC" longname "Expenditure Aggregates";

Set INCMAC # Income Aggregates # (Land, Labour, Capital, OCT, IndTaxes);
Coefficient (all,i,INCMAC)  INCGDP(i) # Income Aggregates #;
Formula
 INCGDP("Land")     = V1LND_I;
 INCGDP("Labour")   = V1LAB_IO;
 INCGDP("Capital")  = V1CAP_I;
 INCGDP("OCT")      = V1OCT_I;
 INCGDP("IndTaxes") = V0TAX_CSI;
Write INCGDP to file SUMMARY header "IMAC" longname "Income Aggregates";
```

[15] GEMPACK stores data in its own, binary, format. A Windows program, ViewHAR, is normally used for viewing or modifying these so-called HAR files. The data matrices created here are designed to be convenient for examining with ViewHAR. ViewHAR automatically calculates and displays subtotals, so that total GDP, for example, does not need to be included in the summary vectors defined here.

```
Set TAXMAC # Tax Aggregates #
  (Intermediate,Investment,Consumption,Exports,Government,Tariff);
Coefficient (all,t,TAXMAC)  TAX(t) # Tax Aggregates #;
Formula
 TAX("Intermediate") = V1TAX_CSI;
 TAX("Investment")   = V2TAX_CSI;
 TAX("Consumption")  = V3TAX_CS;
 TAX("Exports")      = V4TAX_C;
 TAX("Government")   = V5TAX_CS;
 TAX("Tariff")       = V0TAR_C;
Write TAX to file SUMMARY header "TMAC" longname "Tax Aggregates";
```

Excerpt 38 forms a matrix showing the main parts of production cost for each industry. After being stored on file, the matrix is converted to show percentages of total costs and written out again. Both forms are useful for explaining results.

```
! Excerpt 38 of TABLO input file: !
! Matrix of Industry Costs !

Set COSTCAT # Cost Categories #
 (IntDom, IntImp, Margin, IndTax, Lab, Cap, Lnd, ProdTax); ! co !
Coefficient (all,i,IND)(all,co,COSTCAT) COSTMAT(i,co);
Formula
(all,i,IND) COSTMAT(i,"IntDom") = sum{c,COM, V1BAS(c,"dom",i)};
(all,i,IND) COSTMAT(i,"IntImp") = sum{c,COM, V1BAS(c,"imp",i)};
(all,i,IND) COSTMAT(i,"Margin") =
            sum{c,COM, sum{s,SRC, sum{m,MAR, V1MAR(c,s,i,m)}}};
(all,i,IND) COSTMAT(i,"IndTax") = sum{c,COM, sum{s,SRC, V1TAX(c,s,i)}};
(all,i,IND) COSTMAT(i,"Lab") =V1LAB_O(i);
(all,i,IND) COSTMAT(i,"Cap") =V1CAP(i);
(all,i,IND) COSTMAT(i,"Lnd") =V1LND(i);
(all,i,IND) COSTMAT(i,"ProdTax") =V1OCT(i);
Write COSTMAT to file SUMMARY header "CSTM" longname "Cost Matrix";
Formula (all,i,IND)(all,co,COSTCAT) ! convert to % shares and re-write !
            COSTMAT(i,co)= 100*COSTMAT(i,co)/(TINY+V1TOT(i));
Write COSTMAT to file SUMMARY header "COSH" longname "Cost Share Matrix";
```

Excerpt 39 calculates the main destinations for domestic output of each commodity. The last column shows the corresponding total imports. Again, the matrix is written out a second time in percentage form. For domestically-produced goods, the percentages show what proportion of local output goes to, say, consumption. For imports, the percentage shows, for example, the share of imported Textiles in total local sales of domestic + imported textiles. The flows are all valued at basic prices.

```
! Excerpt 39 of TABLO input file: !
! Matrix of domestic commodity sales with total imports !

Set ! Subscript !
SALECAT # SALE Categories #
(Interm, Invest, HouseH, Export, GovGE, Stocks,Margins, Total, Imports);

Coefficient (all,c,COM)(all,sa,SALECAT) SALEMAT(c,sa);

Formula
(all,c,COM) SALEMAT(c,"Interm") = sum{i,IND, V1BAS(c,"dom",i)};
(all,c,COM) SALEMAT(c,"Invest") = sum{i,IND, V2BAS(c,"dom",i)};
(all,c,COM) SALEMAT(c,"HouseH") = V3BAS(c,"dom");
(all,c,COM) SALEMAT(c,"Export") = V4BAS(c);
(all,c,COM) SALEMAT(c,"GovGE") = V5BAS(c,"dom");
(all,c,COM) SALEMAT(c,"Stocks") = V6BAS(c,"dom");
(all,c,COM) SALEMAT(c,"Margins") = MARSALES(c);
(all,c,COM) SALEMAT(c,"Total") = SALES(c);
(all,c,COM) SALEMAT(c,"Imports") = V0IMP(c);
write SALEMAT to file SUMMARY header "SLSM" longname
    "Matrix of domestic commodity sales with total imports";
```

```
Formula
 (all,c,COM)(all,sa,SALECAT) SALEMAT(c,sa) = 100*SALEMAT(c,sa)/[TINY+SALES(c)];
 (all,c,COM) SALEMAT(c,"Imports")= 100*V0IMP(c)/[TINY+DOMSALES(c)+V0IMP(c)];
Write SALEMAT to file SUMMARY header "SLSH" longname
    "market shares for domestic goods with total import share";
```

### *4.24. Storing Data for Other Computations*

It is often useful to extract data from the model for other calculations. For example, we might wish to combine levels data with change results in our presentation of simulation results. Another important use of such data is in aggregating the model database. It is customary to prepare the initial model database at the highest level of disaggregation supported by available Input-Output tables. This large database can be aggregated later, if desired, to a smaller number of sectors.

For flows data, each item in the aggregated database is simply the sum of corresponding sectors in the original database. Parameters, however, can not normally be added together. Instead, aggregated parameters are normally weighted averages of the original parameters. The purpose of Excerpt 40 is store such weights on a file. For example, the parameter SIGMA2 (Armington elasticity between domestic and imported commodities used for investment) could be aggregated using the weight vector V2PUR_SI.

A special purpose program, DAGG, is available to ease the aggregation task[16].

```
! Excerpt 40 of TABLO input file: !
! Weight Vectors for use in aggregation and other calculations !

Write
V1TOT    to file SUMMARY header "1TOT" longname "Industry Output";
V2TOT    to file SUMMARY header "2TOT" longname "Investment by Industry";
V1PUR_SI to file SUMMARY header "1PUR" longname "Interm.Usage by com at PP";
V2PUR_SI to file SUMMARY header "2PUR" longname "Invest.Usage by com at PP";
V3PUR_S  to file SUMMARY header "3PUR" longname "Consumption at Purch.Prices";
V4PUR    to file SUMMARY header "4PUR" longname "Exports at Purchasers Prices";
V1LAB_O  to file SUMMARY header "LAB1" longname "Industry Wages";
V1CAP    to file SUMMARY header "1CAP" longname "Capital Rentals";
V1PRIM   to file SUMMARY header "VLAD" longname "Industry Factor Cost";
```

[16] DAGG may be downloaded from http://www.monash.edu.au/policy/gpmark.htm

## 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<br>Dimension | 2<br>Variable<br>Count | 3<br>Equation<br>Count | 4<br>Exogenous<br>Count | 5<br>Unexplained<br>Variables |
|---|---|---|---|---|
| MACRO | 61 | 48 | 13 | f0tax_s f1lab_io f4_ntrad f4tax_ntrad *f5tot2* phi q *omega* *w3lux* f1tax_csi 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 finv x1lnd a2tot x1cap |
| IND*OCC | 3 | 2 | 1 | f1lab |
| OCC | 2 | 1 | 1 | f1lab_i |
| TOTAL | 145 | 100 | 45 | |

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;
- industry capital stocks, x1cap;
- foreign prices, pf0cif, and the average rate of return omega;
- inventory changes, delx6;
- the exchange rate phi, which could serve as numeraire;
- w3lux (household above-subsistence expenditure); and

Although Column 5 contains a perfectly valid exogenous set for the model, we choose, for typical shortrun simulations, to adopt a slightly different closure. The macro variables italicised in Column 5 are replaced as follows.

- We exogenize x5tot instead of f5tot2, so disconnecting government from household consumption.
- We exogenize x2tot_i (aggregate investment), rather than omega.
- We exogenize x3tot (household consumption), rather than w3lux.

With its 23 commodities, 22 industries, 2 sources, 2 margin goods and 2 occupations, our version of ORANI-G has about 20,000 scalar variable elements and 13,000 scalar equations. Full-size ORANI 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.

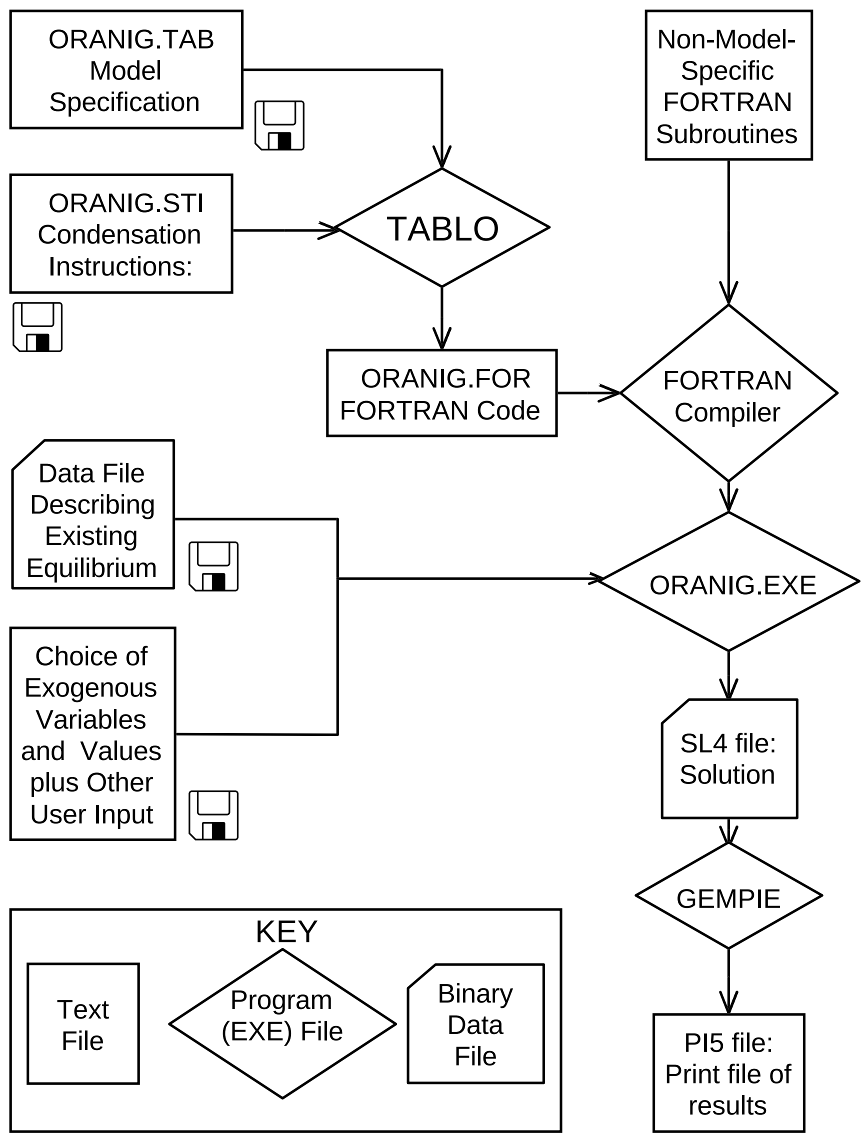


**Figure 8. Stages in the GEMPACK process**

## 6. Using GEMPACK to Solve the Model

Figure 8 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 ORANIG.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-G 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: ORANIG.STI.

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

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

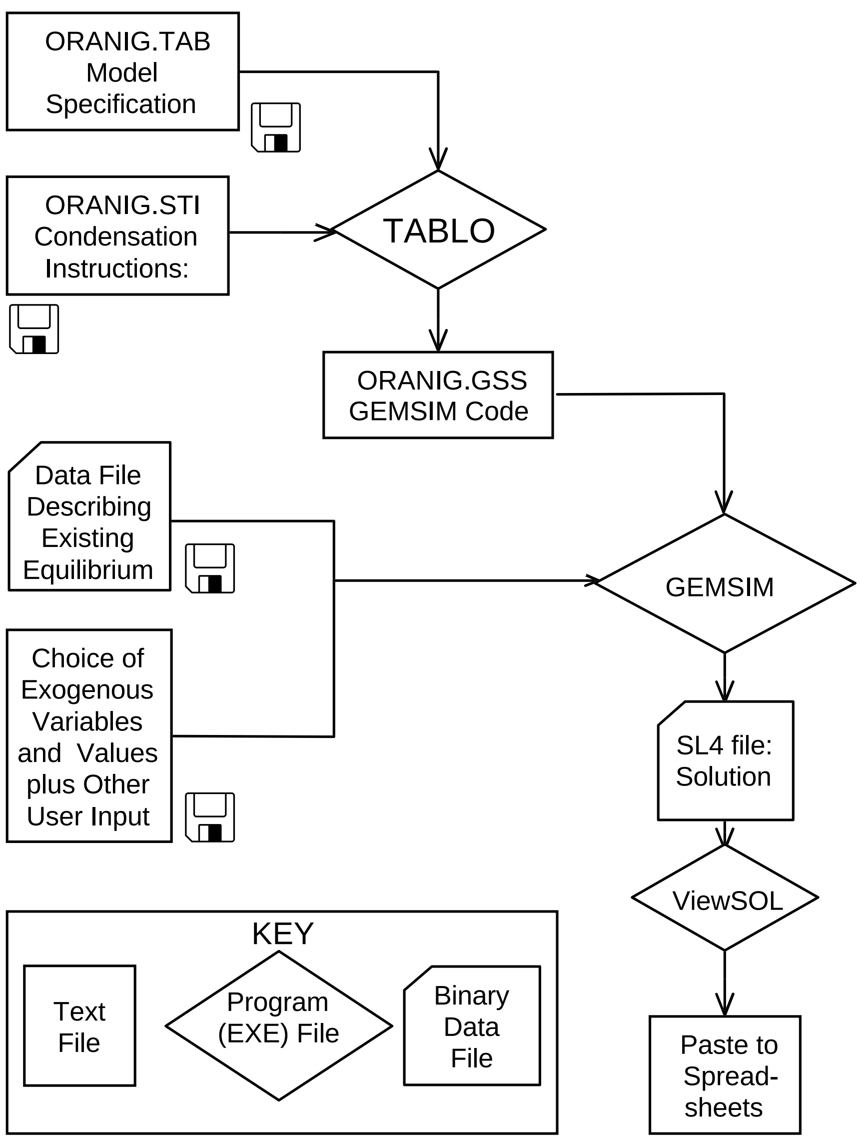


**Figure 9. Variation on the GEMPACK process**

Simulations are conducted using ORANIG.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 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 computer files which are companion to this article (see Appendix B) are marked in Figure 8. A version of GEMPACK would be needed to make good use of them. With GEMPACK, a user could either run the Australian model, or use ORANI-G as a starting point to build their own general equilibrium model—they might well start by editing the ORANIG.TAB file to alter the dimensions and equations of the model to suit their own needs.

Figure 9 shows a variation on the process depicted in Figure 8. This time, TABLO has produced a GSS file. Unlike the FOR file of Figure 8, the GSS file need not be compiled: it is interpreted directly by the standard program GEMSIM. The advantage of this approach is that no FORTRAN compiler is needed. The disadvantage is that larger models may solve only slowly, or may altogether exceed size limits built in to GEMSIM. Both methods give the same numerical results.

As an entirely independent variation, the Windows program ViewSOL provides a way to interactively examine results.

## 7. 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 generic version of the model (ORANI-G). ORANI-G can be used for comparative-static policy analysis of the Australian economy as well as for developing similar models for other countries.

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 files (see Appendix B) contain enough of the GEMPACK system to allow readers to conduct their own simulations with ORANI-G.

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 with the companion files is required. Appendix C explains how the necessary software can be obtained.

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

or $\quad X_i^{-\rho} = \left(\dfrac{\delta_i P_k}{\delta_k P_i}\right)^{-\rho/(\rho+1)} X_k^{-\rho}$. (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 $\quad X_k = Z\, \delta_k^{1/(\rho+1)} \left[\dfrac{P_k}{P_{ave}}\right]^{-1/(\rho+1)}$, (A7)

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

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

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

and $\quad p_{ave} = \sum_i S_i p_i$, (A10)

where $\quad \sigma = \dfrac{1}{\rho+1}$ and $S_i = \delta_i^{1/(\rho+1)}\, P_i^{\rho/(\rho+1)} \Big/ \sum_k \delta_k^{1/(\rho+1)} P_k^{\rho/(\rho+1)}$. (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 $\dfrac{P_k X_k}{\sum_i P_i X_i} = \delta_k^{1/(\rho+1)}\, P_k^{\rho/(\rho+1)} \Big/ \sum_i \delta_i^{1/(\rho+1)}\, P_i^{\rho/(\rho+1)} = S_i$, (A13)

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

***Technical Change Terms***

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

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

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

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

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

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

and $$\tilde{p}_{ave} = \sum_i S_i\tilde{p}_i. \quad \text{(A18)}$$

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

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

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

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

The following two sub-topics are more advanced, and could be omitted at the first reading.

***Two Input CES: Reverse Shares***

Where a CES nest has only two inputs we can write (A19) and (A20) in a way which speeds up computation. Suppose we have domestic and imported inputs, with suffixes d and m. (A19) becomes:

$$x_d - a_d = z - \sigma\left(p_d + a_d - S_d(p_d + a_d) - S_m(p_m + a_m)\right),$$

and $$x_m - a_m = z - \sigma\left(p_m + a_m - S_d(p_d + a_d) - S_m(p_m + a_m)\right). \quad \text{(A21)}$$

Simplifying, we get:

$$x_d - a_d = z - \sigma S_m\left((p_d + a_d) - (p_m + a_m)\right),$$

and $$x_m - a_m = z + \sigma S_d\left((p_d + a_d) - (p_m + a_m)\right). \quad \text{(A22)}$$

In order for TABLO to substitute out x, we must express (A22) as a single vector equation:

$$x_k - a_k = z - \sigma R_k\left((p_d + a_d) - (p_m + a_m)\right). \qquad k = d, m \quad \text{(A23)}$$

The $R_k$ are *reverse shares*, defined by:

$$R_d = S_m \quad \text{and} \quad R_m = R_d - 1 = S_m - 1 = - S_d \qquad \text{note that } R_d - R_m = 1 \quad \text{(A24)}$$

(A20) becomes:

$$\tilde{p}_{ave} = \sum_i S_i\,(p_i + a_i) = R_d(p_m + a_m) - R_m(p_d + a_d). \quad \text{(A25)}$$

***Twist for Two Input CES***

A twist is a combination of small technical changes which, taken together, are locally cost neutral. For example, we might ask, what values for $a_d$ and $a_m$ would, in the absence of price changes, cause the ratio $(x_d - x_m)$ to increase by t% without affecting $\tilde{p}_{ave}$? That is, find $a_d$ and $a_m$ such that:

$$S_da_d + S_ma_m = 0, \qquad \text{using (A20), and} \quad \text{(A26)}$$

$$x_d - x_m = (1-\sigma)(a_d - a_m) = t, \qquad \text{using (A21);} \quad \text{(A27)}$$

giving

$$a_d = S_mt/(1-\sigma) \quad \text{and} \quad a_m = -S_dt/(1-\sigma). \quad \text{(A28)}$$

Adopting *reverse share* notation:

$$a_k = R_k t/(1-\sigma) \qquad k = d, m \qquad \text{(A29)}$$

Substituting (A29) back into (A23) we get:

$$x_k = z + R_k t/(1-\sigma) - \sigma R_k\Big(p_d - p_m + R_d t/(1-\sigma) - R_m t/(1-\sigma)\Big) \qquad k = d, m$$

so $$x_k = z + R_k t - \sigma R_k\Big(p_d - p_m\Big) \qquad k = d, m$$

allowing us to rewrite (A19) and (A20) as:

$$x_k = z + R_k\Big(t - \sigma(p_d - p_m)\Big) \qquad k = d, m \qquad \text{(A30)}$$

and $$\tilde{p}_{ave} = R_d p_m - R_m p_d. \qquad \text{(A31)}$$

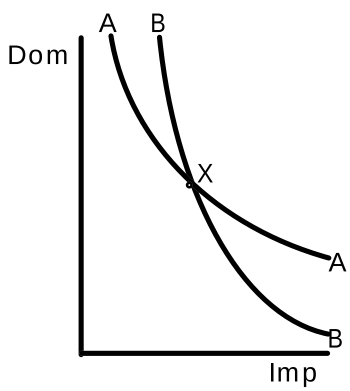

Figure A1

Twist variables, such as t, are heavily used in MONASH where they are used to simulate secular (i.e., not price-induced) trends in import shares. Figure A1 shows how 'twist' variables get their name. AA is an isoquant showing what quantities of domestic and imported goods can be combined to give the same utility. The chosen combination is at X. Technical changes $a_d$ and $a_m$ translate AA both down and to the right, in such a way that BB still passes through X. It is as if AA had been twisted or pivoted around X.

A small change concept of cost neutrality is used to develop the notion of twist variables. Where budget shares change by a large amount, the same technical change cannot be cost-neutral at both initial and final input proportions, although it will usually be cost-neutral at some intermediate proportion. Thus, there are no levels formulae corresponding to (A28).

## Appendix B: ORANI-G on the World Wide Web

All the computer files mentioned in this document can be downloaded from:

http://www.monash.edu.au/policy/oranig.htm

The site also contains supplementary material used for preparing or aggregating data, plus information about some of the adaptations of ORANI-G that have been made for different countries.

## Appendix C: Hardware and Software Requirements for Using GEMPACK

GEMPACK can be used on most desktop and mainframe computers: wherever an ANSI-standard FORTRAN is available. Customized installation kits are available for VAX-VMS, UNIX, and DOS/Windows machines. A typical GEMPACK user might run a Win95 Pentium with 32 Mbytes of RAM. The minimum DOS system requirements are:

- a 386 or 386SX machine with math coprocessor, or a 486DX machine;
- DOS version 3.3 or higher (some supplementary programs require Windows);
- at least 8 Mbytes total RAM;
- at least 15 Mb free hard disk space.

To use the source-code version, you would also need:

- an ANSI-compatible FORTRAN. The only DOS/Windows FORTRAN compiler recommended and supported by GEMPACK is the Lahey compiler. This must be purchased separately from GEMPACK.

At the time of writing, the cost of GEMPACK is between 2000 and 5000 dollars; the Lahey compiler costs about $US1000. Current details may be obtained from the address below.

GEMPACK Manager,

C/- Dr. K.R. Pearson,
Impact Project, 11th Floor Menzies Building,
Monash University, Wellington Road,
Clayton VIC 3168
AUSTRALIA
Telephone (03) 9905 5112 (from overseas: 61 3 9905 5112)
FAX (03) 9905 5486 (from overseas; 61 3 9905 5486)

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

Our version follows ORANI very closely. The main departures from the full-size version of ORANI described by 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-CRETH 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.

**Table E1 Examples of Percentage-Change Forms**

| Example | (1) Original or Levels Form | (2) Intermediate Form | (3) Percentage-Change Form |
|---|---|---|---|
| 1 | $Y = 4$ | $Yy = 4*0$ | $y = 0$ |
| 2 | $Y = X$ | $Yy = Xx$ | $y = x$ |
| 3 | $Y = 3X$ | $Yy = 3Xx$ | $y = x$ |
| 4 | $Y = XZ$ | $Yy = XZx + XZz$ | $y = x + z$ |
| 5 | $Y = X/Z$ | $Yy = (X/Z)x - (X/Z)z$ | $y = x - z$ *or* $100(Z)\Delta Y = Xx - Xz$ |
| 6 | $X_1 = M/4P_1$ | $X_1x_1 = (M/4P_1)m - (M/4P_1)p_1$ | $x_1 = m - p_1$ |
| 7 | $Y = X^3$ | $Yy = X^3 3x$ | $y = 3x$ |
| 8 | $Y = X^\alpha$ | $Yy = X^\alpha \alpha x$ | $y = \alpha x$ ($\alpha$ assumed constant) |
| 9 | $Y = X + Z$ | $Yy = Xx + Zz$ | $y = S_x x + S_z z$ where $S_x = X/Y$, etc |
| 10 | $Y = X - Z$ | $Yy = Xx - Zz$ | $y = S_x x - S_z z$ *or* $100(\Delta Y) = Xx - Zz$ |
| 11 | $PY = PX + PZ$ | $PY(y+p) = PX(x+p) + PZ(z+p)$ *or* $PYy = PXx + PZz$ | $y = S_x x + S_z z$ where $S_x = PX/PY$, etc |
| 12 | $Z = \Sigma X_i$ | $Zz = \Sigma X_i x_i$ *or* $0 = \Sigma X_i(x_i - z)$ | $z = \Sigma S_i x_i$ where $S_i = X_i/Z$ |
| 13 | $XP = \Sigma X_i P_i$ | $XP(x+p) = \Sigma X_i P_i(x_i+p_i)$ | $x+p = \Sigma S_i(x_i+p_i)$ where $S_i = X_i P_i/XP$ |

## 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.

Column (2) in Table E1 corresponds closely to the total differential form of column (1), and may be thought of as a step on the way to column (3). Alternatively, we may use column (2) directly, either because it is simpler, or to avoid computing shares.

The 2nd alternate form in column (3) 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: Algebra for the Linear Expenditure System

The purpose of this appendix is to expand on some of the algebra underlying Excerpts 22 and 23 of the TABLO input file.

First note that, the utility function (22) in the text can be written:

$$\text{Utility per household} = \prod_{c} \left\{\frac{X3\_S(c)}{Q} - A3SUB(c)\right\}^{S3LUX(c)}, \tag{F1}$$

using equation (27). Here, X3_S(c)/Q is the average consumption of each composite good c, and A3SUB(c) is a parameter. The household's problem is to choose X3_S(c)/Q to maximise utility subject to the constraint:

$$\sum_{c} X3\_S(c)/Q*P3\_S(c) = V3TOT/Q, \tag{F2}$$

The associated additional first order conditions are:

$$\Lambda P3\_S(c) = \frac{\partial U}{\partial(X3\_S(c)/Q)}$$

$$= S3LUX(c).U.\left\{\frac{X3\_S(c)}{Q} - A3SUB(c)\right\}^{-1} \tag{F3}$$

Manipulation (and use of equation (27)) yields:

$$P3\_S(c)\{X3\_S(c) - X3SUB(c)\} = S3LUX(c).Q.U/\Lambda. \tag{F4}$$

or $$P3\_S(c).X3\_S(c) = P3\_S(c).X3SUB(c) + S3LUX(c).Q.U/\Lambda. \tag{F5}$$

(F5) is really the same as equations (25) to (27) in the text. The key to the simplicity of the equations there is that no attempt is made to eliminate the Lagrange multiplier term, Q.U/Λ. Instead, the constraint (F2) is written down as part of the equation system: see (28). This implicit approach often yields dividends. Here in the appendix we press forward more conventionally to express demands directly as a function of prices and income. Summing over c and using (F2), we see that

or $$Q.U/\Lambda = V3TOT - .\sum_{c} P3\_S(c).X3SUB(c) \tag{F6}$$

so that Q.U/Λ is identified as the V3LUX_C of equation (24) in the text. Equation (23) then follows from (F4) above. Combining (F4) with (F6) we get the linear expenditure system (LES):

$$P3\_S(c).X3\_S(c) = P3\_S(c).X3SUB(c)$$
$$+ S3LUX(c).\{V3TOT - \sum_{k} X3SUB(k)*P3\_S(k)\}. \tag{F7}$$

To find the expenditure elasticities, we convert to percentage change form, ignoring all changes in prices and tastes:

$$x3\_s(c) = - FRISCH.B3LUX(c).\ w3tot \tag{F8}$$

where FRISCH is defined, by tradition, as $- \frac{V3TOT}{V3LUX\_C}$,

and the B3LUX(c) are the shares of 'luxury' in total expenditure on good c,

i.e. $$B3LUX(c) = \frac{X3\_S(c) - X3SUB(c)}{X3\_S(c)}.$$

Thus the expenditure elasticities are given by:

$$EPS(c) = - FRISCH.B3LUX(c) \tag{F9}$$

In the TABLO program, (F9) is reversed to derive B3LUX(c) from EPS(c) and FRISCH.

***Taste Change Terms***

Often we wish to simulate the effect of a switch in consumer spending, induced by a taste change. This could be brought about by a shock *either* to the a3lux(c) (marginal budget shares) *or* to the a3sub(c) (subsistence quantities). Two problems arise. First, what combination of a3sub and a3lux shocks is best. Second, the a3lux shocks must obey the rule that marginal budget shares add to 1. To tie down the relation between the a3lux and the a3sub, we will assume that they move in proportion:

$$a3lux(c) = a3sub(c) - \lambda, \tag{F12}$$

and that the constant of proportionality λ is given by the adding-up requirement:

$$\sum_{k} S3LUX(k).a3lux(k) = 0 \tag{F13}$$

implying that:

$$a3lux(c) = a3sub(c) - \sum_{k} S3LUX(k).a3sub(k), \qquad \text{E\_a3lux}$$

We also suppose that

$$\sum_{k} S3\_S(k).a3sub(k) = 0 \tag{F14}$$

This is guaranteed by equation E_a3sub:

$$a3sub(c) = a3\_s(c) - \sum_{k} S3\_S(k).a3\_s(k) \qquad \text{E\_a3sub}$$

The effect of these assumptions is to allow budget shares to be shocked whilst altering expenditure elasticities and the Frisch parameter as little as possible.

## Appendix G: Making your own AGE model from ORANI-G

In conjunction with the full GEMPACK system, the ORANI-G.TAB file which appears in Excerpts 1-34 forms an excellent starting-point for constructing your own AGE model. This file is available from the World--Wide Web (see Appendix B). The best plan is to start from something that works (ORANI-G) 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-G 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 | 23x2 | 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 |
| P021 | 1 | Frisch Parameter |
| 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 |
| XPEL | 23 | Household Expenditure Elasticities |

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-G 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.

As your confidence grows, you may wish to change or extend the equation system. For example, you could easily alter the 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.

## Appendix H: Additions and Changes for the 1998 edition

ORANI-G has been adapted to a number of countries beside Australia. Each national version has, in addition to a unique database, various special additions and modifications to the basic TAB file. Some of these changes are so frequently needed that they have now been included in the basic model. They are:

- allowance for imported as well as domestic inventory changes;
- the addition of more TINY coefficients to combat zero-divide errors;
- an optional CET transformation between goods for local and export markets;
- a new output file that contains convenient summaries of the base data;
- the addition of variables which help to explain results

## Appendix I: Formal Checks on Model Validity; Debugging Strategies

A number of tests should be performed each time a model's equations or data are changed. We set out here the proper procedure to follow.

*1. Price homogeneity test*

It is a property of neoclassical models that agents respond to changes in relative prices, but not to changes in the absolute level of prices. That is, a uniform increase in *all* prices does not affect any quantity variables. Nearly always there is only one exogenous variable measured in domestic currency units—it is called the numeraire. Typical choices of numeraire include the exchange rate (phi) or the consumer price index (p3tot). If we shock the numeraire by 1% we would expect to see that all domestic prices and flows increase by 1% while real variables remain unchanged.

The supplied file HOMOTEST.CMF can be used to perform this test. Check that it refers to the right model and data and that the only shock is a 1% shock to phi. Run the simulation and examine the solution file. You should see that all prices move by 1% whilst quantities are unchanged.

*2. Check initial data*

The price homogeneity simulation should have produced a HAR file that summarizes the initial data. Examine this file (using ViewHAR) and check that the database is balanced, using the headers written by Excerpt 37 of the TAB file (see main text).

*3. Real homogeneity test*

Neoclassical models normally display constant returns to scale. This means that if all real exogenous variables (not ratios or prices) are shocked by 1%, all exogenous real variables should also move by 1%, leaving prices unchanged.

To test this properly, you have to ensure that any real ordinary change variables are shocked by the right amount and that export demand curves move outwards by an amount corresponding to a 1% increase in the size of the rest of the world. The supplied file HOMOTEST.CMF simplifies this task. Comment out the numeraire shock used for the price homogeneity test and reinstate the series of real shocks which were originally commented out. Run the simulation and examine the results.

*4. Change in GDP should be the same from both sides*

Now run a simulation where relative prices change, ie, not a homogeneity test. For example, you could use the closure in HOMOTEST.CMF and shock real household consumption by 10%. It's best to administer a shock that is large enough to make at least a 1% difference to the majority of variables. Stick with a one-step or Johansen simulation for now. Check that the results for the two nominal GDP variables, w0gdpexp and w0gdpinc are the same up to 5 significant figures. An unbalanced data-base or errors in equations could disturb this equality.

*5. Updated data-base should also be balanced.*

An updated data file will have been produced by the previous (10% real consumption increase) simulation. Use this updated data as the starting point for a second simulation with the same shock. Again, a HAR file of summary data will be produced, incorporating the effects of the first but not the second simulation. As in Step 2, use this to check whether the updated data is balanced. If not, and if all the previous tests were passed, there is probably something wrong with some Update statement.

*6. Repeat above tests using a multistep solution method.*

Go through the above steps this time using a 2-4-8 Euler extrapolation solution method. If there is a problem, but there was no problem with the Johansen tests, you have a subtle problem. Possibly a percentage change variable is passing through zero; or maybe you are using formulae to alter the data after it has been read (always a bad idea).

*7. Be sure you can explain the results.*

It is important to realize that there are many errors that Tests 1 to 6 above will not detect. For example, if the export demand elasticities in the database had the wrong sign, the model would still pass these tests. Only a careful 'eye-balling' of results will uncover this type of error. After modifying the model, it is a good idea to run a standard experiment for which the results have already been analysed. You should be able to understand how and why the new results differ.

***Other tips***

*Change little, check often*

Although the above tests can reveal the existence of a problem, they give little direct indication of its cause. The wise modeller performs the various tests both before and after making each small alteration to the model. Then, if there is a problem, the cause must lie with the minor changes just made.

*Duplication of previous results.*

Extensions and modifications to model equations should be designed so that you can still duplicate simulation results computed with the previous version of the model. For example, when adding new equations it is often a good idea to include shift variables which can be left endogenous. This prevents the new equations from affecting the rest of the system, and allows a standard closure to be used. To 'switch on' your new equations, exogenize these shift variables while at the same time endogenizing an equal number of other model variables. Sometimes modifications can be switched on and off by suitable parameter settings (an example might be the CET between goods for export and domestic markets in Excerpt 19B of the ORANI-G TAB file).

If you designed your extension in this flexible way, you could test that you are able to duplicate results that you computed before adding new equations. If the new results are different, you may have inadvertently made some other change that was overlooked.

*Always check that GDP results are the same from both sides*

It should become a reflex action, every time you look at results, to check that w0gdpexp and w0gdpinc are the same. It takes little time, and gives early warning of many possible errors.

*Beware of rarely used exogenous variables*

Shocks to rarely used exogenous variables often bring errors to light. Since in nearly all simulations these variables have zero change, the values of their coefficients are usually irrelevant. For example, when you shock normally-omitted technical change variables you are using parts of the model which have undergone relatively infrequent testing. So be alert.

*To identify the problem, try different closures*

Suppose you noticed that some problem occurred in long-run closures where capital stocks are mobile, but did not occur in short-run closures where capital stocks are fixed. That might suggest that some coefficient of x1cap (percentage change in capital stocks) was wrongly computed, or that x1cap had been inadvertently omitted from an equation or update statement.

## Appendix J: Short-Run Supply Elasticity

Where capital stocks are fixed, we can derive an approximate expression for a short-run supply schedule as follows. Imagine that output, z, is a CES function of capital and labour, and that other, material, inputs are demanded in proportion to output. Using percentage change form, we may write:

$p = H_K p_K + H_L p_L + H_M p_M$ zero pure profits (J1)

$x_L - x_K = \sigma(p_K - p_L)$ factor proportions (J2)

$z = S_L x_L + S_K x_K$ production function (J3)

where $H_K$, $H_L$ and $H_M$ are the shares in total costs of capital, labour and materials, and where $S_K$ and $S_L$ are the shares in primary factor costs of capital and labour.

In the short run closure we set $x_K$ to zero, so that the last 2 equations become:

$x_L = \sigma(p_K - p_L)$ and $z = S_L x_L$ giving: (J4)

$z = S_L\sigma(p_K - p_L)$ or $p_K = p_L + z/(S_L\sigma)$ (J5)

Substituting (J5) into (J1) we get:

$$p = H_K\left(p_L + z/(S_L\sigma)\right) + H_L p_L + H_M p_M \qquad (J6)$$

$$p = zH_K/(S_L\sigma) + (H_K + H_L)p_L + H_M p_M \qquad (J7)$$

$$zH_K/(S_L\sigma) = p - (H_K + H_L)p_L - H_M p_M \qquad (J8)$$

$$z = \left(S_L\sigma/H_K\right)\left[p - (H_K + H_L)p_L - H_M p_M\right] \qquad (J9)$$

Call $H_F$ the share of primary factor in total costs ($= H_K + H_L$). Then $H_K = S_K H_F$

so $z = \left(\sigma S_L/S_K\right)\left[p/H_F - p_L - (H_M/H_F)p_M\right]$....compare DPSV eq. 45.19 (J10)

The shortrun supply elasticity is the coefficient on p, namely:

$$\sigma S_L/(S_K H_F) \qquad (J11)$$

In other words, supply is more elastic as either the labour/capital ratio is higher, or the share of materials in total cost is higher. (J11) is only a partial equilibrium estimate; it assumes that all inputs except capital are in elastic supply.

# Appendix K: List of Coefficients, Variables, and Equations of ORANI-G

## The variables of ORANI-G (in alphabetical order)

| | | |
|---|---|---|
| a1(c,s,i) | c∈COM s∈SRC i∈IND | Intermediate basic tech change |
| a1_s(c,i) | c∈COM i∈IND | Tech change, int'mdiate imp/dom composite |
| a1cap(i) | i∈IND | Capital augmenting technical change |
| a1lab_o(i) | i∈IND | Labor augmenting technical change |
| a1lnd(i) | i∈IND | Land augmenting technical change |
| a1mar(c,s,i,m) | c∈COM s∈SRC i∈IND m∈MAR | Intermediate margin tech change |
| a1oct(i) | i∈IND | "other cost" ticket augmenting techncal change |
| a1prim(i) | i∈IND | All factor augmenting technical change |
| a1tot(i) | i∈IND | All input augmenting technical change |
| a2(c,s,i) | c∈COM s∈SRC i∈IND | Investment basic tech change |
| a2_s(c,i) | c∈COM i∈IND | Tech change, investment imp/dom composite |
| a2mar(c,s,i,m) | c∈COM s∈SRC i∈IND m∈MAR | Investment margin tech change |
| a2tot(i) | i∈IND | Neutral technical change - investment |
| a3(c,s) | c∈COM s∈SRC | Household basic taste change |
| a3_s(c) | c∈COM | Taste change, household imp/dom composite |
| a3lux(c) | c∈COM | Taste change, supernumerary demands |
| a3mar(c,s,m) | c∈COM s∈SRC m∈MAR | Household margin tech change |
| a3sub(c) | c∈COM | Taste change, subsistence demands |
| a4mar(c,m) | c∈COM m∈MAR | Export margin tech change |
| a5mar(c,s,m) | c∈COM s∈SRC m∈MAR | Governmnt margin tech change |
| delB | | (Balance of trade)/GDP |
| delx6(c,s) | c∈COM s∈SRC | Inventories demands |
| employ(i) | i∈IND | Employment by industry |
| employ_i | | Aggregate employment: wage bill weights |
| f0tax_s(c) | c∈COM | General sales tax shifter |
| f1lab(i,o) | i∈IND o∈OCC | Wage shift variable |
| f1lab_i(o) | o∈OCC | Occupation-specific wage shifter |
| f1lab_io | | Overall wage shifter |
| f1lab_o(i) | i∈IND | Industry-specific wage shifter |
| f1oct(i) | i∈IND | Shift in price of "other cost" tickets |
| 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 |
| f3tot | | Ratio, consumption/GDP |
| f4p(c) | c∈COM | Price (upward) shift in export demand schedule |
| f4p_ntrad | | Upward demand shift, non-traditional export aggregate |
| f4q(c) | c∈COM | Quantity (right) shift in export demands |
| f4q_ntrad | | Right demand shift, non-traditional export aggregate |
| f4tax_ntrad | | Uniform % change in powers of taxes on nontradtnl exports |
| f4tax_trad | | Uniform % change in powers of taxes on tradtnl exports |
| f5(c,s) | c∈COM s∈SRC | Government demand shift |
| f5tax_cs | | Uniform % change in powers of taxes on government usage |
| f5tot | | Overall shift term for government demands |
| f5tot2 | | Ratio between f5tot and x3tot |
| fandecomp(c,f) | c∈COM f∈FANCAT | Fan decomposition |
| finv(i) | i∈IND | Investment shifter |
| fx6(c,s) | c∈COM s∈SRC | Shifter on rule for stocks |

### The variables of ORANI-G (continued)

| | | |
|---|---|---|
| omega | | Economy-wide "rate of return" |
| p0(c,s) | c∈COM s∈SRC | Basic prices by commodity and source |
| p0cif_c | | Imports price index, C.I.F., $A |
| p0com(c) | c∈COM | Output price of locally-produced commodity |
| p0dom(c) | c∈COM | Basic price of domestic goods = p0(c,"dom") |
| p0gdpexp | | GDP price index, expenditure side |
| p0imp(c) | c∈COM | Basic price of imported goods = p0(c,"imp") |
| p0imp_c | | Duty-paid imports price index, $A |
| p0realdev | | Real devaluation |
| p0toft | | Terms of trade |
| p1(c,s,i) | c∈COM s∈SRC i∈IND | Purchaser's price, intermediate |
| p1_s(c,i) | c∈COM i∈IND | Price, intermediate imp/dom composite |
| p1cap(i) | i∈IND | Rental price of capital |
| p1cap_i | | Average capital rental |
| p1lab(i,o) | i∈IND o∈OCC | Wages by industry and occupation |
| p1lab_io | | Average nominal wage |
| p1lab_o(i) | i∈IND | Price of labour composite |
| p1lnd(i) | i∈IND | Rental price of land |
| p1oct(i) | i∈IND | Price of "other cost" tickets |
| p1prim(i) | i∈IND | Effective price of primary factor composite |
| p1tot(i) | i∈IND | Average input/output price |
| p2(c,s,i) | c∈COM s∈SRC i∈IND | Purchaser's price, investment |
| p2_s(c,i) | c∈COM i∈IND | Price, investment imp/dom composite |
| p2tot(i) | i∈IND | Cost of unit of capital |
| p2tot_i | | Aggregate investment price index |
| p3(c,s) | c∈COM s∈SRC | Purchaser's price, household |
| p3_s(c) | c∈COM | Price, household imp/dom composite |
| p3tot | | Consumer price index |
| p4(c) | c∈COM | Purchaser's price, exports $A |
| p4_ntrad | | Price, non-traditional export aggregate |
| p4tot | | Exports price index |
| p5(c,s) | c∈COM s∈SRC | Purchaser's price, government |
| p5tot | | Government price index |
| p6tot | | Inventories price index |
| pe(c) | c∈COM | Basic price of export commodity |
| pf0cif(c) | c∈COM | C.I.F. foreign currency import prices |
| phi | | Exchange rate, $A/$world |
| q | | Number of households |
| q1(c,i) | c∈COM i∈IND | Output by commodity and industry |
| r1cap(i) | i∈IND | Current rates of return on fixed capital |
| realwage | | Average real wage |
| t0imp(c) | c∈COM | Power of tariff |
| t1(c,s,i) | c∈COM s∈SRC i∈IND | Power of tax on intermediate |
| t2(c,s,i) | c∈COM s∈SRC i∈IND | Power of tax on investment |
| t3(c,s) | c∈COM s∈SRC | Power of tax on household |
| t4(c) | c∈COM | Power of tax on export |
| t5(c,s) | c∈COM s∈SRC | Power of tax on government |
| utility | | Utility per household |
| w0cif_c | | C.I.F. $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 |

## The variables of ORANI-G (continued)

| | | |
|---|---|---|
| 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 export |
| w4tot | | $A border value of exports |
| w5tax_cs | | Aggregate revenue from indirect taxes on government |
| w5tot | | Aggregate nominal value of government demands |
| w6tot | | Aggregate nominal value of inventories |
| x0cif_c | | Import volume index, C.I.F. weights |
| x0com(c) | c∈COM | Output of commodities |
| x0dom(c) | c∈COM | Output of commodities for local market |
| x0gdpexp | | Real GDP from expenditure side |
| x0imp(c) | c∈COM | Total supplies of imported goods |
| x0imp_c | | Import volume index, duty-paid weights |
| x0loc(c) | c∈COM | real percent change in LOCSALES (dom+imp) |
| x1(c,s,i) | c∈COM s∈SRC i∈IND | Intermediate basic demands |
| x1_s(c,i) | c∈COM i∈IND | Intermediate use of imp/dom composite |
| x1cap(i) | i∈IND | Current capital stock |
| x1cap_i | | Aggregate capital stock, rental weights |
| x1lab(i,o) | i∈IND o∈OCC | Employment by industry and occupation |
| x1lab_i(o) | o∈OCC | Employment by occupation |
| x1lab_o(i) | i∈IND | Effective labour input |
| x1lnd(i) | i∈IND | Use of land |
| x1mar(c,s,i,m) | c∈COM s∈SRC i∈IND m∈MAR | Intermediate margin demands |
| x1oct(i) | i∈IND | Demand for "other cost" tickets |
| x1prim(i) | i∈IND | Primary factor composite |
| x1prim_i | | Aggregate output: value-added weights |
| x1tot(i) | i∈IND | Activity level or value-added |
| x2(c,s,i) | c∈COM s∈SRC i∈IND | Investment basic demands |
| x2_s(c,i) | c∈COM i∈IND | Investment use of imp/dom composite |
| x2mar(c,s,i,m) | c∈COM s∈SRC i∈IND m∈MAR | Investment margin demands |
| x2tot(i) | i∈IND | Investment by using industry |
| x2tot_i | | Aggregate real investment expenditure |
| x3(c,s) | c∈COM s∈SRC | Household basic demands |
| x3_s(c) | c∈COM | Household use of imp/dom composite |
| x3lux(c) | c∈COM | Household - supernumerary demands |
| x3mar(c,s,m) | c∈COM s∈SRC m∈MAR | Household margin demands |
| x3sub(c) | c∈COM | Household - subsistence demands |
| x3tot | | Real household consumption |
| x4(c) | c∈COM | Export basic demands |
| x4_ntrad | | Quantity, non-traditional export aggregate |
| x4mar(c,m) | c∈COM m∈MAR | Export margin demands |
| x4tot | | Export volume index |
| x5(c,s) | c∈COM s∈SRC | Government basic demands |
| x5mar(c,s,m) | c∈COM s∈SRC m∈MAR | Government margin demands |
| x5tot | | Aggregate real government demands |
| x6tot | | Aggregate real inventories |

## The equations of ORANI-G (in order of appearance)

| | | |
|---|---|---|
| E_x1lab(i,o) | i∈IND o∈OCC | Demand for labour by industry and skill group |
| E_p1lab_o(i) | i∈IND | Price to each industry of labour composite |
| E_x1lab_o(i) | i∈IND | Industry demands for effective labour |
| E_p1cap(i) | i∈IND | Industry demands for capital |
| E_p1lnd(i) | i∈IND | Industry demands for land |
| E_p1prim(i) | i∈IND | Effective price term for factor demand equations |
| E_x1(c,s,i) | c∈COM s∈SRC i∈IND | Source-specific commodity demands |
| E_p1_s(c,i) | c∈COM i∈IND | Effective price of commodity composite |
| E_x1_s(c,i) | c∈COM i∈IND | Demands for commodity composites |
| E_x1prim(i) | i∈IND | Demands for primary factor composite |
| E_x1oct(i) | i∈IND | Demands for other cost tickets |
| E_p1tot(i) | i∈IND | Zero pure profits in production |
| E_q1(c,i) | c∈COM i∈IND | Supplies of commodities by industries |
| E_x1tot(i) | i∈IND | Average price received by industries |
| E_x0com(c) | c∈COM | Total output of commodities |
| E_x0dom(c) | c∈COM | Supply of commodities to export market |
| E_pe(c) | c∈COM | Supply of commodities to domestic market |
| E_p0com(c) | c∈COM | Zero pure profits in transformation |
| E_p0dom(c) | c∈COM | Basic price of domestic goods = p0(c,"dom") |
| E_p0imp(c) | c∈COM | Basic price of imported goods = p0(c,"imp") |
| E_x2(c,s,i) | c∈COM s∈SRC i∈IND | Source-specific commodity demands |
| E_p2_s(c,i) | c∈COM i∈IND | Effective price of commodity composite |
| E_x2_s(c,i) | c∈COM i∈IND | Demands for commodity composites |
| E_p2tot(i) | i∈IND | Zero pure profits in investment |
| E_x3(c,s) | c∈COM s∈SRC | Source-specific commodity demands |
| E_p3_s(c) | c∈COM | Effective price of commodity composite |
| E_x3sub(c) | c∈COM | Subsistence demand for composite commodities |
| E_x3lux(c) | c∈COM | Luxury demand for composite commodities |
| E_x3_s(c) | c∈COM | Total household demand for composite commodities |
| E_utility | | Change in utility disregarding taste change terms |
| E_a3lux(c) | c∈COM | Default setting for luxury taste shifter |
| E_a3sub(c) | c∈COM | Default setting for subsistence taste shifter |
| E_x4A(c) | c∈TRADEXP | Traditional export demand functions |
| E_x4B(c) | c∈NTRADEXP | Non-traditional export demand functions |
| E_p4_ntrad | | Average price of non-traditional exports |
| E_x4_ntrad | | Demand for non-traditional export aggregate |
| E_x5(c,s) | c∈COM s∈SRC | Government demands |
| E_f5tot | | Overall government demands shift |
| E_x1mar(c,s,i,m) | c∈COM s∈SRC i∈IND m∈MAR | Margins to producers |
| E_x2mar(c,s,i,m) | c∈COM s∈SRC i∈IND m∈MAR | Margins to capital creators |
| E_x3mar(c,s,m) | c∈COM s∈SRC m∈MAR | Margins to households |
| E_x4mar(c,m) | c∈COM m∈MAR | Margins to exports |
| E_x5mar(c,s,m) | c∈COM s∈SRC m∈MAR | Margins to government users |
| E_p1(c,s,i) | c∈COM s∈SRC i∈IND | Purchasers prices - producers |
| E_p2(c,s,i) | c∈COM s∈SRC i∈IND | Purchasers prices - capital creators |
| E_p3(c,s) | c∈COM s∈SRC | Purchasers prices - households |
| E_p4(c) | c∈COM | Zero pure profits in exporting |
| E_p5(c,s) | c∈COM s∈SRC | Zero pure profits in distribution of government |
| E_p0A(c) | c∈COM | Zero pure profits in importing |
| E_p0B(n) | n∈NONMAR | Demand equals supply for non margin commodities |
| E_p0C(m) | m∈MAR | Demand equals supply for margin commodities |
| E_x0imp(c) | c∈COM | Import volumes |
| E_x1lab_i(o) | o∈OCC | Demand equals supply for labour of each skill |
| E_t1(c,s,i) | c∈COM s∈SRC i∈IND | Power of tax on sales to intermediate |
| E_t2(c,s,i) | c∈COM s∈SRC i∈IND | Power of tax on sales to investment |
| E_t3(c,s) | c∈COM s∈SRC | Power of tax on sales to households |

## The equations of ORANI-G (continued)

| | | |
|---|---|---|
| E_t4A(c) | c∈TRADEXP | Power of tax on sales to traditional exports |
| E_t4B(c) | c∈NTRADEXP | Power of tax on sales to non-traditional exports |
| E_t5(c,s) | c∈COM s∈SRC | Power of tax on sales to government |
| E_w1tax_csi | | Revenue from indirect taxes on flows to intermediate |
| E_w2tax_csi | | Revenue from indirect taxes on flows to investment |
| E_w3tax_cs | | Revenue from indirect taxes on flows to households |
| E_w4tax_c | | Revenue from indirect taxes on exports |
| E_w5tax_cs | | Revenue from indirect taxes on flows to government |
| E_w0tar_c | | Tariff revenue |
| E_w1lnd_i | | Aggregate payments to land |
| E_w1lab_io | | Aggregate payments to labour |
| E_w1cap_i | | Aggregate payments to capital |
| E_w1oct_i | | Aggregate other cost ticket payments |
| E_w0tax_csi | | Aggregate value of indirect taxes |
| E_w0gdpinc | | Aggregate nominal GDP from income side |
| E_x2tot_i | | Total real investment |
| E_p2tot_i | | Investment price index |
| E_w2tot_i | | Total nominal investment |
| E_x3tot | | Real consumption |
| E_p3tot | | Consumer price index |
| E_w3tot | | Household budget constraint |
| E_x4tot | | Export volume index |
| E_p4tot | | Exports price index, $A |
| E_w4tot | | $A border value of exports |
| E_x5tot | | Aggregate real government demands |
| E_p5tot | | Government price index |
| E_w5tot | | Aggregate nominal value of government demands |
| E_x6tot | | Inventories volume index |
| E_p6tot | | Inventories price index |
| E_w6tot | | Aggregate nominal value of inventories |
| E_x0cif_c | | Import volume index, C.I.F. weights |
| E_p0cif_c | | Imports price index, $A C.I.F. |
| E_w0cif_c | | Value of imports, $A C.I.F. |
| E_x0gdpexp | | Real GDP, expenditure side |
| E_p0gdpexp | | Price index for GDP, expenditure side |
| E_w0gdpexp | | Nominal GDP from expenditure side |
| E_delB | | (Balance of trade)/GDP |
| E_x0imp_c | | Import volume index, duty paid weights |
| E_p0imp_c | | Duty paid imports price index |
| E_w0imp_c | | Value of imports (duty paid) |
| E_x1cap_i | | Aggregate usage of capital,rental weights |
| E_p1cap_i | | Average capital rental |
| E_employ(i) | i∈IND | Employment by industry |
| E_employ_i | | Aggregate employment,wage bill weights |
| E_p1lab_io | | Average nominal wage |
| E_realwage | | Average real wage |
| E_x1prim_i | | Aggregate output: value-added weights |
| E_p0toft | | Terms of trade |
| E_p0realdev | | Real devaluation |
| E_r1cap(i) | i∈IND | Definition of rates of return to capital |
| E_x2totA(i) | i∈ENDOGINV | Investment rule |
| E_x2totB(i) | i∈EXOGINV | Investment in exogenous industries |
| E_p1lab(i,o) | i∈IND o∈OCC | Flexible setting of money wages |
| E_p1oct(i) | i∈IND | Indexing of prices of "other cost" tickets |
| E_f3tot | | Consumption function |
| E_delx6(c,s) | c∈COM s∈SRC | possible rule for stocks |
| E_x0loc(c) | c∈COM | %growth in local market |
| E_fandecompA(c) | c∈COM | growth in local market effect |
| E_fandecompB(c) | c∈COM | export effect |
| E_fandecompC(c) | c∈COM | import leakage effect - via residual |
| E_fandecompD(c) | c∈COM | Fan total = x0com |

## The coefficients of ORANI-G (in alphabetical order)

| | | |
|---|---|---|
| B3LUX(c) | c∈COM | Ratio, (supernumerary expenditure/total expenditure), by commodity |
| COSTMAT(i,co) | i∈IND co∈COSTCAT | Summary Costs data |
| DOMSALES(c) | c∈COM | Total sales to local market |
| EPS(c) | c∈COM | Household expenditure elasticities |
| EPSTOT | | Average Engel elasticity: should = 1 |
| EXP_ELAST(c) | c∈COM | Export demand elasticities: typical value -20.0 |
| EXP_ELAST_NT | | Non-traditional export demand elasticity |
| EXPGDP(e) | e∈EXPMAC | Expenditure Aggregates |
| EXPSHR(c) | c∈COM | share going to exports |
| FRISCH | | Frisch LES 'parameter'= - (total/luxury) |
| INCGDP(i) | i∈INCMAC | Income Aggregates |
| INITSALES(c) | c∈COM | Initial volume of SALES at final prices |
| LEVP0(c,s) | c∈COM s∈SRC | Levels basic prices |
| LOCSALES(c) | c∈COM | Total local sales of dom + imp commodity c |
| LOST_GOODS(c) | c∈COM | SALES-MAKE_I : should be zero |
| MAKE(c,i) | c∈COM i∈IND | Multiproduction matrix |
| MAKE_C(i) | i∈IND | All production by industry i |
| MAKE_I(c) | c∈COM | Total production of commodities |
| MARSALES(c) | c∈COM | Total usage for margins purposes |
| PURE_PROFITS(i) | i∈IND | COSTS-MAKE_C : should be zero |
| S1(c,s,i) | c∈COM s∈SRC i∈IND | Intermediate source shares |
| S2(c,s,i) | c∈COM s∈SRC i∈IND | Investment source shares |
| S3(c,s) | c∈COM s∈SRC | Households source shares |
| S3_S(c) | c∈COM | Household average budget shares |
| S3LUX(c) | c∈COM | Marginal household budget shares |
| SALEMAT(c,sa) | c∈COM sa∈SALECAT | Summary Sales data |
| SALES(c) | c∈COM | Total sales of domestic commodities |
| SIGMA1(c) | c∈COM | Armington elasticities: intermediate |
| SIGMA1LAB(i) | i∈IND | CES substitution between skill types |
| SIGMA1OUT(i) | i∈IND | CET transformation elasticities |
| SIGMA1PRIM(i) | i∈IND | CES substitution, primary factors |
| SIGMA2(c) | c∈COM | Armington elasticities: investment |
| SIGMA3(c) | c∈COM | Armington elasticities: households |
| TAU(c) | c∈COM | 1/elast. of transformation, exportable/locally used |
| TAX(t) | t∈TAXMAC | Tax Aggregates |
| TINY | | Small number to prevent singular matrix |
| V0CIF(c) | c∈COM | Total ex-duty imports of good c |
| V0CIF_C | | Total $A import costs, excluding tariffs |
| V0GDPEXP | | Nominal GDP from expenditure side |
| V0GDPINC | | Nominal GDP from income side |
| V0IMP(c) | c∈COM | Total basic-value imports of good c |
| V0IMP_C | | Total basic-value imports (includes tariffs) |
| V0TAR(c) | c∈COM | Tariff revenue |
| V0TAR_C | | Total tariff revenue |
| V0TAX_CSI | | Total indirect tax revenue |
| V1BAS(c,s,i) | c∈COM s∈SRC i∈IND | Intermediate basic flows |
| V1CAP(i) | i∈IND | Capital rentals |
| V1CAP_I | | Total payments to capital |
| V1LAB(i,o) | i∈IND o∈OCC | Wage bill matrix |
| V1LAB_I(o) | o∈OCC | Total wages, occupation o |
| V1LAB_IO | | Total payments to labour |
| V1LAB_O(i) | i∈IND | Total labour bill in industry i |
| V1LND(i) | i∈IND | Land rentals |
| V1LND_I | | Total payments to land |
| V1MAR(c,s,i,m) | c∈COM s∈SRC i∈IND m∈MAR | Intermediate margins |
| V1OCT(i) | i∈IND | Other cost tickets |

## The coefficients of ORANI-G (continued)

| | | |
|---|---|---|
| V1OCT_I | | Total other cost ticket payments |
| V1PRIM(i) | i∈IND | Total factor input to industry i |
| V1PRIM_I | | Total primary factor payments |
| V1PUR(c,s,i) | c∈COM s∈SRC i∈IND | Intermediate purch. value |
| V1PUR_S(c,i) | c∈COM i∈IND | Dom+imp intermediate purch. value |
| V1PUR_SI(c) | c∈COM | Dom+imp intermediate purch. value |
| V1TAX(c,s,i) | c∈COM s∈SRC i∈IND | Taxes on intermediate |
| V1TAX_CSI | | Total intermediate tax revenue |
| V1TOT(i) | i∈IND | Total cost of industry i |
| V2BAS(c,s,i) | c∈COM s∈SRC i∈IND | Investment basic flows |
| V2MAR(c,s,i,m) | c∈COM s∈SRC i∈IND m∈MAR | Investment margins |
| V2PUR(c,s,i) | c∈COM s∈SRC i∈IND | Investment purch. value |
| V2PUR_S(c,i) | c∈COM i∈IND | Dom+imp investment purch. value |
| V2PUR_SI(c) | c∈COM | Dom+imp investment purch. value |
| V2TAX(c,s,i) | c∈COM s∈SRC i∈IND | Taxes on investment |
| V2TAX_CSI | | Total investment tax revenue |
| V2TOT(i) | i∈IND | Total capital created for industry i |
| V2TOT_I | | Total investment usage |
| V3BAS(c,s) | c∈COM s∈SRC | Household basic flows |
| V3MAR(c,s,m) | c∈COM s∈SRC m∈MAR | Households margins |
| V3PUR(c,s) | c∈COM s∈SRC | Households purch. value |
| V3PUR_S(c) | c∈COM | Dom+imp households purch. value |
| V3TAX(c,s) | c∈COM s∈SRC | Taxes on households |
| V3TAX_CS | | Total households tax revenue |
| V3TOT | | Total purchases by households |
| V4BAS(c) | c∈COM | Export basic flows |
| V4MAR(c,m) | c∈COM m∈MAR | Export margins |
| V4NTRADEXP | | Total non-traditional export earnings |
| V4PUR(c) | c∈COM | Export purch. value |
| V4TAX(c) | c∈COM | Taxes on export |
| V4TAX_C | | Total export tax revenue |
| V4TOT | | Total export earnings |
| V5BAS(c,s) | c∈COM s∈SRC | Government basic flows |
| V5MAR(c,s,m) | c∈COM s∈SRC m∈MAR | Government margins |
| V5PUR(c,s) | c∈COM s∈SRC | Government purch. value |
| V5TAX(c,s) | c∈COM s∈SRC | Taxes on government |
| V5TAX_CS | | Total government tax revenue |
| V5TOT | | Total value of government demands |
| V6BAS(c,s) | c∈COM s∈SRC | Inventories basic flows |
| V6TOT | | Total value of inventories |