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WAYANG: a general equilibrium model adapted for the Indonesian economy

Adapted by

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Abstract:

This paper is an adaptation to the WAYANG model of Indonesia of the ORANI-G course paper authored by Horridge, Parmenter and Pearson. WAYANG is based partly on an earlier version of WAYANG documented by Peter Warr and associates, and uses the database devised by them, and partly on ORANI-G. The 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 main adaptations in WAYANG include a treatment of primary factor resource allocation specific for a less developed, strongly agrarian economy in the short- to medium- term. The linear expenditure system of household demands covers ten different households. The consumption function ties household consumption to income earned by household factors. In addition, the model includes a top-down regional extension and a fiscal extension.

[1] *Based on the template authored by* J.M. Horridge, B.R. Parmenter and K.R. Pearson (Centre of Policy Studies and Impact Project, Monash University), *ORANI-G: A General Equilibrium Model of the Australian Economy*, prepared for an *ORANI* -G course at Monash University, June 29th – July 3rd 1998.

Contents

Preface

This paper seeks to combine the transparency of the ORANI-G document (Horridge, Parmenter and Pearson, 1998) with the factor mobility features of the earlier WAYANG model (Warr, Marpudin, da Costa and Tharpa, 1998). The latter are tailored for a less developed economy in which agriculture accounts for a substantial proportion of national income. The ORANI-G template made available by the Centre of Policy Studies and Impact Project at Monash University explains the theory of the model in blocks alongside TABLO code, which resembles ordinary algebra. This paper keeps intact virtually all the ORANI-G documentation, and therefore is very much an adaptation rather than an original work. The authors of the parent document have devised an easy-to-follow system of naming variables and coefficients. They have also written a series of checking formulae that the modeller may inspect after each simulation.

Warr *et al*. (1998) explain the origin of the name "WAYANG" as follows:

> Obviously, [the AGE model] WAYANG is not in itself the answer to Indonesia's problems. No single model or group of models could ever provide the sole basis for policy determination on any significant issue of public policy. Many factors other than those captured in the models will be relevant and must be considered. The virtue of models of this type is that, if they are well-designed, they can draw out relationships among the variables they do contain that might otherwise not be fully appreciated. Economic models are in this respect similar to theatrical performances. The characters depicted in them are over-simplified caricatures of real-world people and the ways in which they interact take exaggerated forms, constrained by the designer of the performance. Nevertheless, this simplified representation of reality is capable of drawing out relationships and developing themes that are not normally obvious within the immense complexity of everyday existence. Once these relationships have been understood, reality can thereafter be perceived differently and more insightfully. For this to happen, the designer of the model or theatrical performance must ensure that the simplified representation provided focuses on the most relevant issues, excluding less relevant ones.
>
> Like the Javanese *wayang* theatre, from which it takes its name, the WAYANG model is not meant to be an exact description of reality. It is a simplification which nevertheless brings to our attention relationships of interest and importance for real-world affairs and which is thereby capable of enhancing our capacity to understand the world and to act well within it.

WAYANG, like the original WAYANG model of the Indonesian economy and its predecessors, has some distinct features concerning factor markets (Warr *et al*., 1998). For example, fertiliser is substitutable with primary factors of production in agriculture. In non-agricultural industries, there are two types of capital. One type is mobile between industries, while the other is specific to each industry. These features are designed for short- to medium-term scenarios, in which there is insufficient time for all types of capital to be reallocated. Households supply all factors of production. The income earned from these factors consequently determines household income. The modeller may tie household income to expenditure directly through the consumption function.

There are two further additions in this model to the standard ORANI-G framework. WAYANG contains a fiscal extension, based on that of the original WAYANG model. And it includes a regional extension, modelling three regions of the Indonesian economy in a top-down manner. The code for the regional extension has been borrowed from the MONASH95 model. Some features, notably dealing with multiple households, have been borrowed from the PRCGEM model of the Chinese economy.

The objective of this document is to detail a model of the Indonesian economy in a form that is both recognisable to experienced CGE modellers and helpful to less experienced modellers seeking to understand the basic theory of WAYANG. By conforming with the basic ORANI-G representation, this manual helps make clear both the general and model-specific features of WAYANG.

I thank Peter Warr and his assistants for devising the initial WAYANG model and making it and its database available for the project. I am also grateful to the Centre of Policy Studies for making available GEMPACK software, AGE models and documentation, and for rendering such models more usable and transparent for those without specialist computing or AGE modelling skills. Thanks are also due to ACIAR for financing the project and to other members of the ACIAR-Indonesia trade project for inputs.

1. Introduction

WAYANG is in the ORANI family of models. Its applications are confined to comparative-static analysis. It includes 65 industries each producing a single commodity. There are ten households within the model and a top-down regional extension, .

GEMPACK, a flexible system for solving AGE models, is used to formulate and solve WAYANG (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 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.

2. Model Structure and Interpretation of Results

WAYANG 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, WAYANG 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, WAYANG 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.

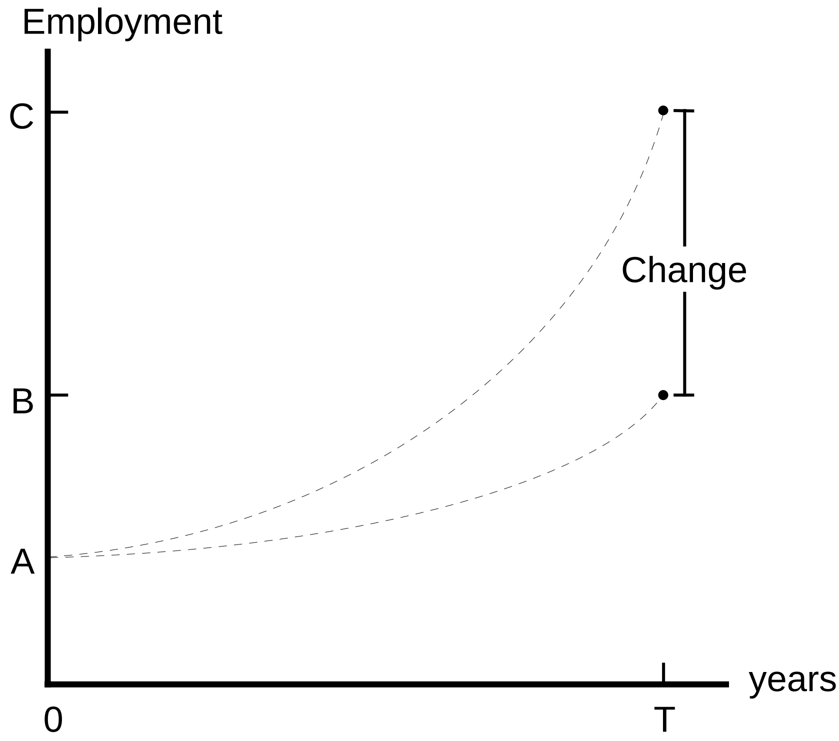

Figure 1. Comparative-static interpretation of results

Many comparative-static 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.

3. The Percentage-Change Approach to Model Solution

Many of the WAYANG 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[2].

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

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

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

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

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

[2] 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.

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 **F** function it will be true that for small changes **dY** and **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 **F** with respect to **Y** and **X**, evaluated at $\{\mathbf{Y}^0,\mathbf{X}^0\}$. For reasons explained below, we find it more convenient to express **dY** and **dX** as small percentage changes **y** and **x**. Thus y and x, some typical elements of **y** and **x**, are given by:

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

Correspondingly, we define:

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

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

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

Such systems are easy for computers to solve, using standard techniques of linear algebra. But they are accurate only for small changes in **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}.

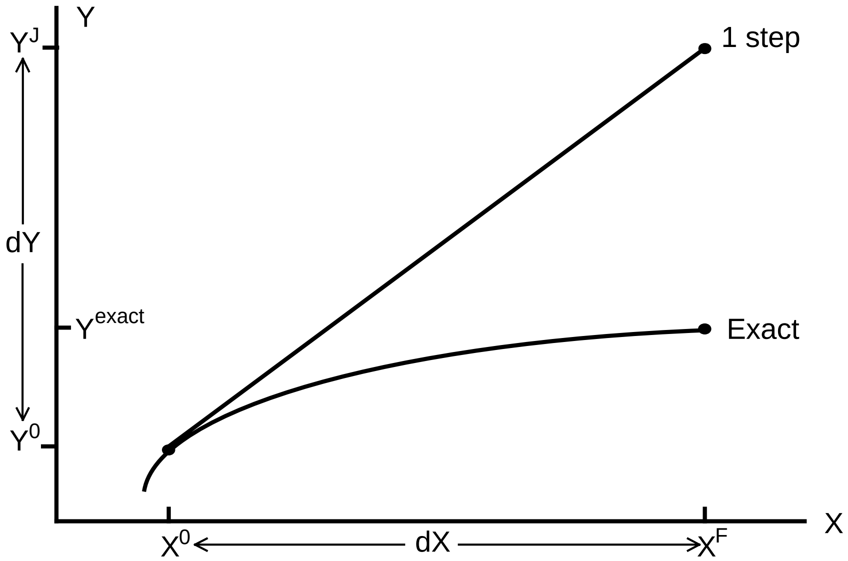

Figure 2. Linearisation error

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%.

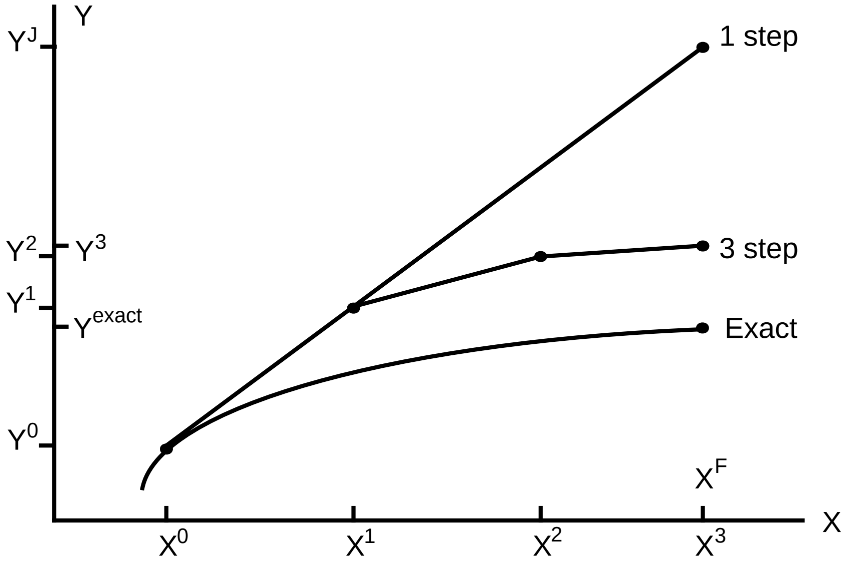

Figure 3. Multistep process to reduce linearisation error

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 (**X**,**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[3], 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):

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

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

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

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

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

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

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

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

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

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

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 WAYANG 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 coefficents equally; it does not affect WAYANG 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).[4]

4. The Equations of WAYANG

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.[5]

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

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[4] 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. If a forecasting model’s control scenario had textile employment growing annually by 1.5%, the 7% reduction could be absorbed without actually firing any textile workers.

[5] 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.

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 '$\times$'.

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 WAYANG 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) ten representative households;
(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 →	← H →	← 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

H = Number of Households

	Joint Production Matrix
Size	← I →
↑ C ↓	MAKE

	Import Duty
Size	← 1 →
↑ C ↓	V0TAR

Figure 4. The WAYANG 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.

The WAYANG model contains 65 industries, each which 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 rural industries. Labour is disaggregated into 2 occupational categories.

The transport commodities plus trade 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).

```
! Excerpt 1 of TABLO input file: !
! Definitions of sets !
Set                                    ! Subscript !
 COM        # Commodities #
 (C1paddy, C2beans,      C3maize, C4cassava, C5vegfruit, C6othcrop, C7rubber, C8sugarcane,
C9coconut, C10oilpalm, C11tobacco, C12coffee, C13tea, C14clove, C15fibre, C16othescrop,
C17othagric, C18livest, C19mslaugth, C20poultry, C21wood, C22othforest, C23sfish, C24cmetal,
C25crudoil, C26omining, C27foodp, C28moilfat, C29ricemill, C30mflour, C31sugarfac,
C32mothfood, C33beverages, C34cigar, C35yarn, C36textiles,  C37bamwood, C38mpaper,
 C39fertilize, C40chemical, C41petrol, C42rplastic, C43nonmetp, C44cement,     C45basiron,
C46nonfermet,   C47metalp, C48electrcl, C49mtransp, C50othmanuf,  C51egw, C52construct,
C53trade, C54reshot, C55railtr, C56roadtr, C57seawltr, C58airtr, C59servtr,
C60communic, C61finance, C62restate, C63govdef, C64soscom, C65othserv);
SRC        # Source of commodities #   (dom,imp);               ! s !
 IND        # Industries #
(C1paddy, C2beans,C3maize, C4cassava, C5vegfruit, C6othcrop, C7rubber, C8sugarcane,
C9coconut, C10oilpalm, C11tobacco, C12coffee, C13tea, C14clove, C15fibre, C16othescrop,
C17othagric, C18livest, C19mslaugth, C20poultry, C21wood, C22othforest, C23sfish, C24cmetal,
C25crudoil, C26omining, C27foodp, C28moilfat, C29ricemill, C30mflour, C31sugarfac,
C32mothfood, C33beverages, C34cigar, C35yarn, C36textiles,  C37bamwood, C38mpaper,
 C39fertilize, C40chemical, C41petrol, C42rplastic, C43nonmetp, C44cement,     C45basiron,
C46nonfermet,   C47metalp, C48electrcl, C49mtransp, C50othmanuf,  C51egw, C52construct,
C53trade, C54reshot, C55railtr, C56roadtr, C57seawltr, C58airtr, C59servtr,
C60communic, C61finance, C62restate, C63govdef, C64soscom, C65othserv);

OCC        # Occupation types #       (skilled,unskilled);       ! o !
 MAR        # Margin commodities #
(C53trade, C55railtr, C56roadtr,   C57seawltr, C58airtr,       C59servtr); ! m !
Subset MAR is subset of COM;
Set NONMAR  # Non-margin commodities # = COM - MAR;             ! n !
Set TRADEXP  # Traditional export commodities #
   (C3maize, C4cassava, C7rubber, C9coconut, C16othescrop, C17othagric, C22othforest,
C23sfish, C24cmetal, C25crudoil,       C27foodp,    C28moilfat,  C29ricemill, C34cigar, C36textiles,
C37bamwood,   C41petrol, C42rplastic, C44cement, C57seawltr);
Subset TRADEXP is subset of COM;
Set NTRADEXP # Nontraditional Export Commodities # = COM - TRADEXP;
Set EXOGINV  # 'exogenous' investment industries # (C51egw,C63govdef);
Subset EXOGINV is Subset of IND;
Set ENDOGINV # 'endogenous' investment industries # = IND - EXOGINV;
```

```
SET HH  #household types#  (rural1-rural7, urban1-urban3);
!ru1=landless; ru2=<0.5ha; ru3=0.5-1.0ha; ru4=>1.0ha; ru5=low, non-ag;
ru6=medium, non-ag; ru7=high, non-ag; urb1=low; urb2=medium; urb3=high!
SET AGIND (C1paddy, C2beans,C3maize, C4cassava, C5vegfruit, C6othcrop,
C7rubber, C8sugarcane, C9coconut,  C10oilpalm, C11tobacco, C12coffee,  C13tea,
C14clove,   C15fibre,    C16othescrop,   C17othagric,     C18livest);
Subset AGIND is Subset of IND;
SET N_AGIND = IND - AGIND;
SET KAP # Types of capital #(fixcap ,varcap ) ;
SET FERT (C39fert);
Subset FERT is subset of COM;
SET NONFERT = COM - FERT;
```

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 six elements of MAR, 'C53Trade', 'C55railtr', ‘C56roadtr’, ‘C57seawltr’, ‘C58airtr’ and ‘C59servtr’ are the same as the 53rd and 55th to 59th 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

1 paddy	23 sfish	45 basiron
2 beans	24 cmetal	46 nonfermet
3 maize	25 crudoil	47 metalp
4 cassava	26 omining	48 electrcl
5 vegfruit	27 foodp	49 mtransp
6 othcrop	28 moilfat	50 othmanuf
7 rubber	29 ricemill	51 egw
8 sugarcane	30 mflour	52 construct
9 coconut	31 sugarfac	53 trade
10 oilpalm	32 mothfood	54 reshot
11 tobacco	33 beverages	55 railtr
12 coffee	34 cigar	56 roadtr
13 tea	35 yarn	57 seawltr
14 clove	36 textiles	58 airtr
15 fibre	37 bamwood	59 servtr
16 othescrop	38 mpaper	60 communic
17 othagric	39 fertilizer	61 finance
18 livest	40 chemical	62 restate
19 mslaugth	41 petrol	63 govdef
20 poultry	42 rplastic	64 soscom
21 wood	43 nonmetp	65 othserv
22 othforest	44 cement	

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 database depicted in Figure 4. The first group of variables contains the quantities associated with row 1 (basic flows) of the database, i.e., the flow matrices V1BAS, V2BAS, and so on. All these quantities are valued at basic prices, p0, which are listed next[6]. 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.)

```
! 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)(all,h,HH)      x3(c,s,h)      # 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)(all,h,HH) x3mar(c,s,m,h)  # 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 #;
```

[6] 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.

```
! 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)(all,h,HH)         p3(c,s,h)        # 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 #;
```

The last group of variables in excerpt 2 contains the purchasers' prices which include basic, margin and tax components.

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 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,o,OCC)             f1lab_i_x(o)   #Supply shifter in labour market#;
! 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 #;
! Variables relating to usage of land !
(all,i,IND)          x1lnd(i)       # Use of land #;
(all,i,IND)          p1lnd(i)       # Rental price of land #;
! 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 #;
(change)
(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)(all,h,HH)     x3_s(c,h)    # Household use of imp/dom composite #;
(all,c,COM)(all,h,HH)     x3lux(c,h)   # Household - supernumerary demands #;
(all,c,COM)(all,h,HH)     x3sub(c,h)   # 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)(all,h,HH)     p3_s(c,h)    # 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)(all,h,HH)     a3_s(c,h)    # Taste change, h'hold imp/dom composite #;
(all,c,COM)(all,h,HH)     a3lux(c,h)   # Taste change, supernumerary demands #;
(all,c,COM)(all,h,HH)     a3sub(c,h)   # 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,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 #;
(all,h,HH)     q(h)          # Number of households #;
(all,h,HH)     utility(h)    # Utility per household #;
(all,h,HH)     w3lux(h)      # Total nominal supernumerary household expenditure #;
(all,h,HH)     w3tot_hh(h)   # Nominal total consumption, each household  #;
(all,h,HH)     x3tot_hh(h)   # Real total consumption, each household  #;
(all,h,HH)     p3tot_hh(h)   # Consumer price index, each household  #;
```

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.

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

Variable
(change) delB           # % (Balance of trade)/GDP #;
employ_i                # Aggregate employment: wage bill weights #;
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/income #;
f3tot                 # Ratio, consumption/income by hh #;
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 #;
realwage                # Average real wage #;
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 #;
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 #;
p1cap_ag                # National variable capital rental, agri. #;
p1cap_nagv              # National variable capital rental, non-ag. #;
x1cap_ag                # variable capital, agriculture #;
x1cap_nag             # variable capital, non-ag. #;
```

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 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)(all,h,HH)       V3BAS(c,s,h)        # 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)(all,h,HH)       V3BAS(c,s,h)  =     p0(c,s)*x3(c,s,h);
 (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)(all,h,HH) V3MAR(c,s,m,h)   # 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)(all,h,HH)  V3MAR(c,s,m,h)  =  p0dom(m)*x3mar(c,s,m,h);
 (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:

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

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

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)(all,h,HH)        V3TAX(c,s,h)        # 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)(all,h,HH)
     V3TAX(c,s,h) = V3TAX(c,s,h)* [x3(c,s,h) + p0(c,s)]/100 +    [V3BAS(c,s,h)+V3TAX(c,s,h)]*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,k,KAP)(all,i,N_AGIND)   V1CAPN(k,i)             # Capital rentals, non-ag.  #;
 (all,i,AGIND)                V1CAPA(i)               # Capital rentals, ag.  #;
(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
 V1CAPN from file  MDATA header "1CAP";
 V1CAPA from file  MDATA header "1CAG";
 V1LAB from file   MDATA header "1LAB";
 V1LND from file   MDATA header "1LND";
 V1OCT from file   MDATA header "1OCT";
Variable
 (all,k,KAP)(all,i,N_AGIND)   p1capn(k,i)  # price of non-agri capital by type #;
(all,k,KAP)(all,i,N_AGIND)    x1capn(k,i)     # quantity of non-agri capital by type #;
(all,h,hh)                    w1cap_v(h)  # Returns to variable capital by household #;
(all,h,hh)                    w1cap_f(h)  # Returns to fixed capital by household #;
(all,h,hh)                    x1cap_vah(h)    # Variable capital supply by household, agri. #;
(all,h,hh)                    x1cap_vnh(h)    # Variable capital supply by household, non-agri. #;
 (all,i,N_AGIND)(all,h,hh)    x1cap_f_hh(i,h)   # Fixed capital supply by household #;

Update
  (all,k,KAP)(all,i,N_AGIND)      V1CAPN(k,i)      = p1capn(k,i)*x1capn(k,i);
(all,i,AGIND)                     V1CAPA(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)(all,h,HH)           V3PUR(c,s,h)     # 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)(all,h,HH)
  V3PUR(c,s,h)    = V3BAS(c,s,h) + V3TAX(c,s,h)  + sum{m,MAR,V3MAR(c,s,m,h) };
 (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)(all,h,HH)           V3PUR_S(c,h)      # 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)(all,h,HH)           V3PUR_S(c,h)  =   sum{s,SRC,V3PUR(c,s,h)};

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)(all,h,HH)      S3(c,s,h)        # 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)(all,h,HH)      S3(c,s,h) = V3PUR(c,s,h)/V3PUR_S(c,h);
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,f,AGRIFAC)(all,i,AGIND)V1FAC(f,i)# Total factor input to ind. i, agri.#;
 (all,f,N_AGRIFAC)(all,i,N_AGIND)V1FACO(f,i) # Total factor input non-agri. #;
 (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,AGIND)      V1CAP(i)    = V1CAPA(i);
 (all,i,AGIND)     V1FAC("unskil",i) = V1LAB_O(i);
 (all,i,AGIND)     V1FAC("varcap",i) = V1CAPA(i);
 (all,i,AGIND)     V1FAC("fert",i) =V1PUR_S("C39fert",i);
 (all,i,AGIND)     V1FAC("land",i) =V1LND(i);
 (all,i,N_AGIND)V1CAP(i)  = sum{k,KAP,V1CAPN(k,i)  };
 (all,k,KAP)(all,i,N_AGIND)    V1FACO(k,i) = V1CAPN(k,i);
 (all,i,N_AGIND)   V1FACO("labcomp",i) =V1LAB_O(i);
(all,i,AGIND)  V1PRIM(i) = sum{f,AGRIFAC,V1FAC(f,i)};
 (all,i,N_AGIND)  V1PRIM(i) = sum{f,N_AGRIFAC,V1FACO(f,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,sum{h,HH,V3MAR(c,s,m,h)} + 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) }
    + sum(h,HH,V3BAS(c,"dom",h)) + 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) }
 + sum(h,HH,V3BAS(c,"imp",h)) + 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, sum{h,HH,  V3TAX(c,s,h) }}};
 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;
```

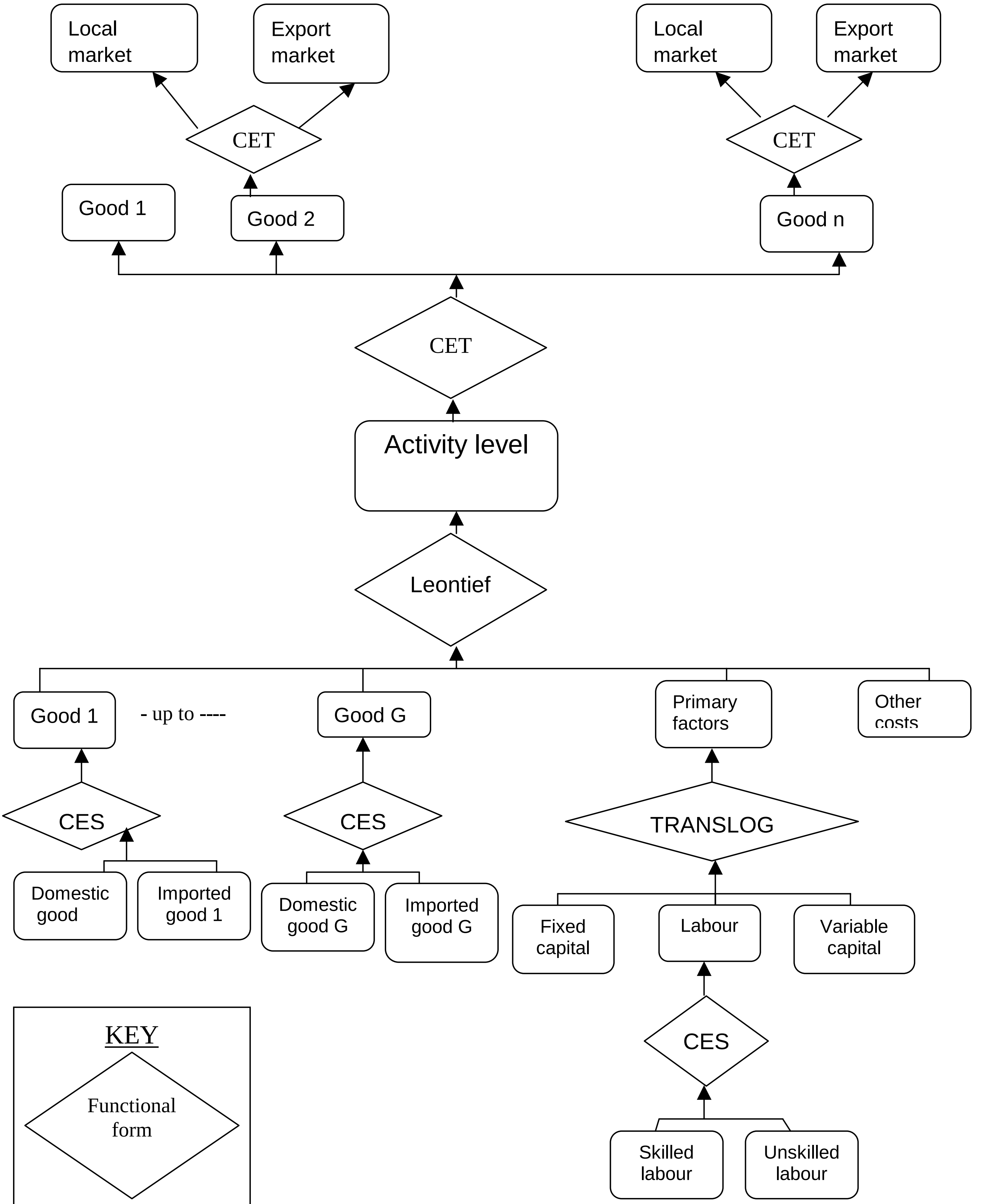
Excerpt 14 covers the computation of GDP from the expenditure side.

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.

Figure 5. Structure of Production



Note: primary factor demands above apply to non-agricultural industries only. In agriculture, the four factors of production are unskilled labour, land, variable capital and a domestic-import fertiliser composite.

```
! 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 #;
 (all,h,HH)V3TOT_HH(h)  # Total purchases by each households #;
 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) };
 (all,h,HH)V3TOT_HH(h)    =        sum{c,COM, V3PUR_S(c,h) };
 V3TOT                =        sum(h,HH,V3TOT_HH(h));
 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;
```

4.7. Structure of production

The theory of WAYANG 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.

```
! 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) };
```

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.

4.9. The unique primary factor demand system in WAYANG

The main model-specific features of WAYANG appear in excerpts 16A to 16E. WAYANG has two different sets of primary factors for agricultural and non-agricultural production. In agriculture, there are four factors, land, unskilled labour, variable capital and fertiliser. In other industries, the three substitutable factors are labour, variable capital and fixed capital. Therefore, two different types of capital are mobile between mutually exclusive subsets of industries. While only unskilled labour is used in agriculture, it is mobile between all industries. Fertiliser is treated as a primary input to recognise its substitutability with other factors of production in agriculture. In the non-agricultural subset, each industry uses specific capital in production (i.e., immobile between industries) in addition to variable capital, implying a short- to medium-run time horizon. Excerpt 16 contains equations determining the composition of demand for primary factors.

Their derivation follows a translog functional form (see appendix G). In this case, total primary factor costs are minimised subject to the production function (in agriculture):

$$X1PRIM(i) = TRANSLOG\left[\frac{X1FAC(f,i)}{A1FAC(f,i)}\right];$$

and in non-agricultural industries (where there are two types of capital, fixed and mobile):

$$X1PRIM(i) = TRANSLOG\left[\frac{X1FACO(f,i)}{A1FACO(f,i)}\right];$$

Because we may wish to introduce factor-saving technical changes, we include explicitly the coefficients A1FAC(i) and A1FACO(i).

The solution to this problem, in percentage-change form, is given by equations E_x1fac and E_x1faco. The motivation for using the translog form for deriving these equations is to preserve, as much as possible, econometric estimates of primary factor input demand price elasticities while retaining homogeneity of degree one, subject to the restrictions given in appendix G.

The coefficient TRNL provides the modeller with a choice of functional form, and is equal to one for the translog form. But in large change simulations, this form may lack concavity. If the CES form is preferred for a particular simulation, the modeller may set the coefficient TRNL in the database to zero.

```
! Excerpt 16 of TABLO input file: !
! Excerpt 16A: Primary factor proportions !
!Translog unit cost function. This is outlined in appendix G.
It is used to preserve a matrix of factor demand elasticities without the
restrictions of CRESH or CDE. See p.133-141 of the Black Book.!

Variable
(all,f,AGRIFAC)(all,i,AGIND)       x1fac(f,i) # Primary factor demands, agriculture #;
(all,f,AGRIFAC)(all,i,AGIND)       p1fac(f,i) # Primary factor pirces, agriculture #;
(all,f,AGRIFAC)(all,i,AGIND)       a1fac(f,i) # Primary factor augmenting tech. change, agri. #;
(all,f,N_AGRIFAC)(all,i,N_AGIND) a1faco(f,i)# Prim. factor augmenting tech. change, other #;
(all,f,N_AGRIFAC)(all,i,N_AGIND)     x1faco(f,i) # Primary factor demands, other #;
(all,f,N_AGRIFAC)(all,i,N_AGIND)     p1faco(f,i) # Primary factor price, other #;
Coefficient
(all,f,AGRIFAC) (all,i,AGIND) V1FACSH(f,i) #Agri. ind. factor share#;
(all,f,AGRIFAC)(all,v,AGRIFAC)(all,i,AGIND)
                       SHR_FAC(f,v,i)#Agri. industry modified factor share (for translog)#;
(all,f,AGRIFAC)(all,v,AGRIFAC)(all,i,AGIND)
                       BETA_A(f,v,i)#Factor demand elasticities, agri.#;
(all,f,N_AGRIFAC)(all,i,N_AGIND)    V1FACSH_N(f,i) #Non-ag ind. factor share#;
(all,f,N_AGRIFAC)(all,v,N_AGRIFAC)(all,i,N_AGIND)
                       SHR_FAC_N(f,v,i)#Non-ag. ind. modified factor share (for translog)#;
(all,f,N_AGRIFAC)(all,v,N_AGRIFAC)(all,i,N_AGIND)
                       BETA_N(f,v,i)#Factor demand elasticities, non-ag.#;

Zerodivide Default 0.25;
Read BETA_A from file MDATA header "ALPH";
BETA_N from file MDATA header "ALP2";
Formula !calculate the modified cost shares, appendix G, equation G.17!
(all,f,AGRIFAC)(all,i,AGIND)V1FACSH(f,i)=    V1FAC(f,i)/sum{g,AGRIFAC,V1FAC(g,i)};
(all,f,N_AGRIFAC) (all,i,N_AGIND)V1FACSH_N(f,i)=
                       V1FACO(f,i)/sum{g,N_AGRIFAC,V1FACO(g,i)};
(all,f,AGRIFAC)(all,v,AGRIFAC)(all,i,AGIND)SHR_FAC(f,v,i)=
                       V1FACSH(v,i) + BETA_A(f,v,i)/V1FACSH(f,i);
(all,f,N_AGRIFAC)(all,v,N_AGRIFAC)(all,i,N_AGIND)SHR_FAC_N(f,v,i)=
                       V1FACSH_N(v,i) + BETA_N(f,v,i)/V1FACSH_N(f,i);
Zerodivide off;
```

```
Coefficient (all,i,IND)SIGMA1PRIM(i);
TRNL;
CESFORM;
Read TRNL from file MDATA header "TRNL";
Formula (all,i,IND)SIGMA1PRIM(i)=0.5; !CES alternative!
CESFORM = 1 - TRNL; !if TRNL =0, CES functional form!
Equation E_x1fac  # Primary factor demands, agriculture # ! equation G.16!
(all,f,AGRIFAC)(all,i,AGIND)x1fac(f,i) - a1fac(f,i)=
 x1prim(i)  - TRNL*[p1fac(f,i)  - Sum{v,AGRIFAC,SHR_FAC(f,v,i)*p1fac(v,i)}]
           - TRNL*[a1fac(f,i)  - Sum{v,AGRIFAC,SHR_FAC(f,v,i)*a1fac(v,i)}]
           - CESFORM*SIGMA1PRIM(i)*[p1fac(f,i) +  a1fac(f,i) -p1prim(i)] ;

Equation E_x1faco  # Primary factor demands, non-agriculture # ! equation G.16!
(all,f,N_AGRIFAC)(all,i,N_AGIND)x1faco(f,i) - a1faco(f,i)=
  x1prim(i)-TRNL*[p1faco(f,i)  - Sum{v,N_AGRIFAC,SHR_FAC_N(f,v,i)*p1faco(v,i)}]
          -TRNL*[a1faco(f,i)  - Sum{v,N_AGRIFAC,SHR_FAC_N(f,v,i)*a1faco(v,i)}]
          - CESFORM*SIGMA1PRIM(i)*[p1faco(f,i) +  a1faco(f,i) -p1prim(i)] ;
```

Excerpt 16B lists the coefficients describing factor supplies by household. The household factor supply equations follow. In the usual short- to medium-run setting, household supplies of land (x1lndi_hh), labour(x1lab_i_h), specific capital (x1cap_f_hh) and variable capital (x1cap_vnh and x1cap_vah) are exogenous. The excerpt also includes the equations solving for p1prim and, in non-agricultural industries, p1cap. The percentage change in the average effective cost, p1prim(i), given by equations E_p1primA and E_p1primN, is a cost-weighted Divisia index of individual prices and technical changes.

```
!Excerpt 16B: household supply and prices of primary factors!
!WAYANG factor market modifications!

Variable
(all,i,AGIND)(all,h,HH)       x1lndi_hh(i,h)      # Household supply of land, agri. #;
                              p1cap_ag            # National variable capital rental, agri. #;
                              p1cap_nagv          # National variable capital rental, non-ag. #;
(all,h,hh)                    w1cap_v(h)          # Returns to variable capital by household #;
(all,h,hh)                    w1cap_f(h)          # Returns to fixed capital by household #;
(all,h,hh)                    x1cap_vah(h)        # variable capital by household, agri. #;
(all,h,hh)                    x1cap_vnh(h)        # variable capital by household, non-agri. #;
                              x1cap_ag            # variable capital, agriculture #;
                              x1cap_nag           # variable capital, non-ag. #;
(all,i,N_AGIND)               x1cap_f(i)          # fixed capital, non-ag. #;
(all,i,N_AGIND)(all,h,hh)     x1cap_f_hh(i,h)     # fixed capital by h'hold, non-ag. #;

Coefficient
(all,h,hh)(all,f,occ)         HINC(h,f) # household factor income #;
(all,i,AGIND)(all,h,HH)       LANDS(i,h) # household land rentals by industry #;

Read
HINC    from file MDATA header "HINC";
LANDS       from file MDATA Header "LAND";
Update
(all,i,AGIND)(all,h,HH)       LANDS(i,h)      = p1fac("land",i)*x1lndi_hh(i,h);
(all,i,AGIND)                 V1CAPA(i)       = p1fac("varcap",i)*x1fac("varcap",i);
(all,k,KAP)(all,i,N_AGIND)    V1CAPN(k,I)     = p1faco(k,i)*x1faco(k,i);
```

```
Equation E_p1lab_i  # Supply of labour #
(all,o,OCC)sum{h,HH,HINC(h,o)}* x1lab_i(o) =
      sum{h,HH,HINC(h,o)*[x1lab_i_h(o,h)+f1lab_i_x(o)]};

Equation E_p1lnd    # supply of land #
(all,i,AGIND)V1LND(i)*x1lnd(i) = Sum{h,HH, LANDS(i,h)*x1lndi_hh(i,h)};

Equation E_p1capA     # Price of variable + fixed capital, non-agri. #
(all,i,N_AGIND)V1CAP(i)*p1cap(i) = sum{k,KAP, V1CAPN(k,i)*p1faco(k,i)};

Equation E_p1primA # Effective price term for factor demand equations, ag. #
(all,i,AGIND)  V1PRIM(i)*p1prim(i) =
           sum{f,AGRIFAC,V1FAC(f,i)*[p1fac(f,i) + a1fac(f,i)]};

Equation E_p1primN  # Effective price term for factor demand equations, N_AG #
(all,i,N_AGIND)  V1PRIM(i)*p1prim(i) =
           sum{f,N_AGRIFAC,V1FACO(f,i)*[p1faco(f,i) + a1faco(f,i)]};
```

The equations in excerpt 16C match percentage changes in factor prices and quantities that appear in equations E_x1fac and E_x1faco to variables elsewhere in the model. Clearly, each equation can only solve for either a price or a quantity at one time. For example, E_x1faco solves for the percentage change in the quantity of composite labour demanded in non-agricultural industries (x1faco("labcomp")). Equation E_x1lab_oB sets x1lab_o equal this variable, which in turns appears in equation E_x1lab. The corresponding price term in E_x1faco (p1faco("labcomp")), is solved in E_p1lab_o, and also appears in equation E_x1lab.

```
!Excerpt 16C: Matching factor p and x to E_x1fac and E_x1faco!

Equation E_p1facLB  # Industry demands for effective labour #
(all,i,AGIND)  p1lab_o(i)=p1fac("unskil",i);

Equation  E_x1lab_oA      # Effective labour input, agriculture #
(all,i,AGIND)  x1lab_o(i)= x1fac("unskil",i);

Equation E_p1facF  # Price of fertiliser in agri.#
(all,i,AGIND)  p1fac("fert",i) = p1_s ("C39fert",i);

Equation E_p1capB     # Price of variable  capital, agri. #
(all,i,AGIND)p1cap(i) = p1fac("varcap",i);

Equation E_x1lnd  # Industry demands for land #
(all,i,AGIND)  x1lnd(i)   = x1fac("land",i);

Equation E_p1facL # Price of land in agri.  #
(all,i,AGIND)p1lnd(i) = p1fac("land",i);

Equation E_x1lab_oB  # Industry demands for effective labour #
(all,i,N_AGIND)  x1lab_o(i) = x1faco("labcomp",i);

Equation E_p1facoLC  # Price to each industry of labour composite #
(all,i,N_AGIND)p1faco("labcomp",i) = p1lab_o(i) ;

Equation E_p1facoKN   # Price of variable capital in non-ag #
(all,i,N_AGIND)p1faco("varcap",i)=p1cap_nagv;

Equation E_p1facoFC      # supply of fixed capital by household #
(all,i,N_AGIND)x1cap_f(i) = x1faco("fixcap",i);

Equation E_x1capA       # agri. industry capital, variable #
   (all,i,AGIND)x1cap(i)=x1fac("varcap",i);
```

Excerpt 16D lists the remaining coefficients for household supplies of primary factors. FIXEDK contains the fixed capital owned by each household by industry. MMA and MMN include household supplies of variable capital in agriculture and non-agriculture respectively.

```
!Excerpt 16D: additional household supply coefficients!
Coefficient
(all,h,HH)(all,i,N_AGIND)FIXEDK(h,i) # Household supplies of fixed capital #;
(all,h,HH)          MMA(h) # Household supplies of agri variable capital #;
(all,h,HH)          MMN(h) # Household supplies of non-agri variable capital #;
Read
FIXEDK      from file MDATA Header "CAPS";
MMA         from file MDATA Header "CAPA";
MMN         from file MDATA Header "CAPN";
Update
(all,h,hh)     (all,o,OCC) HINC(h,o)      = x1lab_i_h(o,h)*p1lab_i(o)*f1lab_i_x(o);
(all,h,HH)(all,i,N_AGIND)FIXEDK(h,i)     = p1faco("fixcap",i)*x1cap_f_hh(i,h);
(all,h,HH)          MMA(h)         = p1cap_ag   * x1cap_vah(h);
(all,h,HH)          MMN(h)         = p1cap_nagv * x1cap_vnh(h);

Equation E_p1lab # Equalising of money wages #
(all,i,IND)(all,o,OCC)
p1lab(i,o)= p1lab_i(o);
```

Excerpt 16E contains the market-clearing equations for factors of production.

```
!Excerpt 16E: Market clearing of household factors!
Equation E_x1cap_f     # supply of fixed capital by household #
(all,i,N_AGIND)sum{h,HH,FIXEDK(h,i)}*x1cap_f(i) =
   sum{h,HH,FIXEDK(h,i)*x1cap_f_hh(i,h)};

Equation E_p1cap_ag     # market clearing, variable capital, agriculture  #
sum{i,AGIND,V1CAP(i)}*x1cap_ag = sum{i,AGIND,V1CAP(i)*x1cap(i)};

Equation E_x1cap_ag     # household supply of variable capital, ag.#
sum{h,HH,MMA(h)}*x1cap_ag = sum{h,HH,MMA(h)*x1cap_vah(h)};

Equation E_p1cap_nagv     # variable capital, non-ag. #
sum{h,HH,MMN(h)}*x1cap_nag = sum{h,HH,MMN(h)*x1cap_vnh(h)};

Equation E_x1cap_nag     # market clearing for variable capital, non-ag. #
sum{i,N_AGIND,V1CAPN("varcap",i)}*x1cap_nag =
   sum{i,N_AGIND,V1CAPN("varcap",i)*x1faco("varcap",i)};

Equation E_p1facK   # Equalise price of capital in agri.  #
(all,i,AGIND)p1fac("varcap",i)=p1cap_ag ;

Equation E_x1capN     #  non-agri. industry capital, fixed + variable #
   (all,i,N_AGIND)V1CAP(i)*x1cap(i) = sum{k,KAP,  V1CAPN(k,i)*x1faco(k,i)};

!Summing returns to household factors!
Equation E_w1cap_v     # Returns to variable capital by household #
(all,h,HH)[MMA(h)+MMN(h)]*w1cap_v(h) =
MMA(h)* [p1cap_ag   + x1cap_vah(h)] + MMN(h) * [p1cap_nagv + x1cap_vnh(h)];

Equation E_w1cap_f     # Returns to fixed capital by household #
(all,h,HH)sum{i,N_AGIND,FIXEDK(h,i)}*w1cap_f(h) =
sum{i,N_AGIND,FIXEDK(h,i)*[p1faco("fixcap",i) + x1cap_f_hh(i,h)]};
```

4.10. 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:

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

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:

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

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

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

```
! Excerpt 18 of TABLO input file: !
! 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_sA  # Demands for commodity composites #
(all,c,COM)(all,i,N_AGIND)  x1_s(c,i) - [a1_s(c,i) + a1tot(i)] = x1tot(i);

Equation E_x1_sB  # Demands for commodity composites #
(all,c,NONFERT)(all,i,AGIND)  x1_s(c,i) - [a1_s(c,i) + a1tot(i)] = x1tot(i);

Equation E_x1_sC  # Demands for commodity composites #
(all,c,FERT)(all,i,AGIND)  x1_s(c,i) = x1fac("fert",i);
! Note that a1_s("C39fert") = a1fac("fert") !

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_p1totA  # Zero pure profits in production #
(all,i,N_AGIND)
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)];

Equation E_p1totB  # Zero pure profits in production #
(all,i,AGIND)
V1TOT(i)*[p1tot(i)-a1tot(i)] =
 sum{c,NONFERT,  V1PUR_S(c,i)  *[p1_s(c,i) + a1_s(c,i)] }
       +  V1PRIM(i)     *[p1prim(i) + a1prim(i)]
       +  V1OCT(i)      *[p1oct(i) + a1oct(i)];
```

WAYANG allows for each industry to produce a mixture of all the commodities, although in the present database, each industry produces a single, unique commodity. For each industry, the mix varies in theory, 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:

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

The CET (constant elasticity of transformation) aggregation function is identical to CES, except that the transformation parameter in the CET function has the opposite sign to the substitution parameter in the CES function. 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("Maize"). Maize 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.

The WAYANG framework enforces a one-to-one correspondence between industries and commodities[7]. 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.

[7] 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.

```
! 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 the same as those for local use[8]. 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] This feature is not part of ORANI-G or WAYANG, 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");
```

4.11. 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.

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

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

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

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

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.

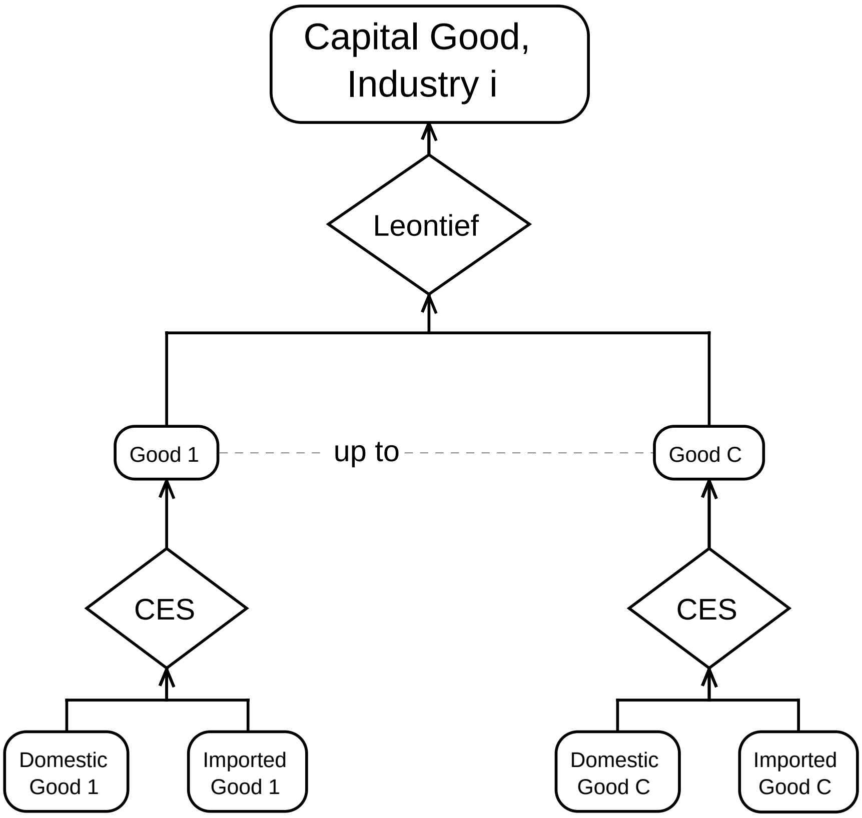


Figure 5. Structure of Investment Demand

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)] };
```

4.12. 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).

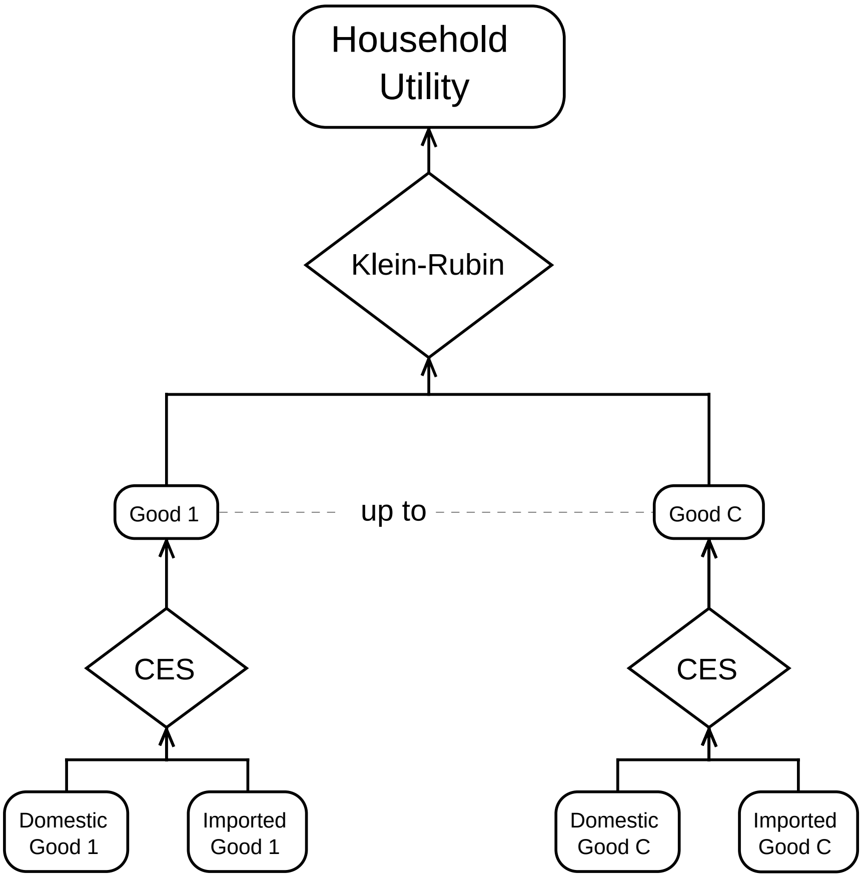


Figure 6. Structure of Consumer Demand

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)(all,h,HH)
x3(c,s,h)-a3(c,s) = x3_s(c,h) - SIGMA3(c)*[ p3(c,s,h)+a3(c,s) - p3_s(c,h) ];

Equation E_p3_s  # Effective price of commodity composite #
(all,c,COM)(all,h,HH) p3_s(c,h) = sum{s,SRC, S3(c,s,h)*[p3(c,s,h)+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:

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

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:

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

where:

$$V3LUX\_C = V3TOT - \quad X3SUB(c)*P3\_S(c) \qquad (24)$$

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:

$$X3\_S(c) = X3SUB(c) + X3LUX(c) \qquad (25)$$

$$X3LUX(c)*P3\_S(c) = S3LUX(c)*V3LUX\_C \qquad (26)$$

$$X3SUB(c) = Q*A3SUB(c) \qquad (27)$$

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 (all,h,HH)              FRISCH(h)      # Frisch LES 'parameter'= - (total/luxury) #;
Read  FRISCH from file MDATA header "P021";
Update (change) (all,h,HH)          FRISCH(h)  =   FRISCH(h)*[w3tot_hh(h) - w3lux(h)]/100.0;

Coefficient (all,c,COM)(all,h,HH)
 EPS(c,h) # Household expenditure elasticities #;
Read  EPS from file MDATA header "XPEL";
Update (change)
(all,c,COM)(all,h,HH) EPS(c,h) =
EPS(c,h)*[x3lux(c,h)-x3_s(c,h)+w3tot_hh(h)-w3lux(h)]/100.0;

Coefficient (all,c,COM)(all,h,HH)          S3_S(c,h)        # Household average budget shares #;
Formula     (all,c,COM)(all,h,HH)          S3_S(c,h)   =    V3PUR_S(c,h)/V3TOT_HH(h);

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

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

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:

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

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)(all,h,HH) x3sub(c,h) = q(h) + a3sub(c,h);

Equation E_x3lux                    # Luxury demand for composite commodities #
(all,c,COM)(all,h,HH) x3lux(c,h) + p3_s(c,h) = w3lux(h) + a3lux(c,h);

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

Equation E_utility                  # Change in utility disregarding taste change terms #
(all,h,HH)utility(h) + q(h) = sum{c,COM, S3LUX(c,h)*x3lux(c,h) };

Equation E_a3lux                    # Default setting for luxury taste shifter #
(all,c,COM)(all,h,HH)a3lux(c,h) = a3sub(c,h) - sum{k,COM,S3LUX(k,h)*a3sub(k,h)};

Equation E_a3sub                 # Default setting for subsistence taste shifter #
(all,c,COM)(all,h,HH)a3sub(c,h) = a3_s(c,h) - sum{k,COM, S3_S(k,h)*a3_s(k,h) };
```

4.13. Export and other final demands

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

Equation E_x4_A in Excerpt 24 specifies downward-sloping foreign demand schedules for traditional exports. In the levels, the equation would read:

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

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 WAYANG 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).

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 WAYANG 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 WAYANG. 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.

```
! 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;
```

4.14. 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)(all,h,HH)
  x3mar(c,s,m,h)  = x3(c,s,h) + 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);
```

4.15. Purchasers' prices

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

X3(c,s)∗P3(c,s) = X3(c,s)∗P0(c,s)∗T3(c,s)

+ sum{m,MAR, X3MAR(c,s,m)∗P0(m,"dom") }.

In percentage-change form this is:

V3PUR(c,s)∗{x3(c,s) + p3(c,s)} =

{V3TAX(c,s)+V3BAS(c,s)}∗{x3(c,s)+p0(c,s)+t3(c,s)}

+ 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 !

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)(all,h,HH)
[V3PUR(c,s,h)+TINY]*p3(c,s,h) =
 [V3BAS(c,s,h)+V3TAX(c,s,h)]*[p0(c,s)+ t3(c,s)]
+ sum{m,MAR,V3MAR(c,s,m,h)*[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);
```

4.16. 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) }
 + sum{h,HH,  V3BAS(n,"dom",h)*x3(n,"dom",h)}
 +          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) }
 + sum{h,HH,    V3BAS(m,"dom",h)*x3(m,"dom",h)}
 +            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,sum(h,HH,  V3MAR(c,s,m,h)*x3mar(c,s,m,h))
 +            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) }
 +  sum{h,HH, V3BAS(c,"imp",h)*x3(c,"imp",h)}
 +          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).

4.17. Indirect taxes

WAYANG 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.[9]

---

[9] 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

```
! 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.,

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

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

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

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

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

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:

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

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

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.

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,sum{h,HH,
  V3TAX(c,s,h)*[p0(c,s)+ x3(c,s,h)] + [V3TAX(c,s,h)+V3BAS(c,s,h)]*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) };
```

4.18. 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 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[10].

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:

V0GDPEXP ≡ V0GDPINC, and w0gdpexp ≡ w0gdpinc. (33)

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

[10] 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.

```
! 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_hh    # Real consumption #
 (all,h,HH)V3TOT_HH(h)*x3tot_hh(h)=sum{c,COM,sum{s,SRC,V3PUR(c,s,h)*x3(c,s,h)}};
E_p3tot_hh    # Household price index #
 (all,h,HH)V3TOT_HH(h)*p3tot_hh(h)=sum{c,COM,sum{s,SRC,V3PUR(c,s,h)*p3(c,s,h)}};
E_w3tot_hh    # Household budget constraint #
(all,h,HH)w3tot_hh(h) = x3tot_hh(h) + p3tot_hh(h);

E_x3tot    # Real consumption #
 V3TOT*x3tot = sum{h,HH,V3TOT_HH(h)*x3tot_hh(h)};
E_p3tot    # Consumer price index #
 V3TOT*p3tot = sum{h,HH,V3TOT_HH(h)*p3tot_hh(h)};
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;
```

4.19. 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 in the balance, not a percentage change. We avoid choosing units by expressing this ordinary change as a percentage 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 #
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) };

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;
```

4.20. 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 (on which this version of WAYANG is based) 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 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.

4.21. Indexation and other equations

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. E_delx6 can be insulated from the rest of the equation system—by leaving fx6 endogenous.

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

Equation E_p1oct # Indexing of prices of "other cost" tickets #
(all,i,IND) p1oct(i) = p3tot + f1oct(i);   ! assumes full indexation !

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);
```

4.22. 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[11], 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:

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

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[12]. 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 acccumulated) is identical to that for x. This leads to the small change equation:

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

and to the revised decomposition:

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

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

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

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

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

(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[13]. Finally, equation E_fandecompD corresponds to equation (36).

```
! 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);
```

4.23. The regional extension to WAYANG

Regional outcomes are frequently of interest to AGE modellers. Some AGE modellers have used the ‘bottom-up’ approach to multi-regional modelling (Madden, 1990; Navqi and Peter, 1994). In doing so, intradomestic trade data to some extent plus intradomestic substitution parameters must be imposed on the model, due to limited data and lack of parameter estimates. These data and parameter requirements present a fundamental difficulty to multi-regional modellers. Nevertheless, a ‘bottom-up’ approach is helpful in analysing region-specific impacts including fiscal effects as the separate endogenous regions compete for resources. An industry in one region may expand at the expense of lagging industries in all regions. But such an expansion may also induce an expansion in relatively non-traded industries in the region with the expanding industry, without such an impact on the same industries in other regions.

The ‘top-down’ approach to modelling regional effects misses out on some aspects of ‘bottom-up’ modelling. The main advantage of the ‘top-down’ approach is that it is relatively parsimonious in data requirements, notably obviating the need for inter-regional trade data. This approach also makes model modifications much simpler, in particular in the case where the modeller wishes to introduce dynamics

[13] 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.

to the AGE model. In the 'top-down' implementation of regional disaggregation, as presented here, the regional equations are simply an extension to the existing national model. In the 'bottom-up' approach, every core equation has a regional dimension, greatly complicating model modifications.

The original ORANI approach, as explained in the Green Book (chapter 6), and modified later in the MONASH model (Dixon and Rimmer, 1998), is used in WAYANG to disaggregate the model to three regions. The first step in bypassing the need for inter-regional trade data is to impose a dichotomy between regionally traded (national) goods and regionally non-traded (local) goods. Local goods are not subject to inter-regional trade.

We turn to excerpt 36 of the TABLO code file which includes the regional SET statements. Industries are divided into national industries (NATIND) and local industries (LOCIND). Commodities are divided into local non-margins commodities, local margins commodities and national commodities. The rationale for local industries producing local commodities (i.e., regional autarky) is that in the model, the Indonesian archipelago is divided into three regions with separate islands or island clusters: Java/Bali, Sumatra and the remaining islands. The natural separation of regions by sea ensures that there are some commodities and industries that are not traded between regions.

```
!Regional extension to model: Java/Bali, Sumatra, Other!
! Excerpt 36 of TABLO input file: !
! Preliminaries
 Within the regional extension we ignore the income distinctions among
households.  So we must define average expenditure elasticities !

Coefficient
(All,c,COM)                 V3PUR_SH(c)             # Total Household expenditure by good #;
(All,c,COM)                 EPS_H(c)            # Average Household expenditure elasticities #;
                       TOTEPS # Temporary sum of expenditure elasticities #;
Zerodivide Default 1.0;
Formula
(All,c,COM)                 V3PUR_SH(c) = Sum(h,HOU, V3PUR_S(c,h) );
(All,c,COM)                 EPS_H(c)= Sum(h,HOU, V3PUR_S(c,h)*EPS(c,h) )/V3PUR_SH(c);
! Now we scale the EPS_H so that expenditure share weighted sum is unity !

TOTEPS = Sum(c,COM, V3PUR_SH(c)*EPS_H(c) )/V3TOT_H;
(All,c,COM) EPS_H(c)= EPS_H(c)/TOTEPS;
Display TOTEPS;   ! should be near to unity, one would hope !
Zerodivide Off;

!Regional sets!

Set     REG             (JavaBali, Sumatra, Other);
Set     LOCCOM          (C1paddy, C8sugarcane, C12coffee, C51egw, C52construct, C53trade,
                        C55railtr, C56roadtr, C63govdef, C65othserv);
Subset      LOCCOM          is subset of COM;
Set     MARLOC     # Local margin commodities # (C53trade, C55railtr, C56roadtr);
Subset      MARLOC          is subset of MAR;
Subset      MARLOC          is subset of LOCCOM;
Set     NONMARLOC # Local non-margin commodities # =  LOCCOM - MARLOC ;
Set     LOCIND              # Local industries #
        (C1paddy, C8sugarcane, C12coffee, C51egw, C52construct, C53trade,
            C55railtr, C56roadtr, C63govdef, C65othserv);
Subset      LOCIND                  is subset of IND;
Set     NATIND      =           IND - LOCIND;
Set     NATCOM      =           COM - LOCCOM;
```

For national commodities, we assume that the regional location of production is independent of the location of demand. Each regions' share of the economy-wide output is exogenous. In addition, the share of each commodity in user region *r* which is sourced from region *s* is the same for all *r*. The approach outlined simplifies the data requirements.

Regional WAYANG computations are decomposed into three parts. In the first part (i.e., all the TABLO code up to excerpt 35), the economy-wide effects of the relevant exogenous shock are computed. In the second part, the economy-wide activity levels in industries producing national commodities are allocated to regions using exogenous shares. In the third part, projections of regional outputs of local goods are computed through a system of commodity-balance equations.

Excerpt 37 of the code lists the regional variables within WAYANG. The variables for regional demands for local commodities correspond closely with the economy-wide variables in the model for production, investment, household consumption and government demands. For national (ie., regionally traded) commodities, separate regional variables corresponding with, for example, x1csi_reg, are not required.

All the additional database requirements for the regional extension to WAYANG are summarised in excerpt 38. That is, for each industry in the three regions, we need to know the initial regional share of output and investment. For each commodity, we need to know the regional share of national exports and the regional share of government demands. No additional data are needed to calculate the regional share of household consumption. It is assumed that the initial share of regional household consumption for all commodities (REGSHARE3) is equal to the share of economy-wide labour income earned in that region multiplied by economy-wide labour income.

```
! Excerpt 37 of TABLO input file: !
! Regional variables !

VARIABLE
      (All,c,LOCCOM)(All,r,REG) x0_reg(c,r)   # Output of region commodities #;
      (all,i,IND)(All,r,REG)          x1tot_r(i,r)    # Output of region industries #;
      (All,r,REG)                labrev_reg(r)     # Wage bills by region #;
      (All,c,LOCCOM)(All,s,SRC)(all,i,IND)(All,r,REG)
x1csi_reg(c,s,i,r)                          # region demands for intermediate inputs #;
      (All,c,LOCCOM)(All,s,SRC)(all,i,IND)(All,r,REG)
x2csi_reg(c,s,i,r)                          # region demands for inputs for investment #;
      (All,c,LOCCOM)(All,s,SRC)(All,r,REG)(all,h,HH)
x3cs_reg(c,s,r,h)                           # region household demand for goods #;
      (All,c,LOCCOM)(All,r,REG)
x4_reg(c,r)                                 # Foreign exports by region #;
      (All,c,LOCCOM)(All,s,SRC)(All,r,REG)
x5cs_reg(c,s,r)                             # region "other" demands #;
      (All,c,COM)(All,s,SRC)(all,i,IND)(All,m,MARLOC)(All,r,REG)
x1marg_reg(c,s,i,m,r)                       # Usage of margins on production by region #;
      (All,c,COM)(All,s,SRC)(all,i,IND)(All,m,MARLOC)(All,r,REG)
x2marg_reg(c,s,i,m,r)                       # Usage of margins on investment by region #;
      (All,c,COM)(All,s,SRC)(All,m,MARLOC)(All,r,REG)(all,h,HH)
x3marg_reg(c,s,m,r,h)                       # Usage of margins on private consumption by region #;
      (All,c,COM)(All,m,MARLOC)(All,r,REG)
x4marg_reg(c,m,r)                           # Usage of margins on foreign exports by region #;
      (All,c,COM)(All,s,SRC)(All,m,MARLOC)(All,r,REG)
x5marg_reg(c,s,m,r)               # Usage of margins on "other" demands by region #;
 (all,i,IND)          rsum1(i)             # Sum of region shares in Indonesia-wide ind. production #;
(all,i,IND)           rsum2(i)             # Sum of region shares in Indonesia-wide ind. investment #;
(All,c,COM)               rsum3(c)         # Sum of region shares in Indonesia-wide consumption #;
(All,c,COM)               rsum4(c)         # Sum of region shares in Indonesia-wide foreign exports #;
(All,c,COM)               rsum5(c)         # Sum of region shares in Indonesia-wide other demands   #;
(all,i,NATIND)            rsum_nat(i)  #Sum of region shares in Indonesia-wide production of nat. inds.#;
(all,i,IND)           ffreg2(i)       # region-uniform shifts in rgshr2(j,r) from rgshr1(j,r) #;
(All,c,COM)           ffreg3(c)       # region-uniform shifts in rgshr3(i,r) #;
(All,c,COM)           ffreg4(c)       # region-uniform shifts in rgshr4(i,r) #;
(All,c,COM)               ffreg5(c)        # region-uniform shifts in rgshr5(i,r) #;
(all,i,IND)(All,r,REG)freg2(i,r)           # Commodity-specific complement of ffreg2 #;
(All,c,COM)(All,r,REG)
freg3(c,r)                                 # Commodity-specific complement of ffreg3 #;
      (All,c,COM)(All,r,REG)
freg4(c,r)                                 # Commodity-specific complement of ffreg4 #;
      (All,c,COM)(All,r,REG)
freg5(c,r)                                 # Commodity-specific complement of ffreg5 #;
```

```
       (all,i,IND)(All,r,REG)
rgshr1(i,r)                      # region shares in Indonesia-wide industry production #;
       (all,i,IND)(All,r,REG)
rgshr2(i,r)                      # region shares in Indonesia-wide industry investment #;
       (All,c,COM)(All,r,REG)
rgshr3(c,r)                      # region shares in Indonesia-wide private consumption #;
       (All,c,COM)(All,r,REG)
rgshr4(c,r)                      # region shares in Indonesia-wide foreign exports     #;
       (All,c,COM)(All,r,REG)
rgshr5(c,r)                      # region shares in Indonesia-wide "other" demands     #;
(all,i,NATIND)(All,r,REG)     f_x1tot_r(i,r) # region-specific deviations from normal nat.ind. rule #;
(all,i,NATIND)       ff_x1tot_r(i)       # region-uniform deviations from normal nat.ind. rule  #;
 (All,r,REG)       ztot_reg(r)           # Real Gross region Products (GSP)#;
(All,r,REG)       persontot_reg(r) # Aggregate region employment, persons #;
(all,i,IND)(All,r,REG)
zcon_reg(i,r)                    # Contrib'ns to deviations in total region outputs from nat. GDP #;
(all,i,IND)(All,r,REG)      person_reg(i,r)    # Employment by industry and region, persons #;
(All,r,REG)       q_reg(r)            # Population by region #;



! Excerpt 38 of TABLO input file: !
! Regional coefficients from database !

Coefficient
(all,i,IND)(all,r,REG)              REGSHARE1(i,r)         # Region output shares #;
(all,i,IND)(all,r,REG)              REGSHARE2(i,r)         # Region investment shares #;
(all,c,COM)(all,r,REG)              REGSHARE3(c,r)         # Region consumption shares #;
(all,c,COM)(all,r,REG)              REGSHARE4(c,r)         # Region export shares #;
(all,c,COM)(all,r,REG)              REGSHARE5(c,r)         # Region 'other' shares #;
Variable
            qnat # national population: q is by household #;

Read
REGSHARE1        from file mdata Header        "1REG";
REGSHARE2        from file mdata Header        "2REG";
REGSHARE4        from file mdata Header        "4REG";
REGSHARE5        from file mdata Header        "5REG";

Update
(all,i,IND)(all,r,REG)      REGSHARE1(i,r)         = rgshr1(i,r);
(all,i,IND)(all,r,REG)      REGSHARE2(i,r)         = rgshr2(i,r);
(all,c,COM)(all,r,REG)    REGSHARE4(c,r)     = rgshr4(c,r);
(all,c,COM)(all,r,REG)    REGSHARE5(c,r)     = rgshr5(c,r);
```

```
! Excerpt 39 of TABLO input file: !
! Regional coefficients calculated within model !

Coefficient
(all,i,IND)(all,r,REG)          LABINDREG(i,r)        # Labour bills by industry and region #;
(all,r,REG)                     LABREGTOT(r)          # Total labour bill by region #;
(all,i,IND)(all,r,REG)          VALUADD(i,r)       # Factor bills by industry and region #;
(all,r,REG)                     VALUADDTOT(r)      # Total factor bill by region #;
Formula
(all,i,IND)(all,r,REG)          LABINDREG(i,r)     =   V1LAB_O(i)*REGSHARE1(i,r);
(all,r,REG)                     LABREGTOT(r)       =   Sum(i,IND, LABINDREG(i,r));
(all,i,IND)(all,r,REG)          VALUADD(i,r)    =   V1PRIM(i)*REGSHARE1(i,r);
(all,r,REG)                     VALUADDTOT(r)      =   SUM(i,IND, VALUADD(i,r));
(all,c,COM)(all,r,REG)          REGSHARE3(c,r)     =
    LABREGTOT(r)/Sum(s,REG,LABREGTOT(s));

Coefficient  (All,c,LOCCOM)(all,r,REG)
                          TOTDEMREG(c,r)        # All basic + margin use of local good i in region r #;


! Excerpt 40 of TABLO input file: !
! Regional formulae !

Formula
(All,c,MARLOC)(all,r,REG)         TOTDEMREG(c,r) =
  SUM(i,IND, REGSHARE1(i,r)*V1BAS(c,"dom",i))
 + SUM(i,IND, REGSHARE2(i,r)*V2BAS(c,"dom",i))
 + Sum(h,HH,V3BAS(c,"dom",h))*REGSHARE3(c,r)
 + V4BAS(c)*REGSHARE4(c,r)
 + V5BAS(c,"dom")*REGSHARE5(c,r)
 + SUM(u,COM, V4MAR(u,c)*REGSHARE4(u,r)
    + SUM(s,Src,SUM(h,HH, V3MAR(u,s,c,h))*REGSHARE3(u,r)
       + V5MAR(u,s,c)*REGSHARE5(u,r)
    + SUM(i,IND, REGSHARE1(i,r)*V1MAR(u,s,i,c)
       + REGSHARE2(i,r)*V2MAR(u,s,i,c) )));

Formula
(All,c,NONMARLOC)(all,r,REG)  TOTDEMREG(c,r) =
     SUM(i,IND, REGSHARE1(i,r)*V1BAS(c,"dom",i))
    + SUM(i,IND, REGSHARE2(i,r)*V2BAS(c,"dom",i))
    + SUM(h,HH,V3BAS(c,"dom",h))*REGSHARE3(c,r)
    + V4BAS(c)*REGSHARE4(c,r)
    + V5BAS(c,"dom")*REGSHARE5(c,r);
```

Part 41 of the code computes total regional demands for local commodities. The five equations starting with E_x1csi_reg calculate percentage changes in direct regional demands for local commodities. The equations for local margins demands, starting with E_x1marg_reg, follow. Equation E_rgshr1 moves each regions' share of total production with differences between regional and economy-wide outputs. Equation E_rgshr2 ties movements in regional shares of investment to each regions' share of total production.

```
! Excerpt 41 of TABLO input file: !
! Regional equations: direct and marginal demands follow region shares !

Equation
E_x1csi_reg
 # Direct intermediate demands by industry and region #
 (All,c,LOCCOM)(All,s,Src)(all,i,IND)(all,r,REG)
 x1csi_reg(c,s,i,r) = x1(c,s,i) + rgshr1(i,r);

E_x2csi_reg
 # Direct investment demands by industry and region #
 (All,c,LOCCOM)(All,s,Src)(all,i,IND)(all,r,REG)
 x2csi_reg(c,s,i,r) = x2(c,s,i) + rgshr2(i,r);

E_x3cs_reg
 # Consumption by region #
 (All,c,LOCCOM)(all,r,REG)(All,s,Src)(all,h,HH)
 x3cs_reg(c,s,r,h) = x3(c,s,h) + rgshr3(c,r);

E_x4_reg
 # Foreign exports by region #
 (All,c,LOCCOM)(all,r,REG)
 x4_reg(c,r) = x4(c) + rgshr4(c,r);

E_x5cs_reg
 # "Other" demands by region #
 (All,c,LOCCOM)(All,s,Src)(all,r,REG)
 x5cs_reg(c,s,r) = x5(c,s) + rgshr5(c,r);

E_x1marg_reg
 # margin intermediate demands by industry and region #
 (all,c,COM)(All,s,Src)(all,i,IND)(All,m,MARLOC)(all,r,REG)
 x1marg_reg(c,s,i,m,r) = x1mar(c,s,i,m) + rgshr1(i,r);

E_x2marg_reg
 # margin investment demands by industry and region  #
 (all,c,COM)(All,s,Src)(all,i,IND)(All,m,MARLOC)(all,r,REG)
 x2marg_reg(c,s,i,m,r) = x2mar(c,s,i,m) + rgshr2(i,r);

E_x3marg_reg
 # margin private consumption by region #
 (all,c,COM)(All,s,Src)(All,m,MARLOC)(all,r,REG)(all,h,HH)
 x3marg_reg(c,s,m,r,h) = x3mar(c,s,m,h) + rgshr3(c,r);

E_x4marg_reg
 # margin to foreign export by region #
 (all,c,COM)(All,m,MARLOC)(all,r,REG)
 x4marg_reg(c,m,r) = x4mar(c,m) + rgshr4(c,r);

E_x5marg_reg
  # margins to "other" by region #
  (all,c,COM)(All,s,Src)(All,m,MARLOC)(all,r,REG)
  x5marg_reg(c,s,m,r) = x5mar(c,s,m) + rgshr5(c,r);
```

Equation E_rgshr3 moves regional shares for each household consumption commodity with regional shares in labour income multiplied by the income elasticity. This appears to be the appropriate assumption in Indonesia. In an economy in which social security benefits account for a significant proportion of household income, as in Australia, movements in regional income per household would be brought closer together across regions. Hence, in the MONASH model of the Australian economy (on which the WAYANG regional extension is based), regional shares of private consumption move with regional population shares.

Regional shares of exports (rgshr4) and government (rgshr5) spending are assumed constant at the commodity level unless exogenously changed. The final block of equations in excerpt 41 (E_rsum1 to

E_rsum5) checks that changes in the shares across regions sum to zero. To enforce this strictly, so that demand equals supply for local commodities, and that the national totals equal the sum of local commodities by region, the variables rsum2 to rsum5 should be exogenous, and the variables ffreg2, ffreg3, ffreg4 and freg5 endogenous.

```
E_rgshr1
 # Region shares of industry production #
 (all,i,IND)(all,r,REG)
 rgshr1(i,r) = x1tot_r(i,r) - x1tot(i);

E_rgshr2
 # Region shares of industry investment related to regional production shares #
 (all,i,IND)(all,r,REG)
 rgshr2(i,r) = rgshr1(i,r) + freg2(i,r)+ ffreg2(i);

E_qnat
 # Indonesia-wide population equals sum of region populations #
  Sum(r,REG,LABREGTOT(r))*qnat = Sum(s,REG,LABREGTOT(s)*q_reg(s));

E_rgshr3
 # Region shares in private cons'n move with regional labour income shares #
 (all,c,COM)(all,r,REG)
 rgshr3(c,r) = 1.0*EPS_H(c)*(labrev_reg(r) - w1lab_io) + freg3(c,r)+ ffreg3(c);

E_rgshr4
 # Region shares in foreign exports #
 (all,c,COM)(all,r,REG)
 rgshr4(c,r) = freg4(c,r)+ ffreg4(c);

E_rgshr5
 # Region shares in "other" demands #
 (all,c,COM)(all,r,REG)
 rgshr5(c,r) = freg5(c,r)+ ffreg5(c);

E_rsum1
 # For checking purposes: rsum1 should be endogenous and zero #
 (all,i,IND)  Sum(r,REG, REGSHARE1(i,r)*rgshr1(i,r)) =    rsum1(i);

E_rsum2
 # For checking purposes: rsum2 should be endogenous and zero #
 (all,i,IND)  Sum(r,REG, REGSHARE2(i,r)*rgshr2(i,r)) =    rsum2(i);

E_rsum3
 # For checking purposes: rsum3 should be endogenous and zero #
 (all,c,COM)     Sum(r,REG, REGSHARE3(c,r)*rgshr3(c,r))     =     rsum3(c);

E_rsum4
 # For checking purposes: rsum4 should be zero #
 (all,c,COM)     Sum(r,REG, REGSHARE4(c,r)*rgshr4(c,r))     =     rsum4(c);

E_rsum5
 # Used to ensure rsum5 is zero #
 (all,c,COM)     Sum(r,REG, REGSHARE5(c,r)*rgshr5(c,r))     =    rsum5(c);
```

Equations E_x0_reg_A and E_x0_reg_B in excerpt 42 impose the intra-regional sourcing constraint on local commodities. The aggregate output of any local commodity is equal to aggregate demand for the commodity within the region. Equation E_x1tot_r_A sets the percentage change in the supply of local commodities in each region equal to the percentage change in production of local industries. The percentage change in output of national industries in each region is set equal to the economy-wide percentage change in output in equation E_x1tot_r_B.

```
! Excerpt 42 of TABLO input file: !
! Output of three regional industry types!

! Following 3 equation blocks contain, for each region
      NONMARLOC + MARLOC + NATIND      equations
   =  LOCCOM + NATIND                  equations
   =  IND                              equations
provided  LOCCOM = LOCIND !

Equation
E_x0_reg_A
 # Output of nonmargins local commodities, Green book, eq39.8a #
 (All,i,NONMARLOC)(all,r,REG)
 TOTDEMREG(i,r)*x0_reg(i,r)
 = SUM(j,IND, REGSHARE1(j,r)*V1BAS(i,"dom",j)*x1csi_reg(i,"dom",j,r))
 + SUM(j,IND, REGSHARE2(j,r)*V2BAS(i,"dom",j)*x2csi_reg(i,"dom",j,r))
 + REGSHARE3(i,r)*SUM{h,HH,V3BAS(i,"dom",h)*x3cs_reg(i,"dom",r,h)}
 + V4BAS(i)*REGSHARE4(i,r)*x4_reg(i,r)
 + V5BAS(i,"dom")*REGSHARE5(i,r)*x5cs_reg(i,"dom",r);

E_x0_reg_B
 # Usage of margins local commodities #
 (All,c,MARLOC)(all,r,REG)
 TOTDEMREG(c,r)*x0_reg(c,r)
 = SUM(i,IND, REGSHARE1(i,r)*V1BAS(c,"dom",i)*x1csi_reg(c,"dom",i,r))
 + SUM(i,IND, REGSHARE2(i,r)*V2BAS(c,"dom",i)*x2csi_reg(c,"dom",i,r))
 + REGSHARE3(c,r)*SUM(h,HH,V3BAS(c,"dom",h)*x3cs_reg(c,"dom",r,h))
 + V4BAS(c)*REGSHARE4(c,r)*x4_reg(c,r)
 + V5BAS(c,"dom")*REGSHARE5(c,r)*x5cs_reg(c,"dom",r)
 + SUM(u,COM, V4MAR(u,c)*REGSHARE4(u,r)*x4marg_reg(u,c,r)
 + REGSHARE3(u,r)*SUM(s,Src,SUM(h,HH, V3MAR(u,s,c,h)*x3marg_reg(u,s,c,r,h)))
 + SUM(s,Src,V5MAR(u,s,c)*REGSHARE5(u,r)*x5marg_reg(u,s,c,r)
 + SUM(i,IND, REGSHARE1(i,r)*V1MAR(u,s,i,c)*x1marg_reg(u,s,i,c,r)
 + REGSHARE2(i,r)*V2MAR(u,s,i,c)*x2marg_reg(u,s,i,c,r) )));

E_x1tot_r_A
  # Supplies of local commodities related to production of local industries #
 (All,c,LOCCOM)(all,r,REG)
x0_reg(c,r) = SUM(j,IND, {MAKE(c,j)/MAKE_I(c)}*x1tot_r(j,r));

E_x1tot_r_B
 # Output of national industries eq39.2, DPSV P.260 #
 (all,i,NATIND)(all,r,REG)
 x1tot_r(i,r) = x1tot(i) + f_x1tot_r(i,r) + ff_x1tot_r(i);

E_rsum_nat
 # Adding up rule for national industries: rsum_nat normally end. and zero #
 (all,i,NATIND)
 SUM(r,REG, REGSHARE1(i,r)*x1tot_r(i,r)) = x1tot(i) + rsum_nat(i);
```

Excerpt 43 includes equations to calculate regional totals of wage bills, gross region products and industry contributions to changes in outputs. The final two equations, E_persontot_reg and E_person_reg, calculate percentage changes in aggregate employment in each region and total employment by industry in each region.

```
! Excerpt 43 of TABLO input file: !
! Extra regions' equations for reporting variables !

Equation
E_labrev_reg          # Total wage bills by region #
 (all,r,REG)
 LABREGTOT(r)*labrev_reg(r)
 = SUM(i,IND, REGSHARE1(i,r)*
   SUM(o,OCC, V1LAB(i,o)*{rgshr1(i,r) + p1lab(i,o) + x1lab(i,o)} ));

E_ztot_reg       # Gross Region Products (income weights) #
 (all,r,REG)
 ztot_reg(r) = x1prim_i + SUM(i,IND, zcon_reg(i,r));

E_zcon_reg       # Contributions to deviations in total region outputs from national GDP #
 (all,i,IND)(all,r,REG)
 zcon_reg(i,r) = {[VALUADD(i,r)/VALUADDTOT(r)]
     - [V1PRIM(i)/SUM(k,IND, V1PRIM(k))]}*[x1tot_r(i,r) - x1prim_i]
     + [V1PRIM(i)/SUM(k,IND, V1PRIM(k))] *[x1tot_r(i,r) - x1tot(i)];

E_persontot_reg      # aggregate region employment#
 (all,r,REG)
 LABREGTOT(r)*persontot_reg(r) =
 SUM(i,IND, LABINDREG(i,r)*person_reg(i,r));

E_person_reg #employment by region and industry#
 (all,i,IND)(all,r,REG)
 person_reg(i,r) = x1lab_o(i) + rgshr1(i,r);

Display LABINDREG;
Display LABREGTOT;
```

4.24.The fiscal extension to the model

In order to make use of the fiscal information in Indonesia's national accounts data and other sources, we use a fiscal extension. Some coefficients and variables appear in the core part of the model, namely indirect taxes and current government expenditures. The core does not provide any information on capital expenditure by the government, except in so far as exogenous investment industries are defined. Public capital expenditure from the national accounts is allocated to exogenous investment industries, and summed in the coefficient V2TOT_G (note that at present, this proportion is hardwired into the code, and would change if the database year changed). Also, income taxes on households vary proportionately with household income. The other missing fiscal details in the core part of the model are transfers to and from households and rest of the world. Database values are added to the model from national accounts in the coefficients TRANSFER_F and TRANSFER_G.

Equation E_w0hhinc calculates the take-home income earned by each household. The consumption function E_w3lux provides the option of linking household expenditure directly to household income.

The simplest theory governs percentage changes in transfers, which depend only on p3tot and exogenous shifters f1gov_f and fgov_h. The modeller can make delbudget exogenous by swapping it with f3tot in the closure.

```
! Excerpt 44 of TABLO input file: !
! Fiscal extension !

Set TYPE   (expend, recp);! expend=govt. payments, recp=govt. receipts !

Variable
(all,h,HH)(all,t,TYPE)fgov_h(h,t)        # Shift in transfers: govt. -- households #;
(all,t,TYPE)              fgov_f(t)        # Shift in transfers: govt. -- foreign #;
(all,h,HH)(all,t,TYPE)gov_h(h,t)         # Transfers: govt. -- households #;
(all,t,TYPE)              gov_f(t)         # Transfers: govt. -- foreign #;
(all,h,HH)                w0hhtax(h)       # % change in personal income tax #;
(all,h,HH)                w0hhinc(h) #Aggregate nominal take-home income earned by households #;
(change)                  delbudget    # Rupiah change in budget balance G-T #;
                          w0govt_t     # Aggregate government revenue#;
                          w0govt_g         # Aggregate government expenditure#;
                          f1inc_tax        # Overall income tax shifter #;

Coefficient
 GOVTREV                      # Total government revenue #;
 GOVTEXP                      # Nominal total current and capital government expenditure #;
 (all,i,EXOGINV)V2TOT_G(i) # Total govt. funding of capital created for i #;
 (all,t,TYPE)TRANSFER_F(t)       # Government transfers: payments/receipts foreign#;
 (all,h,HH)(all,t,TYPE)TRANSFER_H(h,t) # Govt transfers to and from h'holds#;
(all,h,HH)V0HHINC(h) # Aggregate nominal take-home income earned by households #;
(all,h,HH)V0HHTAX(h)   # Personal income tax on all household factors #;
Read
 V0HHTAX           from file MDATA header "PINC";
 TRANSFER_F        from file MDATA header "TRAN";
 TRANSFER_H        from file MDATA header "GOHH";
Update (all,t,TYPE)             TRANSFER_F(t)   = gov_f(t);
      (all,h,HH)(all,t,TYPE)    TRANSFER_H(h,t) = gov_h(h,t);
      (all,h,HH)                V0HHTAX(h)      = w0hhtax(h);
Formula
 (all,i,EXOGINV)V2TOT_G(i) = sum{c,COM,  V2PUR_S(c,i) }*0.83;
                      !allocation of public investment!
 GOVTREV    = V0TAX_CSI +   sum{h,HH,V0HHTAX(h)} +
             TRANSFER_F("recp") +sum{h,HH,TRANSFER_H(h,"recp")};
 GOVTEXP    = V5TOT + Sum{i,EXOGINV, V2TOT_G(i)} +
             TRANSFER_F("expend") +sum{h,HH,TRANSFER_H(h,"expend")};

Equation E_w3lux # consumption function #
(All,h,HH)
w3tot_hh(h) = f3tot  + f3tot_h(h) + w0hhinc(h);

Equation E_w0hhtax #Aggregate nominal income tax paid by households  #
(all,h,HH)w0hhtax(h) = w0hhinc(h) + f1inc_tax;
!Equation E_w0hhtax constrains any exogenous shifts in the income tax rate to
being equal across all household factors of production. Note that take-home
household income is used in the consumption function.!

Equation E_gov_f    # Government transfers to and from foreigners #
(all,t,TYPE)gov_f(t) = p3tot +  fgov_f(t);

Equation E_gov_h    # Government transfers to and from households #
(all,h,HH)(all,t,TYPE)gov_h(h,t) = p3tot +  fgov_h(h,t);

Formula (all,h,HH)V0HHINC(h) =
sum{i,AGIND,LANDS(i,h)} + sum{o,OCC,HINC(h,o)} +
MMA(h)+MMN(h) + sum{i,N_AGIND,FIXEDK(h,i)}
 +      TRANSFER_H(h,"expend") -  TRANSFER_H(h,"recp")
 - V0HHTAX(h);

Equation E_w0hhinc #Aggregate nominal take-home income earned by households  #
(all,h,HH)V0HHINC(h)*w0hhinc(h)=
sum{i,AGIND,LANDS(i,h)*[p1lnd(i) + x1lndi_hh(i,h)]} +
sum{o,OCC,HINC(h,o)*[x1lab_i_h(o,h) + p1lab_i(o) + f1lab_i_x(o)]} +
 [MMA(h)+MMN(h)]*w1cap_v(h)  + sum{i,N_AGIND,FIXEDK(h,i)}*w1cap_f(h)
```

```
 +    TRANSFER_H(h,"expend")*gov_h(h,"expend")
 -    TRANSFER_H(h,"recp")*gov_h(h,"recp")
 -    V0HHTAX(h)*w0hhtax(h);

Equation E_w0govt_t   # Aggregate government revenue #
GOVTREV*w0govt_t = V0TAX_CSI*w0tax_csi + sum{h,HH,V0HHTAX(h)*w0hhtax(h)}
   +  TRANSFER_F("recp")*gov_f("recp") +
     sum{h,HH,TRANSFER_H(h,"recp")*gov_h(h,"recp")};

Equation E_w0govt_g   # Aggregate government expenditure #
GOVTEXP*w0govt_g = V5TOT*w5tot
 +    Sum{i,EXOGINV, V2TOT_G(i)*[x2tot(i) + p2tot(i)]}
 +    TRANSFER_F("expend")*gov_f("expend")
+     sum{h,HH,TRANSFER_H(h,"expend")*gov_h(h,"expend")};

Equation E_delbudget # Change in budget balance G-T # !increased deficit >0!
100*delbudget = GOVTEXP*w0govt_g - GOVTREV*w0govt_t ;
```

4.25.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 45. 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 D.

```
! Excerpt 45 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 #;
  (all,h,HH)        EPSTOT(h)                # 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);
 (all,h,HH)         EPSTOT(h)           =    sum{c,COM, S3_S(c,h)*EPS(c,h)};
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";
Coefficient  (All,i,IND)(all,r,REG)
 TOTSUPREG(i,r) # supply of good i region r #;
Formula (all,i,IND)(all,r,REG)
 TOTSUPREG(i,r) =  V1TOT(i)*REGSHARE1(i,r);

Subset LOCCOM is subset of IND;
Coefficient (all,c,LOCCOM)(all,r,REG) DEMRATIO(c,r)
 # demand/supply ratio for local commodities: should be around one #;
Formula     (All,c,LOCCOM)(All,r,REG)
 DEMRATIO(c,r) = (TINY + TOTDEMREG(c,r))/(TINY + TOTSUPREG(c,r));
Write DEMRATIO to file SUMMARY header "DRAT";
```

4.26. 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 46 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[14].

[14] 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.

```
! Excerpt 46 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";

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 47 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 47 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 48 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 48 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") = sum{h,HH,V3BAS(c,"dom",h)};
(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";
```

4.27. 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[15].

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

```
! Excerpt 49 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";

! Excerpt 50 of TABLO input file: !

Set
SALECAT2 # SALE Categories # (Interm, Invest, HouseH, Export, GovGE, Stocks);
FLOWTYPE # type of flow # (Basic, margin, Tax);

Coefficient
(all,c,COM)(all,f,FLOWTYPE)(all,s,SRC)(all,sa,SALECAT2) SALEMAT2(c,f,s,sa)
   # Basic, margin and tax components of purchasers' values #;

Formula
(all,c,COM)(all,f,FLOWTYPE)(all,s,SRC)(all,sa,SALECAT2) SALEMAT2(c,f,s,sa)=0;

(all,c,COM)(all,s,SRC) SALEMAT2(c,"Basic",s,"Interm") = sum{i,IND,V1BAS(c,s,i)};
(all,c,COM)(all,s,SRC) SALEMAT2(c,"Tax"   ,s,"Interm") = sum{i,IND,V1TAX(c,s,i)};
(all,c,COM)(all,s,SRC) SALEMAT2(c,"margin",s,"Interm") =
                            sum{i,IND, sum{m,MAR, V1MAR(c,s,i,m) }};

(all,c,COM)(all,s,SRC) SALEMAT2(c,"Basic",s,"Invest") = sum{i,IND,V2BAS(c,s,i)};
(all,c,COM)(all,s,SRC) SALEMAT2(c,"Tax"   ,s,"Invest") = sum{i,IND,V2TAX(c,s,i)};
(all,c,COM)(all,s,SRC) SALEMAT2(c,"margin",s,"Invest") =
                            sum{i,IND, sum{m,MAR, V2MAR(c,s,i,m) }};

(all,c,COM)(all,s,SRC) SALEMAT2(c,"Basic",s,"HouseH") = sum{h,HH,V3BAS(c,s,h)};
(all,c,COM)(all,s,SRC) SALEMAT2(c,"Tax"   ,s,"HouseH") = sum{h,HH,V3TAX(c,s,h)};
(all,c,COM)(all,s,SRC) SALEMAT2(c,"margin",s,"HouseH")=
sum{m,MAR,sum(h,HH,V3MAR(c,s,m,h))};

(all,c,COM)(all,s,SRC) SALEMAT2(c,"Basic",s,"GovGE") = V5BAS(c,s);
(all,c,COM)(all,s,SRC) SALEMAT2(c,"Tax"   ,s,"GovGE") = V5TAX(c,s);
(all,c,COM)(all,s,SRC) SALEMAT2(c,"margin",s,"GovGE")= sum{m,MAR,V5MAR(c,s,m)};

(all,c,COM) SALEMAT2(c,"Basic","dom","Export") = V4BAS(c);
(all,c,COM) SALEMAT2(c,"Tax"   ,"dom","Export") = V4TAX(c);
(all,c,COM) SALEMAT2(c,"margin","dom","Export")= sum{m,MAR,V4MAR(c,m)};

(all,c,COM)(all,s,SRC) SALEMAT2(c,"Basic",s,"Stocks") = V6BAS(c,s);

write SALEMAT2 to file SUMMARY header "MKUP" longname
   "Basic, margin and tax components of purchasers' values";
```

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 160 equations and 224 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 55 macro, i.e., scalar, equations.

Table 2 Tally of Variables and Equations

1 Dimension	2 Variable Count	3 Equation Count	4 Exogenous Count	5 Unexplained Variables
MACRO	69	55	14	f0tax_s f4p_ntrad f4q_ntrad f3tot f4tax_trad f4tax_ntrad *f5tot2* phi *omega* f1tax_csi f2tax_csi f3tax_cs f5tax_cs f1inc_tax
HH	13	9	4	q x1cap_vah x1cap_vnh f3tot_h
COM	15	9	6	t0imp f4p f4q pf0cif f4tax_trad f0tax_s
COM*HH	7	6	1	a3_s
COM*IND	7	5	2	a1_s a2_s
COM*MAR	2	1	1	a4mar
COM*SRC	10	7	3	f5 a3 fx6
COM*SRC*HH	2	2	0	—
COM*SRC*IND	8	6	2	a1 a2
COM*SRC*IND*MAR	4	2	2	a1mar a2mar
COM*SRC*MAR	3	1	2	a3mar a5mar
COM*SRC*MAR*HH	1	1	0	—
IND	23	15	8	a1oct a1prim a1tot f1oct finv a2tot ffreg1 ffreg2
N_AGIND*N_AGRIFAC	3	2	1	a1faco
AGIND*AGRIFAC	3	2	1	a1fac
IND*OCC	2	2	0	
N_AGIND	1	1	0	
AGIND	2	2	0	
OCC	3	2	1	f1lab_i_x
TYPE	2	1	1	fgov_f
HH*TYPE	2	1	1	fgov_h
HH*OCC	1	0	1	x1lab_i_h
HH*IND	1	0	1	x1lndi_hh
N_AGIND*HH	1	0	1	x1cap_f_hh
COM*FANCAT	1	1	0	
COM (*regional module*)	6	3	3	ffreg3 ffreg4 ffreg5
Other regional dimensions	32	24	8	q_reg freg2 ffreg2 freg3 freg4 freg5 ff_x1tot_r f_x1tot_r
TOTAL	224	160	64	

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.

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';
- household supplies of factors (x1lab_i_h, x1lndi_hh, x1cap_f_hh, x1cap_vah and x1capvnh) and the number of households q;
- foreign prices, pf0cif, and the average rate of return omega;
- inventory changes, delx6;
- the exchange rate phi, which could serve as numeraire; and
- w3lux (household above-subsistence expenditure).

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.

With its 65 commodities, 65 industries, 2 sources, 6 margin goods and 2 occupations, our version of WAYANG has about 440,000 scalar variable elements and 300,000 scalar equations. In its raw form, even without the regional module, it would be far too big to solve. The next section explains how GEMPACK can condense a model to manageable size.

6. Using GEMPACK to Solve the Model

Figure 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 WAYANG.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  # 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)];
```

which appears in Excerpt 17 of the TABLO Input file in Section 4.9, can be used to substitute out variable x1. In fact the names of the WAYANG 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: WAYANG.STI.

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

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

Simulations are conducted using WAYANG.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 Windows program ViewSOL provides a way to interactively examine results.

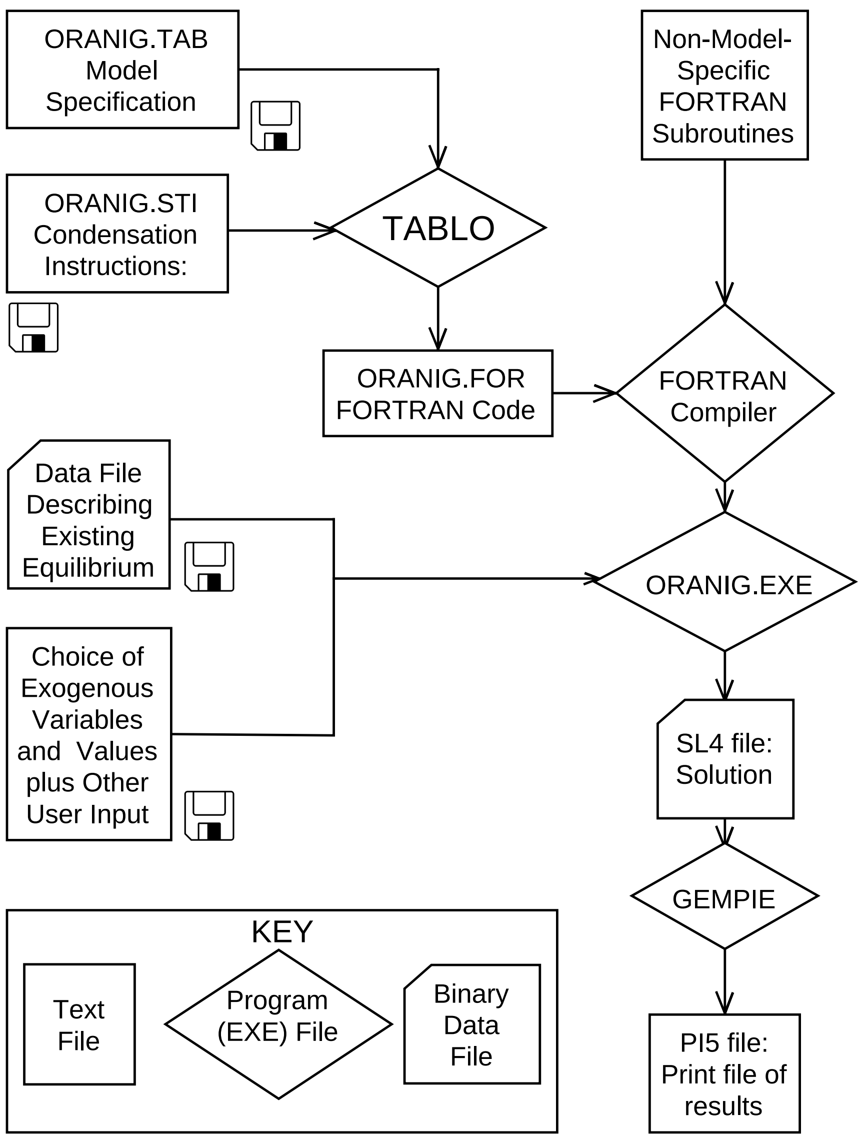


Figure 7. Stages in the GEMPACK process (substitute "WAYANG" for "ORANIG")

7. Conclusion

A distinctive feature of this 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 and model users in CASER, CSIS and CIES to acquire a hands-on familiarity with the model.

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

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

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

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

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

where $\sigma = \dfrac{1}{\rho+1}$ 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:

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

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

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

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

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

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

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

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

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

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:

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

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

Simplifying, we get:

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

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

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

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

The R_k are *reverse shares*, defined by:

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

(A20) becomes:

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

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:

$$S_d a_d + S_m a_m = 0, \qquad \text{using (A20), and} \tag{A26}$$

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

giving

$a_d = S_m t/(1-\sigma)$ and $a_m = -S_d t/(1-\sigma)$. (A28)

Adopting *reverse share* notation:

$a_k = R_k t/(1-\sigma)$ $k = d, m$ (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 $x_k = z + R_k t - \sigma R_k\big(p_d - p_m\big)$ $k = d, m$

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

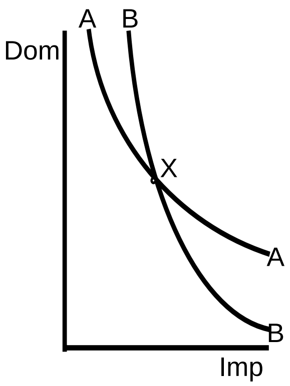

Figure A1

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: 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.

Variables can only be added or subtracted 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 .

Appendix C: Algebra for the Linear Expenditure System

The purpose of this Appendix Ds 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:

$$\text{Utility per household} = \prod_c \{\frac{X3\_S(c)}{Q} - A3SUB(c)\}^{S3LUX(c)}, \qquad (F1)$$

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:

$$\sum_c X3\_S(c)/Q*P3\_S(c) = V3TOT/Q, \qquad (F2)$$

The associated additional first order conditions are:

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

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

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

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

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

(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 $$Q.U/\Lambda = V3TOT - . \sum_c P3\_S(c).X3SUB(c) \qquad (F6)$$

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):

$$P3\_S(c).X3\_S(c) = P3\_S(c).X3SUB(c)$$

$$+ S3LUX(c).\{V3TOT - \sum_k X3SUB(k)*P3\_S(k)\}. \qquad (F7)$$

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

$$x3\_s(c) = - FRISCH.B3LUX(c). w3tot \qquad (F8)$$

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:

$$EPS(c) = - FRISCH.B3LUX(c) \qquad (F9)$$

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 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:

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

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

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

implying that:

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

We also suppose that

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

This is guaranteed by equation E_a3sub:

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

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 D: 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.

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 a closure in which f3tot_h is endogenous and x3tot_hh exogenous, 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 WAYANG.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 E: 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:

$$p = H_K p_K + H_L p_L + H_M p_M \qquad \text{zero pure profits} \qquad \text{(J1)}$$

$$x_L - x_K = \sigma(p_K - p_L) \qquad \text{factor proportions} \qquad \text{(J2)}$$

$$z = S_L x_L + S_K x_K \qquad \text{production function} \qquad \text{(J3)}$$

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:

$$x_L = \sigma(p_K - p_L) \quad \text{and} \quad z = S_L x_L \quad \text{giving:} \qquad \text{(J4)}$$

$$z = S_L \sigma(p_K - p_L) \quad \text{or} \quad p_K = p_L + z/(S_L \sigma) \qquad \text{(J5)}$$

Substituting (J5) into (J1) we get:

$$p = H_K\big(p_L + z/(S_L\sigma)\big) + H_L p_L + H_M p_M \qquad \text{(J6)}$$

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

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

$$z = \big(S_L\sigma/H_K\big)\big[p - (H_K + H_L)p_L - H_M p_M\big] \qquad \text{(J9)}$$

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

so $$z = \big(\sigma S_L/S_K\big)\big[p/H_F - p_L - (H_M/H_F)p_M\big] \text{....compare DPSV eq. 45.19} \qquad \text{(J10)}$$

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

$$\sigma S_L/(S_K H_F) \qquad \text{(J11)}$$

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 F: List of Coefficients, Variables, and Equations of WAYANG

The variables of WAYANG

x1(c,s,i)	c∈COM s∈SRC i∈IND	Intermediate basic demands
x2(c,s,i)	c∈COM s∈SRC i∈IND	Investment basic demands
x3(c,s,h)	c∈COM s∈SRC h∈HH	Household basic demands
x4(c)	c∈COM	Export basic demands
x5(c,s)	c∈COM s∈SRC	Government basic demands
delx6(c,s)	c∈COM s∈SRC	Inventories demands
p0(c,s)	c∈COM s∈SRC	Basic prices by commodity and source
a1(c,s,i)	c∈COM s∈SRC i∈IND	Intermediate basic tech change
a2(c,s,i)	c∈COM s∈SRC i∈IND	Investment basic tech change
a3(c,s)	c∈COM s∈SRC	Household basic taste change
f5(c,s)	c∈COM s∈SRC	Government demand shift
x1mar(c,s,i,m)	c∈COM s∈SRC i∈IND m∈MAR	Intermediate margin demands
x2mar(c,s,i,m)	c∈COM s∈SRC i∈IND m∈MAR	Investment margin demands
x3mar(c,s,m,h)	c∈COM s∈SRC m∈MAR h∈HH	Household margin demands
x4mar(c,m)	c∈COM m∈MAR	Export margin demands
x5mar(c,s,m)	c∈COM s∈SRC m∈MAR	Government margin demands
a1mar(c,s,i,m)	c∈COM s∈SRC i∈IND m∈MAR	Intermediate margin tech change
a2mar(c,s,i,m)	c∈COM s∈SRC i∈IND m∈MAR	Investment margin tech change
a3mar(c,s,m)	c∈COM s∈SRC m∈MAR	Household margin tech change
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
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
p1(c,s,i)	c∈COM s∈SRC i∈IND	Purchaser's price, intermediate
p2(c,s,i)	c∈COM s∈SRC i∈IND	Purchaser's price, investment
p3(c,s,h)	c∈COM s∈SRC h∈HH	Purchaser's price, household
p4(c)	c∈COM	Purchaser's price, exports $A
p5(c,s)	c∈COM s∈SRC	Purchaser's price, government
x1lab(i,o)	i∈IND o∈OCC	Employment by industry and occupation
p1lab(i,o)	i∈IND o∈OCC	Wages by industry and occupation
x1cap(i)	i∈IND	Current capital stock
p1cap(i)	i∈IND	Rental price of capital
x1lnd(i)	i∈AGIND	Use of land
p1lnd(i)	i∈AGIND	Rental price of land
x1oct(i)	i∈IND	Demand for "other cost" tickets
p1oct(i)	i∈IND	Price of "other cost" tickets
a1oct(i)	i∈IND	"other cost" ticket augmenting techncal change
f1oct(i)	i∈IND	Shift in price of "other cost" tickets
q1(c,i)	c∈COM i∈IND	Output by commodity and industry
t0imp(c)	c∈COM	Power of tariff
fx6(c,s)	c∈COM s∈SRC	Shifter on rule for stocks
x1_s(c,i)	c∈COM i∈IND	Intermediate use of imp/dom composite
x2_s(c,i)	c∈COM i∈IND	Investment use of imp/dom composite
x3_s(c,h)	c∈COM h∈HH	Household use of imp/dom composite
x3lux(c,h)	c∈COM h∈HH	Household - supernumerary demands
x3sub(c,h)	c∈COM h∈HH	Household - subsistence demands
p1_s(c,i)	c∈COM i∈IND	Price, intermediate imp/dom composite
p2_s(c,i)	c∈COM i∈IND	Price, investment imp/dom composite

The variables of WAYANG (cont.)

p3_s(c,h)	c∈COM h∈HH	Price, household imp/dom composite
a1_s(c,i)	c∈COM i∈IND	Tech change, int'mdiate imp/dom composite
a2_s(c,i)	c∈COM i∈IND	Tech change, investment imp/dom composite
a3_s(c,h)	c∈COM h∈HH	Taste change, h'hold imp/dom composite
a3lux(c,h)	c∈COM h∈HH	Taste change, supernumerary demands
a3sub(c,h)	c∈COM h∈HH	Taste change, subsistence demands
a1prim(i)	i∈IND	All factor augmenting technical change
a1tot(i)	i∈IND	All input augmenting technical change
a2tot(i)	i∈IND	Neutral technical change - investment
employ(i)	i∈IND	Employment by industry
f0tax_s(c)	c∈COM	General sales tax shifter
f1lab_i_x(o)	o∈OCC	Skill-specific labour shifter
f4p(c)	c∈COM	Price (upward) shift in export demand schedule
f4q(c)	c∈COM	Quantity (right) shift in export demands
p0com(c)	c∈COM	Output price of locally-produced commodity
p0dom(c)	c∈COM	Basic price of domestic goods = p0(c,"dom")
p0imp(c)	c∈COM	Basic price of imported goods = p0(c,"imp")
p1lab_o(i)	i∈IND	Price of labour composite
p1lab_i(o)	o∈OCC	Price of labour for each skill
p1prim(i)	i∈IND	Effective price of primary factor composite
p1tot(i)	i∈IND	Average input/output price
p2tot(i)	i∈IND	Cost of unit of capital
pe(c)	c∈COM	Basic price of export commodity
pf0cif(c)	c∈COM	C.I.F. foreign currency import prices
x0com(c)	c∈COM	Output of commodities
x0dom(c)	c∈COM	Output of commodities for local market
x0imp(c)	c∈COM	Total supplies of imported goods
x1lab_i(o)	o∈OCC	Employment by occupation
x1lab_i_h(o,h)	o∈OCC h∈HH	Household labour supply
x1lab_o(i)	i∈IND	Effective labour input
x1prim(i)	i∈IND	Primary factor composite
x1tot(i)	i∈IND	Activity level or value-added
x2tot(i)	i∈IND	Investment by using industry
delB		(Balance of trade)/GDP
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/income
f3tot_h(h)	h∈HH	Ratio, consumption/income by hh
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

The variables of WAYANG (cont.)

p4tot		Exports price index
p5tot		Government price index
p6tot		Inventories price index
phi		Exchange rate, $A/$world
q(h)	h∈HH	Number of households
realwage		Average real wage
utility(h)	h∈HH	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(h)	h∈HH	Total nominal supernumerary household expenditure
w3tax_cs		Aggregate revenue from indirect taxes on households
w3tot_hh(h)	h∈HH	Nominal total consumption, each household
x3tot_hh(h)	h∈HH	Nominal total consumption, each household
p3tot_hh(h)	h∈HH	Nominal total consumption, each household
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
x1fac(f,i)	f∈AGRIFAC i∈AGIND	Primary factor demands, agriculture
p1fac(f,i)	f∈AGRIFAC i∈AGIND	Primary factor pirces, agriculture
a1fac(f,i)	f∈AGRIFAC i∈AGIND	Primary factor tech. change, agri.
a1faco(f,i)	f∈N_AGRIFAC i∈N_AGIND	Prim. factor tech. change, other
x1faco(f,i)	f∈N_AGRIFAC i∈N_AGIND	Primary factor demands, other
p1faco(f,i)	f∈N_AGRIFAC i∈N_AGIND	Primary factor price, other
x1lndi_hh(i,h)	i∈AGIND h∈HH	Household supply of land, agri.
p1cap_ag		National variable capital rental, agri.
p1cap_nagv		National variable capital rental, non-ag.
w1cap_v(h)	h∈HH	Returns to variable capital by household
w1cap_f(h)	h∈HH	Returns to fixed capital by household
x1cap_vah(h)	h∈HH	variable capital by household, agri.
x1cap_vnh(h)	h∈HH	variable capital by household, non-agri.

x1cap_ag		variable capital, agriculture
x1cap_nag		variable capital, non-ag.
x1cap_f(i)	i∈N_AGIND	fixed capital, non-ag.
x1cap_f_hh(i,h)	i∈N_AGIND h∈HH	fixed capital by h'hold, non-ag.
finv(i)	i∈IND	Investment shifter
r1cap(i)	i∈IND	Current rates of return on fixed capital
omega		Economy-wide "rate of return"
x0_reg(c,r)	c∈LOCCOM r∈REG	Output of region commodities
x1tot_r(i,r)	i∈IND r∈REG	Output of region industries
labrev_reg(r)	r∈REG	Wage bills by region
x1csi_reg(c,s,i,r)	c∈LOCCOM s∈SRC i∈IND r∈REG	Region demands for intermediate inputs
x2csi_reg(c,s,i,r)	c∈LOCCOM s∈SRC i∈IND r∈REG	Region demands for inputs for investment
x3cs_reg(c,s,r,h)	c∈LOCCOM s∈SRC r∈REG h∈HH	Region household demand for goods
x4_reg(c,r)	c∈LOCCOM r∈REG	Foreign exports by region
x5cs_reg(c,s,r)	c∈LOCCOM s∈SRC r∈REG	Region "other" demands
x1marg_reg(c,s,i,m,r)	c∈COM s∈SRC i∈IND m∈MARLOCCOM r∈REG	Usage of margins on production by region
x2marg_reg(c,s,i,m,r)	c∈COM s∈SRC i∈IND m∈MARLOCCOM r∈REG	Usage of margins on investment by region
x3marg_reg(c,s,m,r,h)	c∈COM s∈SRC m∈MARLOCCOM r∈REG h∈HH	Usage of margins on private consumption by region
x4marg_reg(c,m,r)	c∈COM m∈MARLOCCOM r∈REG	Usage of margins on foreign exports by region
x5marg_reg(c,s,m,r)	c∈COM s∈SRC m∈MARLOCCOM r∈REG	Usage of margins on "other" demands by region
rsum1(i)	i∈IND	Sum of region shares in Indonesia-wide ind. production
rsum2(i)	i∈IND	Sum of region shares in Indonesia-wide ind. investment
rsum3(c)	c∈COM	Sum of region shares in Indonesia-wide consumption
rsum4(c)	c∈COM	Sum of region shares in Indonesia-wide foreign exports
rsum5(c)	c∈COM	Sum of region shares in Indonesia-wide other demands
rsum_nat(i)	i∈NATIND	Sum of region shares in Indonesia-wide production of nat. inds.
ffreg2(i)	i∈IND	Region-uniform shifts in rgshr2(j,r) from rgshr1(j,r)
ffreg3(c)	c∈COM	Region-uniform shifts in rgshr3(i,r)
ffreg4(c)	c∈COM	Region-uniform shifts in rgshr4(i,r)
ffreg5(c)	c∈COM	Region-uniform shifts in rgshr5(i,r)
freg2(i,r)	i∈IND r∈REG	Commodity-specific complement of ffreg2
freg3(c,r)	c∈COM r∈REG	Commodity-specific complement of ffreg3
freg4(c,r)	c∈COM r∈REG	Commodity-specific complement of ffreg4
freg5(c,r)	c∈COM r∈REG	Commodity-specific complement of ffreg5
rgshr1(i,r)	i∈IND r∈REG	Region shares in Indonesia-wide industry production
rgshr2(i,r)	i∈IND r∈REG	Region shares in Indonesia-wide industry investment
rgshr3(c,r)	c∈COM r∈REG	Region shares in Indonesia-wide private consumption
rgshr4(c,r)	c∈COM r∈REG	Region shares in Indonesia-wide foreign exports
rgshr5(c,r)	c∈COM r∈REG	Region shares in Indonesia-wide "other" demands
f_x1tot_r(i,r)	i∈NATIND r∈REG	Region-specific deviations from normal nat.ind. rule
ff_x1tot_r(i)	i∈NATIND	Region-uniform deviations from normal nat.ind. rule
ztot_reg(r)	r∈REG	Real Gross region Products (GSP)
persontot_reg(r)	r∈REG	Aggregate region employment, persons
zcon_reg(i,r)	i∈IND r∈REG	Contributions to deviations in total region outputs from national GDP
person_reg(i,r)	i∈IND r∈REG	Employment by industry and region, persons
q_reg(r)	r∈REG	Population by region
qnat		national population: q is by household
fgov_h(h,t)	h∈HH t∈TYPE	Shift in transfers: govt. -- households

The variables of WAYANG (cont.)

fgov_f(t)	t∈TYPE	Shift in transfers: govt. – foreign
gov_h(h,t)	h∈HH t∈TYPE	Transfers: govt. -- households
gov_f(t)	t∈TYPE	Transfers: govt. -- foreign
w0hhtax(h)	h∈HH	% change in personal income tax
delbudget		Rupiah change in budget balance G-T
w0govt_t		Aggregate government revenue
w0govt_g		Aggregate government expenditure
f1inc_tax		Overall income tax shifter
w0hhinc(h)	h∈HH	Aggregate nominal income earned by households
x0loc(c)	c∈COM	real percent change in LOCSALES (dom+imp)
fandecomp(c,f)	c∈COM f∈FANCAT	Fan decomposition

The equations of WAYANG (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_x1fac(f,i)	f∈AGRIFAC i∈AGIND	Primary factor demands, agriculture
E_x1faco(f,i)	f∈N_AGRIFAC i∈N_AGIND	Primary factor demands, non-agriculture
E_p1lab_i(o)	o∈OCC	Supply of labour
E_x1lndi_hh(i)	i∈AGIND	supply of land
E_p1capN(i)	i∈N_AGIND	Price of variable + fixed capital, non-agri.
E_p1primA(i)	i∈AGIND	Effective price term for factor demand equations, ag.
E_p1primN(i)	i∈N_AGIND	Effective price term for factor demand equations, N_AG
E_p1facLB(i)	i∈AGIND	Industry demands for effective labour
E_x1lab_oA(i)	i∈AGIND	Effective labour input, agriculture
E_p1facF(i)	i∈AGIND	Price of fertiliser in agri.
E_p1capA(i)	i∈AGIND	Price of variable capital, agri.
E_x1lnd(i)	i∈AGIND	Industry demands for land
E_p1lndA(i)	i∈AGIND	Price of land in agri.
E_p1facK(i)	i∈AGIND	Equalise price of capital in agri.
E_x1lab_o(i)	i∈N_AGIND	Industry demands for effective labour
E_p1facoLC(i)	i∈N_AGIND	Price to each industry of labour composite
E_p1facoKN(i)	i∈N_AGIND	Price of variable capital in non-ag
E_p1cap_f(i)	i∈N_AGIND	supply of fixed capital by household
E_p1lab(i,o)	i∈IND o∈OCC	Equalising of money wages
E_x1cap_f(i)	i∈N_AGIND	supply of fixed capital by household
E_p1cap_ag		market clearing, variable capital, agriculture
E_x1cap_ag		household supply of variable capital, ag.
E_p1cap_nagv		variable capital, non-ag.
E_x1cap_nag		market clearing for variable capital, non-ag.
E_x1capA(i)	i∈AGIND	agri. industry capital, variable
E_x1capN(i)	i∈N_AGIND	non-agri. industry capital, fixed + variable
E_w1cap_v(h)	h∈HH	Returns to variable capital by household
E_w1cap_f(h)	h∈HH	Returns to fixed capital by household
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∈N_AGIND	Demands for commodity composites, non-agriculture
E_x1_sa(c,i)	c∈NONFERT i∈AGIND	Demands for commodity composites, agriculture
E_x1_sf(i)	i∈AGIND	Demands for composite fertiliser inputs, agri. production
E_x1prim(i)	i∈IND	Demands for primary factor composite
E_x1oct(i)	i∈IND	Demands for other cost tickets
E_p1tot(i)	i∈N_AGIND	Zero pure profits in production
E_p1totA(i)	i∈AGIND	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

The equations of WAYANG (cont.)

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,h)	c∈COM s∈SRC h∈HH	Source-specific commodity demands
E_p3_s(c,h)	c∈COM h∈HH	Effective price of commodity composite
E_x3sub(c,h)	c∈COM h∈HH	Subsistence demand for composite commodities
E_x3lux(c,h)	c∈COM h∈HH	Luxury demand for composite commodities
E_x3_s(c,h)	c∈COM h∈HH	Total household demand for composite commodities
E_utility(h)	h∈HH	Change in utility disregarding taste change terms
E_a3lux(c,h)	c∈COM h∈HH	Default setting for luxury taste shifter
E_a3sub(c,h)	c∈COM h∈HH	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,h)	c∈COM s∈SRC m∈MAR h∈HH	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,h)	c∈COM s∈SRC h∈HH	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
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

The equations of WAYANG (cont.)

E_x2tot_i		Total real investment
E_p2tot_i		Investment price index
E_w2tot_i		Total nominal investment
E_x3tot_hh(h)	h∈HH	Real consumption
E_p3tot_hh(h)	h∈HH	Household price index
E_w3tot_hh(h)	h∈HH	Household budget constraint
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_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_p1oct(i)	i∈IND	Indexing of prices of "other cost" tickets
E_delx6(c,s)	c∈COM s∈SRC	possible rule for stocks
E_x1csi_reg(c,s,i,r)	c∈LOCCOM s∈SRC i∈IND r∈REG	Direct intermediate demands by industry and region
E_x2csi_reg(c,s,i,r)	c∈LOCCOM s∈SRC i∈IND r∈REG	Direct investment demands by industry and region
E_x3cs_reg(c,r,s,h)	c∈LOCCOM r∈REG s∈SRC h∈HH	Consumption by region
E_x4_reg(c,r)	c∈LOCCOM r∈REG	Foreign exports by region
E_x5cs_reg(c,s,r)	c∈LOCCOM s∈SRC r∈REG	Other demands by region
E_x1marg_reg(c,s,i,m,r)	c∈COM s∈SRC i∈IND m∈MARLOCCOM r∈REG	margin intermediate demands by industry and region
E_x2marg_reg(c,s,i,m,r)	c∈COM s∈SRC i∈IND m∈MARLOCCOM r∈REG	margin investment demands by industry and region
E_x3marg_reg(c,s,m,r,h)	c∈COM s∈SRC m∈MARLOCCOM r∈REG h∈HH	margin private consumption by region
E_x4marg_reg(c,m,r)	c∈COM m∈MARLOCCOM r∈REG	margin to foreign export by region
E_x5marg_reg(c,s,m,r)	c∈COM s∈SRC m∈MARLOCCOM r∈REG	margins to "other" by region

The equations of WAYANG (cont.)

E_rgshr1(i,r)	i∈IND r∈REG	Region shares of industry production
E_rgshr2(i,r)	i∈IND r∈REG	Region shares of industry investment related to regional production shares
E_qnat		Indonesia-wide population equals sum of region populations
E_rgshr3(c,r)	c∈COM r∈REG	Region shares in private cons'n move with regional labour income shares
E_rgshr4(c,r)	c∈COM r∈REG	Region shares in foreign exports
E_rgshr5(c,r)	c∈COM r∈REG	Region shares in "other" demands
E_rsum1(i)	i∈IND	For checking purposes: rsum1 should be endogenous and zero
E_rsum2(i)	i∈IND	For checking purposes: rsum2 should be endogenous and zero
E_rsum3(c)	c∈COM	For checking purposes: rsum3 should be endogenous and zero
E_rsum4(c)	c∈COM	For checking purposes: rsum4 should be zero
E_rsum5(c)	c∈COM	Used to ensure rsum5 is zero
E_x0_reg_A(i,r)	i∈NONMARLOCCOM r∈REG	Output of nonmargins local commodities, Green book, eq39.8a
E_x0_reg_B(c,r)	c∈MARLOCCOM r∈REG	Usage of margins local commodities
E_x1tot_r_A(c,r)	c∈LOCCOM r∈REG	Supplies of local commodities related to production of local industries
E_x1tot_r_B(i,r)	i∈NATIND r∈REG	Output of national industries eq39.2, DPSV P.260
E_rsum_nat(i)	i∈NATIND	Adding up rule for national industries: rsum_nat normally end. and zero
E_labrev_reg(r)	r∈REG	Total wage bills by region
E_ztot_reg(r)	r∈REG	Gross Region Products (income weights)
E_zcon_reg(i,r)	i∈IND r∈REG	Contributions to deviations in total region outputs from national GDP
E_persontot_reg(r)	r∈REG	aggregate region employment
E_person_reg(i,r)	i∈IND r∈REG	employment by region and industry
E_w3lux(h)	h∈HH	consumption function
E_w0hhtax(h)	h∈HH	Aggregate nominal income tax paid by households
E_gov_f(t)	t∈TYPE	Government transfers to and from foreigners
E_gov_h(h,t)	h∈HH t∈TYPE	Government transfers to and from households
E_w0hhinc(h)	h∈HH	Aggregate nominal income earned by households
E_w0govt_t		Aggregate government revenue
E_w0govt_g		Aggregate government expenditure
E_delbudget		Change in budget balance G-T
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 WAYANG (in alphabetical order)

B3LUX(c,h)	c∈COM h∈HH	Ratio, (supernumerary expenditure/total expenditure), by commodity
BETA_A(f,v,i)	f∈AGRIFAC v∈AGRIFAC i∈AGIND	Factor demand elasticities, agri.
BETA_N(f,v,i)	f∈N_AGRIFAC v∈N_AGRIFAC i∈N_AGIND	Factor demand elasticities, non-ag.
COSTMAT(i,co)	i∈IND co∈COSTCAT	
DOMSALES(c)	c∈COM	Total sales to local market
EPS(c,h)	c∈COM h∈HH	Household expenditure elastic ities
EPSTOT(h)	h∈HH	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
FIXEDK(h,i)	h∈HH i∈N_AGIND	Household supplies of fixed capital
FRISCH(h)	h∈HH	Frisch LES 'parameter'= - (total/luxury)
GOVTEXP		Nominal total current and capital government expenditure
GOVTREV		Total government revenue
HINC(h,f)	h∈HH f∈OCC	household factor income
INCGDP(i)	i∈INCMAC	Income Aggregates
INITSALES(c)	c∈COM	Initial volume of SALES at final prices
LABINDREG(i,r)	i∈IND r∈REG	Labour bills by industry and region
LABREGTOT(r)	r∈REG	Total labour bill by region
LANDS(i,h)	i∈AGIND h∈HH	Household land rentals by industry
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
MMA(h)	h∈HH	Household supplies of agri variable capital
MMN(h)	h∈HH	Household supplies of non-agri variable capital
PURE_PROFITS(i)	i∈IND	COSTS-MAKE_C : should be zero
REGSHARE1(i,r)	i∈IND r∈REG	Region output shares
REGSHARE2(i,r)	i∈IND r∈REG	Region investment shares
REGSHARE3(c,r)	c∈COM r∈REG	Region consumption shares
REGSHARE4(c,r)	c∈COM r∈REG	Region export shares
REGSHARE5(c,r)	c∈COM r∈REG	Region 'other' shares
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,h)	c∈COM s∈SRC h∈HH	Households source shares
S3_S(c,h)	c∈COM h∈HH	Household average budget shares
S3LUX(c,h)	c∈COM h∈HH	Marginal household budget shares
SALEMAT(c,sa)	c∈COM sa∈SALECAT	
SALEMAT2(c,f,s,sa)	c∈COM f∈FLOWTYPE s∈SRC sa∈SALECAT2	Basic, margin and tax components of purchasers' values
SALES(c)	c∈COM	Total sales of domestic commodities
SHR_FAC(f,v,i)	f∈AGRIFAC v∈AGRIFAC i∈AGIND	Agri. industry modified factor share (for translog)
SHR_FAC_N(f,v,i)	f∈N_AGRIFAC v∈N_AGRIFAC i∈N_AGIND	Non-ag. ind. modified factor share (for translog)
SIGMA1(c)	c∈COM	Armington elasticities: intermediate
SIGMA1LAB(i)	i∈IND	CES substitution between skill types
SIGMA1OUT(i)	i∈IND	CET transformation elasticities
SIGMA2(c)	c∈COM	Armington elasticities: investment
SIGMA3(c)	c∈COM	Armington elasticities: households

The coefficients of WAYANG (cont.)

TAU(c)	c∈COM	1/elast. of transformation, exportable/locally used
TAX(t)	t∈TAXMAC	Tax Aggregates
TINY		Small number to prevent singular matrix
TOTDEMREG(c,r)	c∈LOCCOM r∈REG	All basic + margin use of local good i in region r
TRANSFER_F(t)	t∈TYPE	Government transfers: payments/receipts foreign
TRANSFER_H(h,t)	h∈HH t∈TYPE	Govt transfers to and from h'holds
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
V0HHINC(h)	h∈HH	Income earned by households
V0HHTAX(h)	h∈HH	Personal income tax on all household factors
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
V1CAPA(i)	i∈AGIND	Capital rentals, agri.
V1CAPN(k,i)	k∈KAP i∈N_AGIND	Capital rentals by mobility
V1FAC(f,i)	f∈AGRIFAC i∈AGIND	Total factor input to ind. i, agri.
V1FACO(f,i)	f∈N_AGRIFAC i∈N_AGIND	Total factor input non-agri.
V1FACSH(f,i)	f∈AGRIFAC i∈AGIND	Agri. ind. factor share
V1FACSH_N(f,i)	f∈N_AGRIFAC i∈N_AGIND	Non-ag ind. factor share
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
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_G(i)	i∈EXOGINV	Total govt. funding of capital created for i
V2TOT_I		Total investment usage
V3BAS(c,s,h)	c∈COM s∈SRC h∈HH	Household basic flows
V3MAR(c,s,m,h)	c∈COM s∈SRC m∈MAR h∈HH	Households margins

The coefficients of WAYANG (in alphabetical order)

V3PUR(c,s,h)	$c\in COM$ $s\in SRC$ $h\in HH$	Households purch. Value
V3PUR_S(c,h)	$c\in COM$ $h\in HH$	Dom+imp households purch. value
V3TAX(c,s,h)	$c\in COM$ $s\in SRC$ $h\in HH$	Taxes on households
V3TAX_CS		Total households tax revenue
V3TOT		Total purchases by households
V3TOT_HH(h)	$h\in HH$	Total purchases by each households
V4BAS(c)	$c\in COM$	Export basic flows
V4MAR(c,m)	$c\in COM$ $m\in MAR$	Export margins
V4NTRADEXP		Total non-traditional export earnings
V4PUR(c)	$c\in COM$	Export purch. Value
V4TAX(c)	$c\in COM$	Taxes on export
V4TAX_C		Total export tax revenue
V4TOT		Total export earnings
V5BAS(c,s)	$c\in COM$ $s\in SRC$	Government basic flows
V5MAR(c,s,m)	$c\in COM$ $s\in SRC$ $m\in MAR$	Government margins
V5PUR(c,s)	$c\in COM$ $s\in SRC$	Government purch. Value
V5TAX(c,s)	$c\in COM$ $s\in SRC$	Taxes on government
V5TAX_CS		Total government tax revenue
V5TOT		Total value of government demands
V6BAS(c,s)	$c\in COM$ $s\in SRC$	Inventories basic flows
V6TOT		Total value of inventories
VALUADD(i,r)	$i\in IND$ $r\in REG$	Factor bills by industry and region
VALUADDTOT(r)	$r\in REG$	Total factor bill by region

Appendix G: Using a translog cost function in WAYANG or ORANI-G

The translog unit cost function is explained in detail on pages 133 to 141 of the Black Book. One motivation for using a translog unit cost function is to preserve, as much as possible, a set of estimated conditional input demand price elasticities within an AGE model while retaining homogeneity of degree one. The translog unit cost function has the form:

$$lnQ(P) = A + \Sigma_i B_i lnP_i + ½\Sigma_i\Sigma_j C_{ij}\,(lnP_i)(lnP_j) \qquad (G.1)$$

where $lnQ(P)$ is the cost per unit of output when the input prices are P' = (P_1,P_2, …,P_n) and A, B_i and C_{ij} are parameters with $C_{ij} = C_{ji}$ for all $i \neq j$. To ensure that Q is homogeneous of degree one with respect to input prices, we require that

$$Q(\lambda P) = \lambda Q(P) \qquad \text{for all } P > 0 \text{ and } \lambda > 0. \qquad (G.2)$$

This is equivalent to requiring

$$lnQ(\lambda P) = lnQ(P) + ln\lambda \qquad \text{for all } P > 0 \text{ and } \lambda > 0. \qquad (G.3)$$

From (G.1), we have

$$lnQ(\lambda P) = A + \Sigma_i B_i ln(\lambda P_i) + ½\Sigma_i\Sigma_j C_{ij}\,[ln(\lambda P_i)][\,ln(\lambda P_j)]. \qquad (G.4)$$

Given that $ln(\lambda P_k) = ln\lambda + ln P_k$ for all k and $C_{ij} = C_{ji}$ for all $i \neq j$, and substituting (G.3) for (G.1), we can expand (G.4) as

$$lnQ(\lambda P) = lnQ(P) + (ln\lambda)\,\Sigma_i B_i + ln\lambda\Sigma_i(lnP_i\,)\,\Sigma_j C_{ij} + ½(ln\lambda)^2\Sigma_i\Sigma_j C_{ij}\,. \qquad (G.5)$$

Necessary and sufficient conditions to ensure that Q is homogeneous of degree one with respect to input prices, as in G.3, are

$$\Sigma_i B_i = 1 \qquad (G.6)$$

and

$$\Sigma_j C_{ij} = 0 \qquad \text{for all } i. \qquad (G.7)$$

The next step is to derive a percentage change form for the input demand functions convenient for use in ORANI-G or WAYANG. We start by rewriting (G.1):

$$Q(P) = exp[A + \Sigma_i B_i lnP_i + ½\Sigma_i\Sigma_j C_{ij}(lnP_i)(lnP_j)]. \qquad (G.8)$$

From Shephard's lemma, the input demands are the derivatives

$$X_k = Y\,[\delta Q(P)/\delta P_k] \qquad \text{for all k,} \qquad (G.9)$$

where Y is the level of output and X_k is the demand for input k. From (G.8), we have

$$X_k = Y\,Q(P)[\,B_k + \Sigma_j C_{kj}(lnP_j)]/\,P_k \qquad \text{for all } k. \qquad (G.10)$$

In percentage change form, (G.10) becomes

$$x_k = y + q + \Sigma_j[C_{kj})/(B_k + \Sigma_t C_{kt}(lnP_t)]p_j — p_k \qquad \text{for all k,} \qquad (G.11)$$

where the lower case symbols, x, y, q and p represent the percentage changes in the variables denoted by the corresponding upper case symbols. We must eliminate q in order to obtain the required input demand functions. First, we note that

$$q = \Sigma_k[\delta Q(P)/\delta P_k][P_k/Q(P)]p_k \,. \qquad \text{(G.12)}$$

From Shephard's lemma (G.9), we know that the elasticities of the unit cost function are the input shares in total costs:

$$[\delta Q(P)/\delta P_k][P_k/Q(P)] = S_k \qquad \text{for all k,} \qquad \text{(G.13)}$$

where $S_k = P_kX_k/[YQ(P)]$. Hence, we may rewrite (G.12) as

$$q = \Sigma_k S_k p_k \;. \qquad \text{(G.14)}$$

From (G.10), the cost shares for translog unit cost functions are given by

$$S_k = B_k + \Sigma_j C_{kj}(ln P_j) \qquad \text{for all } k \text{ and } j. \qquad \text{(G.15)}$$

Next, we substitute (G.14) and (G.15) into (G.11) to obtain

$$x_k = y - (p_k - \Sigma_j S_{kj}\, p_j) \qquad \text{for all k,} \qquad \text{(G.16)}$$

where the S_{kj} terms are modified cost shares, defined by

$$S_{kj} = S_j + (C_{kj}/S_k) \qquad \text{for all } k \text{ and } j. \qquad \text{(G.17)}$$

Equation (G.16) is a suitable expression for use in WAYANG or ORANI-G. The C_{kj} terms are input demand price elasticities as in (G.1), with $C_{ij} = C_{ji}$ for all $i \neq j$ and $\Sigma_j C_{ij} = 0$.

Parameters C_{ij} and B_i in equation (G.1) entail additional restrictions relating to the requirement that cost functions are concave with respect to input prices. The Black Book examines this requirement using two methods. The first involves a Taylor's-series approximation of the true unit cost function. On this interpretation, Q(P) need only exhibit concavity in the neighbourhood of a central price vector. Where **C** is the n x n matrix of C_{ij}s, **B** is the n x 1 vector of B_is and $\mathbf{B}^d$ is the diagonal matrix formed by **B**, the following must be negative semi-definite:

$$\mathbf{C} + \mathbf{BB}' - \mathbf{B}^d. \qquad \text{(G.18)}$$

Under a second interpretation, (G.1) or (G.8) is the true unit cost function. To ensure concavity, we examine the first derivative of the unit cost function with respect to prices, as used to derive equation (G.10):

$$\delta Q(P)/\delta P_i = Q(P)[\, B_i + \Sigma_j C_{ij}(ln P_j)]/\, P_i. \qquad \text{(G.19)}$$

For $\delta Q(P)/\delta P_i$ to be nonnegative for all $P > 0$ to ensure global concavity, $C_{ij} = 0$ for all i and j. If this is so, the function simplifies to fixed cost shares, as in the Cobb-Douglas case. Therefore, in using the translog function, we cannot insist on global monoticity, under which condition (G.19) is non-negative for all $P > 0$. Consequently, (G.8) is not a globally valid description of unit costs. Jorgenson

(1984) assumed that (G.8) was the true unit cost function and imposed an additional restriction, that **C** is negative semidefinite. This is more restrictive on the parameter estimates than the concavity condition imposed under the Taylor's-series expansion.

In old WAYANG, the initial parameters based on econometric estimates are analogous to the S_{kj} terms (for small changes in price), as the conditional input demand equation is:

$$x_k = y + \Sigma_j \eta_{kj}\, p_j \qquad \text{for all } k, \qquad \text{(G.20)}$$

where η_{kj} is the derived demand elasticity, conditional on a given activity level.

Therefore, we rearrange (G.17) to calculate the unconditional C_{kj} terms given S_{kj}s. We can do the necessary data manipulation in a TABLO-generated program (based on excerpt 16A).

```
Coefficient (all,f,AGRIFAC)(all,v,AGRIFAC)(all,i,AGIND)
          BETA1_A(f,v,i) # Unrestricted factor demand elasticities, agri.#;
all,f,N_AGRIFAC)(all,v,N_AGRIFAC)(all,i,N_AGIND)
          BETA1_N(f,v,i) # Unrestricted factor demand elasticities, non-ag.#;
Read SHR_FAC from file INDATA header "BEAP";
SHR_FAC_N from file INDATA header "BETP";
Formula !calculate the C parameters from modified cost shares, ie., initial parameters !
(all,f,AGRIFAC)(all,v,AGRIFAC)(all,i,AGIND)BETA1_A(f,v,i)=
  [ SHR_FAC(f,v,i) -  V1FACSH(v,i)]*V1FACSH(f,i);
(all,f,N_AGRIFAC)(all,v,N_AGRIFAC)(all,i,N_AGIND)BETA1_N(f,v,i)=
   [ SHR_FAC_N(f,v,i) -  V1FACSH_N(v,i)]*V1FACSH_N(f,i);
```

Next, we impose the restrictions on the C_{kj}s in the TABLO-generated program.

```
Coefficient
(all,f,AGRIFAC)(all,v,AGRIFAC)(all,i,AGIND)BETA_A(f,v,i) # C(ij), ag.#;
(all,f,AGRIFAC)(all,v,AGRIFAC)(all,i,AGIND)ALPHA1(f,v,i)#New C(ij), 2#;
(all,f,N_AGRIFAC)(all,v,N_AGRIFAC)(all,i,N_AGIND)BETA_N(f,v,i)#C(ij), non-ag.#;
(all,f,N_AGRIFAC)(all,v,N_AGRIFAC)(all,i,N_AGIND) ALPHA_N2(f,v,i)#New C(ij),  2#;
(all,v,AGRIFAC)(all,i,AGIND)ALP_SUM(v,i) #sum across v#;
 (all,v,N_AGRIFAC)(all,i,N_AGIND)ALP_SUMN(v,i);
Formula
 (all,f,AGRIFAC)(all,v,AGRIFAC)(all,i,AGIND)BETA_A(f,v,i)=
   {BETA1_A(f,v,i)+BETA1_A(v,f,i)}/2;!impose symmetry!
(all,f,AGRIFAC)(all,i,AGIND)BETA_A(f,f,i)= BETA_A(f,f,i);
(all,f,N_AGRIFAC)(all,v,N_AGRIFAC)(all,i,N_AGIND) BETA_N(f,v,i)=
{BETA1_N(f,v,i)+BETA1_N(v,f,i)}/2;!impose symmetry!
(all,f,AGRIFAC)(all,i,AGIND)ALP_SUM(f,i)=sum{v,AGRIFAC,BETA_A(f,v,i)};
(all,f,N_AGRIFAC)(all,i,N_AGIND)ALP_SUMN(f,i)=sum{v,N_AGRIFAC,BETA_N(f,v,i)};
(all,f,AGRIFAC)(all,v,AGRIFAC)(all,i,AGIND)ALPHA1(f,v,i)=
BETA_A(f,v,i)-ALP_SUM(f,i)/4;!impose sum to zero!
(all,f,N_AGRIFAC)(all,v,N_AGRIFAC)(all,i,N_AGIND)ALPHA_N2(f,v,i)=
ALPHA_N(f,v,i)-ALP_SUMN(f,i)/3;!impose sum to zero!
!--------------------------------------------------------------------------------------------------!
 (all,f,AGRIFAC)(all,v,AGRIFAC)(all,i,AGIND)BETA_A(f,v,i)=
  {ALPHA1(f,v,i)+ALPHA1(v,f,i)}/2;!round 2 of 20 or so in this recursive program!
(all,f,N_AGRIFAC)(all,v,N_AGRIFAC)(all,i,N_AGIND)BETA_N(f,v,i)=
{ALPHA_N2(f,v,i)+ALPHA_N2(v,f,i)}/2;! round 2 of 20 or so in this recursive program!
(all,f,AGRIFAC)(all,i,AGIND)ALP_SUM(f,i)=sum{v,AGRIFAC,BETA_A(f,v,i)};
(all,f,N_AGRIFAC)(all,i,N_AGIND)ALP_SUMN(f,i)=sum{v,N_AGRIFAC,ALPHA_N(f,v,i)};
(all,f,AGRIFAC)(all,v,AGRIFAC)(all,i,AGIND)ALPHA1(f,v,i)=
BETA_A(f,v,i)-ALP_SUM(f,i)/4;
(all,f,N_AGRIFAC)(all,v,N_AGRIFAC)(all,i,N_AGIND)ALPHA_N2(f,v,i)=
BETA_N(f,v,i)-ALP_SUMN(f,i)/3;
!repeat round 2 (copy and paste) to impose restrictions to a number of decimal places!
!--------------------------------------------------------------------------------------------------!
Write
BETA_A to file MDATA header "ALPH";
BETA_N to file MDATA header "ALP2";
```