

## Explanation of the MONASH Equations represented in TABLO Code

**19. Introduction**

The aim of this chapter is to explain the TABLO representation of MONASH given in section 18. We consider each of the equations in subsection 18.8 in turn, discussing, where appropriate: its theoretical justification; its derivation from the levels representation; its role in MONASH simulations; and the setting of its parameters and the evaluation of its coefficients.

The explanation of each equation is largely self-contained. This means that there are some repetitions. The advantage of our approach is that it enables readers to be selective. They can find answers to questions about particular equations without having to work through the whole chapter.

In the main part of the chapter (sections 20 to 36), we try to be comprehensive but intuitive. To avoid interruptions in the flow of the presentation, we place explanations of difficult technical points in appendices (sections 37 to 44). Among other things, the appendices contain:

- derivations of equations for the composition of an industry's outputs and inputs, together with economic interpretations of technical-change variables;
- derivations of equations for the composition of household demands, together with economic interpretations of taste-change variables;
- derivations of equations for export demands and a description of a back-of-the-envelope approach to the setting of export-demand elasticities;
- a demonstration in the context of MONASH that the income measure of GDP must equal the expenditure measure, both in nominal and in real terms;
- definitions of the levels versions of Divisia indexes and a justification of the percentage change versions appearing in the TABLO code for MONASH; and
- an explanation of our algorithm for solving MONASH with forward-looking expectations.

In the remainder of this section we describe a stylized version of the MONASH model together with a trial closure. Our aim is to give readers an intuitive understanding of where each group of MONASH equations fits into the overall structure of the model.

Table 19.1 lists the stylized equations in groups corresponding to sections 20 to 36. Table 19.2, which is presented in three parts, defines the notation used in Table 19.1. The first two parts of Table 19.2 list the endogenous and exogenous variables in the trial closure. The third part lists other notation from Table 19.1. In subsection 19.1 we work through Table 19.1 and then in subsection 19.2 we discuss the closure set out in Table 19.2.

**Table 19.1. Stylized Representation of the MONASH Equations**

	<b>Dimension</b>	<b>Identifier</b>
<b>Section 20: composition of outputs and inputs</b>		
$X0(i,1,j) = Z(j)*\psi_{0ij}(P_1, A_{0j})$	$N_C N_I$	(19.1)
$X0DOM(i) = \sum_j X0(i,1,j)$	$N_C$	(19.2)
$X1(i,s,j) = Z(j)*\psi_{1isj}(P_1(i), P_2(i), A_{1j})$	$N_C N_S N_I$	(19.3)
$L(j) = Z(j)*\psi_{Lj}(W, Q(j), A_{PFj})$	$N_I$	(19.4)
$K(j) = Z(j)*\psi_{Kj}(W, Q(j), A_{PFj})$	$N_I$	(19.5)
<b>Section 21: inputs to capital creation and asset prices</b>		
$X2(i,s,j) = Y(j)*\psi_{2isj}(P_1(i), P_2(i), A_{2j})$	$N_C N_S N_I$	(19.6)
$PI(j) = \psi_{PIj}(P_1, P_2, A_{2j})$	$N_I$	(19.7)
<b>Section 22: household demands for commodities</b>		
$X3(i,s) = \psi_{3is}(C, P3_1, P3_2, A_3)$	$N_C N_S$	(19.8)
<b>Section 23: exports</b>		
$X4(i) = \psi_{4i}(PE(i)) + A_4(i)$	$N_C$	(19.9)
<b>Section 24: other demands</b>		
$X5(i,s) = A_5(i,s)*A_{(5)}$	$N_C N_S$	(19.10)
<b>Section 25: demands for margin services</b>		
$X3MAR(k,s,i) = A3MAR(k,s,i)*X3(k,s)$	$N_C^2 N_S$	(19.11)
<b>Section 26: supply equals demand for commodities</b>		
$X0DOM(i) = \sum_j X1(i,1,j) + \sum_j X2(i,1,j) + X3(i,1)$ $+ X4(i) + X5(i,1) + \sum_k \sum_s X3MAR(k,s,i)$	$N_C$	(19.12)
$X0IMP(i) = \sum_j X1(i,2,j) + \sum_j X2(i,2,j) + X3(i,2) + X5(i,2)$	$N_C$	(19.13)
<b>Section 27: zero profits in production, importing, exporting and distribution</b>		
$\sum_i P_1(i) X0(i,1,j) = \sum_i \sum_s P_s(i) X1(i,s,j) + W * L(j) + Q(j) * K(j)$	$N_I$	(19.14)
$P_2(i) = [PM(i)/\Phi] * TM(i)$	$N_C$	(19.15)
$P_1(i) = [PE(i)/\Phi] / T4(i)$	$N_C$	(19.16)
$P3_s(k) = P_s(k) * T3(k,s) + \sum_i P_1(i) * A3MAR(k,s,i)$	$N_C N_S$	(19.17)

...continued

Table 19.1 continued

	<b>Dimension</b>	<b>Identifier</b>
<b>Section 28: genuine and phantom indirect taxes</b>		
$T4(i) = T4G(i)*T4PH(i)$	N <sub>C</sub>	(19.18)
<b>Section 29: definitions of macro variables</b>		
$CPI = \psi_{CPI}(P3_1, P3_2)$	1	(19.19)
$WR = W/CPI$	1	(19.20)
$LTOT = \sum_j L(j)$	1	(19.21)
$KTOT = \sum_j K(j)$	1	(19.22)
$GDP = C + \sum_j PI(j)*Y(j) + \sum_s \sum_i P_s(i)*X5(i,s)$ $+ \sum_i [PE(i)/\Phi]*X4(i) - \sum_i [PM(i)/\Phi]*X0IMP(i)$	1	(19.23)
<b>Section 30: capital stocks, investment and rates of return</b>		
$K_+(j) = (1-D(j))*K(j) + Y(j)$	N <sub>I</sub>	(19.24)
$IKRATIO(j) = Y(j)/K(j)$	N <sub>I</sub>	(19.25)
$K_+(j)/K(j) - 1 = \psi_{KG}(EROR(j)) + A_{KG}(j)$	N <sub>I</sub>	(19.26)
$EROR(j) = \psi_{ERORj}(Q(j), PI(j)) + A_{EROR}(j)$	N <sub>I</sub>	(19.27)
<b>Section 31: equations for facilitating historical and forecast simulations</b>		
$LG(q) = \sum_{j \in G(q)} L(j)$	N <sub>LG</sub>	(19.28)
<b>Section 32: equations for facilitating policy simulations</b>		
$\left[ \frac{WR}{WR_f} - 1 \right] = \left[ \frac{WR_{lag}}{WR_{flag}} - 1 \right] + \alpha \left[ \frac{LTOT}{LTOT_f} - 1 \right] + A_{WR}$	1	(19.29)
<b>Section 33: the government accounts</b>		
$PSD = \sum_s \sum_i P_s(i)X5(i,s) - \sum_s \sum_k [T3(k,s) - 1]P_s(k)X3(k,s)$ $- \sum_i (TM(i)-1)[PM(i)/\Phi]X0IMP(i) - \sum_i (T4G(i)-1)*P_1(i)*X4(i)$ $+ TRANSFERS$	1	(19.30)
<b>Section 34: equations for facilitating decomposition simulations</b>		
$NFLF = \psi_{NFLF}(NFLF_{-\tau}, KTOT/KTOT_{-\tau}, GNP/GNP_{-\tau}, \Phi/\Phi_{-\tau}) + A_{NFLF}$	1	(19.31)
$GNP = GDP - R0IF*(NFLF/\Phi)$	1	(19.32)

....continued

Table 19.1 continued

	Dimension	Identifier
<b>Section 35: balance of payments</b>		
$NFLF_+ = NFLF + CAD * \Phi$	1	(19.33)
$CAD = \sum_i (PM(i)/\Phi) * X0IMP(i) - \sum_i (PE(i)/\Phi) * X4(i) + R0IF * (NFLF/\Phi)$	1	(19.34)
<b>Section 36: household disposable income and consumption function</b>		
$HDY = GNP - \sum_s \sum_k [T3(k,s) - 1] * P_s(k) X3(k,s)$ $- \sum_i (TM(i) - 1) [PM(i)/\Phi] X0IMP(i) - \sum_i (T4G(i) - 1) P_1(i) X4(i)$ $+ TRANSFERS$	1	(19.35)
$C = A_C * HDY$	1	(19.36)
<b>Total number of equations:</b>		
$N_C^2 N_S + N_C N_I + 3 N_C N_S + 2 N_C N_S N_I + 8 N_I + 7 N_C + N_{LG} + 13$		

### 19.1. Stylized version of the MONASH model

#### Stylized version of section 20

The first five equations in Table 19.1 are concerned with the compositions of industry outputs and inputs. As explained in section 20, each industry in MONASH can produce a variety of domestic commodities,  $(i,1)$   $i=1, 2, \dots, N_C$ . Industry  $j$  chooses the composition of its output to maximize revenue subject to a transformation frontier. This gives commodity supply functions of the forms shown in (19.2) and (19.1). In (19.2) the total output of  $(i,1)$   $[X0DOM(i)]$  is the sum over industries of outputs  $[X0(i,1,j), j = 1, 2, \dots, N_I]$  of this commodity, and in (19.1) the output of  $(i,1)$  by industry  $j$  is a function of prices  $(P_1)$  of domestic commodities, of technology variables  $(A0j)$  determining the shape of  $j$ 's transformation frontier, and of the level of  $j$ 's activity  $[Z(j)]$ . The level of  $j$ 's activity determines the distance of  $j$ 's transformation frontier from the origin. We assume constant returns to scale implying that an  $x$  per cent increase in  $Z(j)$  allows industry  $j$  to produce  $x$  per cent more of all commodities. An  $x$  per cent increase in activity can be achieved with an  $x$  per cent increase in all inputs. Thus, as indicated in equations (19.3) to (19.5),  $j$ 's demands for inputs are proportional to  $Z(j)$ . They also depend on technology variables  $(A1j, APFj)$  that affect the location and shape of  $j$ 's isoquants and on input prices. The input prices enter  $j$ 's demand functions via cost-minimizing assumptions. With the particular production functions adopted in MONASH, the demands by industry  $j$  for inputs of domestic and imported good  $i$   $[X1(i,s,j), s= 1,2]$  depend on the prices  $[P_s(i), s= 1,2]$  of the two varieties of good  $i$ , and the demands by industry  $j$  for primary factors  $[L(j)]$  and

**Table 19.2. Notation in the Stylized Model**

		<b>Dimension</b>	<b>Determining equation</b>
<b>I. Endogenous variables in the trial closure</b>			
T4(i)	Power of tax on exports of commodity i	$N_C$	(19.18)
$P_1$	Basic prices of domestic commodities	$N_C$	(19.16)
$P_2$	Basic prices of imported commodities	$N_C$	(19.15)
$P_{3_1}, P_{3_2}$	Vectors of household purchasers' prices for domestic and imported commodities	$N_C N_S$	(19.17)
CPI	Consumer price index	1	(19.19)
W	Wage rate	1	(19.20)
Q(j)	Rental rate on capital in industry j	$N_I$	(19.14)
Z(j)	Activity level in industry j	$N_I$	(19.5)
$X_0(i, 1, j)$	Output of commodity (i,1) by industry j	$N_C N_I$	(19.1)
$X_0DOM(i)$	Total output of commodity (i,1)	$N_C$	(19.2)
$X_1(i, s, j)$	Input of (i,s) to production in industry j	$N_C N_S N_I$	(19.3)
L(j)	Employment in industry j	$N_I$	(19.4)
PI(j)	Asset price of capital in industry j	$N_I$	(19.7)
EROR(j)	Expected rate of return in industry j	$N_I$	(19.27)
$K_+(j)$	End-of-year stock of capital in industry j	$N_I$	(19.26)
Y(j)	Investment in industry j	$N_I$	(19.24)
IKRATIO(j)	Ratio of investment to capital in industry j	$N_I$	(19.25)
$X_2(i, s, j)$	Input of (i,s) to j's capital creation	$N_C N_S N_I$	(19.6)
$X_3(i, s)$	Household consumption of commodity (i,s)	$N_C N_S$	(19.8)
$X_5(i, s)$	Government consumption of good (i,s)	$N_C N_S$	(19.10)
$X_3MAR(k, s, i)$	Margin use of domestic good i in facilitating the flow of (k,s) from producers and ports of entry to households	$N_C^2 N_S$	(19.11)
X4(i)	Exports of commodity i	$N_C$	(19.12)
$X_0IMP(i)$	Total imports of commodity i	$N_C$	(19.13)
$A_4(i)$	Slack in export-demand function for i	$N_C$	(19.9)

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Table 19.2 continued

		<b>Dimension</b>	<b>Determining equation</b>
LTOT	Total employment	1	(19.21)
KTOT	Total start-of-year capital stock	1	(19.22)
GDP	Gross domestic product	1	(19.23)
LG(q)	Employment in qth group of industries	$N_{LG}$	(19.28)
$A_{WR}$	Slack in wage-determination equation	1	(19.29)
PSD	Public sector deficit	1	(19.30)
CAD	Current account deficit	1	(19.34)
$NFLF_+$	End-of-year net foreign liabilities in foreign currency	1	(19.33)
GNP	Gross national product	1	(19.32)
$A_{NFL}$	Slack in decomposition equation for net foreign liabilities	1	(19.31)
HDY	Household disposable income	1	(19.35)
$A_C$	Slack in consumption function	1	(19.36)
<b>Total number of endogenous variables:</b>			
$N_C^2 N_S + N_C N_I + 3N_C N_S + 2N_C N_S N_I + 8N_I + 7N_C + N_{LG} + 13$			

**II. Exogenous variables in the trial closure**

$K(j)$	Start-of-year capital stock in industry j
$NFLF$	Start-of-year net foreign liabilities in foreign currency
$\Phi_{-\tau}$	Exchange rate in base year ( $\tau$ years earlier than solution year)
$NFLF_{-\tau}$	Start-of-year net foreign liabilities in foreign currency in base year ( $\tau$ years earlier than solution year)
$KTOT_{-\tau}$	Total capital stock in base year ( $\tau$ years earlier than solution year)
$GNP_{-\tau}$	Base year gross national product
$WR_{lag}$	Real wage rate in previous year
$WR_{flag}$	Forecast for real wage rate in previous year
$WR_f$	Forecast for real wage rate

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Table 19.2 continued

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LTOT <sub>f</sub>	Forecast for total employment
TM(i)	Power (one plus the rate) of tariff on imports of commodity i
T3(k,s)	Power of tax on household consumption of good (k,s)
T4G(i)	Power of genuine tax on exports of commodity i
TRANSFERS	Transfers from the public sector to households, e.g., unemployment benefits and interest on the public debt
T4PH(i)	Power of phantom tax on exports of commodity i
PM(i)	Foreign currency c.i.f. price of imports of commodity i
ROIF	Rates of interest or dividends applying to net foreign liabilities
Φ	Exchange rate
C	Total household expenditure
WR	Real wage rate
PE(i)	Foreign-currency price of exports of commodity i
All the A's except A <sub>NFLF</sub> , A <sub>C</sub> , A <sub>WR</sub> and A <sub>4</sub> (i) for all i	Potential slack variables and variables used to represent shifts in technology and preferences

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**III. Other notation**

N <sub>C</sub>	Number of commodities (115 in MONASH)
N <sub>I</sub>	Number of industries (113 in MONASH)
N <sub>S</sub>	Number of sources (2 in MONASH, namely domestic and imported)
N <sub>LG</sub>	Number of industry groups for which data on employment are available
D(j)	Depreciation rate in industry j, treated as a parameter
G(q)	Set of industries in the group q
α	Positive parameter

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K(j)] depend on the wage rate (W) and the rental price [Q(j)] of j's capital.

*Stylized version of section 21*

With the capital-creation functions used in MONASH, cost-minimizing assumptions produce input-demand functions of the form (19.6): the demand for inputs of commodity i from source s to be used by industry j for capital creation depends on the quantity of capital creation [Y(j)] in industry j, on the prices of domestic and imported commodity i, and on variables (A<sub>2j</sub>) reflecting the

technology for creating units of capital for use in industry  $j$ . As implied by (19.7), the cost  $[PI(j)]$  of a unit of capital in industry  $j$  depends on input prices and technology. We assume that the cost of creating a unit of capital is also the price at which a unit can be sold (the asset price).

*Stylized version of section 22*

Demands for commodities by households are derived in MONASH from utility maximization subject to a budget constraint. A stylized version of the resulting demand functions is given in (19.8) which shows household demands as functions: of the household budget ( $C$ ); of variables reflecting household preferences ( $A_3$ ); and of purchasers' prices to households of domestic commodities ( $P3_1$ ) and imported commodities ( $P3_2$ ). In MONASH, *all* demands for commodities depend on purchasers' prices. In the stylized version we simplify MONASH by assuming that margins occur only on commodity flows to households and that the only indirect taxes are tariffs, export taxes and taxes on consumption. Thus, in (19.3), (19.6) and (19.7) we used basic prices.<sup>1</sup>

*Stylized version of section 23*

The treatment of exports in MONASH differs between four groups of commodities. In the stylized version we show only one treatment: we relate foreign demand for domestic good  $i$   $[X4(i)]$  to the foreign-currency price  $[PE(i)]$  and to a shift variable  $[A_4(i)]$ . If the shift variable is exogenous, then by shocking it we can simulate the effects of movements in the foreign-demand curve for commodity  $i$ . If the shift variable is endogenous, then it can be allowed to adjust to accommodate an exogenous forecast for either  $X4(i)$  or  $PE(i)$ .

*Stylized version of section 24*

In MONASH, equations such as (19.10) allow for different treatments of government demands for commodities. Changes in government demand for a particular commodity ( $i,s$ ) or for all commodities can be introduced by shocks to  $A_5(i,s)$  or  $A_{(5)}$ . Alternatively  $A_{(5)}$  can be used as an endogenous variable which adjusts so that government spending meets a budget constraint.

*Stylized version of section 25*

With  $A3MAR(k,s,i)$  set exogenously, (19.11) implies that the use of commodity  $i$  (e.g. retail trade) as a margin service in facilitating the flow of commodity ( $k,s$ ) from producers or ports of entry to households is proportional to household demand for ( $k,s$ ). MONASH contains equations similar to (19.11) for flows of commodities to all users. As mentioned in the discussion of (19.8), in the stylized

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<sup>1</sup> The basic price of a domestic commodity is the price received by producers and the basic price of an imported commodity is the landed-duty-paid price.

version we assume that there are no margins services associated with commodity flows except those to households.

*Stylized version of section 26*

In (19.12) we equate the supply (output) of commodity (i,1) to the sum of demands for (i,1). Similarly, in (19.13) we equate the supply (imports) of (i,2) to the sum of demands for (i,2). Consistent with MONASH, imported commodities are not directly exported or used to satisfy margin demands.

*Stylized version of section 27*

Equations (19.14) to (19.17) are stylized versions of the MONASH zero-pure-profits conditions for production, importing, exporting and distribution. The LHS of (19.14) is revenue in industry  $j$  and the RHS is costs. The LHS of (19.15) is the price  $[P_2(i)]$  received by importers of commodity  $i$  and the RHS is the cost of importing a unit of  $i$  made up of the foreign-currency price  $[PM(i)]$  converted to domestic currency via the exchange rate  $[\Phi]$  and inflated by the power of the tariff  $[TM(i)]$ . The LHS of (19.16) is the cost of exporting a unit of commodity  $i$  (that is the revenue foregone by not selling on the domestic market) and the RHS is the revenue received per unit of export made up of the foreign-currency price  $[PE(i)]$  converted to domestic currency and deflated by the power of the export tax  $[T4(i)]$ . The LHS of (19.17) is the price paid by households for commodity (k,s). This is equal to the cost of supplying a unit of (k,s) to households and is made up of the price received by producers or importers  $[P_s(k)]$  inflated by the power of the consumption tax  $[T3(k,s)]$  plus the costs of transferring units of (k,s) from producers or ports of entry to households. As mentioned in our discussion of (19.12) and (19.13), we assume that transferring (margin) activities use only domestic commodities, e.g. domestic transport and domestic retail trade. Thus the cost of commodity  $i$  used in transferring a unit of (k,s) to households is the price of domestic commodity  $i$   $[P_1(i)]$  multiplied by the number of units of  $i$   $[A3MAR(k,s,i)]$  required per unit of transfer.

*Stylized version of section 28*

MONASH contains many equations expressing the power (one plus the rate) of an indirect tax as the product of the powers of a genuine tax and a phantom tax. Equation (19.18) is an example.

Genuine taxes are those collected by the government. As explained in subsection 12.1, endogenous movements in phantom taxes are often used to reconcile contradictory data items on prices and costs. However, for obtaining an initial understanding of the MONASH equations, it is reasonable to assume that the powers of all the phantom taxes are set exogenously at one.

As well as including equations such as (19.18), section 28 also includes equations for the collections of both genuine and phantom taxes.

*Stylized version of section 29*

Equations (19.19) to (19.23) are a sample of the macro definitions used in MONASH. Equation (19.19) defines the consumer price index (CPI) as a function of the vectors  $[P3_1$  and  $P3_2]$  of consumer prices for domestic and imported goods. Equation (19.20) defines the real wage rate as the nominal wage rate deflated by the CPI. Equations (19.21) and (19.22) define total employment and total capital stock as sums across industries, and equation (19.23) is the GDP identity in nominal terms.

*Stylized version of section 30*

Equation (19.24) relates capital stock in industry  $j$  at the end of the year  $[K_t(j)]$  to depreciated capital stock from the beginning of the year  $[(1-D(j))*K(j)]$  and investment during the year  $[Y(j)]$ . Equation (19.25) defines the ratio of investment to capital in industry  $j$ . When the shift variable,  $A_{KG}(j)$ , in (19.26) is exogenous, capital growth in industry  $j$  during the year, and hence investment, is determined by  $j$ 's expected rate of return  $[EROR(j)]$ . If  $A_{KG}(j)$  is endogenous, then investment in industry  $j$  can be determined by an alternative mechanism, for example via (19.25) with  $IKRATIO(j)$  set exogenously. With its shift variable  $[A_{EROR}(j)]$  set exogenously, (19.27) determines the expected rate of return in industry  $j$  as a function of the current rental rate  $[Q(j)]$  and asset price  $[PI(j)]$  of  $j$ 's capital. Under this treatment, expectations are static or adaptive. As can be seen in section 30, MONASH contains additional equations which allow for forward-looking expectations.

*Stylized version of section 31*

As explained in section 31, available data in Australia on outputs, inputs, prices and other variables occur in various industrial/commodity classifications. So that we can use these data, we include in MONASH many equations that define variables at different levels of aggregation. This is illustrated by (19.28) which defines employment  $[LG(q)]$  in the  $q$ th group of industries, e.g. all industries in the agricultural sector. In most simulations, sectoral variables such as  $LG(q)$  are endogenous. However, in historical simulations they may be exogenized and given shocks reflecting observed movements. When  $LG(q)$  is exogenized, we endogenize a variable which moves the technologies of industries in group  $q$ . As well as explaining equations such as (19.28), section 31 also explains various equations which allow MONASH to generate conveniently a uniform movement in technology variables for all industries in a given group.

*Stylized version of section 32*

Policy results are generated in MONASH as deviations from explicit forecasts. As explained in section 32, this requires several equations that relate policy values for variables to forecast values. For example, as indicated by (19.29), we often assume in policy simulations that the proportionate deviation in year  $t$  in the real wage rate from its forecast value  $[WR/WR_t - 1]$  equals the proportionate deviation in year  $t-1$

$[\text{WR}_{\text{lag}}/\text{WR}_{\text{flag}} - 1]$  plus a positive multiple of the proportionate deviation in year  $t$  in total employment  $[\text{LTOT}/\text{LTOT}_f - 1]$ . In other words, we assume that while employment is above its forecast level, the real wage deviation will be increasing. In simulations in which we want a different approach to wage determination, we can endogenize the shift variable  $A_{\text{WR}}$ .

*Stylized version of section 33*

Equation (19.30) defines the public sector deficit (PSD) as government consumption expenditures less tax collections plus transfers. In this stylized equation, we recognize only the taxes (consumption taxes, import duties and export taxes) appearing in other stylized equations and we treat transfers as a single item with no explaining equations. As can be seen from section 33, MONASH contains numerous other taxes and other sources of government income. It also contains separate equations for each of the main categories of transfers, e.g. unemployment benefits and interest on the public debt. For modelling interest on the public debt, we include in MONASH dynamic equations relating the public debt in year  $t$  to the public debt and public sector deficit in year  $t-1$ .

*Stylized version of section 34*

In decomposition simulations we explain economic developments between two widely separated years, a base year (e.g. 1987) and a final year (e.g. 1994). In these simulations, there is no explicit modelling of variables for intermediate years.

To avoid intermediate years in our specification of movements in net foreign liabilities, we adopt smooth growth assumptions for capital and GNP. This gives implicit intermediate-year values for investment and domestic saving, and consequently for the current account deficit and the accumulation of net foreign liabilities. Thus, through smooth growth assumptions, we are able to relate the value of total net foreign liabilities in foreign currency at the start of the final year (NFLF) to its value at the start of the base year (NFLF<sub>τ</sub>) and to the growth between the two years in total capital and GNP. This is indicated by the stylized equation (19.31).

The MONASH equation corresponding to (19.31) includes changes between the base and final years in various prices. In (19.31) we leave out all the price variables except the exchange rate.

With the introduction in (19.31) of GNP as a variable, we require a defining equation. This is provided by (19.32) which defines GNP as GDP less the domestic-currency value of net interest and dividend payments to foreigners.

For year-to-year simulations, equations such as (19.31) can be turned off by endogenizing their shift variables ( $A_{\text{NFLF}}$ ).

*Stylized version of section 35*

As can be seen from section 35, MONASH contains a detailed description of the balance of payments. This includes equations for the year-to-year accumulation of

different types of foreign assets and liabilities and equations for associated incomes and payments. In the stylized version given in (19.33) and (19.34), we show a single accumulation equation relating the end-of-year foreign-currency value of net foreign liabilities to the start-of-year value and to the foreign-currency value of the current account deficit ( $CAD*\Phi$ ). The current account deficit is shown as the trade deficit (imports less exports) plus interest and dividend payments on net foreign liabilities.

*Stylized version of section 36*

Equation (19.35) defines household disposable income as GNP less taxes plus transfers. The corresponding MONASH equation includes more tax terms than are shown in (19.35) and also includes net transfers from foreigners in addition to those from the government. With the shift variable  $A_C$  set exogenously, (19.36) links movements in total household expenditure to movements in household disposable income.

**19.2. A trial closure of the stylized version of MONASH**

To check our understanding of the stylized model, it is useful to write a trial list of exogenous variables that we think should constitute a closure. We have composed such a list in part II of Table 19.2. If we cannot show that our trial list constitutes a closure, then we should check the list and equations. If we fail to find an error, then we should reassess our understanding of how the stylized model transforms values of exogenous variables into outcomes for endogenous variables.

In writing our trial list, we had in mind a short-run policy closure<sup>2</sup>. In such a closure we would expect to be able to include on the exogenous list all start-of-year stock variables, all lagged variables, all forecast variables and all policy instruments. This explains the inclusion in part II of Table 19.2 of the variables from  $K(j)$  down to TRANSFERS. As mentioned in our discussion above of (19.18), phantom taxes are endogenized to reconcile contradictory data items. Because we would expect to be able to run a short-run policy simulation without having reconciliation problems, we have included  $T4PH(i)$  in our trial list of exogenous variables.  $PM(i)$  and  $ROIF$  are included because both are naturally exogenous: there are no equations in the stylized model (or in MONASH) for explaining either foreign-currency import prices or foreign rates of interest. For the numeraire in our trial closure we use the exchange rate ( $\Phi$ ).

In a short-run policy simulation, none of the next three variables [ $C$ ,  $WR$  and  $PE(i)$ ] in part II of Table 19.2 would normally be exogenous. We would expect to explain: movements in  $C$  by movements in household disposable income via

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<sup>2</sup> By a short-run closure, we mean one that is used in computing a solution for year  $t+1$  starting from a solution for year  $t$ . By a policy closure, we mean one that is used in computing deviations from a forecast path caused by changes in policy variables or in other naturally exogenous variables.

(19.36); movements in WR by deviations in total employment and lagged deviations in WR via (19.29); and movements in PE(i) by movements in exports of i via (19.9). In the trial closure we exogenize C, WR and PE(i) because, as we will see shortly, this makes it easy to establish that our trial exogenous list is a closure. To exogenize C, WR and PE(i), we endogenize the shift variables  $A_C$ ,  $A_{WR}$  and  $A_4(i)$  appearing in (19.36), (19.29) and (19.9). Because we would expect in a short-run policy simulation to exogenize taste and technology variables, almost all the other A variables are exogenous. The only exception is  $A_{NFLF}$  which is endogenized to turn off the long-run treatment of net foreign liabilities specified by (19.31).

Establishing the validity of our trial closure now becomes easy because with this particular list of exogenous variables our stylized model is recursive. As indicated by the last column in part I of Table 19.2, we can start a solution of the stylized model by using (19.18) to determine T4(i). Having determined T4(i) we can then use (19.16) to determine  $P_1(i)$  for all i. Equation (19.15) can be used to determine  $P_2(i)$  for all i, then allowing us to use (19.17) to determine  $P_{3_1}$  and  $P_{3_2}$ . Proceeding in this way through part I of Table 19.2, we establish the validity of our trial closure by showing that a value for each endogenous variable can be determined for any given values of the exogenous variables.

The only slight difficulty occurs when we reach the rental rate on j's capital,  $Q(j)$ . As indicated in part I of Table 19.2,  $Q(j)$  can be computed using (19.14) after the determination T4(i),  $P_1$ ,  $P_2$ , ..., W. This can be done by first using (19.1), (19.3), (19.4) and (19.5) to eliminate the quantity variables [ $XO(i,1,j)$ ,  $X1(i,s,j)$ ,  $L(j)$  and  $K(j)$ ] from (19.14) and then cancelling out  $Z(j)$ , thereby creating an equation in which  $Q(j)$  is the only unknown. In effect, we create an equation which exploits constant returns to scale to express the rental rate on j's capital purely in terms of input prices and technology variables.

As explained in Chapter 6, we develop new closures for MONASH by starting from a simple closure and making variable-by-variable modifications. This process can be visualized via our stylized model. For example, starting from the exogenous list in part II of Table 19.2, we could develop a more interesting short-run policy closure by endogenizing C, WR and PE(i) and exogenizing  $A_C$ ,  $A_{WR}$ ,  $A_4(i)$ . This would give us a closure in which policy shocks could affect aggregate consumption, the real wage and export prices by affecting household disposable income, employment and export volumes. We could then move to a long-run closure (similar to the decomposition closure illustrated in Figure 5.1) by: endogenizing the start-of-year stock variables, NFLF and  $K(j)$  and exogenizing  $A_{NFLF}$  and EROR(j); by endogenizing  $A_{KG}(j)$  and exogenizing IKRATIO(j); and by endogenizing  $A_{WR}$  and exogenizing LTOT. Finally, we could move towards forecast and historical closures by exogenizing variables for which we have either forecasts or historical observations and endogenizing corresponding A terms

representing shifts in technologies, consumer preferences and export-demand functions.

## 20. *Composition of Outputs and Inputs*

### 20.1. *Overview of production technology*

The equations in subsections 18.8a, b and c describe for each industry the composition of its outputs and inputs. Before becoming embroiled in the details of the algebra, readers may find it helpful to look at Figure 20.1 which sets out the technology assumptions.

As can be seen from the figure, industries are assumed to have production technologies of the form:

$$Z = F(X) \quad (20.1)$$

$$Z = G(Y) \quad (20.2)$$

where

X is the vector of inputs;

Y is the vector of outputs; and

Z is a scalar variable representing the industry's activity level.

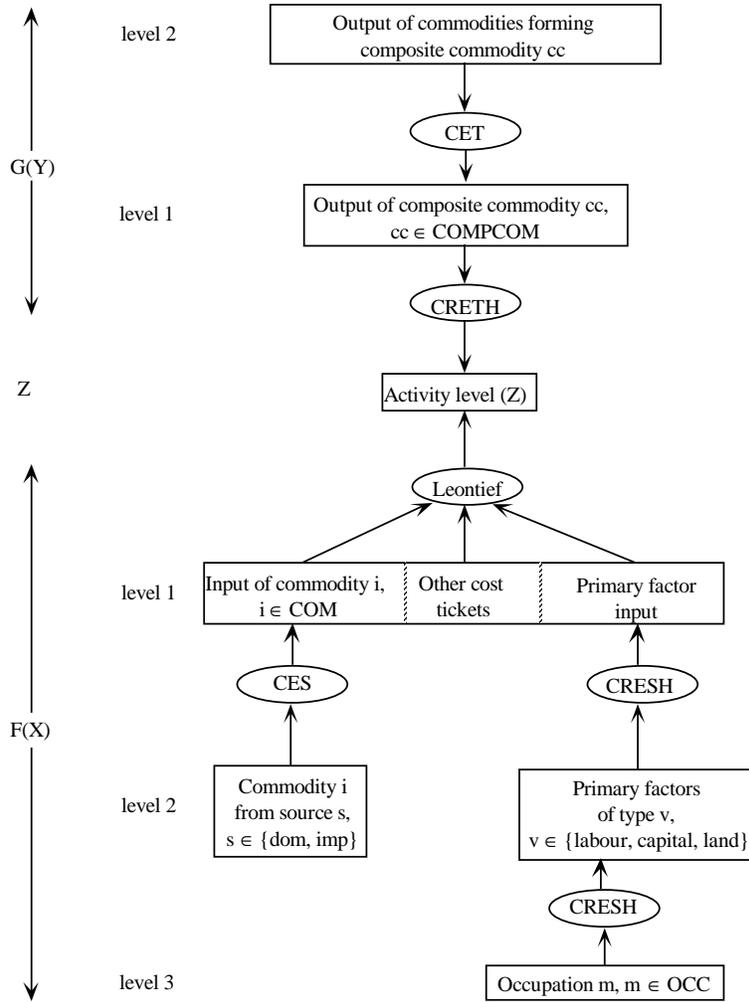
Both F and G are assumed to be homogeneous of degree 1 implying constant returns to scale. F is assumed to be concave while G is convex. In two dimensions, this means that F's contour lines are concave from above while G's are concave from below.

Most MONASH industries are assumed to produce only one product. For these industries, Y is a scalar, G is the identity function and (20.1)-(20.2) can be reduced to

$$Y = F(X) \quad (20.3)$$

However, from some agricultural industries, MONASH allows production of several products. For these industries, (20.1)-(20.2) simplify reality by implying that inputs are non-specific to products, i.e., all increases in inputs which generate a unit increase in Z have an identical effect on the industry's production possibilities. This assumption is appropriate in MONASH where we deal with broadly defined inputs such as labour, capital, fertilizers and agricultural machinery. It would not be appropriate if our commodity classification separately identified silo-storage (specific to grain production) or shearing (specific to wool production).

Figure 20.1. MONASH Production Technology



The specification of  $F$  adopted in the version of MONASH being described here is indicated in the lower part of Figure 20.1.<sup>3</sup> It has three levels. At the first level, we assume that there is no substitution between different types of intermediate inputs or between intermediate inputs and primary factors, i.e., the activity level ( $Z$ ) is assumed to be a Leontief combination of intermediate inputs and primary factors. Also included in this Leontief combination are other cost tickets, which allow for costs not explicitly modelled in MONASH such as the costs of holding inventories.

At the second level, we adopt CES and CRESH specifications for intermediate inputs and primary factors. Following Armington (1969, 1970), we assume that intermediate inputs of  $i$  are a CES combination of domestically produced and imported inputs of  $i$ . This means that changes in the ratio of domestic to import prices of  $i$  cause, in our model, changes in the ratio of domestic to import quantities without causing a complete replacement of one source of supply by the other. Complete specialization in one source or the other is the likely (but unrealistic) outcome in models in which domestic and imported varieties of commodity  $i$  are treated as a single good.

The CRESH specification (Hanoch, 1971) for primary factors is more flexible than the CES specification. Whereas, under CES, the elasticities of substitution between land and labour, land and capital and capital and labour all have the same value, under CRESH they can have different values. However, the greater flexibility of CRESH has not as yet been of practical significance in MONASH. It is only for the agricultural industries that we include land as a primary factor. For all other industries, with just the labour/capital substitution elasticity to be specified, CRESH offers no practical advantage over CES. For the agricultural industries, we do not have estimates which allow us to distinguish between the different pairwise substitution elasticities. In effect, we adopt the CES specification by assuming that all of these substitution elasticities have the same value.

At the third level of our specification of the input side of production technologies, we assume that labour input is a CRESH combination of labour hours from different occupations. Again, the CRESH specification offers only a potential advantage over CES. We have no empirical basis on which to assign different values to substitution elasticities between different pairs of occupational inputs. Consequently, we normally use a common value. Thus, although the

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<sup>3</sup> Other specifications have been used in the MONASH/ORANI framework. For example, in energy-oriented versions of ORANI and MONASH, McDougall (1993), McDougall and Dixon (1996) and Adams *et al.* (2000b) allow for substitution between different energy products and between energy and primary factors. Hanslow (1992) describes GEMPACK code which gives users considerable flexibility in the specification of input nests. In a series of papers, Jorgenson and his collaborators incorporate flexible-functional-form production functions into CGE models, allowing unrestricted substitution possibilities between inputs, see for example Jorgenson (1983) and Jorgenson and Wilcoxon (1993b).

MONASH code allows for CRESH combinations of occupational inputs, the model is usually run as if the combining functions are CES.

The top part of Figure 20.1 shows that the MONASH specification of industries' transformation frontiers,  $G$ , has two levels. At the first level, we assume that a CRETH combination of an industry's outputs of composite commodities exhausts its capacity to produce, where capacity to produce is given by the activity level,  $Z$ . CRETH is a generalization of CET.<sup>4</sup> Whereas the CET specification forces all pairwise transformation elasticities to be equal, CRETH allows them to differ. This extra flexibility of CRETH over CET has proved worthwhile. In some applications of MONASH we have used estimates that suggest different values for the transformation elasticities between different pairs of agricultural products.

At the second level of the MONASH specification of the  $G$  functions, composite commodities are formed as CET combinations of commodities. For example, wool/sheepmeat might be a composite commodity formed as a CET combination of the two commodities, wool and sheepmeat. Further details on composite commodities are in the next subsection.

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<sup>4</sup> See Vincent *et al.* (1980).

### 20.2. Outputs of commodities (subsection 18.8a in the TABLO code)

The main role of the equations in subsection 18.8a is to link percentage changes in outputs of commodities [ $x0dom(i)$ ] with percentage changes in industries' activity levels [ $z(j)$ ]. This link is straightforward for a commodity,  $i$ , which is produced in a single, one-product industry,  $j$ . However, in the agricultural sector we allow for commodities that are produced in several industries and for industries that produce several commodities. This means that we must specify the commodity composition of outputs by industries and then obtain in the economy-wide output of each commodity by adding across industries. In MONASH the specification of the commodity composition of industry outputs is complicated by the use of composite commodities. These are combinations of commodities.

#### *E\_x0ccom*

The first seven industries in MONASH (I1 to I7) form the set IND\_JP, the joint-product industries. Each of them produces either more than one product or a single product which is produced by more than one industry. The commodities (C1 to C9) produced by the joint-product industries form the set COM\_JP, the joint-product commodities.

The joint-product industries and commodities are shown in Table 20.1. As indicated, the commodities produced by each joint-product industry are grouped in composite commodities. The composite commodities are CC1 to CC6. They form the set COMPCOM. Composite commodity 1 for industry 1 is a combination of wool and sheepmeat, composite commodity 2 for industry 1 is meat cattle and composite commodity 3 is a combination of wheat, barley, other grains and other farming import-competing. Notice that composite commodity  $i$  for industry  $j$  is not necessarily the same as composite commodity  $i$  for other industries. For example composite commodity 1 for industry 2 is wool, not wool/sheepmeat as in industry 1. The choice of composite commodities reflects econometric work done on agricultural supply elasticities for the ORANI model (Dixon *et al.*, 1982, pp. 191-4). In that econometric work, data were available for industry 1 for prices and quantities of wool/sheepmeat, meat cattle and other agricultural products.

$E\_x0ccom$  specifies that the percentage change in the supply of composite commodity  $cc$  by industry  $j$  (for  $cc \in COMPCOM$  and  $j \in IND\_JP$ ) is made up of three parts. The first is  $z(j)$ , the percentage change in the overall level of effective inputs to industry  $j$ .<sup>5</sup> The second is a price-substitution term. This compares the percentage change [ $p0ccom(cc,j)$ ] in the price received by industry  $j$  per unit of

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<sup>5</sup> The overall level of effective inputs to industry  $j$  is an aggregation of inputs of materials and primary factors, adjusted for input-saving technical change. As we will see in subsection 20.3 and 20.4,  $z(j)$  is increased either by the use of greater quantities of inputs or by technical changes which enhance the efficiency of inputs.

**Table 20.1. Joint-product industries and commodities, and composite commodities<sup>(a)</sup>**

		j ∈ IND_JP						
		I1 Pastoral zone	I2 Wheat- sheep zone	I3 High rainfall zone	I4 Northern beef	I5 Milk cattle and pigs	I6 Other farming export- oriented	I7 Other farming import- competing
i ∈ COM_JP								
C1	Wool	CC1	CC1	CC1				
C2	Sheepmeat	CC1	CC2	CC2				
C3	Wheat	CC3	CC4	CC4				
C4	Barley	CC3	CC5	CC4				
C5	Other grains	CC3	CC6	CC4				
C6	Meat cattle	CC2	CC3	CC3	CC1	CC1		
C7	Milk cattle and pigs		CC6	CC4		CC1		
C8	Other farming, export-oriented <sup>(b)</sup>		CC6	CC4		CC1		
C9	Other farming import-competing <sup>(c)</sup>	CC3	CC6					CC1

(a) Industry 1 (I1) produces three composite products. The first consists of commodities 1 and 2 (C1 and C2), the second is consists of C6 and the third consists of C3, C4, C5 and C9. Commodities 7 and 8 are not produced by industry 1. Hence the coefficient  $CCPROD(i, I1, cc)$  is zero for all  $cc$  when  $i = C7$  or  $C8$ .

(b) Mainly sugar.

(c) Mainly tobacco, fruit and vegetables

output of composite commodity  $cc$  with a weighted average of the percentage changes in the prices of all industry  $j$ 's composite commodities. The weights,  $MH0CC(t, j)$ , are calculated in subsection 18.5c and explained in section 37. They are closely related to the shares of composite commodities in  $j$ 's total revenue. The positive parameter  $SIG0CC(cc, j)$ , which is read in section 18.4 from the PARAMS file, controls the sensitivity of the supply of composite commodity  $cc$  from industry  $j$  to variations in the price of  $j$ 's composite commodity  $cc$  relative to the prices of  $j$ 's other composite commodities.

The third set of terms on the RHS of  $E\_x0ccom$  allows for technical change. The variable  $a0ind(j)$  allows for a commodity-neutral shift in industry  $j$ 's transformation frontier. If  $a0ind(j)$  is set at -10, for example, then we are allowing industry  $j$  to produce 10 per cent more of each of its composite commodities with no change in the level of any of its inputs. The variable  $a0ccom(cc, j)$  allows for a  $cc$ -expanding shift in  $j$ 's transformation frontier. If  $a0ccom(cc, j)$  is set at -10, then we are allowing industry  $j$  to produce 10 per cent more of its composite commodity  $cc$  with no change in the output of any of its other composite commodities or in the levels of its inputs. Negative moments in  $a0ccom(cc, j)$  induce shifts by industry  $j$  in favour of supplying composite commodity  $cc$  rather than other composite

commodities. This substitution effect is accommodated by the last term on the RHS of  $E_{x0ccom}$ .

The optimization behaviour underlying  $E_{x0ccom}$  is set out in section 37.

### $E_{x0ci}$

In the absence of changes in technology and prices, this equation specifies that the output of each MONASH commodity from a joint-product industry moves by the same percentage as the output of the composite commodity in which it is included. Consider, for example, the output of wool (C1) by the pastoral zone (I1). With the technical change and price terms ( $a0com$ ,  $a0ci$  and  $p0dom$ ) set at zero, the output of C1 by I1 is specified in  $E_{x0ci}$  as a weighted sum of the percentage changes [ $x0ccom(cc, I1)$ ] in the outputs of industry 1's composite commodities. The weights are the coefficients  $CCPROD(C1, I1, cc)$ , read, as indicated in subsection 18.4, from the data file PARAMS.  $CCPROD(i, j, cc)$  is 1 if commodity  $i$  forms part of industry  $j$ 's composite commodity  $cc$ , otherwise it is zero. Because each MONASH commodity  $i$  in the set  $COM\_JP$  belongs to no more than one of  $j$ 's composite commodities, for any given values of  $i$  and  $j$ ,  $CCPROD(i, j, cc)$  has a non-zero value for no more than one value of  $cc$ . Thus, for example,  $CCPROD(C1, I1, cc)$  is 1 for  $cc = CC1$  and is zero for other values of  $cc$ , reflecting the fact that C1 (wool) is part of industry 1's (pastoral zone) first composite commodity. This means that with the technical change and price variables set at zero, the percentage change in the output of C1 by I1 equals the percentage change in the output of CC1 by I1, that is  $x0ci(C1, I1)$  equals  $x0ccom(CC1, I1)$ .

Now consider the second term on the RHS of  $E_{x0ci}$ . This is concerned with price-induced transformations in the commodity composition of composite commodities. For example, it allows for a switch by industry 1 towards the production of wheat (part of I1's composite commodity 3) if the price of wheat rises relative to the price of the other commodities (barley, other grains and other-farming import-competing) in CC3 for industry 1.

The price-transformation term is represented in  $E_{x0ci}$  as a sum over all  $cc$  in  $COMPCOM$ . However, when we are dealing with  $x0ci(i,j)$ , only one component of this sum can be non-zero; that for industry  $j$ 's composite commodity ( $cc$ ) to which  $i$  belongs. With  $i$  forming part of  $cc$ , the price transformation term for  $x0ci(i,j)$  compares the percentage change in the basic price (price received by the producer) of commodity  $i$  [ $p0dom(i)$ ] with a weighted sum of the percentage changes in the basic prices of all commodities  $ii$  in the set  $COM\_JP$ . The weights are:

$$CCPROD(i,j,cc)*CCPROD(ii,j,cc)*SOC(ii,j),$$

i.e., the weight zero is given to  $p0dom(ii)$  if  $ii$  is not part of the composite commodity  $cc$  containing  $i$  and the weight  $SOC(ii,j)$  is given to  $p0dom(ii)$  if  $ii$  is part of the composite commodity containing  $i$ . As calculated in subsection 18.5c,  $SOC(ii,j)$  is commodity  $ii$ 's share in  $j$ 's revenue from the composite commodity to which  $ii$  belongs. Thus, transformation within  $j$ 's composite commodity  $cc$  is

induced in favour or against commodity  $i$  by percentage movements in the price of  $i$  relative to a revenue-weighted average of the percentage movements in the prices of all the commodities  $ii$  in  $j$ 's composite  $cc$ . The strength of these price-induced transformations is controlled by the parameter  $SIGMACC(cc,j)$ , read from the file `PARAMS` (subsection 18.4). In most MONASH simulations all the  $SIGMACC$ s are set at 2.0, implying that commodities in the same composite (such as different types of grains) are good transformates.

The technical change variable  $a0com(i)$  in  $E\_x0ci$  allows for commodity- $i$ -expanding technical change ( $i \in COM\_JP$ ) in all joint-product industries ( $j \in IND\_JP$ ). If we set  $a0com(i)$  at -10 for  $i \in COM\_JP$ , then all joint-product industries are able to increase their outputs of commodity  $i$  by 10 per cent with no change in the outputs of their composite commodities. This means that they are able to increase their output of commodity  $i$  by 10 per cent with no change in the outputs of their other commodities or in the levels of their inputs. The technical change variable  $a0ci(i,j)$  allows for  $i$ -expanding technical change confined to industry  $j$ . If  $a0ci(i,j)$  is set at -10, then joint-product industry  $j$  alone is able to increase its output of commodity  $i$  by 10 per cent with no change in the outputs of its other commodities or in the levels of its inputs. On the RHS of  $E\_x0ci$ , we see that  $i$ -expanding technical change not only has a direct effect  $[-a0com(i) - a0ci(i,j)]$  on industry  $j$ 's output of  $i$ , but also a transformation effect. Assume that commodity  $i$  is in  $j$ 's composite commodity  $cc$ . Then if  $i$ -expanding technical change in industry  $j$  is more rapid than an average of the rates of  $ii$ -expanding technical change for all commodities  $ii$  in  $j$ 's composite  $cc$ , then  $j$  transforms the composite  $cc$  in favour of the production of  $i$  and away from the production of other commodities in  $cc$ . The form of the technology transformation term is the same as that of the price-transformation term (see section 37).

### ***E\_p0ccom***

In the absence of technical change, the percentage change in the price received by industry  $j$  per unit of composite commodity  $cc$  ( $j \in IND\_JP$  and  $cc \in COMPCOM$ ) is a weighted average of the percentage changes in the basic prices of the commodities that make up  $j$ 's composite commodity  $cc$ . The weights are the revenue shares of each commodity  $i$  in  $j$ 's composite  $cc$ , calculated as  $CCPROD(i,j,cc)*S0C(i,j)$ .

The percentage change in the price received by industry  $j$  per unit of composite commodity  $cc$  depends not only on changes in basic prices but also on technical changes affecting the outputs of commodities per unit of composite commodity. Such changes are allowed for by the "a" terms on the RHS of  $E\_p0ccom$  (see section 37).

### ***E\_x0dom\_JP***

This equation defines the percentage change in the economy-wide output of domestic commodity  $i$  ( $i \in COM\_JP$ ) as a weighted average of the percentage

changes in the output of  $i$  in all joint-product industries. The weights  $[B0CI(i,j)]$  are the shares of each industry  $j$  in the economy's production of  $i$ . These are calculated in subsection 18.5c.

### ***E\_x0dom\_UP***

The industries in the set  $IND\_UP$  produce a single product which is not produced by any other industry. These industries are called unique-product industries. The union of  $IND\_UP$  and  $IND\_JP$  is the set of all industries  $IND$ , and their intersection is empty. The products produced by the unique-product industries form the set  $COM\_UP$ . The union of the sets  $COM\_UP$  and  $COM\_JP$  is the set of all commodities  $COM$ , and their intersection is empty.

In  $E\_x0dom\_UP$ , the percentage change in the output of commodity  $i$ ,  $i \in COM\_UP$ , is equal to the percentage change in the overall input level (adjusted for technical change) of industry  $j$ , where industry  $j$  is the unique producer of commodity  $i$ . The matching of commodity  $i$  with its producer industry  $j$  is achieved via the coefficient  $B0CI(i,j)$ . As before, this is the share of industry  $j$  in the economy's production of  $i$ . Where  $i \in COM\_UP$  and  $j \in IND\_UP$ , this coefficient has the value 1 if  $i$  is produced by industry  $j$  and has the value zero otherwise.

The technical-change terms on the RHS of  $E\_x0dom\_UP$  allow for changes in the output of commodity  $i$  per unit of input. If either  $a0ind(j)$  or  $a0com(i)$  is set at -10, then industry  $j$  can increase its output of commodity  $i$  by 10 per cent with no change its activity level ( $z(j) = 0$ ). For unique-product industries and commodities,  $a0ind(j)$  and  $a0com(i)$  play the same role where  $i$  is the product produced by industry  $j$ . We retain both variables for notational symmetry with the joint-product case where these variables play different roles.

### ***20.3. The composition of each industry's intermediate inputs (subsection 18.8b in the TABLO code)***

The equations in this group describe industry  $j$ 's demands for intermediate inputs (inputs to be used in current production). As discussed in subsection 20.1 and explained further in section 38, the equations are derived under the assumption of Leontief technology (zero substitution between different types of inputs) with Armington nests (imperfect substitution between domestically produced and imported inputs of the same type).

### ***E\_x1csi***

This equation specifies the percentage change in demand for commodity  $i$  ( $i \in COM$ ) from source  $s$  ( $s \in SOURCE$ ) by industry  $j$  ( $j \in IND$ ) for use as an input to current production. Current production is indicated in the notation by the "1" in  $x1csi$ .

As can be seen from subsection 18.2,  $SOURCE$  contains two elements,  $dom$  and  $imp$ . When  $s=dom$  we are referring to a domestically-produced commodity and when  $s=imp$  we are referring to an imported commodity.

On the RHS of  $E\_x1csi$ , the first term is the percentage change in the overall input level  $[z(j)]$  to industry  $j$ . In the absence of changes in prices and technology, it is assumed in MONASH that the use of all intermediate inputs to industry  $j$  expands proportionately with  $j$ 's overall input level.

The second term on the RHS allows for price-induced substitution between inputs of good  $i$  from different sources. In the determination of the demand by industry  $j$  for good  $i$  from source  $s$ , this substitution term compares the percentage change in the price to industry  $j$  of good  $i$  from source  $s$  with a weighted average of the percentage changes in the prices to industry  $j$  of good  $i$  from both sources. The weights  $[SOURCE\_SHR1(i, t, j)]$  are calculated in subsection 18.5e. They are the shares in industry  $j$ 's purchases of good  $i$  accounted for by domestic goods ( $t=dom$ ) and imported goods ( $t=imp$ ). The sensitivity of industry  $j$ 's domestic/import sourcing choice for good  $i$  to changes in relative prices is controlled by the value of the positive substitution parameter  $SIGMA1(i)$  read in subsection 18.4 from the file PARAMS.

The "a" terms on the RHS of  $E\_x1csi$  allow for technical changes. If we set  $a1(j)$  equal to  $-10$ , then we are allowing industry  $j$  to achieve any given level of  $Z(j)$  (that is any given overall capacity to produce) with 10 per cent less of all inputs. If  $a1ci(i,j) = -10$ , then we are allowing for 10 per cent input- $i$  saving technical change by industry  $j$ , i.e., we are allowing for the achievement of any given level of  $Z(j)$  with 10 per cent less input of good  $i$  from both sources and no change in the level of any other inputs. If we set  $a1csi(i,s,j) = -10$ , then we are allowing for a 10 per cent input- $(i,s)$ -saving technical change. As indicated in  $E\_x1csi$ , input- $(i,s)$ -saving technical change induces substitution in favour of good  $(i,s)$  and away from good  $i$  from the alternative source (see section 38). Whether this substitution effect is powerful enough to lead to a net increase in the use of good  $(i,s)$  per unit of  $Z(j)$  depends on the value of the substitution parameter  $SIGMA1(i)$  and on the share coefficients,  $SOURCE\_SHR1(i,t,j)$ . With a high enough value of  $SIGMA1(i)$ , the substitution effect in favour of using  $(i,s)$  can outweigh the input-saving effect [the term  $a1csi(i,s,j)$ ] working against using  $(i,s)$ .

The next term on the RHS of  $E\_x1csi$  is useful in historical simulations in which movements in import volumes are given exogenously. It allows for *cost-neutral twists* in domestic/import preferences for commodity  $i$ . To see how the *twist* aspect works, consider  $E\_x1csi$  for given values of  $i$  and  $j$ . Assume that the "a", "f1"<sup>6</sup> and price terms on the RHS are set at zero. Taking account of the definition of  $SOURCE\_DOM(s)$  (equals 1 for  $s=dom$  and zero otherwise, see subsection 18.5a), and recognizing that

$$SOURCE\_SHR1(i, dom, j) + SOURCE\_SHR1(i, imp, j) = 1,$$

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<sup>6</sup> The role of "f1" variables,  $f1\_trans(j)$  and  $f1\_commun(j)$ , is explained shortly. Here, we assume that they are set at zero.

we see that

$$x(i, \text{dom}, j) - x(i, \text{imp}, j) = -\text{twist\_src}(i) \quad .$$

Hence, in the absence of changes in prices and "a" and "f1" terms, if  $\text{twist\_src}(i)$  is set at -10, then industry  $j$  increases the ratio of its domestic to imported inputs of commodity  $i$  by 10 per cent. In other words, there is a 10 per cent twist by industry  $j$  in favour of the use of domestic good  $i$  relative to imported good  $i$ .

To see how the *cost-neutral* aspect works, continue to assume zero values for the "a" and "f1" terms and no changes in prices. Also assume no change in  $Z(j)$ . Now

$$x1\text{csi}(i, \text{dom}, j) = -\text{SOURCE\_SHR1}(i, \text{imp}, j) * \text{twist\_src}(i)$$

and

$$x1\text{csi}(i, \text{imp}, j) = \text{SOURCE\_SHR1}(i, \text{dom}, j) * \text{twist\_src}(i).$$

By making a weighted sum of these percentage changes in industry  $j$ 's inputs of domestic and imported good  $i$  using as weights the shares of the two inputs in industry  $j$ 's total costs, we find that the effect on  $j$ 's costs is zero. In other words, shocks to  $\text{twist\_src}(i)$  are cost-neutral.

The final two terms [the "f1" terms] on the RHS of  $E\_x1\text{csi}$  allow us to override this equation in specifying the demands by industry  $j$  for imports of transport services and imports of communication. As we will see, alternative specifications are given in  $E\_f1\_trans$  and  $E\_f1\_commun$ .

The first step in seeing how the "f1" terms work is to check the definitions of the coefficients  $\text{TRANSERVDUM}(i)$  and  $\text{COMMUNICDUM}(i)$ . From subsection 18.5a we see that  $\text{TRANSERVDUM}(i) = 0$  for all  $i$  in COM except  $i$  in  $\text{TRANSERV}$ . For  $i$  in  $\text{TRANSERV}$ ,  $\text{TRANSERVDUM}(i)=1$ . The set  $\text{TRANSERV}$  contains the single commodity C99 (transport services), see subsection 18.2. Thus, the coefficient  $[(1-\text{SOURCE\_DOM}(s))*\text{TRANSERVDUM}(i)]$  on  $f1\_trans(j)$  in  $E\_x1\text{csi}$  is zero for all intermediate inputs bought by industry  $j$  except imported ( $s=\text{imp}$ ) transport services ( $i=\text{C99}$ ). For imported transport services, the coefficient on  $f1\_trans(j)$  is one. Similarly, the coefficient on  $f1\_commun$  in  $E\_x1\text{csi}$  is zero for all intermediate inputs bought by industry  $j$  except imported ( $s=\text{imp}$ ) communications ( $i=\text{C100}$ ). For imported communication, the coefficient on  $f1\_commun(j)$  is one.

Now assume that we have specified demands by industry  $j$  for imported transport services and communications independently of  $E\_x1\text{csi}$ . We make room for the alternative specification (i.e., we override the specification of these particular demands in  $E\_x1\text{csi}$ ) by endogenizing  $f1\_trans(j)$  and  $f1\_commun(j)$ . With  $x1\text{csi}(C99, \text{imp}, j)$  and  $x1\text{csi}(C100, \text{imp}, j)$  determined elsewhere,  $f1\_trans(j)$  and  $f1\_commun(j)$  are determined by  $E\_x1\text{csi}$ . That is, for  $i=\text{C99}$  and  $\text{C100}$ , and  $s=\text{imp}$ , the role of  $E\_x1\text{csi}$  has been reduced to the determination of  $f1\_trans(j)$  and  $f1\_commun(j)$ .

The endogenous determination of these two variables raises the issue of their effects on the rest of the model. There are two points to be made. First, because of the way in which we have specified their coefficients in  $E\_xlcsi$ , the endogenously determined values of  $fl\_trans(j)$  and  $fl\_commun(j)$  do not interfere with the determination of demands for intermediate inputs apart from imported commodities C99 and C100. Second, because in our parameter file, the values of  $SIGMA1(C99)$  and  $SIGMA1(C100)$  are both zero,<sup>7</sup>  $fl\_trans(j)$  plays the same role in  $E\_xlcsi$  as the variable  $alcsi(C99, imp, j)$ , and  $fl\_commun(j)$  plays the same role as  $alcsi(C100, imp, j)$ . That is, non-zero values for  $fl\_trans(j)$  and  $fl\_commun(j)$  are equivalent to commodity (i,s)-saving or -using technical change, where  $s=imp$  and  $i=C99$  and C100. Consequently, wherever it is appropriate for  $alcsi(i, imp, j)$ ,  $i=C99$  and C100, to appear in the rest of the model,  $fl\_trans(j)$  and  $fl\_commun(j)$  should also appear. Whatever is the appropriate value for the coefficient on  $alcsi(C99, imp, j)$ , it is also the appropriate value for the coefficient on  $fl\_trans(j)$ . Similarly, the appropriate value for the coefficient on  $fl\_commun(j)$  is the same as that for the coefficient on  $alcsi(C100, imp, j)$ . Apart from its use in  $E\_xlcsi$ , the only appearances of  $alcsi(i,s,j)$  are in  $E\_a\_JP$  and  $E\_a\_UP$ . Thus, the variables  $fl\_trans(j)$  and  $fl\_commun(j)$  appear in these two equations with the same coefficient values as those on  $alcsi(C99, imp, j)$  and  $alcsi(C100, imp, j)$ .

In effect, by endogenizing  $fl\_trans(j)$  and  $fl\_commun(j)$ , we are reconciling extraneously determined values of  $xlcsi(i, imp, j)$ ,  $i=C99$  and C100, with  $E\_xlcsi$  by endogenizing technological changes which use or save imported C99 and C100. Why don't we do this simply by endogenizing  $alcsi(i, imp, j)$ ,  $i=C99$  and C100? Why have we introduced  $fl\_trans(j)$  and  $fl\_commun(j)$ ? The reason is purely computational. It is important to treat all components of a large array of variables such as  $alcsi(i,s,j)$  as either exogenous or endogenous. Mixed treatment, such as would be involved by endogenizing  $alcsi(i, imp, j)$  for  $i=C99$  and C100, is computationally expensive. This is because with a mixed treatment, an array can be neither omitted or substituted out (see section 15).

#### ***E\_fl\_trans and E\_fl\_commun***

These equations are the alternative specifications of demands by industries for imported transport services (C99) and imported communications (C100) alluded to in our discussion of the "fl" terms in  $E\_xlcsi$ . If their shift variables [ $fl\_trans\_u$ ,  $fl\_trans\_a$ ,  $fl\_commun\_u$  and  $fl\_commun\_a$ ] are set exogenously at zero, then these equations mean that industry  $j$ 's demands for imported good  $r$ ,  $r=transport$

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<sup>7</sup> Given the nature of these products zero seems the right value. As will be apparent from our discussion of  $E\_fl\_trans$  and  $E\_fl\_commun$ , zero values mean that Australian harbour and airport services cannot be substituted for foreign harbour and airport services, and that telephone calls within Australia cannot be substituted for international calls. In the present context we take advantage of the fact that the zero values imply that good-(i,s)-saving technical change does not induce substitution between alternative sources of good  $i$  for  $i=C99$  or C100.

services and communications, [i.e.,  $r \in \text{TRANSERV}$  and  $\text{COMMUNICAT}$ ] are determined by the percentage changes in three variables:  $j$ 's level of activity; the volume of imported inputs to industry  $j$ ; and  $j$ 's exports. The percentage change in  $j$ 's activity level is measured by the percentage change in the overall level of  $j$ 's inputs,  $z(j)$ . The percentage change in the volume of imported inputs to  $j$  is computed as a weighted average over all  $i \in \text{COM}$  of  $x1csi(i, \text{imp}, j)$ , with the weight on commodity  $i$  being the share of the basic value of  $j$ 's imports of  $i$  [ $\text{BAS1}(i, \text{imp}, j)$ ] in the basic value of  $j$ 's total intermediate usage of imported inputs [ $\text{IMPORTS\_IND}(j)$ ]. The percentage change in  $j$ 's exports is a weighted average of the percentage changes [ $x4(i)$ ] in the exports of all goods  $i$ ,  $i \in \text{COM}$ . The weights are estimated shares of industry  $j$ 's exports [ $\text{EXPORTS\_IND}(j)$ ] accounted for by good  $i$ . In calculating these weights, we assume that  $j$ 's exports of  $i$  are total exports of  $i$  [ $\text{BAS4}(i)$ ] multiplied by  $j$ 's output of  $i$  [ $\text{MAKE}(i, j)$ ] expressed as a share of the total sales of domestically produced  $i$  [ $\text{SALES}(i)$ ], i.e. if industry  $j$  produces 10 per cent of the economy-wide output of commodity  $i$ , then we assume that 10 per cent of the exports of commodity  $i$  come from industry  $j$ . The  $\text{BAS1}$ ,  $\text{MAKE}$  and  $\text{BAS4}$  coefficients are read in subsection 18.4 from the input-output data and updated in subsection 18.7.  $\text{SALES}(i)$ ,  $\text{IMPORTS\_IND}(j)$  and  $\text{EXPORTS\_IND}(j)$  are calculated in subsections 18.5j and 18.5o.

In deciding relative strengths of the three variables [activity, imports and exports] in determining industry  $j$ 's usage of imported transport services and communications, we considered the nature of these import flows. Imported transport services consist mainly of foreign harbour and airport fees, foreign travel-agent services, and the services of foreign shipping agents. Nearly all Australian industries use these services with the principal using industries being water transport (I95) and air transport (I96). Other significant users are hotels (I111) and wholesale trade (I89).

In  $E\_fl\_trans$ , for water transport (I95) and air transport (I96) we set the coefficient on the percentage changes in the exports of the two industries at one, and the coefficients on the percentage changes in their activity levels and imports at zero, i.e., we assumed that these industries' imports of transport services are related only to the industries' exports. This seems a reasonable assumption for the water transport industry (I95). All I95's exports involve the use of foreign ports and all of the industry's use of foreign ports is in generating the industry's exports.<sup>8</sup> For air transport (I96), it is true that the industry's provision of exports<sup>9</sup> involves

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<sup>8</sup> Exports of water transport are shipping services provided by Australian firms outside Australia. As explained in section 23, these exports include shipping services provided by Australian firms to Australian exporters of wool, sheep, wheat etc.

<sup>9</sup> Exports of air transport are air transport services provided outside Australia, excluding services provided to Australians flying between Australia and foreign destinations.

the use of foreign airports. However, the industry uses foreign airports in some of its sales to the domestic economy (e.g., flying Australians to and from foreign destinations). By assuming that the use of imported transport services by Australia's airlines is proportional to Australia's exports of air services, we are assuming a fixed mix of Australian and foreign passengers in the overseas business of Australian airlines. Mechanically the setting of the coefficient values in  $E\_fl\_trans$  for imports of transport services by I95 and I96 is handled via the coefficient  $DUMMY\_WAT(j)$ . As can be seen in subsection 18.5o this coefficient has the value one for water and air transport and the value zero otherwise.

For each of the remaining industries  $j$  (i.e., industries other than I95 and I96), we assumed that a unit of output requires the use of  $\alpha_j$  units of imported transport services, and that units of exports and of imported inputs each require an additional  $\alpha_j$  units of imported transport services. That is, we assumed that industry  $j$ 's international activities are twice as intensive in their use of imported travel services as  $j$ 's production activity. This double-intensity assumption, which is no more than a reasonable guess, is implemented by the settings for coefficients  $C\_SPECIMP1(j)$ ,  $C\_SPECIMP2(j)$  and  $C\_SPECIMP3(j)$  given in subsection 18.5o.

Communication imports consist largely of charges made by foreign telephone companies for directing calls emanating from Australia. Although these charges are imposed on Australian telephone companies, they are distributed in our input-output data across industries and households. In  $E\_fl\_commun$  we adopted the double intensity assumption, this time for all industries. For households, MONASH does not contain special modelling of the demand for imported communication. This means that in deriving household demands, we treat international telephone calls as competing with other products in a constrained utility maximizing framework for a share of the household budget (section 22).<sup>10</sup>

#### ***E\_xloct and E\_del\_ploct***

These two equations specify the movements in the usage and prices of other cost tickets. Other cost tickets allow for costs not explicitly identified in MONASH such as the costs of holding inventories.

In  $E\_xloct$ , the quantity of other cost tickets used by industry  $j$  is assumed to be proportional to  $j$ 's overall activity level  $Z(j)$ . The variables  $a1(j)$  and  $a1oct(j)$  can be used to simulate technological changes. Shocks to  $a1(j)$  affect the use of all inputs, including other cost tickets, per unit of activity in industry  $j$ . Shocks to  $a1oct(j)$  affect only the use of other costs per unit of activity in industry  $j$ .

The price of other cost tickets to industry  $j$  is specified as

$$P1OCT(j) = LEV\_CPI * LEV\_F1OCT(j), \quad (20.4)$$

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<sup>10</sup> We set the Armington elasticity for household consumption of communications at zero, that is we assume that households substitute between communications and other products but not between imported and domestic communications.

where  $LEV\_CPI$  is the level of the consumer price index and  $LEV\_FIOCT(j)$  is a shift variable. If  $LEV\_FIOCT(j)$  is assumed to be constant, then the price of other cost tickets moves with the CPI. By moving  $LEV\_FIOCT(j)$ , we cause changes in the price of other cost tickets relative to the CPI.

$E\_del\_pioct$  is a change (rather than a percentage change) version of (20.4). We prefer the change version because it allows  $PIOCT(j)$  to pass through zero. Occasionally we interpret other cost tickets as a tax or subsidy on production. For simulating the effects of a subsidy, it is useful to be able to let  $PIOCT(j)$  change from being positive to negative. The coefficient  $LEV\_CPI$  in  $E\_del\_pioct$  is read in subsection 18.4 and updated in subsection 18.7. The coefficient  $LEV\_FIOCT$  is set by Formula in subsection 18.51.

#### **20.4. Demands by industries for primary factors (subsection 18.8c in the TABLO code)**

The equations in this group specify industry demands for labour, capital and land. They are derived (section 39) under the assumption that industries choose their primary-factor inputs to minimize primary-factor costs subject to obtaining sufficient primary-factor input to satisfy their requirements. As indicated in Figure 20.1, we assume that primary-factor input is a CRESH aggregation of inputs of labour, capital and land, and that labour input is a CRESH aggregation of occupational inputs. Because we assume that there is no substitution between primary factors and other inputs (the Leontief assumption), industry  $j$ 's primary-factor requirement is determined by its overall activity level,  $Z(j)$ , and by price-insensitive technology variables specifying the use of primary factors per unit of activity.

##### ***E\_labind, E\_cap\_at\_t and E\_plland***

These three equations specify industry  $j$ 's demands for: labour in general (i.e., a composite of occupational inputs); physical capital; and land. In the current version of MONASH, only agricultural industries use land in non-negligible quantities. Nevertheless, we allow for a third primary factor in all industries. Some users of ORANI (predecessor of MONASH) have found this additional flexibility to be useful in modelling mining, forestry and fishing industries where resource constraints may apply.

The first term on the RHSs of  $E\_labind$ ,  $E\_cap\_at\_t$  and  $E\_plland$  is  $z(j)$ . In the absence of changes in prices and technology, a 10 per cent increase in industry  $j$ 's activity level causes 10 per cent increases in its demands for the three primary factors. This reflects the assumption of constant returns to scale.

The next term in each of the three equations deals with price-induced substitution between primary factors. In  $E\_labind$ , the price-substitution term compares the percentage movement in the unit cost of labour to industry  $j$  [ $p1lab(j)$ ] with a weighted average of the percentage movements in the prices to industry  $j$  of labour, capital and land. The weights,  $SSTARIFAC(v,j)$ ,  $v \in$

FAC={labour, capital, land} are calculated in subsection 18.5m and explained in section 39. They are closely related to the shares of labour, capital and land in industry  $j$ 's primary factor costs. The positive parameter  $SIGMA1LAB(j)$  determines the sensitivity of  $j$ 's demand for labour to variations in the price to  $j$  of labour relative to the prices to  $j$  of all primary factors.

In  $E\_cap\_at\_t$ , the price-substitution term compares the rental price of capital to industry  $j$  [ $p1cap(j)$ ] with the same weighted average of percentage changes in factor prices as in  $E\_labind$ . However, the sensitivity parameter,  $SIGMA1CAP(j)$ , need not have the same value as  $SIGMA1LAB(j)$ . Unlike the CES specification, with CRESH the sensitivity of the demand for labour to variations in relative factor prices can differ from that of the demand for capital. The price-substitution term in  $E\_p1land$  follows the same pattern as in the previous two equations.

The "a" terms on the RHSs of  $E\_labind$ ,  $E\_cap\_at\_t$  and  $E\_p1land$  allow for changes in technology. The first of these,  $a1(j)$ , appears in all three equations and has already appeared in  $E\_x1csi$  and  $E\_xloct$ . If  $a1(j)$  is set at -10, then industry  $j$  can achieve any given activity level,  $Z(j)$ , with 10 per cent less of all inputs.

The second and third "a" terms on the RHS of  $E\_labind$ ,  $E\_cap\_at\_t$  and  $E\_p1land$  are  $a1prim(j)$  and  $a1primgen$ . If  $a1prim(j)$  is set at -10, then industry  $j$  can achieve any given activity level with 10 per cent less of all primary factor inputs, holding constant all its other inputs. If  $a1primgen$  is set at -10, then all industries can reduce their primary factor inputs by 10 per cent without reducing their activity levels or changing the levels of their other inputs.

The fourth and fifth "a" terms on the RHS of  $E\_labind$  are  $a1lab(j)$  and  $a1labgen$ . These allow for labour-saving technical progress in industry  $j$  alone [ $a1lab(j)$ ] and in all industries [ $a1labgen$ ]. If  $a1lab(j)$  is set at -10, industry  $j$  can achieve a given activity level with 10 per cent less labour and unchanged inputs of capital and land. If  $a1labgen$  is set at -10, all industries can reduce their labour inputs by 10 per cent with no change in either their activity levels or in their inputs of other primary factors.

Similarly,  $a1cap(j)$  and  $a1land(j)$  allow for capital- and land-saving technical progress in industry  $j$ , but there is no  $a1capgen$  or  $a1landgen$ . Such terms could be added if there were a need for them. With the present code, we could allow exogenously for 10 per cent capital-saving technical progress in all industries by setting  $a1cap(j)$  at -10 for all  $j \in IND$ . However, it would be difficult to generate endogenously a uniform rate of capital-saving technical progress to meet, for example, an exogenously specified economy-wide level of capital usage.

Labour-saving technical progress induces substitution in favour of the use of labour. Similarly, capital- and land-saving technical progress induce substitution in favour of capital and land. As demonstrated in section 39, and as can be seen on the RHSs of  $E\_labind$ ,  $E\_cap\_at\_t$  and  $E\_p1land$ , the technology-substitution terms have the same structure as the price-substitution terms.

$E_{labind}$  and  $E_{cap\_at\_t}$  each contain one more term, allowing for cost-neutral twists in industry  $j$ 's technology affecting its choice of labour and capital. The twist terms are useful in simulations in which factor prices and quantities are largely exogenous. The mechanics of how they work can be seen by assuming that there are no changes in  $j$ 's activity level, prices and other technology variables. Then from  $E_{labind}$  and  $E_{cap\_at\_t}$ , we obtain

$$labind(j) = SOURCE\_SHRLK(capital, j)*twistlk(j) \quad (20.5)$$

and

$$cap\_at\_t(j) = - SOURCE\_SHRLK(labour, j)*twistlk(j) \quad (20.6)$$

With the coefficients on the RHSs of (20.5) and (20.6) being shares (calculated in subsection 18.5m) of capital and labour in  $j$ 's capital-plus-labour costs, we find that the percentage change in  $j$ 's labour/capital ratio is given by:

$$labind(j) - cap\_at\_t(j) = twistlk(j) \quad (20.7)$$

To obtain the change in  $j$ 's costs arising from  $twistlk(j)$ , we make a weighted sum of  $labind(j)$  and  $cap\_at\_t(j)$  given in (20.5) and (20.6), using as weights the shares of labour and capital in  $j$ 's costs. This weighted sum is zero.

Thus, if  $twistlk(j)$  is set at 10, we impart a 10 per cent increase in industry  $j$ 's labour/capital ratio with no direct impact on  $j$ 's costs per unit of activity.

### ***E\_x1laboi***

This equation specifies the occupational composition of industry  $j$ 's labour input. On the LHS is the percentage change in the demand by industry  $j$  for labour hours from occupation  $qq$ ,  $qq \in OCC$ . The first term on the RHS is the percentage change in  $j$ 's overall demand for labour [ $labind(j)$ ]. In the absence of changes in technology and occupational wage rates, industry  $j$ 's demand for occupational inputs will expand in line with its overall demand for labour.

The second term on the RHS of  $E\_x1laboi$  allows for price-induced substitution. It compares the percentage change [ $p1laboi(qq,j)$ ] in the price to industry  $j$  of units of occupation  $qq$  with the average percentage change in the price to  $j$  of occupational inputs. The weights [ $SSTAR1LABOCC(m,j)$ ] used in calculating the average percentage change are closely related to occupational shares in the cost of  $j$ 's labour input (see section 39 and the calculation in subsection 18.5m). The positive parameter  $SIGMA1LABOCC(qq,j)$  controls the sensitivity of  $j$ 's demand for occupation  $qq$  to changes in relative occupational wage rates.

The technological specification underlying  $E\_x1laboi$  is CRESH. As mentioned in subsection 20.1, in effect we usually adopt a CES specification by assigning the same value to  $SIGMA1LABOCC(qq,j)$  for all  $qq \in OCC$ . In most MONASH applications, the value assigned is not important because we assume no change in relative occupational wage rates. Under this assumption, the price-substitution term on the RHS of  $E\_x1laboi$  is zero.

The remaining three terms on the RHS of  $E\_x1laboi$  allow for non-price-induced shifts in the occupational composition of  $j$ 's labour input. The first two of these terms have a familiar form: an input-saving technological change term [ $a1laboi(qq,j)$ ] followed by a technology-substitution term similar in structure to the price-substitution term. In the technology-substitution term for occupation  $qq$ , we compare the extent to which technological change is expanding the capabilities of people in occupation  $qq$  relative to its effects on people in other occupations.

As explained further in section 39, the final term on the RHS of  $E\_x1laboi$  ensures that movements in  $a1laboi(m,j)$ ,  $m \in OCC$  are labour-neutral. That is, holding  $j$ 's non-labour inputs constant, movements in  $a1laboi(m,j)$ ,  $m \in OCC$ , do not change the overall amount of labour (measured as the appropriate aggregation of occupational inputs) required to achieve any given activity level,  $Z(j)$ . When we need to simulate the effects of labour-saving or labour-using technical progress in industry  $j$ , we use the variable  $a1lab(j)$ . The inclusion of the last term [the negative of the average over the occupations of the  $a1laboi(m,j)$ ] ensures that if we set  $a1laboi(qq,j)$  at -10, say, then the overall labour-saving effect for industry  $j$  is offset by labour-using technological shifts in  $j$ 's use of all occupations.

The coefficients  $LABOCCIND(m,j)$  and  $LABIND\_J(j)$  in the last term on the RHS of  $E\_x1laboi$  are  $j$ 's expenditure on inputs of occupation  $m$  (read in subsection 18.4 and updated in subsection 18.7) and  $j$ 's total expenditure on labour (calculated in subsection 18.5i).

### ***E\_lambda***

This equation adds over all industries to generate the percentage change,  $\lambda(m)$ , in the economy-wide demand for labour in occupation  $m$ . The coefficient  $LABOCC(m)$  on the LHS is the total hours worked in occupation  $m$ , calculated in subsection 18.5i by adding  $HOURS(m,j)$  over all industries  $j$ .  $HOURS(m,j)$  is calculated in subsection 18.5i by deflating the costs to industry  $j$  of labour in occupation  $m$  by the relevant wage rate including payroll taxes.

### ***E\_p1lab***

This equation defines the percentage change [ $p1lab(j)$ ] in the overall price of labour to industry  $j$  as a weighted average of the percentage changes in the payroll-tax-inclusive occupational wage rates [ $p1laboi(m,j)$ ] paid by industry  $j$ . The weights are occupational shares in  $j$ 's labour costs. Section 39 provides the justification for using  $p1lab(j)$ , defined in  $E\_p1lab$ , as the labour-cost variable in the factor-demand equations,  $E\_labind$ ,  $E\_cap\_at\_t$  and  $E\_p1land$ .

Some industries use no labour. The inclusion of the TINY coefficients on both sides of  $E\_p1lab$  ensures that if  $LABIND\_J(j)$  is zero, then

$$p1lab(j) = (1/M) \text{Sum}(m, OCC, p1laboi(m,j))$$

where  $M$  is the number of components in  $OCC$ . Thus,  $p1lab(j)$  can be treated as an endogenous variable for all  $j$ . By making  $p1lab(j)$  a weighted average of  $p1laboi(m,j)$ ,  $m \in OCC$ , even for industries which use no labour, we allow the

model to pass homogeneity tests, e.g., to produce ones for endogenous percentage-change nominal variables and zeros for real variables when the numeraire variable is increased by one per cent.

### ***E\_p1laboi***

This equation relates the percentage movement in the cost of employing labour in each occupation/industry category [ $p1laboi(m,j)$ ] to the percentage movement in the wage received by workers [ $wlaboi(m,j)$ ] and the percentage movement in the power of the payroll tax [ $powpayroll(j)$ ]. The payroll tax in Australia is paid by firms on their wagebills, at rates between zero and 6 per cent. Firms with small wagebills pay at the zero rate. We do not model this aspect of the payroll-tax system directly. However, as indicated in  $E\_p1laboi$ , we allow for variations in payroll tax rates across industries. In this way we recognise, for example, that agriculture (which is dominated by small firms) has a lower rate of payroll tax than mining (which is dominated by large firms).

### ***E\_wlaboi***

If we set the shift variables [ $fwage$ ,  $fwagei$ ,  $fwageo$ ,  $fwageoi$  and  $fwage_s$ ] at zero, then all industry/occupation wage rates [ $wlaboi(m,j)$ ] will move with the consumer price index [ $xi3$ ]. The shift variable  $fwage$  allows for a general change in real wage rates;  $fwagei(j)$  allows for a change in real wage rates confined to industry  $j$ ;  $fwageo(m)$  allows for a change in real wage rates confined to occupation  $m$ ; and  $fwageoi(m,j)$  allows for a change in real wage rates confined to occupation  $m$  in industry  $j$ .

The final term on the RHS of  $E\_wlaboi$  facilitates the use of data available at the 20-sector level on wage rates and employment. It allows a change in real wage rates [ $fwage_s(rr)$ ] to be confined to industries in sector  $rr$ . As explained in subsection 17.3 (example 4), the coefficient  $INDTOIA20(j)$  appearing in this term takes a value between 1 and 20 according to the sector to which  $j$  belongs, and as explained in subsection 17.5 (example 5),  $\$POS(rr)$  takes the value  $q$  when  $rr$  is the  $q$ th element of the relevant set, in this case  $INDSAGGTO20$ . By following the Read Elements instruction in subsection 18.2 for  $INDSAGGTO20$ , we find that the contents of this set are the names of the 20 sectors: AgForestFish; Mining; ..., Repairs. With  $INDTOIA20(j)$  equal to 1 for any industry  $j$  in the first sector, we see that for these industries the last term on the RHS of  $E\_wlaboi$  reduces to  $fwage_s(\text{AgForestFish})$ . Similarly, for industries in the second sector, the last term on the RHS of  $E\_wlaboi$  reduces to  $fwage_s(\text{Mining})$ . Thus, as required, the direct effect of movements in  $fwage_s(rr)$  is confined to industries belonging to the sector  $rr$ .

### ***E\_wlab\_s, E\_labind\_s, E\_wagebill\_s and E\_ave\_wage***

These equations define wage and employment variables that are useful for introducing observations into historical simulations.

$E\_wlab\_s$  defines percentage movements in sectoral wage rates,  $wlab\_s(jj)$ , excluding payroll taxes. On the LHS, the coefficient multiplying  $wlab\_s(jj)$  is the wagebill for sector  $jj$  calculated by adding the wagebills of all industries  $j$  satisfying the condition  $INDTOIA20(j) = \$POS(jj)$ , i.e., by adding the wagebills for all industries  $j$  in the  $jj$ th sector. The wagebill for industry  $j$  is calculated by dividing the costs of employing labour [ $LABIND\_J(j)$ ] by the power of the payroll tax [ $POW\_PAYROLL(j)$ ]. On the RHS of  $E\_wlab\_s$  is a weighted sum of the percentage changes in industry wage rates for industries  $j$  in the  $jj$ th sector, with the weights being industry wagebills. Percentage changes in industry wage rates are percentage changes in unit costs of labour by industry less percentage changes in the powers of payroll taxes. Thus,  $E\_wlab\_s$  determines percentage movements in sectoral wage rates as weighted averages of percentage movements in industry wage rates with the weights being industry shares in sectoral wagebills.

Similarly,  $E\_labind\_s$  determines the percentage movement in employment in sector  $jj$  [ $labind\_s(jj)$ ] as a weighted average of the percentage movements in employment in industries  $j$  belonging to sector  $jj$ , with the weights being industry shares in  $jj$ 's wagebill excluding payroll tax.

$E\_wagebill\_s$  determines the percentage change in the wagebill (excluding payroll tax) for sector  $jj$  as the sum of the percentage changes in the sector's wage rate and employment.

Finally,  $E\_ave\_wage$  determines the percentage change in the economy-wide average wage rate as a weighted sum of industry wage rates with the weights being industry shares in labour costs excluding payroll tax.

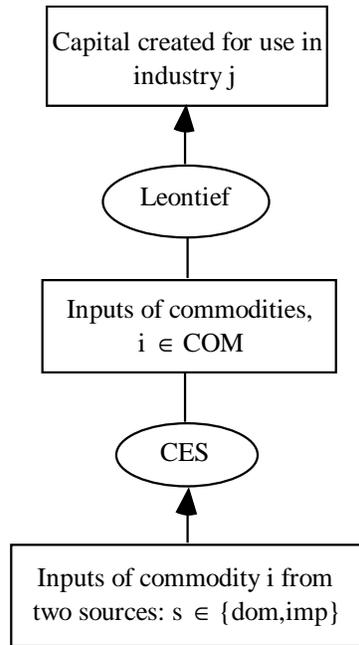
### **21. *Demands for inputs to capital creation and the asset price of units of capital (subsection 18.8d in the TABLO code)***

We assume that units of capital stock are created for industry  $j$  according to the two-level production function illustrated in Figure 21.1. At the first level, commodities are combined via a Leontief function. No price-induced substitution is allowed between different types of machinery and between machinery and buildings. At the second level, domestic and imported goods are combined via a CES function (the Armington assumption).

No primary factors or other costs tickets are used in capital creation. The use of these inputs is recognized through the construction industry. The production of construction services, a major input to capital creation, uses primary factors and other cost tickets.

#### ***$E\_x2csi$***

We assume that any given level [ $Y(j)$ ] of capital creation for industry  $j$  is achieved at minimum cost. Under the technology assumptions described above, cost minimization produces the input-demand equations,  $E\_x2csi$ . The algebra underlying these equations is similar to that set out in section 38 for  $E\_x1csi$ .

**Figure 21.1. Technology for creating units of capital for industry  $j$** 

On the LHS of  $E_{x2csi}$  is the percentage change in the demand for commodity  $i$  ( $i \in \text{COM}$ ) from source  $s$  ( $s \in \text{SOURCE}$ ) by industry  $j$  ( $j \in \text{IND}$ ) for use in capital creation (indicated by the notation “2” in  $x2csi$ ). The first term on the RHS is the percentage change  $[y(j)]$  in the level of capital creation for industry  $j$ . In the absence of changes in prices and technology, inputs to capital creation for industry  $j$  are proportional to the industry’s capital creation.

The second term on the RHS allows for price-induced substitution between inputs of good  $i$  from different sources. This term is identical in form to the price-substitution term in  $E_{x1csi}$ . Because that term was discussed fully in subsection 20.3, no further explanation is given here.

The remaining terms on the RHS of  $E_{x2csi}$  are also counterparts of terms on the RHS of  $E_{x1csi}$ . In  $E_{x2csi}$ , the “a” terms allow for: all input-saving technical change in capital creation in industry  $j$  [ $a2ind(j)$ ]; input- $i$ -saving technical change in capital creation in industry  $j$  [ $a2ci(i,j)$ ]; and input- $(i,s)$ -saving technical change in capital creation in industry  $j$  [ $a2csi(i,s,j)$ ]. As recognized in the second last term on the RHS of  $E_{x2csi}$ , input- $(i,s)$ -saving technical change induces substitution in favour of the use of commodity  $i$  from source  $s$  and against the use of  $i$  from the

alternative source. The last term on the RHS of  $E_{x2csi}$  allows for cost-neutral twists in domestic/import preferences for commodity  $i$ .

### $E_{pi}$

If the “a” terms are zero (i.e., no technical change) then this equation implies that the percentage movement  $[pi(j)]$  in the asset price (price to buy, not rent) of a unit of capital for industry  $j$  is a weighted average of the percentage movements in the prices of inputs to capital creation in  $j$ . The weights are the shares of each input in the costs of creating units of capital for industry  $j$ . The coefficients used in calculating these weights are  $PURCHVAL2(i,s,j)$  [the value of  $j$ 's purchases of  $(i,s)$  for capital creation, calculated in subsection 18.5d] and  $VINVEST(j)$  [the total value of  $j$ 's capital creation, calculated in subsection 18.5h].

If  $a2ind(j) = -10$ , then a unit of capital for industry  $j$  can be constructed with 10 per cent less of all inputs. It is assumed in  $E_{pi}$  that this would reduce the price of a unit of capital in industry  $j$  by 10 per cent. If  $a2ci(i,j) = -10$ , allowing a unit of capital in industry  $j$  to be constructed with 10 per cent less input of commodity  $i$ , then it is assumed that the percentage reduction in the price of a unit of capital in industry  $j$  would be 10 times the share of  $i$  in the cost of capital in industry  $j$ . Similarly, if  $a2csi(i,s,j) = -10$ , then the reduction in the price of a unit of capital in industry  $j$  is assumed to be 10 times the  $(i,s)$ -share in  $j$ 's capital costs.

### **22. Demands for commodities by households (subsection 18.8e in the TABLO code)**

The household demand equations are derived in two stages. First, the household sector is assumed to allocate its budget between commodities  $i \in COM$ , according to a utility-maximizing specification:

choose  $X3(i), i \in COM,$

to maximize  $U(X3(1)/Q, \dots, X3(G)/Q)$  (22.1)

subject to  $\sum_i P3(i) X3(i) = C$  , (22.2)

where

$X3(i)$  is consumption of good  $i$ ;

$Q$  is the number of households in the household sector;

$P3(i)$  is the price to households of a unit of good  $i$ ;

$C$  is the household budget; and

$G$  is the number of commodities. For notational convenience, we assume in this section that  $COM = \{1, \dots, G\}$ .

In the second stage, households allocate their expenditures between domestic and imported good  $i$  to minimize the costs of their purchases of  $i$ , subject to achieving the overall level of consumption  $[X3(i)]$  determined in (22.1)-(22.2), i.e., households,

choose  $X3(i,s), s \in \text{SOURCE}$

$$\text{to minimize } \sum_s P3(i,s) X3(i,s) \quad (22.3)$$

$$\text{subject to } X3(i) = F_{3i}(X3(i,1), X3(i,2)) \quad (22.4)$$

where

$P3(i,s)$  is the price to households of domestic ( $s=1$ ) or imported ( $s=2$ ) good  $i$ ;

$X3(i,s)$  is the quantity consumed by households of good  $i$  from source  $s$ ; and

$F_{3i}$  is a linearly homogeneous function which combines units of domestic and imported good  $i$  into the overall level of consumption of  $i$ .

By assuming that  $F_{3i}$  is linearly homogeneous, we ensure that if there is a 10 per cent (say) increase in the consumption of both domestic and imported  $i$ , then there is a 10 per cent increase in the overall consumption of  $i$ . We also ensure that if there are 10 per cent increases in the prices of domestic and imported good  $i$ , then the ratios  $X3(i,s)/X3(i)$  will be unaffected and the overall price of  $i$ , defined by

$$P3(i) = \sum_s P3(i,s) X3(i,s) / X3(i) \quad (22.5)$$

will increase by 10 per cent.

#### *E\_x3, E\_ave\_a3com, E\_deltapc, E\_d\_gamma and E\_aa3com*

The utility-maximizing problem (22.1)-(22.2) implies a demand system of the form:

$$X3(i)/Q = g_i(P3(1), \dots, P3(G), C/Q), i \in \text{COM}. \quad (22.6)$$

If there are no changes in consumer preferences (so that there are no changes in the form of the demand functions,  $g_i$ ), then (22.6) gives

$$x3(i) - q = \text{EPS}(i)(c - q) + \sum_j \text{ETA}(i, j) p3(j) \quad (22.7)$$

where: the lowercase symbols,  $x3(i)$ ,  $q$ ,  $c$  and  $p3(j)$  are percentage changes in the variables denoted by the corresponding uppercase symbols;  $\text{EPS}(i)$  is the expenditure elasticity of demand for good  $i$ ; and  $\text{ETA}(i, j)$  is the elasticity of demand for  $i$  with respect to changes in the price of  $j$ .

To obtain  $E_x3$ , we add the term  $(a3com(i) - \text{ave}_a3com)$  to the RHS of (22.7). This additional term allows for changes in preferences (i.e., shifts in the  $U$  function generating shifts in the  $g_i$  functions).

Three aspects of  $E_x3$  deserve comment. First, it implies the budget constraint, i.e., from  $E_x3$  we find that

$$\sum_i S3COM(i) * (p3(i) + x3(i)) = c \quad (22.8)$$

where  $S3COM(i)$  [computed in subsection 18.5k] is the share of good  $i$  in the household budget. In deriving (22.8) we use both the definition of  $ave\_a3com$  given in  $E\_ave\_a3com$  and two properties of price and expenditure elasticities:

$$\sum_i \text{ETA}(i, j) S3COM(i) = -S3COM(j) \text{ for all } j, \quad (22.9)$$

and

$$\sum_i \text{EPS}(i) S3COM(i) = 1. \quad (22.10)$$

Because the budget constraint can be derived from  $E\_x3$ , it does not appear in our list of equations for the MONASH model.

The second aspect of  $E\_x3$  requiring explanation is the treatment of taste changes. If we give  $a3com(i)$  a positive value with all the other  $a3com$  at zero, then we are allowing for a movement in consumer preferences in favour of commodity  $i$  and away from other commodities. With a fixed budget, fixed prices and a fixed number of households, a value of 1 for  $a3com(i)$  causes consumption of good  $i$  to increase by  $(1 - S3COM(i))$  per cent while the consumption of any other good  $j$  declines by  $S3COM(i)$  per cent. The total percentage effect on household expenditure is

$$S3COM(i) (1 - S3COM(i)) - \sum_{j \neq i} S3COM(j) S3COM(i) = 0.$$

This means that the taste changes in  $E\_x3$  are budget neutral. That is, for any given set of values for the  $P3(i)$ s and  $Q$ , non-zero values for the  $a3com$  have zero effect on  $C$ .

Can we be sure that our specification of taste changes in  $E\_x3$  is compatible with the utility function  $U$ ? In the current version of MONASH,  $U$  is specified according to the Klein-Rubin form<sup>12</sup>:

$$U = \sum_i \Delta_i \ln(X3(i)/Q - \Gamma_i), \quad (22.11)$$

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<sup>11</sup> Under the utility maximizing behaviour specified by (22.1)-(22.2), the demand functions,  $g_i$ , satisfy the budget constraint, i.e.,

$$\sum_i P3(i) g_i = C/Q. \quad (a)$$

$$\text{From (a) we find that } \sum_i P3(i) \left[ \frac{\partial g_i}{\partial P3(j)} \right] + g_j = 0 \quad (b)$$

$$\text{and } \sum_i P3(i) \left[ \frac{\partial g_i}{\partial (C/Q)} \right] = 1. \quad (c)$$

On recognizing that  $S3COM(i) = P3(i) g_i / (C/Q)$ , we can rearrange (b) to obtain (22.9) and (c) to obtain (22.10).

<sup>12</sup> See Klein and Rubin (1948-49). Utility functions of the form (22.11) are also referred to as Stone-Geary functions in recognition of the contributions of Stone (1954) and Geary (1950-51).

where  $\Gamma_i$  and  $\Delta_i$  are preference variables,<sup>13</sup> with the  $\Delta_i$  being non-negative and summing to one. There are many ways in which the movements in  $\Gamma_i$  and  $\Delta_i$  could be specified to produce the taste-change effects in E\_x3. In subsection 40.1, we show that one way is to specify the percentage movement in  $\Delta_i$  [deltapc(i)] according to E\_deltapc and the change in  $\Gamma_i$  as a per cent of per-household consumption of  $i$  [d\_gamma(i)] according to E\_d\_gamma(i). As shown in subsection 40.1, these specifications of deltapc(i) and d\_gamma(i) normally imply that a 10 per cent taste shift towards good  $i$  [i.e., a3com(i) - ave\_a3com = 10] is achieved by approximately 10 per cent increases in both  $\Gamma_i$  and  $\Delta_i$ .

The final aspect of E\_x3 requiring comment is the setting of the values of the expenditure elasticities, EPS(i), and the price elasticities, ETA(i,j). These are set in accordance with the linear expenditure system [the demand system implied when the utility function has the form (22.11)] using: estimates of marginal budget shares, the  $\Delta_i$ ; an estimate of the FRISCH coefficient, i.e.  $-C/(C - \sum_i P_3(i)\Gamma_i)$ ; and input-output data on budget shares, S3COM(i). The estimated marginal budget shares are read as DELTA(i) in subsection 18.4, normalized to ensure that they add to one in subsection 18.5k and updated by the variable deltapc(i) in subsection 18.7. The estimated value for FRISCH is read in subsection 18.4 and updated in subsection 18.7. Because it is unusual, the form of the update for FRISCH is discussed in subsection 40.1. The budget shares, S3COM(i), are computed in subsection 18.5k. The formulas for EPS(i) and ETA(i,j) are in subsection 18.5k and are derived in subsection 40.1.

E\_aa3com is occasionally useful in analysing results. It defines the contribution to growth in the sales of domestic commodity  $i$  of the change in household preferences towards or away from  $i$ .

### **E\_x3cs**

E\_x3cs specifies the percentage change [x3cs(i,s)] in household demand for good  $i$  from source  $s$ . It is derived from (22.3)-(22.4), with  $F_{3i}$  assumed to be CES (see section 40).

The form of E\_x3cs is similar to that of E\_x1csi and E\_x2csi. The first term on the RHS is an activity variable [x3(i), the percentage change in household demand for  $i$ ] and the second deals with price substitution.

The remaining terms, involving the variables a3cs and twist\_src, allow for changes in household preferences between domestic and imported good  $i$ . For example, by setting a3cs(i,dom) at -1, we generate percentage changes in household consumption of domestic good  $i$  of  $-(1-$

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<sup>13</sup>  $\Gamma_i$  and  $\Delta_i$  are usually referred to as the *parameters* of the Klein-Rubin utility function. Because we allow them to change from year to year, reflecting changes in consumer preferences, we prefer to call them preference or taste variables.

$SIGMA3(i)*SOURCE\_SHR3(i,imp)$  and of imported good  $i$  of  $(1-SIGMA3(i))*SOURCE\_SHR3(i,dom)$ . Adding these percentage changes with  $SOURCE\_SHR3$  weights we find that there is no effect on the consumption of good  $i$  [ $x3(i)$ ]. This explains the absence of  $a3cs(i,s)$  from  $E\_x3$ .

Whether a negative value for  $a3cs(i,dom)$  will increase or decrease the consumption of good  $(i,dom)$  depends on the substitution parameter  $SIGMA3(i)$ . If this is more than one, then there will be a positive effect on the consumption of domestic good  $i$ . If  $SIGMA3(i)$  is less than one, then there will be a negative effect. If  $SIGMA3(i)$  equals one, then non-zero values for  $a3cs(i,s)$  will have no effect on  $x3cs(i,t)$  for  $t \in SOURCE$ .

As demonstrated in subsection 40.2, provided  $SIGMA3(i)$  is not equal to one, non-zero values for  $a3cs(i,s)$  and  $twist\_src(i)$  can be interpreted as imposing combinations of  $(i,dom)$ - and  $(i,imp)$ -saving changes in preferences. When  $SIGMA3(i)$  is equal to one, these interpretations are not valid. Nevertheless,  $twist\_src(i)$  [but not  $a3cs(i,s)$ ] can still be used to simulate changes in the domestic/import preferences of households.

### ***E\_p3***

This equation can be derived from (22.5) and  $E\_x3cs$ , see subsection 40.3.

### ***23. Demands for exports, export aggregates and foreign-currency price indexes (subsection 18.8f in the TABLO code)***

There are four categories of exports in MONASH: traditional (mainly agricultural and mineral products, accounting for about 65 per cent of total exports); non-traditional (mainly manufactured goods, about 20 per cent of exports); tourism (mainly travel and hotel services, about 10 per cent of exports); and special (consisting of water transport, transport services and communications, about 5 per cent of exports). For each category, the model allows a different treatment of export demands.

#### ***E\_x4\_TRADEXP, E\_tradexpvol and E\_xi4trad***

In  $E\_x4\_TRADEXP$ , the percentage change in export demand for traditional export  $i$  depends on the percentage changes in a price and in three shift variables.

The price variable [ $pe(i)$ ] is the percentage change in the f.o.b. price of good  $i$  (value on departure from Australia) expressed in foreign currency, e.g., \$US. The prices that we expect to influence export demands are purchasers' prices in foreign countries. These are the sum of f.o.b. values and transport, tariff and other charges separating Australian ports of exit and foreign sites of use. Because MONASH is a single country model, it contains no equations explaining these separating changes. In section 41, we show how percentage movements in separating changes can be absorbed into the shift variables,  $fep(i)$ , leaving the f.o.b. price as a separate variable on the RHS of the export demand functions,  $E\_x4\_TRADEXP$ .

The sensitivity of export demand to price changes is controlled by the parameter  $EXP\_ELAST(i)$ , the foreign elasticity of demand. This is read in subsection 18.4

from the file PARAMS. As justified in section 41, for most traditional export commodities we set  $EXP\_ELAST(i)$  at  $-4$ . For these commodities,  $E\_x4\_TRADEXP$  implies that variations in Australia's export volumes have only a mild influence on world prices. For two traditional export commodities, wool and scoured wool<sup>14</sup>, Australia is a major world supplier. Smaller absolute values for  $EXP\_ELAST(i)$  are then appropriate (see section 41). For wool, the value of  $EXP\_ELAST(i)$  currently in the PARAMS files is  $-1.3$  and for wool scouring it is  $-2.6$ .

The three shift variables on the RHS of  $E\_x4\_TRADEXP$  allow for vertical ( $fep$ ) and horizontal movements ( $feq$  and  $feq\_general$ ) in export-demand curves. In section 41, we show that vertical shifts can be associated with changes in separating charges and changes in the prices of foreign products competing with Australia's exports of good  $i$ . Horizontal shifts can be associated with changes in world demand for good  $i$  and shifts in foreign preferences towards or away from Australia's variety for good  $i$ .

Unlike  $fep$  and  $feq$  which are commodity specific,  $feq\_general$  generates a uniform horizontal shift in all export-demand curves. As we will see,  $feq\_general$  is included not only in  $E\_x4\_TRADEXP$  but also in the demand equations dedicated to non-traditional and tourism exports.

$E\_tradexpvol$  and  $E\_xi4trad$  define volume and foreign-currency price indexes for traditional exports. Both are Divisia indexes.<sup>15</sup> In the two indexes, the weight given to the percentage movement in either the volume or price of a commodity is the commodity's share in the f.o.b. value of traditional exports. The components of these weights [ $PURCHVAL4(i)$  and  $AGGTRADEXP$ ] are calculated in subsections 18.5d and 18.5h.

#### ***E\_x4\_NTRADEXP, E\_ntradexpvol, E\_xi4ntrad and E\_hs\_ntrad***

$E\_x4\_NTRADEXP$  specifies the export demand for commodities in the set  $NTRADEXP$  (non-traditional exports). As indicated in subsection 18.2,  $NTRADEXP$  consists of all commodities except the three for which MONASH provides special modelling of export demands and the commodities in  $TRADEXP$  and  $TOURISM$  (the traditional exports and the tourist commodities).

The main difference between  $E\_x4\_NTRADEXP$  and  $E\_x4\_TRADEXP$  is in their price variables. In  $E\_x4\_TRADEXP$ , the price variable [ $pe(i)$ ] carries an  $i$  subscript. In  $E\_x4\_NTRADEXP$  the price variable [ $xi4ntrad$ ] has no  $i$  subscript. It is a Divisia index defined in  $E\_xi4ntrad$  of the prices of all non-traditional exports.

In the usual case, where we set  $f\_ntrad(i)$  and  $fep\_ntradi(i)$  equal to zero for all  $i$  in  $NTRADEXP$ , the lack of an  $i$  subscript in the price term on the RHS of

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<sup>14</sup> Wool scouring is a main component of MONASH commodity 32, ginning.

<sup>15</sup> Divisia indexes in the context of MONASH are discussed in section 43.

$E_{x4\_NTRADEXP}$  means that export demands for all non-traditional exports move by the same percentage. The obvious alternative treatment is to allow demands for non-traditional exports to be specified through equations similar to  $E_{x4\_TRADEXP}$ . However, we do not feel confident in the ability of MONASH to generate realistic values for movements  $[pe(i)]$  in the foreign-currency export prices of individual commodities in  $NTRADEXP$ . For most of these commodities, the share of exports in total sales is less than 10 per cent. As is clear from  $E_{pe}$  (discussed in section 27), MONASH generates  $pe(i)$  from movements in: the unit production cost of  $i$ ; transport and other margins costs incurred in facilitating flows of  $i$  from producers to ports of exit; export taxes; and the exchange rate. Where exports are a small share of the economy's output of commodity  $i$ , movements in the overall unit production cost of  $i$  may be a poor guide to movements in the unit production cost of exported  $i$ . This is because the small subset of  $i$  which is exported might have a cost structure quite different from the overall cost structure of commodity  $i$ . Without having confidence in the determination of  $pe(i)$ ,  $i \in NTRADEXP$ , we prefer to avoid having to justify simulation results indicating large price-induced changes in the commodity composition of non-traditional exports. Such results could occur if we allowed each non-traditional export to have a demand function with its own price term.<sup>16</sup>

By multiplying  $E_{x4\_NTRADEXP}$  through by the share of  $i$  in non-traditional exports, adding over all  $i \in NTRADEXP$  and then using  $E_{ntradexpvol}$  (which defines the quantity index for non-traditional exports), we obtain

$$\begin{aligned} ntradexpvol &= EXP\_ELAST\_N * [xi4ntrad - fep\_ntrad] \\ &- \text{Sum} \left( i, NTRADEXP, \left[ \frac{PURCHVAL4(i)}{AGGNTRADEXP} \right] * EXP\_ELAST\_N * fep\_ntradi(i) \right) \\ &+ \text{Sum} \left( i, NTRADEXP, \left[ \frac{PURCHVAL4(i)}{AGGNTRADEXP} \right] * f\_ntrad(i) \right) \\ &+ feq\_ntrad + feq\_general. \end{aligned} \tag{23.1}$$

Thus, if in addition to setting  $f\_ntrad(i)$  and  $fep\_ntradi(i)$  exogenously for all  $i$  in  $NTRADEXP$ , we also exogenize  $feq\_ntrad$ ,  $fep\_ntrad$  and  $feq\_general$ , then we have an export-demand function for aggregate non-traditional exports with the parameter  $EXP\_ELAST\_N$  (set in subsection 18.5a at -4) being the foreign

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<sup>16</sup> Another difficulty with equations like  $E_{x4\_TRADEXP}$  applied to non-traditional exports is the over-specialization problem (see, for example, Dervis *et al.*, 1982, p. 228). Because CGE models do not include all real-world supply-side constraints, they often need artificial demand-side constraints (e.g., the locking together of the percentage movements in export demands for minor export commodities) to prevent them from implying that a country will specialize in a small, unstable set of exports.

elasticity of demand for these exports with respect to their overall foreign-currency price. When we follow this approach, non-traditional exports (mainly manufactures) respond in MONASH as a group to changes in the group's international competitiveness (determined mainly by changes in costs in manufacturing industries expressed in foreign currency).

To simulate vertical and horizontal shifts in the export demand curve for non-traditional exports, we can use non-zero settings for  $fep\_ntrad$  and  $feq\_ntrad$ . If  $feq\_general$  has a non-zero value, then we are imposing a horizontal shift on the group's export-demand curve as part of a more general shift in export demands.

To simulate changes in the commodity composition of non-traditional exports, we can use non-zero settings for  $f\_ntrad(i)$ ,  $i \in NTRADEXP$ .<sup>17</sup> Notice, however, that a non-zero value for  $f\_ntrad(i)$  imparts a horizontal shift to the demand curve (23.1). To provide a convenient method for holding constant the position of this demand curve while imposing exogenous changes<sup>18</sup> on the commodity composition of non-traditional exports, we include in MONASH the equation  $E\_hs\_ntrad$ . This defines  $hs\_ntrad$  (a horizontal shift specific to the non-traditional export-demand curve) as the sum of the third and fourth terms on the RHS of (23.1). To simulate the effects of a change in the composition of non-traditional exports, holding constant the position of the overall demand curve, we: (a) adopt non-zero values for  $f\_ntrad(i)$ ; (b) set  $hs\_ntrad$ ,  $feq\_general$ ,  $fep\_ntrad$  and  $fep\_ntradi(i)$  exogenously at zero; and (c) endogenize  $feq\_ntrad$ .

#### ***E\_x4 TOURISM, E\_agg\_tour and E\_xi4tour***

These three equations specify demands by foreign visitors to Australia for air transport<sup>19</sup> (C98), entertainment and leisure (C112), restaurants and hotels (C113) and personal services (C114), the commodities in the set TOURISM.

The parameter  $EXP\_ELAST\_T$  in  $E\_x4\_TOURISM$  is the foreign elasticity of demand for tourism services from Australia. It is set in subsection 18.5a at -3.<sup>20</sup> The coefficients [ $PURCHVAL4(i)$  and  $AGGTTOURISM$ ] appearing in  $E\_agg\_tour$  and  $E\_xi4tour$  are calculated in subsections 18.5d and 18.5h.

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<sup>17</sup> Alternatively we could use non-zero values for the  $fep\_ntradi(i)$ s.

<sup>18</sup> These changes may also be imposed endogenously, see the discussion in section 31 of  $E\_hist\_cont$  and  $E\_f\_forc$ .

<sup>19</sup> There is some foreign use of Australian airlines for travel between non-Australian destinations. This is relatively minor and is ignored in our current treatment of air transport exports.

<sup>20</sup> This elasticity was important in a recent politically sensitive application of MONASH to an analysis of the effects of a broad-based consumption tax, Dixon and Rimmer (1999b and 2000). Some participants in the debate claimed that much lower values (in absolute terms) for the tourism elasticity are appropriate. However such values imply unrealistic levels of market power for Australia in the world tourism market.

Since the form of the three tourism equations is identical to that of the corresponding three equations for non-traditional exports, detailed discussion of them is not required. It is worth noting, however, that using  $E_{x4\_TOURISM}$  as a specification of export demands for tourism exports is theoretically more attractive than using  $E_{x4\_NTRADEXP}$  as a specification of demands for non-traditional exports. Locking together the percentage movements in demands for non-traditional exports via  $E_{x4\_NTRADEXP}$  is merely expedient. By contrast, it is reasonable to think of foreign tourists as buying service bundles consisting of a fixed combination of commodities from the set  $TOURISM$ , with the number of bundles purchased being sensitive to the cost of a bundle. That is, it is reasonable to think of the  $x4(i)$ s for commodities in the set  $TOURISM$  as being tightly linked, each being determined not by  $pe(i)$  but by the price  $[xi4tour]$  of a bundle of tourist services.

#### ***E<sub>x4</sub>\_WATERTRAN***

This equation deals with exports of commodities in the set  $WATERTRAN$ . As can be seen from subsection 18.2, this set contains the single commodity,  $C97$  (water transport).

The main use of Australian water-transport services outside Australia is in shipping traditional exports (e.g., iron ore, coal, sheep and grain) to foreign countries. Although payments for these services may involve transfers from one Australian company to another, they are, nevertheless, export earnings. This is because in calculating the value of Australia's exports of iron ore, coal, etc. we use f.o.b. prices. Consequently Australian shipping services used to transfer Australian goods to foreign ports are an additional source of export earnings.

In  $E_{x4\_WATERTRAN}$ , we assume that the volume of exports of water transport services moves with the volume of traditional exports. We include a shift variable on the RHS to allow for changes in the ratio of exports of water transport services to the volume of traditional exports.

#### ***E<sub>x4</sub>\_TRANSERV, E<sub>merch</sub>\_trad and E<sub>tt</sub>***

$E_{x4\_TRANSERV}$  is concerned with exports of good  $i$  in the set  $TRANSERV$ . In subsection 18.2 we find that this set contains the single commodity  $C99$  (services to transport).

Exports of  $C99$  consist mainly of harbour and airport services provided to foreign ships and planes visiting Australia. We recognize three reasons for these visits: (a) to carry Australian passengers in and out of Australia; (b) to carry foreign passengers in and out of Australia; and (c) to facilitate Australia's merchandise trade. Almost all passenger services in and out of Australia are air services. We use imports of air services (i.e., imports of commodity  $j$  in the single commodity set  $AIRTRAN$ ) to reflect the demand for exports of  $C99$  associated with reason (a). We use tourist activity (i.e.,  $agg\_tour$ ) to reflect demand for exports of  $C99$

associated with reason (b). Finally, we use a measure of the volume of Australia's merchandise trade (i.e., *merch\_trad*) to reflect reason (c).

We do not have any data to indicate the split between the three sources of demand for exports of C99. The weighting scheme (0.25, 0.25, 0.5) on the RHS of *E\_x4\_TRANSERV* is a reasonable guess. The shift variable, *fx4\_transerv* gives users of MONASH the option of determining exports of C99 independently of our 0.25/0.25/0.5 combination of variables.

In *E\_merch\_trad* we define the percentage change in the volume of merchandise trade [*merch\_trad*] as a weighted average of the percentage changes [*tt(i)*] in the volumes of trade of all goods *i* belonging to the set *MERCHANDISE*. This set contains C1 to C85, i.e., all commodities except services. The percentage change [*tt(i)*] in the trade volume for commodity *i* is defined in *E\_tt* as a weighted average of the percentage changes in the volumes of exports [*x4(i)*] and imports [*x0imp(i)*] of *i*. The coefficients used in forming the weights in *E\_merch\_trad* and *E\_tt* are: *TOT\_T(i)*, total trade in commodity *i*; *PURCHVAL4(i)*, the f.o.b. value of exports of *i*; and *IMPCOST(i)*, the c.i.f. value of imports of *i*. *TOT\_T(i)* is calculated in subsection 18.5h as the sum of *IMPCOST(i)* (calculated in 18.5f) and *PURCHVAL4(i)* (calculated in 18.5d).

#### ***E\_x4\_COMMUNICAT***

This equation specifies exports of communications (C100), the single element in the set *COMMUNICAT*.

Communication exports consist mainly of charges imposed by Australian telephone companies and the Australian postal company on foreign communication companies for distributing incoming phone calls and mail within Australia. Communication imports consist of payments from Australia to foreigners for the symmetrical services. On the assumption that outgoing calls and mail generate incoming calls and mail, we drive the volume of exports by the volume of imports. Changes in the ratio of communication exports to imports are introduced through non-zero values for the shift variable, *fx4\_commun*.

#### **24. Other demands for commodities (subsection 18.8g in the *TABLO* code)**

Here we deal with demands by governments and demands for inventories. Neither of these sources of demand is explained in MONASH.

For inventories we simply include a variable [*d\_x6cs(i,s)*,  $i \in \text{COM}$ ,  $s \in \text{SOURCE}$ ] and no equation.<sup>21</sup> The change rather than the percentage change version of the variable is used because inventory demands can pass through zero. In most simulations *d\_x6cs(i,s)* is set exogenously on zero for nearly all commodities (*i,s*). However, for agricultural commodities we often have information on changes in

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<sup>21</sup> Otim (1999) includes in a dynamic CGE model equations relating changes in inventory demands to acceleration in sales. In future work we plan to add such equations to MONASH.

the rate at which inventories are being accumulated or decumulated. For these commodities, non-zero settings for  $d_{x6cs}(i,s)$  are appropriate. For some simulations we have information on the output of agricultural products. In these simulations we can exogenize agricultural outputs and leave  $d_{x6cs}(i,s)$  to be endogenously determined.

### ***E\_x5cs***

For government demands it is convenient to include an equation,  $E_{x5cs}$ . In a typical application of MONASH,  $f5gen$  on the RHS of this equation is set at the predicted rate of growth (say 3 per cent) in public expenditure and  $f5dom(i)$  and  $f5imp(i)$  are set at zero. Because government-dominated commodities (public administration, defence, health, education and libraries, and welfare services) are almost entirely domestically produced, the twist term in  $E_{x5cs}$  has little effect [ $SOURCEDOM(dom)-SOURCE\_SHR5(i,dom)$  is close to 0 for these commodities]. Thus, in a typical application, government demands for domestically produced public administration, defence, etc. all increase by approximately  $f5gen$  (e.g., 3 per cent). To impose a non-uniform expansion in real public expenditure, we can use non-zero settings for  $f5dom(i)$ .

### **25. Demands for margin services (subsection 18.8h in the TABLO code)**

Nine commodities (wholesale trade, retail trade, road transport, rail transport, water transport, air transport, services to transport, insurance, and restaurants and hotels), those in the set MARGCOM, can be used as margins. The role of margins is to facilitate flows of commodities from points of production ( $s=dom$ ) or points of entry ( $s=imp$ ) to either domestic users or to ports of exit.

We assume that all margin demands are met by domestic production. In connection with this assumption, it is worth emphasizing that the margin demands modelled in subsection 18.8h relate only to the facilitation of commodity flows within Australia. In the case of exports, we are concerned with transport and other margin costs incurred in transferring commodities from Australian producers to ports of exit. In the case of imports, we are concerned with margin costs incurred between Australian ports of entry and Australian users. Australian transport and other margin services used outside Australia are treated in MONASH as exports.

Although we assume that there are no imported margin services, we do allow for imports of commodities in the set MARGCOM. For example, the MONASH database shows imports of air and water transport. We assume that these are predominately passenger services purchased from foreign carriers for direct use (not margin use) by Australians.

### ***E\_x1marg, E\_x2marg, E\_x3marg, E\_x4marg and E\_x5marg***

The use [ $X1MARG(i,s,j,r)$ ] of margin service  $r$  in facilitating the flow [ $X1CSI(i,s,j)$ ] of good  $(i,s)$  to industry  $j$  to be absorbed in current production is specified by

$$X1MARG(i, s, j, r) = A1MARG(i, s, j, r) * X1CSI(i, s, j) \quad , \quad (25.1)$$

where  $A1MARG(i, s, j, r)$  is a technological variable representing the use of margin service  $r$  per unit of demand for  $(i, s)$  as an intermediate input to industry  $j$ . In percentage-change form, (25.1) becomes  $E\_x1marg$ .

Similarly, we model all other demands for margin services as the product of a technological variable and a flow variable. This leads to the remaining equations in subsection 18.8h. We assume that there are no margin services associated with inventory accumulation.

**26. Supply equals demand for domestic and imported commodities (subsection 18.8i in the TABLO code)**

The changes in the supplies of domestic and imported products are assumed to equal the changes in the demands for them.

***E\_p0dom\_NM***

We write the market-clearing equations for commodities in terms of basic values rather than quantities. This assists in working out the appropriate coefficients for the differential versions.

For non-margin commodities, we assume that

$$\begin{aligned} P0LEV(r, dom) * X0DOM(r) &= \sum_{j \in IND} P0LEV(r, dom) * [X1CSI(r, dom, j) + X2CSI(r, dom, j)] \\ &+ P0LEV(r, dom) * X3CS(r, dom) + P0LEV(r, dom) * X4(r) \\ &+ P0LEV(r, dom) * X5CS(r, dom) + P0LEV(r, dom) * X6CS(r, dom) \end{aligned} \quad \text{for } r \in \text{NONMARGCOM}, \quad (26.1)$$

where

$P0LEV(r, dom)$  is the basic price of domestic good  $r$ ;

$X0DOM(r)$  is the output of domestic good  $r$ ; and

$X1CSI(r, dom, j)$ ,  $X2CSI(r, dom, j)$ ,  $X3CS(r, dom)$ ,  $X4(r)$ ,  $X5CS(r, dom)$  and  $X6CS(r, dom)$  are the various demands for domestic good  $r$ .

On the LHS of (26.1) is the basic value of the output of domestic good  $r$  [ $SALES(r)$ ] and on the RHS are the basic values of intermediate [ $BAS1(r, dom, j)$ ], investment [ $BAS2(r, dom, j)$ ], household [ $BAS3(r, dom)$ ], export [ $BAS4(r)$ ], government [ $BAS5(r, dom)$ ] and inventory [ $BAS6(r, dom)$ ] demands.

$E\_p0dom\_NM$  is a differential form of (26.1). In deriving it, we recognize that the percentage change in the basic price of  $r$  [ $p0dom(r)$ ] can be eliminated because  $SALES(r)$  is the sum of demands in basic values (subsection 18.5j). In addition, we recall from section 24 that MONASH includes changes in inventory demands, not percentage changes.

***E\_p0dom\_M***

This equation imposes supply/demand balance for domestic, margin commodities, i.e., commodities in the set MARGCOM. The equation is similar to  $E_{p0dom\_NM}$ , except that it contains additional terms for margin demands. In these additional terms, the percentage changes in the margin demands for domestic good  $r$  are weighted by the basic values of their associated margin flows. Thus, for example, if margin usage in facilitating the flow of  $(i,s)$  to households represents 10 per cent of the demand for domestic good  $r$  [ $MAR3(i,s,r)/SALES(r) = 0.1$ ], then  $E_{p0dom\_M}$  implies that a 50 per cent increase in  $X3MAR(i,s,r)$  generates a 5 per cent increase in the overall demand for domestic good  $r$ .

### ***E\_x0imp***

This equation imposes supply/demand balance for imported commodities. Alternatively, it can be interpreted as simply defining the percentage change in total imports of good  $i$ ,  $i \in COM$ . Its derivation is similar to the derivation of  $E_{p0dom\_NM}$  from (26.1).

### ***27. Zero pure profits in production, importing, exporting and distribution, and total technical change by industry (subsection 18.8j in the TABLO code)***

The common theme of the equations described in this section is that the price received for any activity is equal to the costs per unit of the activity. A feature of the equations is that they contain no activity variables such as outputs and demands. This reflects constant returns to scale (CRS). Under the CRS assumptions adopted in MONASH, unit costs are independent of the scale at which activities are conducted.

### ***E\_p0ind, E\_z, E\_a\_JP and E\_a\_UP***

Together, these four equations impose zero pure profits in production. For each industry ( $j \in IND$ ), they equate percentage changes in prices received by producers (industry basic prices) to percentage changes in unit costs of production. Here, we describe the equations. In section 42 we give an algebraic justification.

In  $E_{p0ind}$ , we define the percentage change [ $p0ind(j)$ ] in industry  $j$ 's basic price as a weighted average of percentage changes in prices [ $p0dom(i)$ ,  $i \in COM$ ] received for individual commodities.<sup>22</sup> The weights are commodity shares [ $HOCI(i,j)$ ] in  $j$ 's revenue, calculated in subsection 18.5c.

In  $E_z$ , we equate  $p0ind(j)$  to the percentage change in  $j$ 's costs per unit of output. The first term on the RHS of  $E_z$  captures the effects on  $j$ 's unit costs of changes in technology. If, for example,  $a(j)$  is -10, then the effect of changes in technology is to reduce  $j$ 's unit costs by 10 per cent. The specification of  $a(j)$  is given in  $E_a\_JP$  and  $E_a\_UP$ , discussed below. The remaining terms on the RHS

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<sup>22</sup> We assume that all producers receive the same price for units of domestic good  $i$ . That is, we assume that there is only one basic price for good  $(i, dom)$ .

of  $E_z$  capture the effects of changes in input prices [ $p_{lcsi}(i,s,j)$ ,  $p_{llaboi}(m,j)$ , etc] and in the powers<sup>23</sup> of production taxes [ $powtax0(j)$ ].

The percentage change (or change in the case of other costs) in each input price receives a weight on the RHS of  $E_z$  reflecting the share of the input in  $j$ 's costs net of production taxes. The coefficients used in forming these shares are:

$COSTS(j)$ , total costs incurred by industry  $j$  (calculated in subsection 18.5j);

$PURCHVAL1(i,s,j)$ , the cost to industry  $j$  of its purchases of commodity  $i$  from source  $s$  (calculated in subsection 18.5d);

$LABOCCIND(m,j)$ , the cost to industry  $j$  of inputs of labour from skill group  $m$  (read in subsection 18.4 and updated in subsection 18.7);

$CAPITAL(j)$ , the cost to industry  $j$  of rentals on capital (read in subsection 18.4 and updated in subsection 18.7);

$LAND(j)$ , the cost to industry  $j$  of rentals on agricultural land (read in subsection 18.4 and updated in subsection 18.7);

$ROTHCOST(j)$ , the quantity of other costs incurred by industry  $j$  (calculated in subsection 18.5l); and

$TAX0(j)$ , the production taxes paid by industry  $j$  (calculated in subsection 18.5d).

There are two features of the input-price terms on the RHS of  $E_z$  requiring discussion. First, why are the shares on input prices calculated as input costs divided by total costs *net* of production taxes? This is to ensure that these shares sum to one. As will be seen in subsection 28.1, we model production taxes as a rate times the basic value of output. If production taxes are 25 per cent of costs, then a 1 per cent increase in all input prices has an initial impact on the industry basic price of 0.75 per cent. This causes a 0.75 per cent increase in production taxes per unit of output, translating to an increase in the industry basic price of  $0.25 \times 0.75$  per cent. But then there is a further increase in production taxes causing a further increase in the industry basic price of  $0.25 \times 0.25 \times 0.75$  per cent. Eventually the total increase in the industry basic price is 1 per cent ( $= 0.75 + 0.25 \times 0.75 + 0.25^2 \times 0.75 + \dots$ ), that is a 1 per cent increase in all input prices causes a 1 per cent increase in the industry basic price.

The second feature of the input price term requiring discussion is the treatment of other costs. For other costs, the coefficient in  $E_z$  is a quantity, not a value. As explained in subsection 20.3 in our discussion of  $E_{x1oct}$  and  $E_{del\_p1oct}$ , the price of other costs is represented in the TABLO version of MONASH as a change,

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<sup>23</sup> The power of a tax is one plus the tax rate. We use the power rather than the rate as our production tax variable to avoid difficulties in the percentage-change representation of our model. Unlike the rate, the power cannot be zero.

not a percentage change. Thus,  $100 \cdot \text{ROTHCOST}(j) \cdot \text{del\_p1oct}(j)$  is one hundred times the product of a quantity and a change in a price. It is, therefore, similar to the other price terms on the RHS of  $E\_z$ : it is equivalent to the product of a value and a percentage change in a price.

In interpreting the production tax term on the RHS of  $E\_z$  it is helpful to consider two examples. First, assume that the power of the production tax is one, that is the rate is zero. Then a 1 per cent increase in the power is equivalent to the imposition of a one per cent production tax. This would raise the industry basic price by 1 per cent. Consistent with this, we see that when  $\text{POW\_TAX0}(j)$  is one, the coefficient on  $\text{powtax0}(j)$  is also one. Now assume that the power of the production tax is 1.25, implying that production taxes represent 25 per cent of costs. A 1 per cent increase in the power raises the rate by 5 per cent ( $= 100 \times 0.0125 / 0.25$ ), increasing the collection of production taxes per unit of output by 5 per cent. This initially increases the industry basic price by  $0.25 \times 5$  per cent. But this causes a further increase in the collection of production taxes of  $0.25 \times 5$  per cent generating a further increase in the industry basic price of  $0.25 \times 0.25 \times 5$  per cent. The eventual increase in the industry basic price is 1.67 per cent ( $= 0.25 \times 5 + 0.25^2 \times 5 + \dots$ ). Consistent with this, we see on the RHS of  $E\_z$  that when  $\text{POW\_TAX0}(j)$  is 1.25, the coefficient on  $\text{powtax0}(j)$  is 1.67.

In  $E\_a\_JP$  and  $E\_a\_UP$  we define  $a(j)$  for joint-product ( $j \in \text{IND\_JP}$ ) and unique-product ( $j \in \text{IND\_UP}$ ) industries as an aggregation of all the different types of technical change which affect  $j$ 's unit costs. On the RHSs of these equations, the different types of technical changes appear with weights reflecting their influence on  $j$ 's unit costs.

The first technical change variable on the RHSs of  $E\_a\_JP$  and  $E\_a\_UP$  is  $a0\text{ind}(j)$ . As explained in subsection 20.2 in our discussions of  $E\_x0\text{ccom}$  and  $E\_x0\text{dom\_UP}$ , if  $a0\text{ind}(j) = -10$ , then industry  $j$  can expand its output of all commodities by 10 per cent with no change in its use of inputs. This implies that industry  $j$  can reduce the costs of its inputs per unit of output by 10 per cent. With the costs of its inputs per unit of output falling by 10 per cent, the cost of its production taxes per unit of output also falls by 10 per cent. Consequently,  $a0\text{ind}(j)$  appears on the RHSs of  $E\_a\_JP$  and  $E\_a\_UP$  with a weight of one. Similarly,  $a1(j)$  appears on the RHSs of the two equations with a weight of one. As is apparent from our discussions in subsection 20.3 and 20.4 of the input-demand equations, if  $a1(j)$  is set at -10, then industry  $j$  can reduce its use of all inputs by 10 per cent without changing its outputs of any commodity. Thus, the industry can reduce its input costs and production taxes per unit of output by 10 per cent.

The next technical change variable on the RHS of  $E\_a\_JP$  is  $a0\text{ccom}(cc,j)$ . As discussed in subsection 20.2 in connection with  $E\_x0\text{ccom}$ , if  $a0\text{ccom}(cc,j)$  is set at -10, industry  $j$  can expand its output of composite commodity  $cc$  by 10 per cent with no change in its output of other composite commodities, or in the level of any of its inputs. Assume that composite commodity  $cc$  generates 50 per cent of  $j$ 's

revenue. Then at given input and commodity output prices,  $j$  can reduce its input costs per unit of output by 5 per cent. This leads to successive reductions in the industry's basic price and production taxes per unit of output until the industry's basic price has fallen by 5 per cent. Thus, on the RHS of  $E\_a\_JP$ , the coefficient on  $a0ccom(cc,j)$  is the share  $[H0CC(cc,j)]$ , calculated in subsection 18.5c] of  $j$ 's revenue accounted for by composite commodity  $cc$ . Because  $a0ccom(cc,j)$  is defined in subsection 18.6 only for  $j \in IND\_JP$ , it does not appear in  $E\_a\_UP$ .

In subsection 20.2 we saw that if  $a0com(i)$  is set at -10, then all industries can expand their outputs of commodity  $i$  by 10 per cent, with no change in their inputs or in their outputs of other commodities. Thus, on the RHS of both  $E\_a\_JP$  and  $E\_a\_UP$ , the coefficient on  $a0com(i)$  is the share  $[H0CI(i,j)]$ , calculated in subsection 18.5c] of industry  $j$ 's revenue accounted for by commodity  $i$ . On the RHS of  $E\_a\_JP$ , we find the coefficient  $H0CI(i,j)$  is also attached to the variable  $a0ci(i,j)$ . This variable is defined in subsection 18.6 only for  $j \in IND\_JP$ . Its effect on  $j$ 's production technology (and unit costs) is the same as that of  $a0com(i)$ .

If  $a1ci(i,j)$  is -1, then industry  $j$  can reduce its overall input of commodity  $i$  by 1 per cent without changing its outputs or other inputs (subsection 20.3,  $E\_x1csi$ ). Assuming that inputs of  $i$  are 20 per cent of  $j$ 's costs, then the initial impact is to reduce  $j$ 's basic price by 0.2 per cent. This will induce a reduction in production taxes. If production taxes are 30 per cent of costs, then the consequent reduction in  $j$ 's basic price will be  $0.3 \times 0.2$  per cent. With further rounds of tax/price reductions, the eventual fall in the industry's basic price is  $0.2/0.7$  ( $= 0.2 + 0.3 \times 0.2 + 0.3^2 \times 0.2 + \dots$ ). Consistent with this, the coefficient on  $a1ci(i,j)$  on the RHSs of both  $E\_a\_JP$  and  $E\_a\_UP$  is the share of  $i$  in  $j$ 's *input* costs, that is  $TPURCHVAL1(i,j)/\{COSTS(j) - TAX0(j)\}$  where:  $TPURCHVAL1(i,j)$  is  $j$ 's expenditure on domestic and imported good  $i$ , calculated in subsection 18.5d; and  $COSTS(j)-TAX0(j)$  is the total value of inputs to industry  $j$ .

No new issues are raised by any of the other "a" terms on the RHS of  $E\_a\_JP$  and  $E\_a\_UP$ . Consequently, we skip to the "fl" terms. These were discussed in subsection 20.3 in connection with  $E\_x1csi$ . There we explained that  $fl\_trans(j)$  and  $fl\_commun(j)$  are equivalent to technological changes which save imported good  $i$  for  $i$  in the single-commodity sets  $TRANSERV$  and  $COMMUNICAT$ . That is, setting  $fl\_trans(j)$  at -10 has the same effect on  $j$ 's production technology and unit costs as setting  $a1csi(i, imp, j)$  at -10 for  $i \in TRANSERV$ , and setting  $fl\_commun(j)$  at -10 has the same effect as setting  $a1csi(i, imp, j)$  at -10 for  $i \in COMMUNICAT$ . Thus, the coefficient attached to  $fl\_trans(j)$  on the RHSs of both  $E\_a\_JP$  and  $E\_a\_UP$  is the share of  $j$ 's input costs accounted for by the use of imported good  $i$ ,  $i \in TRANSERV$ . This is calculated as  $PURCHVAL1(i, imp, j)/\{COSTS(j) - TAX0(j)\}$  for  $i \in TRANSERV$ . Similarly, the coefficient attached to  $fl\_commun(j)$  is  $PURCHVAL1(i, imp, j)/\{COSTS(j) - TAX0(j)\}$  for  $i \in COMMUNICAT$ .

***E\_p0imp***

This equation imposes zero pure profits in importing. It is a percentage change version of the equation:

$$POIMP(i) = PM(i)*POWTAXM(i)/PHI . \quad (27.1)$$

On the LHS of (27.1) is the basic price of imported good *i*, i.e., the value of a unit of imported good *i* after clearing customs. The basic price can be interpreted as the revenue earned per unit by the importer. On the RHS is the unit cost to the importer. This consists of the foreign-currency payment [PM(*i*)] to the producer and transporter,<sup>24</sup> divided by the \$foreign/\$A exchange rate [PHI], and multiplied by the power of the tariff applying to imports of good *i* [POWTAXM(*i*)].

***E\_p0***

This equation brings the percentage changes in the basic prices [p0dom(*i*) and p0imp(*i*)] of domestic and imported goods into a single matrix variable, [p0(*i*,*s*)]. On checking the formula for SOURCEDOM(*s*) given in subsection 18.5a, we see that *E\_p0* implies that p0(*i*,*s*) is p0dom(*i*) if *s*=dom and p0imp(*i*) if *s*=imp. As will be apparent later in this section, the use of p0 shortens the presentation of the equations for purchasers' prices.

***E\_fpdm***

This equation defines the percentage change [fpdm(*i*)] in the ratio of the basic prices of domestic and imported good *i*. Results for fpdm(*i*) can be useful in interpreting simulations in which changes in the competitiveness of Australia's import-competing sector play a key role.

***E\_p1csi, E\_p2csi, E\_p3cs, E\_p5cs and E\_pe***

These equations impose zero pure profits in distributing commodities. They equate purchasers' prices to basic prices plus sales taxes and margins costs.

The first of the equations (*E\_p1csi*) can be represented in levels as:

$$P1CSI(i,s,j)*X1CSI(i,s,j) = P0(i,s)*X1CSI(i,s,j)*POWTAX1(i,s,j) \\ + \sum_{r \in MARGCOM} P0(r, dom)*A1MARG(i,s,j,r)*X1CSI(i,s,j), \\ i \in COM, s \in SOURCE \text{ and } j \in IND . \quad (27.2)$$

On the LHS of (27.2) is the amount paid by industry *j* for its intermediate inputs of good *i* from source *s*. This is the purchaser's price to industry *j* for intermediate inputs of (*i*,*s*) [P1CSI(*i*,*s*,*j*)] multiplied by the quantity of *j*'s intermediate inputs of (*i*,*s*) [X1CSI(*i*,*s*,*j*)]. The first term on the RHS is the basic value of *j*'s purchases of (*i*,*s*) [P0(*i*,*s*)\*X1CSI(*i*,*s*,*j*)] multiplied by the power of the sales tax (one plus the

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<sup>24</sup> PM(*i*) is the foreign-currency c.i.f. price.

rate) on these purchases [POWTAX1(i,s,j)]. The second term is a sum over  $r \in \text{MARGCOM}$  of margin costs. As we saw in (25.1), the quantity of  $r$  used to facilitate the intermediate input flow of (i,s) to industry  $j$  is  $\text{A1MARG}(i,s,j,r) * \text{X1CSI}(i,s,j)$ . This is converted into a cost by multiplying by the basic price of domestic commodity  $r$  [ $\text{P0}(r, \text{dom})$ ], reflecting our assumptions that there are no margins on margins and that all margin services are domestically produced.

A feature of (27.2) worth noting is that it implies that variations in purchasers' prices across intermediate users of (i,s) arise only from variations in sales-tax rates and in margin services per unit of sale [ $\text{A1MARG}(i,s,j,r)$ ]. We assume that the basic price (price received by the producer) is the same for all purchasers.

In deriving  $E\_p1csi$  from (27.2), we recognized that

$$\text{P1CSI}(i,s,j) * \text{X1CSI}(i,s,j) = \text{PURCHVAL1}(i,s,j), \quad (27.3)$$

$$\text{P0}(i,s) * \text{X1CSI}(i,s,j) * \text{POWTAX1}(i,s,j) = \text{BAS1}(i,s,j) + \text{TAX1}(i,s,j) \quad (27.4)$$

and

$$\text{P0}(r, \text{dom}) * \text{A1MARG}(i,s,j,r) * \text{X1CSI}(i,s,j) = \text{MAR1}(i,s,j,r). \quad (27.5)$$

These three equations can be assumed to hold in our initial input-output data. Equation (27.3) can be used to define the initial value of  $\text{P1CSI}$ , (27.4) can be used to define the initial value of  $\text{POWTAX1}$  and (27.5) can be used to define the initial value of  $\text{A1MARG}$ . The equations are preserved throughout any sequence of MONASH solutions via updates and formulas.

The theoretical underpinnings of  $E\_p2csi$ ,  $E\_p3cs$ ,  $E\_p5cs$  and  $E\_pe$  are similar to those of  $E\_p1csi$ . The only additional points worth making concern  $E\_pe$ . First, unlike  $E\_p1csi$ ,  $E\_p2csi$ ,  $E\_p3cs$  and  $E\_p5cs$ ,<sup>25</sup>  $E\_pe$  is concerned with purchasers' prices only for the domestic variety of good  $i$ . Only the domestic variety is exported. Second, the purchasers' prices of exports recognized in MONASH are \$A prices at Australian ports of exit, i.e., f.o.b. prices. The implications of using f.o.b. prices in our model are discussed in section 41.

## 28. Genuine and phantom indirect taxes (subsections 18.8k and 18.5b in the TABLO code)

This section is divided into two subsections. The first describes the equations in subsection 18.8k. These are concerned mainly with collections of genuine and phantom indirect taxes. The second subsection describes the formulas in subsection 18.5b used to eliminate phantom tax collections from the data input to a MONASH simulation for year  $t$ .

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<sup>25</sup> Notice that it is in these equations we receive the payoff from defining  $p0$ .

**28.1. Collections of indirect taxes, specification of indirect tax rates, and division of tax collections between genuine and phantom**

***E\_del\_tax1, E\_del\_tax2, ..., E\_del\_tax5 and E\_del\_tax0***

Sales tax revenue on any commodity flow or production tax revenue on the basic value of an industry's output can be written as

$$T = P * X * (\Pi - 1) \quad , \quad (28.1)$$

where

T is the tax revenue;

P is the basic price of the relevant commodity or industry output;

X is the quantity flow or output; and

$\Pi$  is the power (one plus the rate) of the tax applicable to the basic value of the flow or output.

From (28.1), we obtain

$$100 * \text{del}_T = T * (p + x) + (T + B) * \pi \quad (28.2)$$

where

$\text{del}_T$  is the change<sup>26</sup> in tax revenue;

B is the basic value of the flow, i.e.,  $B = P * X$ ; and

p, x and  $\pi$  are percentage changes in P, X and  $\Pi$ .

Equation (28.2) provides the underlying theory for  $E\_del\_tax1$  through  $E\_del\_tax5$  and  $E\_del\_tax0$ . For example, to derive  $E\_del\_tax1$ , we replace  $\text{del}_T$  in (28.2) with  $\text{del\_tax1}(i,s,j)$ ; T with  $\text{TAX1}(i,s,j)$ ; p with  $p0(i,s)$ ; x with  $x1\text{csi}(i,s,j)$ ; B with  $\text{BAS1}(i,s,j)$  and  $\pi$  with  $\text{powtax1}(i,s,j)$ .

***E\_powtax1, E\_powtax2, ..., E\_powtax5 and E\_powtax0***

Continuing to use simplified notation, we express  $\Pi$  as the product of two shift variables,  $\Pi_g$  and  $\Pi_{ph}$ :

$$\Pi = \Pi_g \Pi_{ph} \quad . \quad (28.3)$$

We then express each of these shift variables as a product of other shift variables,  $\Pi_{g,1} \dots \Pi_{g,n}$  and  $\Pi_{ph,1}, \dots, \Pi_{ph,m}$ . This leads to the percentage-change equation:

$$\pi = \sum_{q=1}^n \pi_{g,q} + \sum_{q=1}^m \pi_{ph,q} \quad . \quad (28.4)$$

With obvious translations in notation, (28.4) can be used to obtain the equations  $E\_powtax1$  through  $E\_powtax5$  and  $E\_powtax0$ .

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<sup>26</sup> Because taxes can be zero, we avoid percentage changes in tax collections.

In MONASH computations we use some of the shift variables (those with “g”) on the RHSs of  $E\_powtax1$  to  $E\_powtax5$  and  $E\_powtax0$  to cause movements in the genuine components of the powers of the taxes and some (those with “ph”) to cause movements in the phantom components. As mentioned in subsection 12.1, genuine taxes are those collected by the government and phantom taxes are a device for reconciling incompatible data items on prices and costs.

The first variable on the RHSs of  $E\_powtax1$ ,  $E\_powtax2$ ,  $E\_powtax3$  and  $E\_powtax5$  is  $powtaxgg(i,s)$ . This can be used to impose a uniform increase in the powers of the genuine taxes applying to all domestic sales of good  $(i,s)$ . To impose increases in the powers of these taxes which differ across domestic sales, we can use the variables  $fpowtax1gg(i,s)$ ,  $fpowtax2gg(i,s)$ ,  $fpowtax3g(i,s)$  and  $fpowtax5g(i,s)$ .

Exports are usually taxed (or subsidized) at quite different rates from domestic sales. Consequently, we have not included  $powtaxgg(i, dom)$  on the RHS of  $E\_powtax4$ . To allow for movements in the powers of the genuine taxes applying specifically to exports, we use  $powtax4g(i)$ .

In  $E\_powtax3$ , we have included two extra variables [ $powtax3vg(i)$  and  $fpowtax3gu$ ] for moving the powers of the genuine taxes on purchases by households. We found  $powtax3vg(i)$  to be useful in our historical simulation for 1987 to 1994 (section 5). For that simulation, we observed the change in the tax collection on sales of good  $i$  to households. To explain this observation, we needed to calculate endogenously in MONASH the percentage change in the power of the genuine tax applying uniformly to household purchases of domestic and imported good  $i$ . We did this by endogenizing  $powtax3vg(i)$ . We found  $fpowtax3gu$  to be useful in our simulation of the effects of reducing tariffs on motor vehicles (section 7). For that simulation we endogenized  $fpowtax3gu$ , allowing us to assume that lost tariff revenue is replaced by a uniform increase in the power of the tax applying to all consumer expenditures.

Following the terms for handling genuine movements in the powers of taxes, the RHS of each of the equations  $E\_powtax1$  through  $E\_powtax5$  and  $E\_powtax0$  contains terms for handling phantom movements. The variable  $powtax4sph(i)$  allows for a uniform phantom movement in the powers of the taxes applying to all sales (domestic and export) of domestically<sup>27</sup> produced good  $i$ . The variable  $powtaxphph(i,s)$  allows for a uniform phantom movement in the powers of the taxes applying to all domestic sales of good  $(i,s)$ , and the variables  $fpowtax1phph(i,s)$ ,  $fpowtax2phph(i,s)$ ,  $fpowtax3ph(i,s)$  and  $fpowtax5ph(i,s)$  allow for phantom movements which differ across domestic sales of  $(i,s)$ . To impose

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<sup>27</sup> The coefficient  $SOURCEDOM(s)$  eliminates  $powtax4sph(i)$  from the equations for the powers of taxes on imported goods.

phantom movements in the powers of taxes applying only to exports, we use  $\text{powtax4ph}(i)$ .

Readers will be able to think of other tax variables which could have been included on the RHSs of  $E_{\text{powtax1}}$  through  $E_{\text{powtax5}}$  and  $E_{\text{powtax0}}$ . For example, we could have included in  $E_{\text{powtax1}}$  through  $E_{\text{powtax5}}$  a variable called  $\text{powtaxg}_u$ . This would be a convenient vehicle for imposing a uniform increase in the powers of the taxes applying to all sales of all goods.

As already implied in our discussion of  $\text{powtax3vg}(i)$  and  $\text{fpowtax3gu}$ , the RHSs of  $E_{\text{powtax1}}$  through  $E_{\text{powtax5}}$  and  $E_{\text{powtax0}}$  have evolved largely through applications of MONASH. As another example of the influence of applications, we explain the origin of  $\text{powtax4sph}(i)$ , known as the spreading phantom.

In our historical simulation we had observations on movements over the period 1987 to 1994 in the f.o.b. prices of Australia's exports. For most of Australia's export commodities we reconciled these observations with cost data using endogenous phantom export tax variables. For some of these export commodities (those for which the exported product and the product sold domestically are very similar) we assumed that movements in the export price are reflected in movements in prices charged to domestic customers. For these commodities, we needed a phantom tax variable which would spread the information on export prices to the prices faced by domestic purchasers. To achieve the desired spreading effect, we added  $\text{powtax4sph}(i)$  to the model. Then, for example, by endogenizing  $\text{powtax4sph}(\text{iron ore})$ , we ensured in our historical simulation that the observed export price for iron ore was fully reflected in the simulated price of iron ore faced by Australian steel makers and other domestic iron ore users. For other export commodities, we judged that movements in prices on the domestic market are not closely related to movements in export prices. An example is fish. For this commodity, Australia's exports are predominantly crustaceans taken from tropical coastal waters, whereas Australia's consumption is predominantly soft fish taken from cold ocean waters. Because we considered that the observed movement in the export price for fish contains little or no information on the movements in the prices faced by domestic users, we endogenized  $\text{powtax4ph}(\text{fish})$ . By using this variable, we insulated the simulated movements in the prices paid by domestic purchasers of fish from the observed movement in the export price of fish.

***$E_{\text{del\_tax1g}}$ ,  $E_{\text{del\_tax1ph}}$ , ...,  $E_{\text{del\_tax5g}}$ ,  $E_{\text{del\_tax5ph}}$ ,  $E_{\text{del\_tax0g}}$  and  $E_{\text{del\_tax0ph}}$***

These equations split collections of sales and production taxes into genuine and phantom collections. In making the splits, we preserve the straightforward interpretation of genuine tax rates as the ratio of government collections of taxes to basic values of flows. Thus, in simplified notation, we assume that the genuine tax collection on each flow is given by:

$$T_g = \text{PX}(\Pi_g - 1) \quad (28.5)$$

where

$T_g$  is the genuine collection;

$\Pi_g$  is the power of the genuine tax; and

P and X are as already defined in (28.1).

Phantom collections ( $T_{ph}$ ) are then a residual from total collections (T):

$$T_{ph} = T - T_g . \quad (28.6)$$

From (28.5) and (28.6) we obtain

$$100 * del\_T_g = T_g * (p + x) + (T_g + B) * \pi_g, \quad (28.7)$$

and

$$del\_T_{ph} = del\_T - del\_T_g , \quad (28.8)$$

where

$del\_T_g$  and  $del\_T_{ph}$  are changes in genuine and phantom tax collections;

$\pi_g$  is the percentage change in  $\Pi_g$ ; and

the remaining notation is as defined in (28.2) and (28.5).

Equations (28.7) and (28.8) provide the underlying theory for the MONASH equations  $E\_del\_tax1g$ ,  $E\_del\_tax1ph$ , ...,  $E\_del\_tax5g$ ,  $E\_del\_tax5ph$ ,  $E\_del\_tax0g$  and  $E\_del\_tax0ph$ . For example, to derive  $E\_del\_tax1g$  and  $E\_del\_tax1ph$ , we replace  $del\_T_g$  in (28.7) and (28.8) by  $del\_tax1g(i,s,j)$ ;  $del\_T_{ph}$  by  $del\_tax1ph(i,s,j)$ ;  $del\_T$  by  $del\_tax1(i,s,j)$ ;  $T_g$  by  $TAX1G(i,s,j)$ ; B by  $BAS1(i,s,j)$ ; p by  $p0(i,s)$ ; x by  $x1csi(i,s,j)$ ; and  $\pi_g$  by  $powtaxgg(i,s) + fpowtax1gg(i,s)$ .

While (28.5) makes it clear that we have adopted the basic values of sales and output as the bases for genuine taxes, it is not yet clear what bases we are using for phantom taxes. This issue is worth investigating because in looking at MONASH results we will want to know, for example, how to interpret a 5 per cent increase in the power of the phantom tax on exports of iron ore. Does this indicate an incompatibility between our data on prices and unit costs which is 5 per cent of the basic price, 5 per cent of the unit cost or 5 per cent of something else?

Using our simplified notation, we find from (28.1), (28.3) (28.5) and (28.6), that

$$T_{ph} = P * X * \Pi_g * (\Pi_{ph} - 1) . \quad (28.9)$$

Thus, we can interpret  $\Pi_{ph}$  as the power of the tax applicable to the commodity or output flow valued at the basic price plus the genuine tax. Now assume, for example, that

$$powtax4sph(\text{iron ore}) + powtax4ph(\text{iron ore}) = 5 .$$

This should be interpreted as indicating an increase in the unexplained gap ( $T_{ph}$ ) between receipts from and costs of exporting iron ore, with the increase being 5 per cent of  $P * X * \Pi_g * \Pi_{ph}$ , i.e., 5 per cent of the f.o.b. value of iron ore exports less

the margin costs involved in transferring these exports from Australian producers to ports of exit.

***E\_del\_taxm***

This equation specifies the change [del\_taxm(i)] in the collection of tariff revenue on the imports of good i. It is derived from the equation:

$$\text{TARIFF}(i) = [\text{PM}(i)/\text{PHI}] * \text{XOIMP}(i) * [\text{POWTAXM}(i) - 1] \quad , \quad (28.10)$$

where

TARIFF(i) is the level of tariff revenue on imports of i;

PM(i) is the c.i.f. price of imported good i in foreign-currency;

PHI is the exchange rate (\$foreign per \$A);

XOIMP(i) is the quantity of imports of i; and

POWTAXM(i) is the power of the tariff applying to the c.i.f price of imported good i.

The coefficients IMPORTS(i) and TARIFF(i) on the RHS of E\_del\_taxm are computed in subsection 18.5f.

***E\_powtaxm, E\_powtaxmo and E\_ft2***

These equations allow various treatments of import tariffs. With powtaxmo(i) set exogenously on zero for all  $i \in \text{COM}$ , we can use fpowtaxm(i) and ffpowtaxm in E\_powtaxm to impose either non-uniform or uniform percentage changes in the powers of tariffs. Another possibility is to impose non-uniform or uniform percentage changes in the rates of tariffs. This can be done via ft2(i) or t2\_star in E\_ft2. For example, assume that we want to simulate the effects of a 60 per cent increase in the tariff rate on imported cars. Then in E\_ft2 we set ft2(cars) = 60 and t2\_star = 0. With fpowtaxmo(cars) set at zero, E\_powtaxmo implies that

$$\text{powtaxmo}(\text{cars}) = \left[ \frac{\text{LEV\_PTAXM}(\text{cars}) - 1.0}{\text{LEV\_PTAXM}(\text{cars})} \right] * 60 \quad . \quad (28.11)$$

From subsections 18.3, 18.4 and 18.7, we see that the coefficient LEV\_PTAXM(i): is the level of the power of the tariff on imports of good i; is read from a data file; and is updated by the percentage movement, powtaxm(i), in the power of the tariff on i. If the tariff on cars is initially 50 per cent, [i.e., LEV\_PTAXM(cars) = 1.5], then (28.11) gives powtaxmo(cars) a value of 20. With fpowtaxm(i) and ffpowtaxm in E\_powtaxm set at zero, the result for powtaxm(cars) is also 20. This correctly reflects the 60 per cent increase in the rate of the tariff which takes the power of the tariff from 1.5 to 1.8, an increase of 20 per cent.

Readers may wonder why we bother with powtaxmo(i). Why not eliminate it by substituting the RHS of E\_powtaxmo into E\_powtaxm? As will be discussed in section 32, variables such as powtaxmo(i) and equations such as E\_powtaxmo are useful in transferring results from forecasting simulations into deviation or policy simulations.

***E\_taxrev1, E\_taxrev1g, ..., E\_taxrevm and E\_taxindg***

These equations specify various tax aggregates. The RHSs are additions of changes in tax collections specified earlier in subsection 18.8k. For export taxes, taxes on government demands and production taxes, the LHS variable is the change in total collections. These collections may be zero or negative. For the remaining taxes, we can be confident that total collections will be positive. Consequently, we work with percentage changes. With two exceptions, all the coefficients appearing in these equations are calculated in subsection 18.5g: AGGTAXM is calculated in subsection 18.5f and TAX3G(i,s) is read in subsection 18.4 and updated in subsection 18.7.

Not all possible aggregate collections are defined. Those included in the current version of MONASH have been useful in applications. Further definitions of aggregate tax collections can be added to the model as required.

***28.2. Eliminating phantom tax flows from the input-output database***

As explained in section 12 (see particularly Figure 12.3), MONASH simulations for year  $t$  normally start with a picture of the economy generated by a MONASH simulation for an earlier year, usually  $t-1$ . MONASH simulations for the earlier year may generate non-zero entries in the phantom tax matrices, TAX1F to TAX5F and TAX0F.<sup>28</sup>

In conducting a simulation for year  $t$ , we like to work from a realistic picture of the economy. Because phantom taxes are not a real world phenomenon, we usually eliminate them from the data input to our year  $t$  simulation. A phantom-free starting point is particularly desirable if our primary interest is welfare effects. These depend critically on tax wedges and other distortions in the initial situation. Consequently, in welfare-oriented studies we should avoid, as far as possible, purely artificial tax wedges in the initial database.

In the TABLO version of MONASH, phantoms can be eliminated from the data input to a year- $t$  simulation via the formulas in subsection 18.5b. With DUMF set at zero, these formulas eliminate the phantom tax matrices. Eliminating TAX2F to TAX5F causes no balancing problems, but eliminating TAX1F and TAX0F upsets the balance between the value of inputs to industry  $j$  and the basic value of  $j$ 's output. Balance is restored by resetting other costs in industry  $j$  [OTHCOST( $j$ )] to equal the difference between the basic value of  $j$ 's output [ $\Sigma_i$ MAKE( $i,j$ )] and the costs of  $j$ 's inputs excluding phantom taxes.

All of the formulas in subsection 18.5b include the parenthetic instruction, Initial. Hence, in a multi-step simulation for year  $t$ , these formulas alter the input-output database only at the beginning of the first step. This means, first, that in a simulation for year  $t$ , we compute deviations from a phantom-free picture of the

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<sup>28</sup> In the current implementation of MONASH there are no taxes on inventory accumulation. TAX6, TAX6F and TAX6G do not appear in the model.

economy, usually for year  $t-1$ , and second, that during a simulation for year  $t$ , we let phantom taxes accumulate from step to step according to the update statements for TAX1F to TAX5F and TAX0F given in subsection 18.7. Consequently, our preliminary alteration of the data input to a year  $t$  simulation does not cause any theoretical inconsistencies within the year- $t$  simulation.

On the other hand, we do not avoid inter-temporal inconsistencies: we will not, in general, find that

$$\text{Flow}(t) = \text{Flow}(t-n) \prod_{i=1}^n [1 + p(t-n+i)/100][1 + x(t-n+i)/100] , \quad (28.12)$$

where

$\text{Flow}(\tau)$  is the value of an input-output flow in the final solution for year  $\tau$ ; and

$p(\tau)$  and  $x(\tau)$  are the percentage changes in the relevant price and quantity variables computed in the year- $\tau$  simulation.

Because of these inconsistencies, we are faced with a choice of how to report MONASH results for a period of more than one year. We have usually chosen to ignore the flow results and to report the percentage changes in prices and quantities for the period  $t-n$  to  $t$  as

$$p(t-n, t) = 100 \left\{ \prod_{i=1}^n [1 + p(t-n+i)/100] - 1 \right\} \quad (28.13)$$

and

$$x(t-n, t) = 100 \left\{ \prod_{i=1}^n [1 + x(t-n+i)/100] - 1 \right\} . \quad (28.14)$$

In using MONASH we have not found inter-temporal inconsistencies caused by elimination of phantom taxes to be an important practical problem. It is mainly in historical simulations involving the use of considerable cost and price data that phantom taxes become substantial. However, historical simulations are usually conducted as a multi-step simulation for a single year (e.g., a simulation for 1994 using 1987 input-output data to provide an initial solution). In a single-year calculation, adjustment of the initial input-output data does not cause inter-temporal inconsistencies.

Forecasting simulations sometimes produce substantial phantom taxes for exports. This can happen when we use extraneous forecasts for export prices and quantities. Even though in forecasting we usually decide to eliminate phantom taxes from the base data for each year ( $\text{DUMF} = 0$ ), it is useful to keep track of the phantom export taxes generated within each year. This is done by the first formula in subsection 18.5b. In the year  $t$  computation of a year-on-year forecasting

simulation, this formula calculates the aggregate phantom taxes on exports (AGGTAX4F) generated in the computation for year t-1. As we will see in section 35, AGGTAX4F is often used in adjusting the initial value of the current account deficit used in the computation for year one and in calculating the change in the current account deficit (d\_cad) from year to year.

The method adopted in subsection 18.5b is not the only intuitively plausible approach to eliminating phantom taxes from a MONASH input-output database. For example, we have experimented with several methods involving the allocation of the contents of TAX1F, ..., TAX5F to the basic value flows in BAS1 to BAS5. Alteration of the BAS matrices upsets the balance between the basic value of the sales of domestic commodity i and the value of the output of i implied by the MAKE matrix. To restore balance, we revised the MAKE matrix, thereby upsetting the balances between the output of industries and the values of their inputs. To eliminate these imbalances, we altered the OTHCOST(j)s. However, we found in multi-year simulations that the OTHCOST(j)s for some industries became substantial shares of total costs. Unlike the method adopted in subsection 18.5b where phantom taxes on final demands are simply thrown away, in this alternative method phantom taxes on final demands are absorbed eventually in other costs. Because other costs in MONASH act in much the same way as production taxes, artificially high other cost shares in the database for year t reduce the reliability of welfare calculations.

Another approach which we tried involved interpreting the phantom taxes as returns to capital. Instead of spreading the phantoms on good i across basic value flows of i, we allocated them to the profits of the producers of commodity i. However, this approach often gave us an input-output database with unrealistic values for the ratios of the returns to capital and labour,

$$[\text{CAPITAL}(j)/\text{LABIND\_J}(j)], \quad j \in \text{IND}].$$

In the end, we chose the method in subsection 18.5b. This has no clear theoretical superiority over various other methods. Its advantage is purely practical. In numerous applications of MONASH, it has not caused difficulties.

### **29. Definitions of macro variables (subsection 18.8l in the TABLO code)**

The equations in subsection 18.8l define various macro variables, all of which we have found useful in MONASH simulations. Future users of the model, with different applications from our own, may add other macro variables. Thus, as MONASH matures, we expect the list of macro-defining equations to grow.

The equations in the present list define: expenditure components of GDP and related price indexes; income components of GDP; miscellaneous trade variables; miscellaneous factor-market variables; and useful ratios of national-accounts aggregates. Many of these variables are Divisia indexes. In section 43 we discuss the theory of Divisia indexes. Among other things we present their levels form and show that they can be interpreted as averages of Laspeyres (initial weight) and

Paasche (final weight) indexes. We also discuss path dependency. This was encountered several times in section 7 in our interpretation of results for Divisia indexes such as real GDP and the aggregate capital stock.

*E\_c, E\_phi; E\_in, E\_xi2, E\_r\_inv\_cap\_u; E\_othnom, E\_xi5, E\_f5gen, E\_expvald, E\_xi4, E\_expvol, E\_impvald, E\_xim and E\_impvol*

These equations specify percentage movements in nominal expenditure aggregates, price indexes and real expenditure aggregates. They are derived from levels equations of the form

$$R = \sum_k P_k Q_k \quad (29.1)$$

where

R is a nominal expenditure aggregate (household expenditure, investment, public expenditure, exports and imports); and

$P_k$  and  $Q_k$  are the purchasers' price and quantity of item (e.g., commodity) k within the aggregate category.

From (29.1) we can obtain the deviation forms given in  $E_c, \dots, E_{impvol}$ :

$$r = p + q \quad (29.2)$$

$$(\sum_k V_k) * p = \sum_k V_k * p_k \quad (29.3)$$

and

$$(\sum_k V_k) * q = \sum_k V_k * q_k \quad (29.4)$$

where

r,  $p_k$  and  $q_k$  are the percentage changes in R,  $P_k$  and  $Q_k$ ;

$V_k$  is value of k included in R; and

p and q are percentage changes in Divisia price and quantity indexes for the expenditure category under consideration.

For consumption, only two of the equations of the form (29.2)-(29.4) appear in the TABLO code. As discussed in section 22 [see (22.8)],  $E_{x3}$  implies that

$$c = \sum_i S3COM(i) * (p_i(3) + x3(i)) \quad (29.5)$$

Via (29.5),  $E_{p3}$ ,  $E_{x3cs}$ ,  $E_{phi}$  and  $E_c$ , we can derive the "missing" equation for cr:

$$AGGCON * cr = \sum_i \sum_s PURCHVAL3(i,s) * x3cs(i,s) \quad (29.6)$$

#### *E\_d\_xi6 and E\_d\_inventreal*

Now assume that R in (29.1) is the value of inventory accumulation,  $Q_k$  is the quantity of accumulation of inventories of commodity k and  $P_k$  is the price of inventories of commodity k. Where  $k = (i,s)$ , we assume that  $P_k$  is the basic price,  $POLEV(i,s)$ , of good i from source s. Because R and  $Q_k$  can be negative, we avoid percentage changes in these variables and write:

$$d_r = d_{xi6} + d_{inventreal} \quad , \quad (29.7)$$

where

$$d_{xi6} = (1/100) * \sum_k P_k Q_k * p_k \quad ; \quad (29.8)$$

$$d_{inventreal} = \sum_k P_k * d_{qk} \quad ; \quad (29.9)$$

and  $d_r$  and  $d_{qk}$  are changes in  $R$  and  $Q_k$ ; and  $p_k$  is the percentage change in  $P_k$ .

We interpret  $d_{xi6}$  as the effect on the value of inventory accumulation of changes in prices, and  $d_{inventreal}$  as the real value of inventory accumulation. In the TABLO code,  $d_{xi6}$  and  $d_{inventreal}$  are defined according to (29.8) and (29.9) in  $E_{d_{xi6}}$  and  $E_{d_{inventreal}}$ .

### ***E\_gne, E\_xigne and E\_gner***

The starting point for these three equations is

$$GNE = AGGCON + AGGINV + AGGOTH + INVENT \quad , \quad (29.10)$$

where

$GNE$  is gross national expenditure;

$AGGCON$  is nominal household consumption;

$AGGINV$  is nominal investment;

$AGGOTH$  is nominal public consumption; and

$INVENT$  is nominal inventory accumulation.

From (29.10) we obtain

$$GNE * gne = AGGCON * c + AGGINV * in + AGGOTH * othnom + 100 * d_r \quad (29.11)$$

where  $gne$ ,  $c$ ,  $in$  and  $othnom$  are percentage changes in nominal household consumption, nominal investment and nominal public consumption; and  $d_r$  is the change of the nominal value of inventory accumulation.

Then using  $E_c$ ,  $E_{in}$ ,  $E_{othnom}$  and (29.7), we establish  $E_{gne}$  with  $xigne$  and  $gner$  as defined in  $E_{xigne}$  and  $E_{gner}$ .

We interpret  $xigne$  as the percentage change in the price of  $GNE$ , i.e., the percentage effect on  $GNE$  of price changes, holding constant all quantities. Similarly,  $gner$  is the percentage change in real  $GNE$ , i.e., the percentage effect on  $GNE$  of changes in quantities, holding constant all prices.

### ***E\_gdpexp, E\_xigdp and E\_gdpreal***

The derivation of these three equations is similar to that of the previous three. We start from

$$\begin{aligned} GDPEX = AGGCON + AGGINV + AGGOTH + INVENT \\ + AGGEXP - AGGIMP \quad (29.12) \end{aligned}$$

where GDPEX is nominal GDP, AGGEXP is the f.o.b. value of exports, AGGIMP is the c.i.f. value of imports and the remaining notation is the same as that in (29.10). From (29.12) we obtain

$$\begin{aligned} \text{GDPEX} * \text{gdpexp} = & \text{AGGCON} * c + \text{AGGINV} * \text{in\_AGGOTH} * \text{othnom} + 100 * d\_r \\ & + \text{AGGEXP} * \text{expvald} - \text{AGGIMP} * \text{impvald} , \end{aligned} \quad (29.13)$$

where gdpexp, expvald and impvald are percentage changes in GDPEX, AGGEXP and AGGIMP, and c, in, othnom and d\_r are as in (29.11). Then using E\_c, E\_in, E\_othnom, (29.7), E\_expvald and E\_impvald, we establish E\_gdpexp with xigdp and gdpreal as defined in E\_xigdp and E\_gdpreal.

We interpret xigdp as the percentage change in the price of GDP, i.e., the percentage effect on GDP of price changes, holding constant all quantities. Similarly, gdpreal is the percentage change in real GDP, i.e., the percentage effect on GDP of changes in quantities, holding constant all prices.

*E\_labrev, E\_caprev, E\_lndrev, E\_octrev, E\_taxind, E\_gdpinc, E\_gdprealinc, E\_a\_gdp and E\_ave\_aprim*

The first five equations specify percentage changes in income components of GDP and the sixth adds them to generate the percentage change in the income measure of GDP.

A useful check on MONASH computations is that the percentage changes in GDP from the two sides of the national accounts should be equal, i.e., irrespective of the number of steps, Johansen/Euler computations should always give

$$\text{gdpinc} = \text{gdpexp} . \quad (29.14)$$

This is proved in section 42 and reflects the input-output identities discussed in subsection 12.1.

The seventh equation in the group defines movements in the income measure of real GDP in terms of: changes in technology (the "a" terms); changes in factor inputs (x1laboi, cap\_at\_t, n, and x1oct); and changes in numerous tax-carrying flows (x0imp, x0ind, x1csi, ...). In section 42 we show that:

$$\text{gdprealinc} = \text{gdpreal} , \quad (29.15)$$

that is we show that E\_gdprealinc correctly reflects the movement in real GDP defined in E\_gdpreal.

As illustrated in subsection 7.2(b), E\_gdprealinc provides a useful basis for explaining results for real GDP. It allowed us to decompose the deviations in real GDP induced by a reduction in motor vehicle tariffs into the parts attributable to changes in rates of technical progress, changes in factor inputs and changes in tax-carrying flows. We have found decompositions based on the income measure of real GDP to be more informative than the more usual decompositions based on the expenditure measure of real GDP. Saying, for example, that real GDP increased because real consumption increased is not very helpful. It immediately raises the

issue of why real consumption increased, and if the answer to that question is that real GDP increased then we quickly flounder in circular arguments. Put another way, we have found that income-side explanations of real GDP growth lead us much more quickly to the exogenous factors behind our results than do expenditure-side explanations. For example, in a simulation of the effects of a technological improvement, we can calculate the direct effect (exogenous) on GDP plus indirect effects (endogenous) from the induced change in inputs of capital and labour. We usually find that it is straightforward to explain these indirect effects in terms of our labour-market assumptions (e.g. sticky real wages in the short run and fixed labour supply in the long run) and our capital-market assumptions (e.g. sluggish capital change in the short run and fixed rates of return in the long run).

The final two equations in this group are concerned with technical change.  $E\_a\_gdp$  defines the contribution of changes in technology to growth in real GDP as the technology terms appearing on the RHS of  $E\_gdprealinc$ .  $E\_ave\_aprim$  defines the average rate of primary-factor-saving technical change across industries. The variables ( $a\_gdp$  and  $ave\_aprim$ ) defined by these equations are useful in analyzing results.

***$E\_del\_b$ ,  $E\_del\_bt\_gdp$ ,  $E\_realdev$ ,  $E\_toft$ ,  $E\_ximp0$ ,  $E\_expvalf$ ,  $E\_tradexpvalf$ ,  $E\_ntradexpvalf$  and  $E\_impvalf$***

These nine equations specify percentage movements in miscellaneous trade-related macro variables.

The first equation in the group is derived from the levels form

$$1000*B = AGGEXP - AGGIMP , \quad (29.16)$$

where  $B$  is the balance of trade measured in billions of domestic dollars; and  $AGGEXP$  and  $AGGIMP$  are aggregate exports (f.o.b.) and imports (c.i.f.) measured in millions of domestic dollars. From (29.16) we obtain

$$1000*del\_b = (1/100) [AGGEXP*expvald - AGGIMP*impvald]$$

which quickly gives  $E\_del\_b$ .

The levels form for the second equation in the group is

$$BT\_GDP = 100,000*B/GDPEX \quad (29.17)$$

where  $BT\_GDP$  is the balance of trade expressed as a percentage of GDP;

$GDPEX$  is gross domestic product in millions of dollars; and

$B$  is, as before, the balance of trade in billions of dollars.

From (29.17), we obtain

$$del\_bt\_gdp = 100,000*del\_b/GDPEX - 1,000*(B/GDPEX)*gdpexp. \quad (29.18)$$

Substitution of (29.16) into (29.18) gives  $E\_del\_bt\_gdp$ .

The third equation defines the percentage real devaluation. This is normally measured by

$$realdev = inf\_f - phi - inf\_d , \quad (29.19)$$

where

inf\_f is the percentage increase in prices in foreign countries;

phi is the percentage appreciation in the nominal exchange rate; and

inf\_d is the percentage increase in prices in the domestic economy.

In E\_realdev, we measure domestic inflation by the percentage change in the GDP deflator (xigdp), and we assume that foreign inflation is reflected in the foreign currency price of imports, implying that inf\_f - phi is the percentage change in the c.i.f. domestic price of imports (xim).

The fourth equation in the group, E\_toft, defines the percentage change in the terms of trade as the difference between the percentage changes in the f.o.b. price index for exports and the c.i.f. price index for imports.

The fifth equation, E\_ximp0, defines an index for the landed-duty-paid prices of imports. Comparison of results for ximp0 defined in this equation with those for the GDP deflator (xigdp) provides a useful indication of changes in the competitive position of imports in the domestic economy. This can be important in explaining simulated shifts in the ratio of imports to GDP.

The final four equations in the group define the percentage changes in the f.o.b. foreign currency values of exports, tradition exports (agriculture and mining) and non-traditional exports (manufacturing), and the percentage change in the c.i.f. value of imports.

*E\_real\_wage\_c, E\_real\_wage\_e, E\_real\_wage\_e2, E\_xifac, E\_emp\_c\_wgts, E\_fwage, E\_k\_r\_wgts, E\_k\_a\_wgts and E\_lndr.*

These equations define nine factor-market variables. The first equation defines the percentage movement [real\_wage\_c] in the economy-wide real wage rate from the view point of consumers. This is a CPI-deflated weighted average of the percentage movements in occupation/industry wage rates excluding payroll taxes. Movements in the consumer real wage rate are often important in Australia in union/employer/government wage negotiations.

The next two equations define percentage movements [real\_wage\_e and real\_wage\_e2] in two measures of the real wage rate from the point of view of employers. Movements in employer real wage rates are critical determinants in many MONASH simulations of the outcome for employment. The first measure is the economy-wide nominal unit labour cost divided by the GDP deflator (defined earlier in E\_xigdp). In the second measure, the divisor is the deflator for primary factors. Percentage changes [xifac] in this deflator are defined in E\_xifac (the fourth equation in the group) as a weighted average of the percentage movements in the overall prices of labour, capital and land. The percentage changes in these overall prices are defined as differences between the movements in total costs of factors and total quantities of factors.

The next two variables [emp\_c\_wgts and emp\_hours] defined in this group of equations are the percentage changes in measures of aggregate labour input. The first is a weighted average of the percentage changes in the labour inputs of industries [labind(j)], with the weights being industry shares [LABIND\_J(j)/AGGLAB] in aggregate labour costs. The second is a weighted average of the percentage changes in inputs of hours by occupation and industry [x1laboi(m,j)], with the weights being shares [HOURS(m,j)/HOURSTOT] in aggregate labour hours.

In most MONASH simulations, emp\_c\_wgts is the appropriate employment measure to use in calculations of the percentage-point contribution of changes in employment to the percentage change in GDP. The first step in explaining this is to note from E\_x1laboi in subsection 18.8c [or from the version presented in simplified notation in (39.11) and (39.18)] that

$$\text{labind}(j) = \sum_m [\text{LABOCCIND}(m,j)/\text{LABIND\_J}(j)] * x1laboi(m,j), \quad (29.20)$$

where LABOCCIND(m,j) is the cost of labour of occupation m to industry j. By substituting from (29.20) into E\_emp\_c\_wgts, we obtain

$$\text{AGGLAB} * \text{emp\_c\_wgts} = \sum_j \sum_m \text{LABOCCIND}(m,j) * x1laboi(m,j) . \quad (29.21)$$

The RHS of (29.21) is the employment term in the income-side definition of the percentage change in real GDP, see E\_gdprealinc. Holding constant all the other terms on the RHS of E\_gdprealinc, we see that the employment contribution to GDP growth is given by

$$\% \text{point employment contribution} = \frac{\text{AGGLAB}}{\text{GDPIN}} * \text{emp\_c\_wgts} , \quad (29.22)$$

where GDPIN is the income-side measure of GDP. Thus for example, if the labour share in GDP is 0.6 and emp\_c\_wgts is 5, then we say that employment growth contributed 3 percentage points to the growth in GDP.

As will be apparent in sections 33 and 32, we use the second measure of aggregate labour input, emp\_hours, in computing changes in unemployment and changes in wage-demand pressures.

The last three equations in this group provide rental-weighted measures of percentage changes in aggregate capital and land usage (k\_r\_wgts and lndr) together with an asset-weighted measure for capital (k\_a\_wgts). As can be seen by comparing the RHSs of E\_k\_r\_wgts and E\_lndr with the capital and land terms on the RHS of E\_gdprealinc, the rental-weighted measures can be used in calculations of the percentage-point contributions of growth in capital and land to growth in real GDP.

As we saw in subsection 5.3(d), the asset-weighted measure of the percentage change in aggregate capital (k\_a\_wgts) is sometimes helpful in understanding the relationships between capital growth, investment growth and net foreign liabilities. If, for example, a simulation shows rapid expansion in mining capital which has a

high ratio of rental to asset value, then compared with  $k\_a\_wgt$ s, the use of  $k\_r\_wgt$ s in back-of-the-envelope calculations will lead us to overestimate investment expenditure and requirements for foreign borrowing.

***$E\_othreal$ ,  $E\_r\_cr\_gner$ ,  $E\_ir$ ,  $E\_r\_othr\_gner$ ,  $E\_r\_cr\_ir$ ,  $E\_r\_c\_inc$  and  $E\_r\_c\_gdpinc$***

These equations define various useful ratios which can play either active (exogenous) or passive (endogenous) roles. For example, we might set  $r\_c\_inc$  exogenously at zero, thereby forcing consumption to move by the same percentage as factor income. Alternatively, consumption might be determined elsewhere in our model, with  $r\_c\_inc$  merely telling us the implication for the ratio of consumption to factor income.

### ***30. Capital stocks, investment and rates of return***

MONASH allows for two broad treatments of capital and investment. The first, involving direct assumptions about movements in rates of return and investment/capital ratios, is suitable for long-run comparative-static simulations. In such simulations, we are concerned with the effects of a policy or other shock after considerable time, say 7 years. In these circumstances, MONASH allows us to assume directly that the shock under examination does not affect rates of return. Thus, we assume that industries favoured by the shock attract capital until their rates of return are driven down to their initial (basecase forecast) levels and that industries for which the shock is unfavourable lose capital until their rates of return increase to their initial levels. Having, in this way, tied down the long-run effect of the shock on capital stocks, we can tie down the effect on investment by industry by assuming no change in investment/capital ratios. Thus, we assume that if the shock applied in year  $t$  causes capital in industry  $j$  in year  $t+7$  to be 20 per cent greater than it otherwise would have been, then it also causes investment in industry  $j$  in year  $t+7$  to be increased by 20 per cent.

Several variations on this basic long-run comparative-static treatment of capital and investment are available. For example, we might wish to assume that the shock under investigation has no long-run effect on aggregate capital and investment. In this case, the MONASH equations allow for uniform shifts across industries in rates of return and investment/capital ratios. Another variation, which is useful in historical analyses, makes the movement in an industry's rate of return over an historical period (say, 7 years) depend on: (a) its simulated rate of capital growth over the period; (b) its rate of return at the beginning of the period; and (c) the sector to which the industry belongs. This specification allows MONASH to generate rate-of-return movements compatible with sectoral data on the prices of value added. With movements in rates of return tied down, capital growth by industry can be determined. To accommodate sectoral data on capital and investment growth, MONASH allows uniform within-sector twists in the

capital/labour-using technologies of industries and uniform within-sector shifts in industry investment/capital ratios.

As described in subsection 2.1(a), the second broad treatment of capital and investment in MONASH involves explicit capital supply functions, and is used in year-to-year simulations, i.e., simulations tracing out the paths of variables for years  $t$ ,  $t+1$ ,  $t+2$ , etc. While the directly imposed assumption of no change in rates of return may be suitable for long-run analysis, it is unrealistic to assume that movements in an industry's rate of return are eliminated by year-to-year movements in the industry's capital stock. In each year of year-to-year simulations, we assume that industries' capital growth rates (and thus investment) are determined according to functions which specify that investors are willing to supply increased funds to industry  $j$  in response to increases in  $j$ 's expected rate of return. However, investors are cautious. In any year, the capital supply functions in MONASH limit the growth in industry  $j$ 's capital stock so that disturbances in  $j$ 's rate of return are eliminated only gradually.

The rest of this section is organized in two subsections. Subsection 30.1 describes the relationships in MONASH between capital and investment, and between rates of capital growth and expected rates of return. Subsection 30.2 is concerned with actual and expected rates of return. It includes a description of our strategy for obtaining MONASH solutions with forward-looking expectations.<sup>29</sup> Further details of this strategy are in an appendix (section 44).

**30.1. Capital stocks, investment and the inverse-logistic relationship  
(subsection 18.8m in the TABLO code)**

***E\_cap\_at\_tplus1***

We assume that

$$K_{t+1} = (1 - D) * K + I \quad (30.1)$$

where

$K$  is the capital stock at the beginning of year  $t$ ;

$K_{t+1}$  is the capital stock at the end of year  $t$ ;

$I$  is investment during year  $t$ ; and

$D$  is a parameter giving the rate of depreciation.

In change form, (30.1) can be written as

$$K_{t+1} * k_{t+1} = (1 - D) * K * k + I * y \quad (30.2)$$

where  $k_{t+1}$ ,  $k$  and  $y$  are percentage deviations in the values of  $K_{t+1}$ ,  $K$  and  $I$  from their values in the initial solution for year  $t$ . *E\_cap\_at\_tplus1* can be obtained from

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<sup>29</sup> Alternative names for forward-looking expectations are rational expectations and model-consistent expectations.

(30.2) by adding industry identifiers  $j$ , by making obvious notational conversions and by including the coefficient, TINY which prevents indeterminacy problems that arise if  $QCAPATTPLUS1(j)$  is zero.

The coefficients  $QCAPATT(j)$ ,  $QCAPATTPLUS1(j)$  and  $QINVEST(j)$  appearing in  $E\_cap\_at\_tplus1$  are evaluated in subsection 18.5q.  $QCAPATT(j)$  and  $QINVEST(j)$  are both evaluated from values and prices. This approach is convenient because, as we will see in section 34, MONASH needs these values and prices in calculations of Australia's foreign liabilities.  $QCAPATTPLUS1(j)$  is evaluated from  $QCAPATT(j)$  and  $QINVEST(j)$  according to (30.1).

### ***E\_del\_f\_ac\_p\_y***

In most MONASH simulations, the initial solution for year  $t$  is the final solution for year  $t-1$ . In these simulations, the initial solution for an industry's opening capital stock is the opening capital stock in the previous year. In the year  $t$  computation, the percentage deviation ( $k$ ) that should then be imposed on the opening capital stock ( $K$ ) is given by

$$k = 100*(KBASE_{+1} - KBASE)/KBASE \quad (30.3)$$

or equivalently by

$$k = 100*(IBASE - D*KBASE)/KBASE \quad , \quad (30.4)$$

where

$KBASE$ ,  $KBASE_{+1}$  and  $IBASE$  are the initial solutions for  $K$ ,  $K_{+1}$  and  $I$ , i.e.,  $KBASE$  and  $KBASE_{+1}$  are the opening and closing capital stocks in year  $t-1$ , and  $IBASE$  is investment in year  $t-1$ .

In making the year  $t$  computation, we could treat  $k$  as an exogenous variable and compute its value outside the model in accordance with (30.3) or (30.4). It is more convenient, however, to compute  $k$  inside the model. As we show below, this can be done via  $E\_del\_f\_ac\_p\_y$ .

Consider the equation

$$K - KBASE = (IBASE - D*KBASE)*UNITY + F \quad (30.5)$$

where  $K$ ,  $UNITY$  and  $F$  are variables and  $KBASE$ ,  $IBASE$  and  $D$  are parameters. In our initial solution for year  $t$ ,  $K$  equals  $KBASE$ ,  $UNITY$  is zero and  $F$  is zero. Thus, the initial solution satisfies (30.5). By keeping  $F$  on zero and moving  $UNITY$  to one, we cause the correct deviation [namely  $IBASE - D*KBASE$ ] in the opening capital stock for year  $t$  from its value in our initial solution. Hence, we can impose (30.3) or (30.4) by including in our model a change form of (30.5),

$$K*k = 100*(IBASE - D*KBASE)*del\_unity + 100*del\_f \quad , \quad (30.6)$$

and by setting  $del\_unity$  and  $del\_f$  at one and zero.  $E\_del\_f\_ac\_p\_y$  is (30.6) written in more elaborate notation.

In some computations, e.g., historical and long-run comparative static simulations, the initial solution for year  $t$  is not the final solution for year  $t-1$ . Instead it might be the final solution for year  $t-7$ . In these cases, the deviation in an industry's opening capital stock in year  $t$  from its value in the initial solution is not given by  $IBASE-D*KBASE$ , and consequently  $E\_del\_f\_ac\_p\_y$  must be turned off by endogenization of  $del\_f\_ac\_p\_y(j)$ . MONASH must then generate  $k$  (now the percentage growth in capital from the beginning of  $t-7$ , say, to the beginning of  $t$ ) either via observations of capital growth or via assumptions concerning rates of return (see the discussion below of  $E\_del\_ror\_se$  and  $E\_del\_f\_rate$ ).

### ***E\_y***

If we set  $r\_inv\_cap\_u$  exogenously at zero, then this equation can be used to compute percentage changes  $[r\_inv\_cap(j)]$  in investment/capital ratios. Alternatively, we could set the  $r\_inv\_cap(j)$ s exogenously at zero, and use  $E_y$  to force equality across industries in the percentage changes in their I/K ratios. The assumption of equal percentage movements in I/K ratios gives a simple specification of investment determination and is sometimes used in long-run comparative static simulations.

### ***E\_del\_k\_gr***

In simplified notation, the levels form of this equation is

$$K\_GR = (K_+/K - 1) \quad (30.7)$$

where

$K\_GR$  is the proportionate growth in an industry's capital stock between the beginning and end of the year, and

$K_+$  and  $K$  are the opening and closing levels of capital.

### ***E\_d\_eeqror, E\_d\_f\_eeqror\_j, E\_d\_diseq and E\_d\_f\_diseqre***

In simplified notation, the theory underlying these equations starts with

$$EROR_j = EEQROR_j + DIS_j \quad (30.8)$$

where

$EROR_j$  is the expected rate of return<sup>30</sup> in year  $t$  to owners of industry  $j$ 's capital;

$EEQROR_j$  is the equilibrium expected rate of return, i.e., the expected rate of return required to sustain indefinitely the current rate of capital growth in industry  $j$ ; and

$DIS_j$  is a measure of the disequilibrium in  $j$ 's current expected rate of return.

$E\_d\_eeqror$  is the TABLO change version of (30.8).

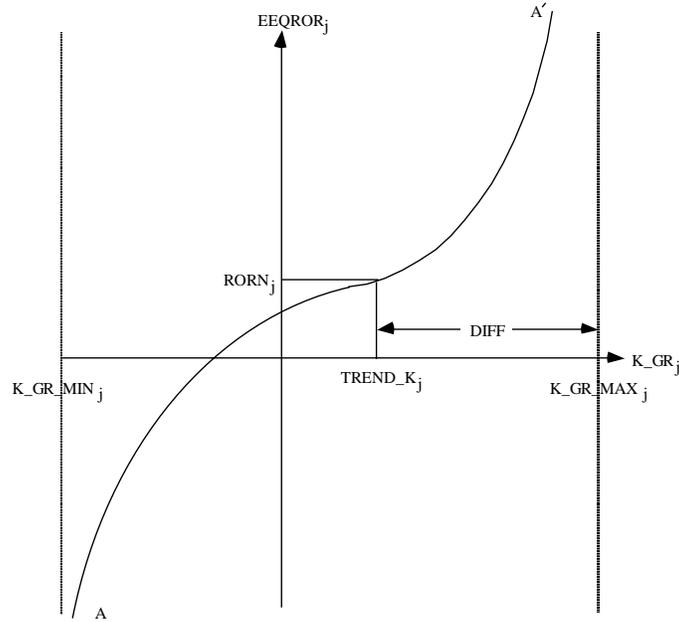
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<sup>30</sup> What we mean by  $j$ 's expected rate of return is defined precisely in the next subsection.

As illustrated by the AA' curve in Figure 30.1, we specify the equilibrium expected rate of return as an inverse logistic function:

$$\begin{aligned} \text{EEQROR}_j = & \{ \text{RORN}_j + F_{\text{EEQROR}_j} + F_{\text{EEQROR}} \} \\ & + (1/C_j) * [ \ln(K_{\text{GR}_j} - K_{\text{GR\_MIN}_j}) - \ln(K_{\text{GR\_MAX}_j} - K_{\text{GR}_j}) \\ & - \ln(\text{TREND\_K}_j - K_{\text{GR\_MIN}_j}) + \ln(K_{\text{GR\_MAX}_j} - \text{TREND\_K}_j) ] \quad (30.9) \end{aligned}$$

**Figure 30.1. The equilibrium expected rate of return schedule for industry j, assuming  $F_{\text{EEQROR}_j}$  and  $F_{\text{EEQROR}}$  are zero**



In this equation,

$K_{\text{GR}_j}$  is the rate of growth of capital in industry j through year t (defined in  $E_{\text{del\_k\_gr}}$ ).

$K_{\text{GR\_MIN}_j}$  is the minimum possible rate of growth of capital and is set in subsection 18.5r at the negative of the rate of depreciation in industry j.

$\text{TREND\_K}_j$  is the industry's historically normal capital growth rate. This is an observed growth rate in capital over an historical period. Its value is data and is read in subsection 18.4.

$K\_GR\_MAX_j$  is the maximum feasible rate of capital growth in industry  $j$ . For all industries having non-negligible capital stocks<sup>31</sup>,  $K\_GR\_MAX_j$  is calculated in subsection 18.5r by adding  $DIFF$  to  $TREND\_K_j$ . In recent MONASH simulations,  $DIFF$  has been set (via a read statement in subsection 18.4) at 0.06. Thus, for example, if the historically normal rate of capital growth in an industry is 3 per cent, we impose an upper limit on its simulated capital growth in any year  $t$  of 9 per cent.

$C_j$  is a positive parameter the setting of which is discussed below.

$RORN_j$  is the industry's historically normal rate of return. The values of  $RORN_j$  are read in subsection 18.4 from data. For each industry  $j$ ,  $RORN_j$  is an estimate of the average rate of return that applied over the historical period in which the industry's average annual rate of capital growth was  $TREND\_K(j)$ .

$F\_EEQROR\_J_j$  and  $F\_EEQROR$  allow for vertical shifts in the capital supply curves (the  $AA'$  curves in Figure 30.1).

The TABLO change version of (30.9) is  $E\_d\_f\_eeqror\_j$ .

For understanding (30.8) and (30.9) it is helpful to start by assuming that  $F\_EEQROR\_J_j$ ,  $F\_EEQROR$  and  $DIS_j$  are all fixed at zero. Then (30.8) and (30.9) mean that for industry  $j$  to attract sufficient investment in year  $t$  to achieve a capital growth rate of  $TREND\_K_j$ , it must have an expected rate of return of

$RORN_j$ . For the industry to attract sufficient investment in year  $t$  for its capital growth to exceed  $TREND\_K_j$ , its expected rate of return must be greater than  $RORN_j$ . Similarly, if the expected rate of return in the industry is less than that observed in the historical period, then provided that there is no disequilibrium, (30.8) and (30.9) imply that investors will restrict their supply of capital to the industry to below the level required to generate capital growth at the historically observed rate.

Consider now the role of non-zero values for  $F\_EEQROR$  and  $F\_EEQROR\_J_j$ . If  $F\_EEQROR$  is non-zero then the capital supply curves to all industries are vertically displaced by a uniform amount from the position of the  $AA'$  curve shown in Figure 30.1. Being able to move the  $AA'$  curves uniformly via non-zero values of  $d\_f\_eeqror$  in  $E\_d\_f\_eeqror\_j$  is useful in forecasting simulations. In these simulations we often have information from outside the model on the path of aggregate investment. Exogenous settings for movements in aggregate investment can be accommodated by endogenous determination of  $d\_f\_eeqror$ . Non-zero values for  $F\_EEQROR\_J_j$  can be used to impose non-uniform shifts in the

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<sup>31</sup> There are a couple of industries (e.g., Defence) in MONASH which do not use capital. For these industries  $K\_GR$  calculated in subsection 18.5q can be quite large, reflecting the use of TINYs. We avoided a numerical problem by allowing these industries to have high values for  $K\_GR\_MAX$ . This is simply a numerical fix and is of no economic significance.

positions of the AA' curves. This is done endogenously in long-run comparative-static and historical simulations. In these simulations we do not use the AA' curves in the determination of the relationship between rates of return and capital growth, and  $E\_d\_f\_eeqr\_j$  is turned off by endogenization of  $d\_f\_eeqr\_j$ .

Next consider the role of  $DIS_j$ , the second term on the RHS of (30.8). Our year  $t-1$  data (either observed or the final  $t-1$  simulated solution) for expected rates of return and for capital growth in industry  $j$  will not usually give a point on  $j$ 's AA' curve. Consequently, in our data for year  $t-1$ ,  $DIS_j$  will normally be non-zero. In year-to-year simulations we usually assume that this disequilibrium is eliminated over time. If the expected rate of return in industry  $j$  was initially high relative to  $j$ 's rate of capital growth ( $DIS_j > 0$ ) then for any given change in the expected rate of return [ $d\_error(j)$ ], the elimination of  $DIS_j$  will (via  $E\_d\_eeqr$ ) increase  $d\_eeqr(j)$  and hence (via  $E\_d\_f\_eeqr\_j$ ) increase  $j$ 's rate of capital growth [ $d\_k\_gr(j)$ ]. Thus we tend to forecast an increased rate of capital growth for any industry currently experiencing a lower growth rate than would be anticipated in light of its expected rate of return and its AA' curve.

The elimination of disequilibrium is achieved according to:

$$\text{either} \quad DISEQ_j = (1 - \Phi_j) * DISEQSE\_B_j, \quad (30.10a)$$

$$\text{or} \quad DISEQ_j = (1 - \Phi_j) * DISEQRE\_B_j, \quad (30.10b)$$

where

$DISEQ_j$  is the value for  $DIS_j$  in the current year ( $t$ );

$DISEQSE\_B_j$  and  $DISEQRE\_B_j$  are alternative values for  $DIS_j$  in the data year ( $t-1$ ); and

$\Phi_j$  is a parameter with a value between 0 and 1, usually set at 0.5.

The alternative measures of  $DIS_j$  reflect alternative definitions (discussed in subsection 30.2) of expected rates of return.  $DISEQSE\_B_j$  is used for static expectations and  $DISEQRE\_B_j$  for forward-looking expectations.

From the view point of the TABLO code, it is useful to express (30.10a) as

$$DISEQ_j - DISEQSE\_B_j = -\Phi_j * DISEQSE\_B_j * UNITY \quad (30.11)$$

In our year  $t$  computation,  $DISEQSE\_B_j$  is treated as a parameter and  $DISEQ_j$  and  $UNITY$  are variables. Under static expectations, (30.11) is satisfied by the initial solution for year  $t$  because in that solution we assume that  $DISEQ_j$  equals  $DISEQSE\_B_j$  and that  $UNITY$  equals zero. In the required or final solution for year  $t$ ,  $UNITY$  must be one to allow the final value of  $DISEQ_j$  to satisfy (30.10a). Thus, if we are assuming static expectations, we evaluate the change in  $DISEQ_j$  in year  $t$  ( $d\_diseq_j$ ) from its initial value ( $DISEQSE\_B_j$ ) according to the equation:

$$d\_diseq_j = -\Phi_j * DISEQSE\_B_j * del\_unity, \quad (30.12a)$$

where  $del\_unity$  is set exogenously at 1. In slightly different notation and with the inclusion of a shift variable, (30.12a) appears in the TABLO code as  $E\_d\_diseq$ . If

we are assuming forward-looking expectations,  $E\_d\_diseq$  is turned off by endogenizing its shift variable. In this case,  $E\_d\_f\_diseqre$  is activated by exogenization of  $d\_f\_diseqre$  and  $d\_diseq_j$  is evaluated according to

$$d\_diseq_j = -\Phi_j * DISEQRE\_B_j * del\_unity \quad (30.12b)$$

The coefficients  $DISEQSE\_B_j$  and  $DISEQRE\_B_j$  are evaluated by Formula (Initial)s in subsection 18.5t. These formulas use the value of  $j$ 's equilibrium expected rate of return  $[EEQROR(j)]$  calculated in subsection 18.5r, and the values (calculated in subsections 18.5s and 18.5t) of  $j$ 's expected rate of return under static and forward-looking assumptions.

Finally, we consider the evaluation of the parameter  $C_j$ . In simulations in which  $E\_d\_f\_eeqrord\_j$  plays an active role, the sensitivity of  $j$ 's capital growth to variations in its equilibrium expected rate of return is controlled by the parameter  $COEFF\_SL(j)$  [denoted by  $C_j$  in (30.9)]. Our first step in choosing the value for  $C_j$  was to note that

$$C_j = \left[ \frac{\partial EEQROR_j}{\partial K\_GR_j} \Big|_{K\_GR_j = TREND\_K_j} \right]^{-1} * \left[ \frac{K\_GR\_MAX_j - K\_GR\_MIN_j}{(K\_GR\_MAX_j - TREND\_K_j)(TREND\_K_j - K\_GR\_MIN_j)} \right] \quad (30.13)$$

Formula (30.13) allows us to evaluate  $C_j$  if we can assign a value to the reciprocal of the slope of the  $AA'$  curve in Figure 30.1 in the region of  $K\_GR_j = TREND\_K_j$ .

We have no data for individual industries to give us a basis for such an assignment. However, by looking at the investment functions in Australian macro models<sup>32</sup>, we obtained an estimate, denoted by  $SMURF$ , of the average value over all industries of the sensitivity of capital growth to variations in expected rates of return. Then, as can be seen in subsection 18.5r, we computed the value of  $C_j$  [i.e.,  $COEFF\_SL(j)$ ] via (30.13) with

$$\left( \frac{\partial EEQROR_j}{\partial K\_GR_j} \Big|_{K\_GR_j = TREND\_K_j} \right)^{-1} = SMURF \quad j \in IND. \quad (30.14)$$

***E\_ch\_kgr1 and E\_ch\_kgr2***

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<sup>32</sup> For example, the Murphy model (Powell and Murphy, 1997) and TRYM (Taplin *et al.*, 1993).

As can be seen from subsection 18.5r, the calculation of EEQROR(j) requires the evaluation of four logarithmic terms. We can be sure that TREND\_K is greater than K\_GR\_MIN and less than K\_GR\_MAX. Thus the last two of these log terms present no computational difficulty. However, during a badly behaved simulation K\_GR could move below K\_GR\_MIN or above K\_GR\_MAX. Rather than terminating the computation it is helpful in diagnosing the problem to allow the computation to continue. This is achieved by a formula in subsection 18.5r which resets errant values of K\_GR(j) at either K\_GR\_MIN(j) + 0.005 or K\_GR\_MAX(j) - 0.005.

When K\_GR(j) is reset, then either CHKGR1(j) or CHKGR2(j) computed in subsection 18.5r takes a positive value. Such a value alerts us that something is amiss.

With del\_unity set exogenously at 1, the values of ch\_kgr1(j) and ch\_kg2(j) generated in E\_ch\_kgr1 and E\_ch\_kgr2 provide a convenient method for detecting positive values for the coefficients CHKGR1(j) and CHKGR2(j).

### **30.2. Actual and expected rates of return under static and forward-looking expectations (subsection 18.8n in the TABLO code)**

In simplified notation, the MONASH calculation of the present value (PV) of purchasing in year t a unit of physical capital for use in industry j is:

$$PV_{j,t} = -\Pi_{j,t} + [Q_{j,t+1}*(1-T_{t+1}) + \Pi_{j,t+1}*(1-D_j) + RALPH*T_{t+1}*\Pi_{j,t+1}*D_j]/[1 + INT_t*(1-T_{t+1})] \quad (30.15)$$

where

$\Pi_{j,t}$  is the cost of buying or constructing in year t a unit of capital for use in industry j;

$D_j$  is the rate of depreciation;

$Q_{j,t}$  is the rental rate on j's capital in year t, i.e. the user cost of a unit of capital in year t;

RALPH is a coefficient showing the proportion of depreciation that is tax deductible;<sup>33</sup>

$T_t$  is the tax rate applying to capital income in all industries in year t; and

$INT_t$  is the nominal rate of interest in year t.

In this calculation we assume that the acquisition in year t of a unit of physical capital in industry j involves an immediate outlay of  $\Pi_{j,t}$  followed in year t+1 by three benefits which must be discounted by one plus the tax-adjusted interest rate

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<sup>33</sup> This coefficient is named for John Ralph, chairman of the committee which produced Ralph (1999), a Government sponsored report recommending changes in the tax treatment of depreciation allowances and in other aspects of business taxation in Australia.

$[\text{INT}_t^*(1-T_{t+1})]$ . The first benefit is the post-tax rental value,  $Q_{j,t+1}^*(1-T_{t+1})$ , of an extra unit of capital in year  $t+1$ . The second is the value,  $\Pi_{j,t+1}^*(1-D_j)$ , at which the depreciated unit of capital can be sold in year  $t+1$ . The third is the depreciation-related tax deduction in year  $t+1$ . With RALPH set on one, this third benefit is calculated by applying the tax rate ( $T_{t+1}$ ) to the value of depreciation ( $\Pi_{j,t+1}^*D_j$ ). In most applications of MONASH, including that in Chapter 2, we have set RALPH at zero. Thus in calculating  $PV_{j,t}$ , we have assumed that taxes are imposed on gross capital income.<sup>34</sup> This treatment is maintained in the formulas and equations for the Government accounts (see for example the formula for TAX\_CAP in subsection 18.5u and the equation for income tax collections, E\_taxrev\_inc, in subsection 18.8q). In applications of MONASH concerned with business taxes it will be necessary: to give RALPH an industry dimension and non-zero values; to recognize that different rates of tax apply to capital income from different industries (that is,  $T_t$  should have an industry dimension); and to introduce other taxes on capital income such as the capital gains tax. For preliminary work aimed at enriching the treatment of capital taxation in MONASH, see Dixon and Rimmer (1999a).

To derive a rate of return formula we divide both sides of (30.15) by  $\Pi_{j,t}$ , i.e., we define the actual<sup>35</sup> rate of return,  $\text{ROR\_ACT}_{j,t}$ , in year  $t$  on physical capital in industry  $j$  as the present value of an investment of one dollar. This gives

$$\begin{aligned} \text{ROR\_ACT}_{j,t} = & -1 + [(1-T_{t+1})^*Q_{j,t+1}/\Pi_{j,t} + (1-D_j)^*\Pi_{j,t+1}/\Pi_{j,t} \\ & + \text{RALPH}^*T_{t+1}^*D_j^*\Pi_{j,t+1}/\Pi_{j,t}]/[1 + \text{INT}_t^*(1-T_{t+1})] \end{aligned} \quad (30.16)$$

As we saw in the previous subsection, the determination of capital growth and investment in MONASH depends on expected (rather than actual) rates of return. In most simulations, we assume that capital growth and investment in year  $t$  depends on expectations held in year  $t$  concerning  $\text{ROR\_ACT}_{j,t}$ .

MONASH allows two possibilities for the specification of expected rates of return: static and forward-looking. Under static expectations, we assume that investors expect no change in the tax rate (i.e., they expect  $T_{t+1}$  will be the same as  $T_t$ ) and that rental rates ( $Q_j$ ) and asset prices ( $\Pi_j$ ) will increase by the current rate of inflation (INF). Under these assumptions, their expectation ( $\text{ROR\_SE}_{j,t}$ ) of  $\text{ROR\_ACT}_{j,t}$  is given by

$$\text{ROR\_SE}_{j,t} = -1 + [(1-T_t)^*Q_{j,t}/\Pi_{j,t} + (1-D_j) + \text{RALPH}^*T_t^*D_j]/(1+\text{R\_INT\_PT\_SE}_t), \quad (30.17)$$

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<sup>34</sup> We have calibrated the tax rate ( $T_t$ ) so that the implied collection of taxes on capital income is consistent with data.

<sup>35</sup> We use the adjective *actual* to emphasise that here we are defining the outcome for the rate of return, not a prior expectation held about that outcome.

where  $R\_INT\_PT\_SE_t$  is the static expectation of the real post-tax interest rate, defined by

$$1 + R\_INT\_PT\_SE_t = [1 + INT_t*(1-T_t)]/[1+INF_t] . \quad (30.18)$$

Under forward-looking or rational expectations, we assume that investors correctly anticipate actual rates of returns, i.e., their expectation of  $ROR\_ACT_{j,t}$  is  $ROR\_ACT_{j,t}$ .

In a year- $t$  simulation under forward-looking expectations, we need to set the change in  $j$ 's expected rate of return [ $d\_eror(j)$ ] between years  $t-1$  and  $t$  equal to the change in  $j$ 's actual rate of return. The difficulty is that  $j$ 's actual rate of return in year  $t$  depends on future rentals ( $Q_{j,t+1}$ ), future tax rates ( $T_{t+1}$ ) and future asset prices ( $\Pi_{j,t+1}$ ) see (30.16). In the sequential approach to computing MONASH solutions, the values of variables in year  $t+1$  cannot normally be known in the computation for year  $t$ . We are forced to adopt an algorithmic approach.

The algorithm embedded in the TABLO code for MONASH allows users to conduct a forecast simulation with forward-looking expectations followed by a policy simulation with forward-looking expectations. In the first iteration of the forecast simulation, we compute solutions for years 1 to  $T$  under the assumption that expected rates of return reflect static expectations:

$$EROR_{j,t}^1 = ROR\_SE_{j,t}^1 , t = 0, 1, \dots, T \quad (30.19)$$

where the superscript 1 refers to iteration 1. We need further iterations (i.e., further calculations of solutions for years 1 to  $T$ ) because the expected rates of return adopted for year  $t$  [ $ROR\_SE_{j,t}^1$ ] are unlikely to equal the actual rates of return [ $ROR\_ACT_{j,t}^1$ ] implied in the first iteration by the solutions for years  $t$  and  $t+1$ . For the final year ( $T$ ), we do not generate information on future values of variables. We assume that industry  $j$ 's actual rate of return in year  $T$  is the same as that in year  $T-1$ :

$$ROR\_ACT_{j,T}^1 = ROR\_ACT_{j,T-1}^1 . \quad (30.20)$$

In the second forecast iteration, we assume that the expected rates of return in years 0 to  $T$  are the actual rates of return calculated from the first iteration, i.e.,

$$EROR_{j,t}^2 = ROR\_ACT_{j,t}^1 , t = 0, \dots, T. \quad (30.21)$$

From the resulting solutions for years 1 to  $T$  and the data for year 0, we compute the implied actual rates of return,  $ROR\_ACT_{j,t}^2$ ,  $t=0, \dots, T-1$ . As in the first iteration, we assume that the actual rates of return in the final year are equal to the actual rates of return in the penultimate year, i.e.,

$$ROR\_ACT_{j,T}^2 = ROR\_ACT_{j,T-1}^2 . \quad (30.22)$$

In the third and subsequent forecast iterations, we continue to assume that actual rates of return in the final year are the same as those in the penultimate year. We adjust the expected rates of return from iteration to iteration according to

$$EROR_{j,t}^n = EROR_{j,t}^{n-1} + ADJ\_RE_j *(ROR\_ACT_{j,t}^{n-1} - EROR_{j,t}^{n-1})$$

$$\text{for } n=3, \dots, N, t=0, \dots, T-1, \quad (30.23a)$$

$$\text{and} \quad \text{EROR}_{j,T}^n = \text{EROR}_{j,T-1}^n \quad \text{for } n=3, \dots, N, \quad (30.23b)$$

where  $\text{ADJ\_RE}_j$  is a parameter set between 0 and 1 and  $N$  is the number of forecast iterations chosen to be sufficiently large that convergence is achieved with

$$\text{EROR}_{j,t}^N = \text{ROR\_ACT}_{j,t}^N \text{ for all } j \text{ and } t. \quad (30.24)$$

If  $\text{ADJ\_RE}_j$  is set at 1, then (30.23a & b) imply that the expected rates of return in iteration  $n$  are the actual rates of return in iteration  $n-1$ . We have found, however, that convergence is more reliable when  $\text{ADJ\_RE}_j$  is set at a low number, e.g. 0.1. Thus, as soon as we have some estimates of actual rates of return, we use them [see (30.21)], but in subsequent iterations, we adjust our assumed values for expected rates of return cautiously. This reduces the likelihood of cycling (see Figure 30.2). With  $\text{ADJ\_RE}_j$  set at 0.1, we find that very tight convergence is achieved in about 30 iterations ( $N=30$ ).

Very tight convergence is required only when the forecast simulation is to be followed by a policy simulation. As mentioned in sections 2 and 7 and explained more fully in sections 32 and 49, policy results are computed as deviations from forecasts. If tight convergence has not been achieved in the forecast simulation, then the subsequent policy iterations pick up more than the effects of the policy shocks. Assume for example that the policy shocks are zero. Then we would still observe differences between the policy results and the results in the final forecast iteration. But these would not reflect the effects of the policy. Rather they would reflect the ongoing movement towards a converged forward-looking forecast solution.

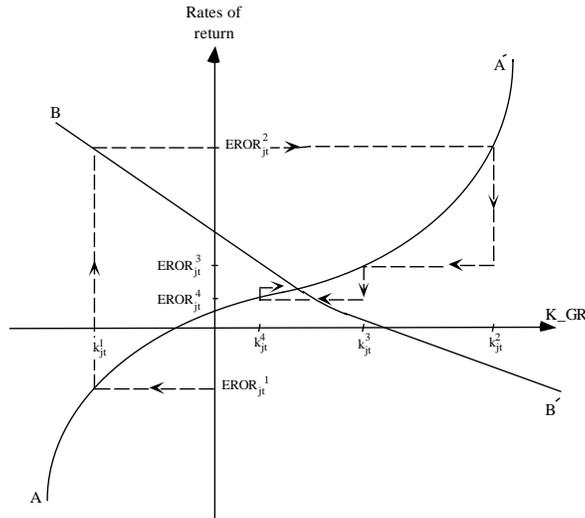
Having completed a tightly converged forecast simulation in  $N$  iterations, we can then undertake a policy simulation. In our policy simulation, policy shocks can occur in any year  $t > 0$ . We assume that year  $t_a$  (denoted in the TABLO code as  $\text{YR\_POLICY}$ ) is the first year in which the policy shocks are anticipated. For years  $t < t_a$  we assume that the policy shocks have no influence on expected rates of return. Consequently, they have no influence on any variables in years prior to  $t_a$  and it is not necessary to include these years in the policy simulation. Because the policy shocks are unanticipated in years before  $t_a$ , expected rates of return in these years are not necessarily equal to the policy-affected actual rates of return.

Before carrying out policy simulations, we have found that it is desirable to use the policy closure in a re-computation of the final forecast iteration for years  $t \geq t_a$ . In this forecast rerun (iteration  $N+1$ ), all of the exogenous variables are given the values that they had either exogenously or endogenously in the final forecast iteration. This means that expected rates of return in iteration  $N+1$  are set at the same values that they had in iteration  $N$ :

$$\text{EROR}_{j,t}^{N+1} = \text{EROR}_{j,t}^N \quad \text{for } t=t_{a-1}, \dots, T. \quad (30.25)$$

In theory the forecast rerun iteration should produce the same results as the final forecast iteration. In practice, the results will differ slightly because of different linearization errors produced under different closures. By adopting the forecast rerun as the simulation from which we calculate policy-induced deviations, we minimize the possibility that these deviations will be contaminated by differences in linearization errors in the forecast and policy simulations.

**Figure 30.2. Convergence of the algorithm for imposing forward-looking expectations**



As in Figure 30.1, we assume that there is no disequilibrium in expected rates of return and that the shift variables ( $F\_EEQROR\_J$  and  $F\_EEQROR$ ) in (30.9) are fixed at zero. Thus, we assume that the MONASH outcomes for expected rates of return and rates of capital growth in year  $t$  in industry  $j$  are on the  $AA'$  schedule. We also assume that MONASH outcomes for actual rates of return and rates of capital growth are on the  $BB'$  schedule. In drawing  $BB'$  we have in mind the capital demand equation,  $E\_cap\_at\_t$ , for year  $t+1$  which, other things being equal, implies a negative relationship between the availability of physical capital to industry  $j$  in year  $t+1$  and its rental rate in year  $t+1$ , and thus a negative relationship between capital growth in year  $t$  and the actual rate of return in year  $t$ . In MONASH computations,  $BB'$  moves between iterations and we do not necessarily operate on  $AA'$ . Nevertheless, we find Figure 30.2 a useful device for thinking about the convergence of our algorithm. For example, with the  $AA'$  and  $BB'$  curves in our diagram, convergence is very rapid when  $ADJ\_REj$  is set at 0.5 (the illustrated case). If  $ADJ\_REj$  is set at 1.0, then readers will find, after a little experimenting with the diagram, that the algorithm may become stuck in a non-converging cycle, or converge very slowly.

As in the first forecast iteration, in the first policy iteration ( $N+2$ ) we must rely largely on static expectations in setting expected rates of return for years  $t \geq t_a$ . We assume

$$EROR_{j,t}^{N+2} = EROR_{j,t}^{N+1} + ROR\_SE_{j,t}^{N+2} - ROR\_SE_{j,t}^{N+1} \quad , \quad t = t_a, \dots, T-1, \quad (30.26a)$$

and 
$$EROR_{j,T}^{N+2} = EROR_{j,T-1}^{N+2} \quad . \quad (30.26b)$$

In (30.26a) expected rates of return for years  $t_a$  to  $T-1$  are those in the forecast rerun ( $EROR_{j,t}^{N+1}$ ) modified by the effect of the policy on the static expectation version of rates of return ( $ROR\_SE_{j,t}^{N+2} - ROR\_SE_{j,t}^{N+1}$ ). In (30.26b) we assume that expected rates of return in the final year ( $T$ ) are the same as in the penultimate year.

In subsequent policy iterations ( $N+3$ ,  $N+4$ , ...), we continue to assume that expected rates of return in the final year are the same as those in the penultimate year. Then we follow a similar approach to that in the second and subsequent forecast iterations:

$$EROR_{j,t}^{N+3} = ROR\_ACT_{j,t}^{N+2}, \quad t = t_a, \dots, T-1. \quad (30.27)$$

and

$$EROR_{j,t}^n = EROR_{j,t}^{n-1} + ADJ\_RE_j * (ROR\_ACT_{j,t}^{n-1} - EROR_{j,t}^{n-1}), \quad t = t_a, \dots, T-1, n > N+3. \quad (30.28)$$

The policy shocks that we consider are usually quite small, that is they do not dramatically affect the forecast paths for actual rates of return for most industries. In any case, unlike the forecast simulation, in the policy simulation very tight convergence is not required. We find that five policy iterations are normally sufficient to achieve a satisfactory level of convergence.

The details of the TABLO implementation of our algorithm for forward-looking expectations are set out in section 44. In the remainder of this subsection we concentrate on the equations in subsection 18.8n. These are concerned mainly with movements in expected and actual rates of return.

#### ***E\_d\_error and E\_d\_f***

In simulations with static expectations we exogenize  $d\_ff(j)$ , usually at zero. Thus through  $E\_d\_error$  we impose the condition that movements in expected rates of return [ $d\_error(j)$ ] equal movements in the static expectations of rates of return [ $del\_ror\_se(j)$ ]. The alternative equation,  $E\_d\_f$ , for movements in expected rates of return is turned off by endogenization of its shift variable,  $d\_f(j)$ .

In simulations with forward-looking expectations we activate  $E\_d\_f$  by exogenizing  $d\_f(j)$  and we turn off  $E\_d\_error$  by endogenizing  $d\_ff(j)$ . As can be seen from formulas in subsection 18.5t, in  $E\_d\_f$ :

ONE\_ITER1 takes the value 1 throughout the first forecast iteration, in other iterations it is zero;

ONE\_IT1\_REP takes the value 1 throughout the first policy iteration ( $N+2$ ), in other iterations it is zero; and

COEFF\_NYEAR is zero in the last year ( $t=T$ ) of all iterations and is one in other years.

Thus, via  $E_{d_f}$  we impose a change version of (30.19) in the first forecast iteration and change versions of (30.26a & b) in the first policy iteration.<sup>36</sup> In other iterations

$$d_{eror}(j) = \{EROR\_F(j) - EROR\_B(j)\} * del\_unity$$

for all except the last year (30.29a)

$$and \quad d_{eror}(j) = 0 \text{ for the last year} \quad . \quad (30.29b)$$

As explained in section 44, in the year  $t$  solution of all iterations for forecast and policy (except the first for both),  $EROR\_F(j)$  and  $EROR\_B(j)$  are the assumed expected rates of return for industry  $j$  in years  $t$  and  $t-1$ , with their values set according to (30.21), (30.23a & b), (30.25), (30.27) and (30.28). With  $del\_unity$  treated as an exogenous variable carrying a shock of 1, (30.29a & b) generate the changes in the expected rates of return required in these iterations.

### ***E\_d\_ave***

$E_{d\_ave}$  provides a measure ( $d_{eror\_ave}$ ) of the average change in expected rates of return. This is sometimes useful in interpreting results. The weights used in computing  $d_{eror\_ave}$  are industry shares in total returns to capital.

### ***E\_p1cap***

Leaving out the  $j$  and  $t$  subscripts, we can write the change form of (33.17) as

$$100 * d_{ror\_se} =$$

$$[1/(1+R\_INT\_PT\_SE)] * \{ [Q(1-T)/\Pi] * (q-\pi) - T * [Q/\Pi - RALPH * D] * t$$

$$- [Q * (1-T) / \Pi + 1-D + RALPH * T * D] * [1/(1+R\_INT\_PT\_SE)] * 100 * d_{r\_int\_pt\_se} \}$$

(30.30)

where

$d_{ror\_se}$  and  $d_{r\_int\_pt\_se}$  are the deviations in  $ROR\_SE$  and  $R\_INT\_PT\_SE$  away from their values in the initial solution for year  $t$ ; and

$q$ ,  $\pi$  and  $t$  are percentage deviations in  $Q$ ,  $\Pi$  and  $T$ .

$E_{p1cap}$  can be obtained from (30.30) by adding the industry dimension ( $j$ ) and by making minor notational adjustments. In reconciling  $E_{p1cap}$  with (30.30), it is useful to note that the rental-rate/asset-price ratio ( $Q/\Pi$ ) equals  $QK/\Pi K$ , i.e.  $Q/\Pi$  equals the ratio of rental payments to capital (denoted by  $CAPITAL(j)$  in the TABLO code) to the value of the capital stock (denoted by  $VCAP\_AT\_TM(j)$ ).

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<sup>36</sup> In forming the change version of (30.26b) we recognize that  $EROR_{T-1}^{N+2}$  is a parameter in the computation for year  $T$ .

***E\_d\_rint\_pt\_se***

From (30.18) we obtain

$$100*d\_rint\_pt\_se = [1/(1+INF)]*$$

$$\{100*(1-T)*d\_int - INT*T*t - 100*[1/(1+INF)]*[1+INT*(1-T)]*d\_inf\} \quad (30.31)$$

where

$d\_int$  is the deviation in the nominal rate of interest; and

$d\_inf$  is the deviation in the rate of inflation.

With obvious changes in notation, (30.31) converts to  $E\_d\_rint\_pt\_se$ .

***E\_d\_int***

We define the pre-tax real rate of interest (RINT) by

$$1 + RINT = (1 + INT)/(1 + INF) \quad . \quad (30.32)$$

On rearranging (30.32) we obtain

$$INT = (1 + RINT)*(1 + INF) - 1 \quad . \quad (30.33)$$

$E\_d\_int$  is a change version of (30.33).

***E\_d\_inf***

The level of inflation (INF) is defined by the formula (subsection 18.5s)

$$INF = LEV\_CPI/LEV\_CPI\_L - 1 \quad , \quad (30.34)$$

where

$LEV\_CPI$  is the level of the consumer price index in the current year (year  $t$ );  
and

$LEV\_CPI\_L$  is its level in the previous year (year  $t-1$ ).

Converting (30.34) to a change form gives  $E\_d\_inf$ , i.e.,

$$100*d\_inf = (1 + INF) (xi3 - xi3\_l) \quad (30.35)$$

where

$d\_inf$  is the deviation in the rate of inflation in year  $t$  from its value in the initial solution for year  $t$  (i.e., its value in year  $\tau$ , usually year  $t-1$ );

$xi3$  is the percentage deviation in  $LEV\_CPI$  in year  $t$  from its value in the initial solution for year  $t$  (i.e., the value of the CPI in year  $\tau$ ); and

$xi3\_l$  is the percentage deviation in the lagged value of the CPI in year  $t$  ( $LEV\_CPI\_L$ ) from its value in the initial solution for year  $t$ , i.e.,  $xi3\_l$  is the percentage difference between the level of the CPI in year  $t-1$  and the level of the CPI in year  $\tau-1$ .

***E\_d\_f\_xi3\_l***

If  $\tau$  is  $t-1$  (i.e., the usual case in which the initial solution for year  $t$  is either data for year  $t-1$  or the final solution for year  $t-1$ ), then we could treat  $xi3\_l$  as an exogenous variable whose value should be set as

$$xi3\_l = 100*(LEV\_CPI\_B/LEV\_CPI\_L\_B - 1) \quad (30.36)$$

where

LEV\_CPI\_B is the level of the CPI in year  $\tau$ ; and

LEV\_CPI\_L\_B is the level of the CPI in year  $\tau-1$ .

However, instead of making computation (30.36) outside the model, it is convenient to work inside the model with  $E\_d\_f\_xi3\_l$ .

A legitimate levels form of  $E\_d\_f\_xi3\_l$  is

$LEV\_CPI\_L - LEV\_CPI\_L\_B =$

$$(LEV\_CPI\_B - LEV\_CPI\_L\_B)*UNITY + F\_XI3\_L \quad (30.37)$$

where, in the year  $t$  computation,

LEV\_CPI\_B and LEV\_CPI\_L\_B are treated as parameters, evaluated via Formula(Initial) statements in subsection 18.5s;

LEV\_CPI\_L is, as already defined, the lagged value of the CPI in year  $t$  and has the value LEV\_CPI\_L\_B in the initial solution for year  $t$ ; and

UNITY and F\_XI3\_L are two further variables, both having values of zero in the initial solution for year  $t$ , ensuring that this initial solution satisfies (30.37).

By keeping F\_XI3\_L on zero and moving UNITY to one (i.e., by setting  $d\_f\_xi3\_l$  at zero and  $del\_unity$  at one), we generate via  $E\_d\_f\_xi3\_l$  a value for  $xi3\_l$  which reflects the required value given by (30.36).

In historical and long-run comparative static simulations,  $\tau$  is not equal to  $t-1$  (i.e., the initial solution for year  $t$  is not provided by information for year  $t-1$ ). In these cases, (30.36) does not give the correct value for  $xi3\_l$ . For example, if  $\tau$  is  $t-7$ , then (30.36) implies, incorrectly, that the percentage deviation in the lagged CPI from its initial solution, that is the percentage change in the CPI between years  $t-8$  and  $t-1$ , is equal to the percentage change in the CPI between  $t-8$  and  $t-7$ . Consequently, when  $\tau$  is not equal to  $t-1$ ,  $E\_d\_f\_xi3\_l$  should be turned off by endogenization of  $d\_f\_xi3\_l$ , and  $xi3\_l$  should be set exogenously to reflect the percentage increase in the CPI between years  $\tau-1$  and  $t-1$ .

#### ***E\_del\_ror\_se and E\_del\_f\_rate***

These two equations have no role in simulations which produce year-to-year results. In such simulations they can be turned off by endogenizing  $del\_ff\_rate(j)$  for all  $j$ . They were activated in the historical and decomposition simulations described in section 5. There we used 1987 data to provide an initial solution for 1994. Then  $E\_del\_ror\_se$  and  $E\_del\_f\_rate$  specified how rates of return [measured by  $ROR\_SE(j)$ ] in 1994 differed from those in 1987. We set exogenously:  $del\_r\_tot$  at zero;  $del\_r$  at 0.5 and  $del\_ff\_rate(j)$  at zero for all

industries  $j$ . The remaining variables in the two equations were endogenous. Thus we assumed

- (a) that industries experiencing rapid capital growth between 1987 and 1994 (i.e., having a high value of  $\text{cap\_at\_t}(j)$  relative to  $\text{k\_r\_wgts}$ ) tended to have higher rates of return in 1994 than in 1987 (note: the coefficients  $\text{BETA\_CH}(j)$  have positive values);
- (b) that industries which initially had below average rates of return [ $\text{ROR\_SE\_BASE}(j) < \text{AV\_ROR\_SE\_B}$ ] tended to have higher rates of return in 1994 than they had in 1987 reflecting weak investment and increasing scarcity of capital; and
- (c) that industries in the same category in the available data on value-added price deflators experienced a common shift in their rates of return in addition to those specified in (a) and (b).

The role of (c) is to allow us to use sectoral data on value-added prices. In our 1987 to 1994 historical simulation we had data on percentage increases over the period in the prices of value-added in each of 20 sectors, i.e., we had values for  $\text{p\_va\_s}(jj)$  for all  $jj$  in the set  $\text{INDSAGGTO20}$ . To make use of these data, we defined  $\text{p\_va\_s}(jj)$  explicitly in MONASH (see  $\text{E\_p\_va\_s}$  in subsection 18.8o) and treated it as an exogenous variable. The final term on the RHS of  $\text{E\_del\_f\_rate}$  allows MONASH to explain our 20 observations for sectoral value-added prices via uniform within-group shifts in rates of return imparted through endogenous determination of the 20 variables  $\text{del\_ff\_rate\_s}(jj)$  for  $jj$  in  $\text{INDSAGGTO20}$ . For example, if  $\text{p\_va\_s}(\text{mining})$  has a high value, then MONASH produces results compatible with a rapid increase in returns to primary factors in the mining sector by imparting a uniform upward shift [a high value for  $\text{del\_ff\_rate\_s}(\text{mining})$ ] to rates of return in mining industries.

The mechanics of this final term on the RHS of  $\text{E\_del\_f\_rate}$  are similar to those of the final term in  $\text{E\_wlaboi}$  in subsection 18.8c, described in subsection 20.4.

### ***E\_f\_r\_inv\_cap***

The second term on the RHS of this equation is similar to the last term on the RHS of the previous equation: it allows MONASH to absorb sectoral data, this time for investment. In our historical simulation for 1987 to 1994, we had investment data for the 26 sectors identified in the set  $\text{INDSAGGTO26}$ . MONASH produced results consistent with these data via endogenous determination of  $\text{r\_inv\_cap\_s}(s)$ . Thus MONASH absorbed investment data for sector  $s$  by imposing a uniform shift in the investment/capital ratios of industries in sector  $s$ . For example, between 1987 and 1994 there was strong growth in investment in the mining sector relative to the sector's growth in capital stock. MONASH reproduced this outcome by imposing a uniform increase [a positive value for  $\text{r\_inv\_cap\_s}(\text{mining})$ ] in the investment/capital ratios of all mining industries.

***E\_d\_ror\_act\_l***

In year  $t$  computations, this equation generates movements  $[d\_ror\_act\_l(j)]$  in actual rates of return on investments made in year  $t-1$ , that is it reveals movements in lagged actual rates of return. [A year  $t$  computation cannot reveal movements in current actual rates of return because these depend on variables for year  $t+1$ .] As described in section 44,  $d\_ror\_act\_l(j)$  in the year  $t$  computation of iteration  $n$  in a simulation with forward-looking expectations is used in setting expected rates of return for year  $t-1$  in iteration  $n+1$ .

To derive  $E\_d\_ror\_act\_l$ , we can start by re-writing (30.16) for year  $t-1$ . Then dropping the  $j$  and  $t$  subscripts we obtain:

$$\begin{aligned} ROR\_ACT_{-1} = & -1 + [(1-T)*Q/\Pi_{-1} + (1-D)*\Pi/\Pi_{-1} \\ & + RALPH*T*D*\Pi/\Pi_{-1}]/[1 + INT_{-1}*(1-T)] . \end{aligned} \quad (30.38)$$

In change form, (30.38) is

$$\begin{aligned} 100*d\_ror\_act_{-1} = & \\ & [1/\{[1+INT_{-1}*(1-T)]*\Pi_{-1}\}]*[-Q*T*t + (1-T)*Q*(q-\pi_{-1}) + (1-D)*\Pi*(\pi-\pi_{-1}) \\ & + RALPH*T*D*\Pi*(t+\pi-\pi_{-1})] \\ & - [(1+ROR\_ACT_{-1})/(1+INT_{-1}*(1-T))]*[100*(1-T)*d\_int_{-1} - INT_{-1}*T*t] . \end{aligned} \quad (30.39)$$

To move from (30.39) to  $E\_d\_ror\_act\_l$ , we: add the industry dimension ( $j$ ); replace the  $-1$  subscripts with the lag indicator ( $\_L$  or  $\_l$ ); and recognize that the rental rate in industry  $j$  ( $Q$  in our simplified notation) is total rentals divided by the number of units of capital [ $CAPITAL(j)/QCAPATT(j)$  in the TABLO notation].

***E\_d\_f\_pi\_l and E\_d\_int\_l***

The RHS of  $E\_d\_ror\_act\_l$  introduces two new lagged variables. The first is  $pi\_l(j)$ , the percentage deviation in the lagged asset price of capital in industry  $j$  in year  $t$  from its value in the initial solution for year  $t$ . In the usual case in which the initial solution for year  $t$  is drawn from values for year  $t-1$ ,  $pi\_l(j)$  is the percentage change in  $j$ 's asset price of capital between years  $t-2$  and  $t-1$ . In this case,  $pi\_l(j)$  is correctly generated by  $E\_d\_f\_pi\_l$  with  $del\_unity$  set exogenously at one and  $d\_f\_pi\_l(j)$  set exogenously at zero.

If the initial solution for year  $t$  is drawn from values for year  $\tau$ ,  $\tau \neq t-1$ , then, ideally,  $E\_d\_f\_pi\_l$  should be turned off by endogenization of  $d\_f\_pi\_l(j)$ , and  $pi\_l(j)$  should be set exogenously at the percentage movement in the asset price of capital in industry  $j$  between years  $\tau-1$  and  $t-1$ . However, it is normally only in historical and long-run decomposition simulations that  $\tau \neq t-1$ . Such simulations require only one iteration. Consequently, in these simulations, the treatment of  $pi\_l(j)$ , which affects only  $d\_ror\_act\_l(j)$ , is unimportant.

The second lagged variable introduced on the RHS of  $E\_d\_ror\_act\_l$  is  $d\_int\_l$ , the deviation in the lagged interest rate in year  $t$  from its value in the initial solution for year  $t$ . The level of the lagged interest rate is given by

$$INT\_l = (1+RINT\_L)(1+INF\_L) - 1 \quad (30.40)$$

where

$INT\_L$  is the rate of interest in year  $t-1$ ,

$RINT\_L$  is the real rate of interest in year  $t-1$ , and

$INF\_L$  is the rate of inflation in year  $t-1$ .

$E\_d\_int\_l$  is the change form of (30.40).

#### ***E\_d\_inf\_l and E\_d\_f\_rint\_l***

These equations deal with the lagged rate of inflation and the lagged real interest rate introduced on the RHS of  $E\_d\_int\_l$ . The level of the lagged inflation rate is

$$INF\_L = LEV\_CPI\_L/LEV\_CPI\_2L - 1 \quad (30.41)$$

where

$LEV\_CPI\_L$  is the level of the CPI in year  $t-1$ , and

$LEV\_CPI\_2L$  is the level of the CPI in year  $t-2$ .

$E\_d\_inf\_l$  is the change form of (30.41).

In  $E\_d\_f\_rint\_l$ ,  $RINT\_B$  and  $RINT\_L\_B$  are the real interest rate and the real lagged interest rate in the initial solution for year  $t$ . If the initial solution for year  $t$  is drawn from values for year  $t-1$ , then  $RINT\_B$  is the real interest rate in year  $t-1$  and  $RINT\_L\_B$  is the real interest rate in year  $t-2$ . In this case, with  $del\_unity$  being exogenously set on one and  $d\_f\_rint\_l$  being exogenously set on zero, the value for  $d\_rint\_l$  generated by  $E\_d\_f\_rint\_l$  is the movement in the real rate of interest between  $t-2$  and  $t-1$ . This is the correct value for  $d\_rint\_l$ , i.e., it is the movement in the lagged real interest rate from its initial value in year  $t$  to its final value in year  $t$ .

If the initial solution for year  $t$  is drawn from values for year  $\tau$  with  $\tau \neq t-1$ , then  $d\_rint\_l$  should be set exogenously and  $d\_f\_rint\_l$  should be endogenous. However, when  $\tau \neq t-1$ , the treatment of  $d\_rint\_l$  is usually of no importance. Remarks similar to those in our discussion of  $E\_d\_f\_pi\_l$  apply.

#### ***E\_d\_f\_xi3\_2l***

This equation ties up a loose end introduced on the RHS of  $E\_d\_inf\_l$ . It defines the percentage movement in the double-lagged CPI ( $xi3\_2l$ ) from its value in the initial solution for year  $t$  to its value in the final solution for year  $t$ .

The coefficients,  $LEV\_CPI\_L\_B$  and  $LEV\_CPI\_2L\_B$  appearing in the equation are the levels of the lagged and double-lagged CPI in the initial solution for year  $t$ . If this initial solution is drawn from values for year  $t-1$ , then  $LEV\_CPI\_L\_B$  is the CPI in year  $t-2$  and  $LEV\_CPI\_2L\_B$  is the CPI in year  $t-3$ . In this case,  $xi3\_2l$  is

correctly generated in  $E\_d\_f\_xi3\_2l$  with  $del\_unity$  set exogenously on one and  $d\_f\_xi3\_2l$  set exogenously on zero.

If the initial solution for year  $t$  is drawn from values for year  $\tau$ ,  $\tau \neq t-1$ , then  $xi3\_2l$  should be set exogenously and  $d\_f\_xi3\_2l$  should be endogenous. However, when  $\tau \neq t-1$ , the treatment of  $xi3\_2l$  is normally of no importance. Again, remarks similar to those in our discussion of  $E\_d\_f\_pi\_l$  apply.

***E\_lev\_erro*** and ***E\_lev\_erro\_1***

With *del\_unity* set exogenously at one, these two equations are convenient vehicles for viewing the levels of expected rates of return. In a year *t* solution, *lev\_erro(j)* is the expected rate of return in industry *j* in year *t* and *lev\_erro\_1(j)* is the expected rate of return in industry *j* in year  $\tau$ , the year from which the initial solution for year *t* is drawn. Usually  $\tau=t-1$ . In this case, *lev\_erro\_1(j)* is *j*'s expected rate of return in year *t-1*.

***E\_lev\_ror\_act\_1***

In a year *t* computation, this equation generates the level [*lev\_ror\_act\_1(j)*] of industry *j*'s actual rate of return in year *t-1* as the sum of the initial value in the year *t* computation for this rate of return [*ROR\_ACT\_L\_B(j)*] and its deviation from this initial value [*d\_ror\_act\_1(j)*].

Providing that *lev\_erro\_1(j)* can be interpreted as *j*'s expected rate of return in year *t-1*,<sup>37</sup> then in considering whether or not sufficient convergence has been achieved in iteration *n*, we compare our year-*t* results (*t=1, ..., T*) for *lev\_ror\_act\_1(j)* (*j*∈IND) with our year-*t* results for *lev\_erro\_1(j)*. For *t=T*, we compare our results for *lev\_ror\_act\_1(j)* not only with our results for *lev\_erro\_1(j)* but also with those for *lev\_erro(j)*. Recall that we assume that actual rates of return in year *T* are the same as actual rates of return in year *T-1*.

**31. Equations for facilitating historical and forecast simulations (subsection 18.8o in the TABLO code)**

In historical and forecast simulations, we are faced with two broad problems. The first is to make use of information supplied in many different industry/commodity classifications. For example, in our historical simulation for 1987 to 1994, we had to work out how to use data on: outputs disaggregated into 104 commodities; on consumption disaggregated into 38 commodities; on employment disaggregated into 87 industries; on capital and investment disaggregated into 26 industrial sectors; on value-added prices disaggregated into 20 industrial sectors; on import and export volumes and prices disaggregated into 115 commodities; and so on. The second problem is to resolve conflicts between information supplied from different sources. For example, what should we do if our detailed export and import data, derived from unpublished tables supplied by the Australian Bureau of Statistics, is inconsistent with macro data on imports and exports published in the National Accounts?

One approach to these two problems is to use spreadsheets, outside MONASH, both to allocate information to standard MONASH classifications and to make data adjustments. For example, if our data indicates that total employment in

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<sup>37</sup> This is the case if the initial solution for year *t* is drawn from values for year *t-1*, see the discussion of *E\_lev\_erro\_1*.

MONASH industries 1 and 2 grew by 15 per cent between 1987 and 1994, then we could assume that employment in each of these industries grew by 15 per cent. In this case, in our historical simulation, we would set both *labind(1)* and *labind(2)* at 15. Similarly, if the detailed data on export prices implies an increase of 5 per cent in the aggregate price index for exports, but the macro data indicates an increase of 7 per cent, then before using the detailed data in MONASH, we could make an across-the-board 2 percentage point upward adjustment.

Instead of relying on a spreadsheet approach external to the model, we have made nearly all allocations and adjustments within the model. Relative to the within-model approach, we see three weaknesses in the external approach. First, in a project involving work by several people over a number of years, with external methods it is easy to lose track of what allocative rules and adjustments were implemented. Second, under external methods, the incorporation of data revisions and of new data in historical simulations is time consuming and error-prone. Third, and most importantly, it is difficult outside the model to design allocative rules which use data on variable B to assist in the allocation of variable A. For example, in allocating an aggregate employment number for industries 1 and 2, we should make use of whatever data we have on output, exports, profitability, capital, investment and any other variables which would help us to distinguish between rates of employment growth in the two industries. Similarly, in resolving data conflicts, we should look at the whole of our database in deciding the relative reliabilities of different pieces of information.

To implement our within-model approach, we have included in MONASH many equations which relate concepts for which we have data to more basic concepts in the model. For example, we include in MONASH an equation which defines capital growth in the mining sector (for which we have data) as an aggregation of capital growth in the six MONASH industries which constitute the mining sector. We also include an equation which allows us to allocate mining capital across the six mining industries in accordance with employment, output, export and other data for the six industries and in accordance with model-generated implications for the industries' rates of return.

In this section, we discuss the equations appearing in subsection 18.8o of the TABLO code. These are most of the equations which have been added to MONASH to deal with data allocation and adjustment. Unlike many of the other equations in subsection 18.8, those in subsection 18.8o do not have easily recognizable counterparts in models of other countries or even in models of Australia for other times. The equations in 18.8o are designed specifically to take advantage of the available data on the Australian economy for the period from the mid-1980s to the mid-1990s. Although the particular equations in 18.8o have a narrow range of applicability, the ideas underlying them could be applied in other model-building projects.

***E\_peobs and E\_pmobs***

In historical simulations we normally have information from outside the model on foreign-currency prices of exports and imports. This information can be introduced to our simulations through exogenous settings of  $peobs(i)$  and  $pmobs(i)$ .  $E\_peobs$  is a convenient device for making uniform adjustments ( $f\_pe\_u$ ) in export prices to allow MONASH to produce results consistent with observations of macro variables such as the total value of exports or the terms of trade. Similarly,  $E\_pmobs$  can be used to make uniform adjustments ( $f\_pm$ ) in import prices.

Because the available data and forecasts for the prices of non-traditional exports are less reliable than those for traditional exports, we sometimes prefer to hit terms-of-trade or other macro targets through a uniform adjustment in the prices of non-traditional exports rather than in the prices of all exports. This option is available in  $E\_peobs$  through the variable  $f\_pe\_u\_nt$ . With the coefficient  $DUMMY\_NT(i)$  being one for  $i \in NTRADEXP$  and zero otherwise (subsection 18.5a),  $f\_pe\_u\_nt$  affects only the export prices of non-traditional exports.

***E\_p3\_obs and E\_pow\_phph3\_ave***

In historical simulations we introduce information on movements in consumer prices via shocks to  $p3\_obs$ .  $E\_p3\_obs$  is a convenient device for making scalar adjustments to these shocks so that movements in consumer prices at the commodity level are brought into line with macro information on, for example, the movement in the consumer price index.

When consumer prices are tied down by shocks to  $p3\_obs$  (and either an endogenous or exogenous scalar adjustment,  $p3\_adj$ ), we must reconcile these prices with costs (see  $E\_p3cs$ , subsection 18.8j). In the historical simulation described in section 5, we used endogenous movements in the phantom tax variables  $powtaxphph(i,s)$  to achieve these reconciliations (see  $E\_powtax3$ , subsection 18.8k).  $E\_pow\_phph3\_ave$  allows us to keep track of the average power ( $pow\_phph3\_ave$ ) of the reconciling phantom taxes.

***E\_pm\_f and E\_pmrel***

The first of these equations defines the percentage movement ( $pm\_f$ ) in the overall foreign currency c.i.f. price of imports. If  $pm\_ff$  is set exogenously at zero, then the second equation defines the percentage movement [ $pmrel(i)$ ] in the foreign currency c.i.f. import price of  $i$  relative to the foreign currency c.i.f. price of all imports.

In forecasting, we sometimes exogenize the  $pmrel(i)s$  at their historical values. Thus, we assume that if the import price of  $i$  grew relatively rapidly in the past, then it will continue to grow relatively rapidly in the future. If all the  $pmrel(i)s$  are set exogenously, then it is necessary to endogenize  $pm\_ff$ . If both  $pm\_ff$  and the  $pmrel(i)s$  are exogenous, then our computations run aground via  $E\_pm\_f$ ,  $E\_pmrel$  and  $E\_xim$  (subsection 18.8l). Together, these equations imply that

$$pm\_ff = \sum_{i \in COM} S_i * pmrel(i) ,$$

where  $S_i$  is the share  $[IMPCOST(i)/AGGIMP]$  of commodity  $i$  in the c.i.f. value of total imports.

***E\_p\_va, E\_p\_va\_s, E\_del\_floct and E\_ff\_p\_va\_s***

This group of equations allows us to use in historical simulations sectoral information on prices of value added. Such information is published regularly as part of Australia's national income statistics.  $E\_p\_va$  and  $E\_p\_va\_s$  define percentage movements in prices of value added for industries and sectors, and  $E\_del\_floct$  and  $E\_ff\_p\_va\_s$  are concerned with absorbing historical information on prices of value added for sectors.

In simplified notation the derivation of  $E\_p\_va$  starts from the equation

$$V = PX - P_m M - T_{ph} \quad (31.1)$$

where

$V$  is an industry's value added;

$P$  is the industry's output price;

$X$  is the industry's quantity of output;

$P_m$  is the price of the industry's intermediate inputs;

$M$  is the quantity of intermediate inputs; and

$T_{ph}$  is the collection of phantom taxes on the industry's production.

Consistent with definitions used in statistical sources, we have included genuine production taxes in value added. We have however excluded our purely artificial phantom production taxes. Put another way, we have defined value added as returns to primary factors plus genuine production taxes.<sup>38</sup>

As in subsection 28.1 [see (28.9)] the collection of phantom taxes on the production of an industry is given by

$$T_{ph} = PX \Pi_g (\Pi_{ph} - 1) \quad (31.2)$$

where  $\Pi_g$  and  $\Pi_{ph}$  are the powers of the genuine and phantom production taxes. Now, with reference to equations (31.1) and (31.2), we interpret the definition in the national income statistics of the percentage change in an industry's price of value added ( $p\_va$ ) as the percentage effect on  $V$  of changes in  $P$ ,  $P_m$ ,  $\Pi_g$  and  $\Pi_{ph}$ , that is

$$V * p\_va = PX * p - P_m M * p_m - PX \Pi_g \Pi_{ph} (p + \pi_g + \pi_{ph}) + PX \Pi_g (p + \pi_g) \quad (31.3)$$

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<sup>38</sup> We also include OTHCOST in value added, see the formula in subsection 18.5i.

where  $p$ ,  $p_m$ ,  $\pi_g$  and  $\pi_{ph}$  are percentage changes in  $P$ ,  $P_m$ ,  $\Pi_g$  and  $\Pi_{ph}$ . Equivalently,  $p_{va}$  is an index of changes in an industry's primary-factor input prices and genuine production tax rate relative to its rate of technical progress.<sup>39</sup>

$E_{p_{va}}$  is a rearranged version of (31.3) in which we use (31.2) and recognize that  $PX = COSTS$  and  $PX\Pi_g\Pi_{ph} = COSTS + TAX0$ .

In looking at  $E_{p_{va}_s}$  it is helpful to start by assuming that  $fvas$  is set on zero. Then  $E_{p_{va}_s}$  defines the percentage change in the value-added price [ $p_{va}_s(jj)$ ] for sector  $jj$  in the set INDSAGGTO20 as a weighted average of the percentage changes in the value-added prices [ $p_{va}(j)$ ] of the industries which make up sector  $jj$ . The weight given to  $p_{va}(j)$  for  $j$  in sector  $jj$  is industry  $j$ 's share in the total value added of sector  $jj$ .

The scalar variable,  $fvas$ , allows MONASH to reconcile observations of sectoral value-added prices with macro price data. For example, if the sectoral prices imply an increase in the price deflator for GDP of 25 per cent but we wish to impose a macro estimate of only 20 per cent, then  $fvas$  can be determined endogenously at -5 per cent. In effect, we let MONASH shave 5 percentage points from each of the sectoral observations.

When we exogenize sectoral value-added prices [ $p_{va}_s(jj)$ ,  $jj \in INDSAGGTO20$ ] in historical simulations, we must decide what to endogenize. Put another way, we must decide how we are going to use information on sectoral value-added prices to inform us about movements in other variables.

In our historical simulations for 1987 to 1994, we had satisfactory information on the prices of labour (i.e., wage rates). Consequently, we decided that the main role of information on sectoral value-added prices should be to help in the determination of movements [ $p_{lcap}(j)$ ] in the user prices of the other major component of value added, namely capital.

One possibility was to allow MONASH to make a uniform adjustment in the movements over the historical period in the rates of return of all industries in the same sector  $jj$ . The aim of this adjustment would be to exploit the close connection between rates of return and user costs of capital to bring the implied movement in the sectoral value-added price for  $jj$  into line with the observed movement. Assume, for example, that the observed percentage increase over an historical period in the value-added price in sector  $jj$  is 20 per cent but that our other information for industries in the sector implies an increase in the sectoral value-

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<sup>39</sup> Leaving out production taxes to simplify matters, the zero-pure-profit condition can be written as

$$p = a + [P_m M / (PX)] * p_m + [P_f F / (PX)] * p_f$$

where  $a$  is the rate of technical change,  $P_f$  and  $F$  are the price and quantity of primary-factor inputs and  $p_f$  is the percentage change in  $P_f$ . Using this equation to eliminate  $p$  from (31.3) we obtain

$$V * p_{va} = PX * a + P_f F * p_f.$$

added price of only 15 per cent. Then we could allow MONASH to make an upward adjustment of  $x$  percentage points in the rates of return of all industries in sector  $jj$ , where  $x$  is calculated in the model so that the revised percentage increases over the historical period in user prices of capital of industries  $j$  in sector  $jj$ , combined with the other information in the historical simulation, give 20 per cent as the implied increase in  $jj$ 's value-added price.

In practice, we found that this approach produced some unrealistic results for the percentage movements in the  $p1cap(j)$ s. Consequently we modified it, eventually settling on an approach with the following properties:

- (i) each industry in sector  $jj$  receives an adjustment of  $y_{jj}$  percentage points in its rate of return,
- (ii) each industry in sector  $jj$  receives an adjustment in the price of its other costs [P1OCT(j)] which imposes a change of  $z_{jj}$  per cent in its value added; and
- (iii) for sector  $jj$  as a whole, the change in value added imposed via the adjustment of rates of return is twice that imposed via adjustments in the prices of other costs.

Under this modified approach, the adjustments in the  $p1cap(j)$ s are relatively damped. Rather than absorbing all of the discrepancies between observed sectoral value-added prices and sectoral value-added prices implied by the other information in our historical simulations, adjustments in rates of return [and the closely related  $p1cap(j)$ s] absorb only two thirds of these discrepancies.

$E\_del\_f1oct$  and  $E\_ff\_p\_va\_s$  allow us to implement strategy (i)-(iii). Assume that  $del\_ff1oct(j)$  and  $ff\_p\_va\_s(qq)$  are set exogenously on zero. Then via  $E\_del\_f1oct$  and  $E\_del\_p1oct$  in subsection 18.8b, a value of 1 for  $f\_1octss(qq)$  gives an increase to  $P1OCT(j)$  for  $j$  in sector  $qq$  of  $\{VALUEADD(j)/100\}/ROTHCOST(j)$ .<sup>40</sup> This, in turn, imparts a 1 per cent increase to value added in industry  $j$ . Via  $E\_ff\_p\_va\_s$ , and  $E\_del\_f\_rate$  and  $E\_del\_ror\_se$  in subsection 18.8n, we see that a value of 1 for  $f\_1octss(qq)$  imparts a uniform change in  $ROR\_SE(j)$  for all  $j$  in sector  $qq$  of:

$$0.02**[1-TAX\_K\_RATE]*VA\_S(qq)/[(1+RINT\_SE\_PT)*VCAPM\_S(qq)]$$

where  $VA\_S(qq)$  and  $VCAPM\_S(qq)$  are value added and value of capital stock in sector  $qq$ . This imparts, via  $E\_p1cap$  in subsection 18.8n, a percentage increase to  $P1CAP(j)$  for  $j$  in  $qq$  of:

$$2*[VA\_S(qq)/VCAPM\_S(qq)]*[VCAP\_at\_TM(j)/CAPITAL(j)]$$

By adding these percentage changes in  $P1CAP(j)$ ,  $j \in qq$ , with the weights  $CAPITAL(j)/VA\_S(qq)$ , we find that their combined effect is to increase value added in sector  $qq$  by 2 per cent. We conclude that with the  $f\_1octss(qq)$ s

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<sup>40</sup> We ignore the possible impact on  $xi3$ . Here, and in the remainder of this paragraph, we look at only direct effects.

determined endogenously, MONASH can achieve given percentage movements in sectoral value-added prices through adjustments consistent with (i) to (iii).

***E\_x3\_m\_na, E\_x3\_imputed, E\_a3shift and E\_x3ncom***

For our historical simulation, we had data from the ABS on the percentage growth from 1987 to 1994 in real household consumption divided into 38 categories. These categories are used by the ABS in the national accounts. The ABS also provided a mapping matrix showing the value  $[MM(i,na)]$  of consumption of MONASH commodity  $i$  in national accounts category  $na$ . For example, the Food column of the MM matrix ( $na=Food$ ) shows the value of consumption of MONASH commodities such as meat products ( $i=Meat$  products), milk products ( $i=Milk$  products), etc. belonging to the Food category in the national accounts. Similarly, the Entertainment row of the MM matrix ( $i=Entertainment$ ) shows the value of consumption of national accounts commodities such as gambling ( $na=Gambling$ ) and other entertainment ( $na=Other$  entertainment) belonging to the Entertainment category in the MONASH commodity classification.

The role of  $E_x3_m_na$ ,  $E_x3_imputed$ ,  $E_a3shift$  and  $E_x3ncom$ , together with the formulas in subsection 18.5n, is to allow us to combine the MM matrix with data on consumption growth in national accounts categories in estimating changes in consumer preferences for commodities in the MONASH classification. As will be explained, these four equations lead to estimates of the taste change variables  $a3com(i)$  appearing in  $E_x3$  (subsection 18.8e).

In  $E_x3_m_na$ , we assume that the percentage change in the consumption of MONASH commodity  $i$  in national accounts category  $na$  [ $x3_m_na(i,na)$ ] depends on three variables driving the consumption of  $i$  and one variable which is specific to national accounts category  $na$ , i.e., in modelling the quantity component of movements in the MM flows we allow for three row variables and one column variable.

The first row variable,  $x3_imputed(i)$ , is computed in  $E_x3_imputed$  as the percentage movement in the consumption  $i$  which would be expected on the basis of movements in: the number of households,  $q$ ; expenditure per household,  $c-q$ ; and consumer prices,  $p3(j)$ . The form taken by  $E_x3_imputed$  follows from  $E_x3$ .

The second row variable [ $ac(i)$ ] allows for general  $i$ -using changes in technology and preferences. As we will see in  $E_a1ci$ ,  $E_a2ci$  and  $E_a1marg, \dots, E_a5marg$ , a value of 1.0 for  $ac(i)$  not only imparts a one per cent increase to the consumption of good  $i$  in all national accounts categories, but also imparts a one per cent increase in the intermediate and investment usage of  $i$  per unit of output and capital creation in each industry, and a one per cent increase in the margin usage of  $i$  per unit of commodity flow.

The third row variable [ $a3shift(i)$ ] allows for  $i$ -using changes affecting only consumption. Notice that  $a3shift(i)$  appears only in  $E_x3_m_na$ .

The final variable on the RHS of  $E\_x3\_m\_na$  is the column shifter  $a3ncom(na)$ . As is the case with  $a3shift(i)$ ,  $a3ncom(na)$  appears only in  $E\_x3\_m\_na$ . A value of one for  $a3ncom(na)$  imparts a one per cent increase in the quantity consumed of all MONASH commodities  $i$  in national accounts category  $na$ .

$E\_a3shift$  and  $E\_x3ncom$  define the percentage movements in the consumption of MONASH commodity  $i$  [ $x3(i)$ ] and of national accounts commodity  $na$  [ $x3ncom(na)$ ] as weighted averages of the  $x3\_m\_na(i,na)$ s. For  $x3(i)$ , the weight given to  $x3\_m\_na(i,na)$  is the share of the expenditure on  $i$  which occurs in national accounts category  $na$ , and for  $x3ncom(na)$  the weight given to  $x3\_m\_na(i,na)$  is the share of the expenditure on  $na$  which occurs in MONASH category  $i$ .

The expenditure shares in  $E\_a3shift$  and  $E\_x3ncom$  are calculated from the ABS mapping matrix  $MM$ . However, before being used in the computation of expenditure shares,  $MM$  is modified by a series of Formula(Initial)s in subsection 18.5n. The main modification is a scaling of each row to bring the row sums [ $\sum_{na} MM(i,na)$ ] into line with the input-output data [ $TPURCHVAL3(i)$ ] on consumption of MONASH commodities. The other modifications involve the use of TINYs to avoid zero-divide and indeterminacy problems. Once  $MM$  has been modified, it stays in line with the input-output flows via an update statement in subsection 18.7.

In most MONASH simulations,  $E\_x3\_m\_na$ ,  $E\_x3\_inputed$ ,  $E\_a3shift$  and  $E\_x3ncom$  have no significance. In these simulations, the  $a3com(i)$ s are exogenous and percentage movements in the consumption of MONASH commodities [ $x3(i)$ ] are determined in  $E\_x3$ . Compatibility of these movements with  $E\_a3shift$  is achieved via  $E\_x3\_m\_na$  with  $a3ncom(na)$  set exogenously on zero and  $a3shift(i)$  determined endogenously. The variables  $x3ncom(na)$  are endogenous and of no particular interest.

However, in historical simulations we set the  $x3ncom(na)$ s at or near their observed values<sup>41</sup>. Compatibility between these values for the  $x3ncom(na)$ s and the values generated in  $E\_x3ncom$  is achieved by endogenizing the  $a3ncom(na)$ s. The  $a3shift(i)$ s and  $ac(i)$ s are either set exogenously or determined elsewhere. Thus, the  $x3\_m\_na(i,na)$ s are tied down and  $x3(i)$  is now determined in  $E\_a3shift$ . Compatibility between  $x3(i)$  determined in this way and  $x3(i)$  given in  $E\_x3$  is achieved by endogenization of the  $a3com(i)$ s. The endogenously determined values for the  $a3com(i)$ s are our estimates of changes in consumer preferences for commodities in the MONASH classification.

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<sup>41</sup> As discussed later in this section in connection with  $E\_x5cs\_obs$ , ...,  $E\_x3ncom\_obs$ , we exogenize  $x3ncom\_obs(na)$  at the observed percentage change in consumption in national accounts category  $na$ . For most categories,  $na$ , this is equivalent to exogenizing  $x3ncom(na)$  at its observed value. For some other categories, it is equivalent to exogenizing  $x3ncom(na)$  at an adjusted value, chosen to enhance compatibility between our data on consumption, on other demands and on supplies.

***E\_labind\_d, E\_flabprod, E\_labprod, E\_x0ind\_UP and E\_x0ind\_JP***

For our historical simulation, we had data on the percentage change in employment between 1987 and 1994 for the 87 groups of industries in the set LAB\_DATA\_IND. Each MONASH industry belongs to precisely one of the 87 groups.

So that we can use these data, we include in MONASH the equation  $E\_labind\_d$  which defines the percentage movement in employment in group  $d$  [ $labind\_d(d)$  for  $d$  in LAB\_DATA\_IND] as a weighted average of the percentage movements in employment in the MONASH industries which constitute group  $d$ . The weights are the shares of the constituent MONASH industries in group  $d$ 's total wagebill.

In the historical simulation, we set the 87  $labind\_d(d)$ s exogenously at their observed values. Then we spread these 87 items of employment information over the 113 MONASH industries by assuming common movements in labour productivity for MONASH industries in the same labour data group. This was done by setting the  $flabprod(i)$ s in  $E\_flabprod$  exogenously on zero so that the percentage movements in labour productivity in any two MONASH industries  $u$  and  $v$  [ $labprod(u)$  and  $labprod(v)$ ] both equalled  $labprod\_d(d)$  if  $u$  and  $v$  were in the same labour data group  $d$ .

Percentage movements in labour productivity in MONASH industries are defined in  $E\_labprod$  as differences between the percentage movements in industry outputs [ $x0ind(j)$ ] and employment [ $labind(j)$ ]. Percentage movements in industry outputs have not been previously defined. Thus we include here  $E\_x0ind\_UP$  and  $E\_x0ind\_JP$ . The first of these equations defines  $x0ind(j)$  for  $j$  in IND\_UP. Each industry in IND\_UP produces only one commodity and is the sole producer of that commodity. Recalling that  $MAKE(i,j)$  is the value of commodity  $i$  produced by industry  $j$ , we see that if  $j$  is the sole producer of  $i$ , then  $E\_x0ind\_UP$  implies that the percentage movement in  $j$ 's output [ $x0ind(j)$ ] equals the percentage movement in the output of commodity  $i$  [ $x0dom(i)$ ]. The remaining MONASH industries, those in the set IND\_JP, may produce several commodities and these commodities may also be produced by other industries. In  $E\_x0ind\_JP$ , we define the percentage movement in the output of industry  $j$ , for  $j$  in IND\_JP, as a weighted average of the percentage movements in  $j$ 's outputs of different commodities  $i$  [ $x0ci(i,j)$ ], with the weights being commodity value shares in  $j$ 's output. The determination of the commodity composition of  $j$ 's output [i.e., the determination of the  $x0ci(i,j)$ s] was discussed in subsection 20.2.

***E\_x0dom\_abs, E\_ffac, E\_a1ci, E\_a2ci and E\_a1marg ... E\_a5marg***

From the ABS and other sources data are available on the percentage changes in output between 1987 and 1994 for the 104 groups of commodities in the set ABS\_COM. Each of the 115 MONASH commodities belongs to precisely one of the 104 groups.

So that we could use these data, we included in MONASH the equation  $E_{x0dom\_abs}$  which defines the percentage movement  $[x0dom\_abs(abs)]$  in the output of commodity group  $abs$  in  $ABS\_COM$  as a weighted average of the percentage movements  $[x0dom(i)]$  in the outputs of the MONASH commodities which constitute the group  $abs$ . The weight given to  $x0dom(i)$  in the determination of  $x0dom\_abs(abs)$  is the share of  $i$  in the total primary-factor inputs used in the production of all the commodities which form the group  $abs$ . Primary-factor usage in the production of  $i$   $[TOTFACCOM(i)]$  is calculated by a formula in subsection 18.5i. This formula attributes the share  $HOCI(i,j)$  of the earnings of labour, capital and land in industry  $j$   $[TOTFACIND(j)]$ , defined in subsection 18.5i to commodity  $i$  and generates  $TOTFACCOM(i)$  by summing these attributions over all  $j$ . As can be seen from subsection 18.5c,  $HOCI(i,j)$  is the share of commodity  $i$  in the output of industry  $j$ .

In our historical simulation, we set most of the  $x0dom\_abs(abs)$ s at or near their observed values.<sup>42</sup> This requires endogenization of demand shift variables. We included  $E\_ffac$  and  $E\_a1ci$ , ...,  $E\_a5marg$  in MONASH so that exogenously given movements in commodity outputs can be accommodated by commodity-using technical changes.<sup>43</sup> To use this approach for commodities  $i$  in group  $abs$ , we exogenize  $ffac(i)$  and  $falc(i)$ ,  $fa1ci(i,j)$ , ...,  $fa5marg(i,s,r)$  at zero and endogenize  $aq(abs)$ . This produces a common rate  $[aq(abs)]$  of  $i$ -using technical and preference change<sup>44</sup> over all uses of all commodities  $i$  in group  $abs$ .

The operation of the  $aq(abs)$ s can be clarified by an example. Over the period 1987 to 1994, our data on finance services, an  $ABS$  group covering the MONASH commodities 101 to 104, indicated supply growth in Australia of about 10 per cent a year. To explain this rapid growth, MONASH generated a large positive value for  $aq(\text{finance services})$ , and the same value for  $ac(101)$  to  $ac(104)$ . Thus, our historical simulation indicated strong  $i$ -using shifts in technology and preferences for the four MONASH commodities 101 to 104. In forecasting simulations, we often extrapolate such findings by setting the  $ac(i)$ s at values similar to those generated in historical simulations.

#### ***E\_del\_f\_a1 and E\_del\_f\_a2***

With the shift variable  $del\_f\_a1(j)$  set exogenously at zero,  $E\_del\_f\_a1$  generates an all-input-using technical change  $[a1(j)]$  which offsets the effects on  $j$ 's unit

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<sup>42</sup> A comment similar to that in the previous footnote applies. Clarification is given in our discussion later in this section of  $E\_x5cs\_obs$ , ...,  $E\_x3ncom\_obs$ .

<sup>43</sup> As explained later in this section and in section 47 (steps 9 and 11), we adopt several other methods for accommodating exogenous output movements.

<sup>44</sup> We assume that the other shift variables in  $E\_x3\_m\_na$  [ $a3shift(i)$  and  $a3ncom(na)$ ] are set exogenously or determined by other mechanisms [e.g.  $a3ncom(na)$  may be determined by exogenization of  $x3ncom(na)$ ].

costs of the  $ac(i)$ s. Without such an offset, positive values in our historical and forecasting simulations for the  $ac(i)$ s would represent technological deterioration. For example, positive values for  $ac(101)$  to  $ac(104)$  would imply that industries are expanding their usage of finance services per unit of output without reducing their usage of other inputs (e.g., in-house clerical services) per unit of output. In most MONASH simulations, we avoid such unrealistic implications by allowing positive  $ac(i)$ s to generate cost-neutralizing reductions in all of industry  $j$ 's inputs per unit of output. Similarly, negative  $ac(i)$ s generate cost neutralizing increases in all of  $j$ 's inputs per unit of output.

$E\_del\_f\_a2$  plays a similar role to  $E\_del\_f\_a1$ . With  $del\_f\_a2(j)$  set exogenously at zero,  $E\_del\_f\_a2$  generates an all-input-using technical change [ $a2ind(j)$ ] in capital creation for industry  $j$  which offsets the effects of the  $ac(i)$ s on the costs per unit of  $j$ 's capital.

#### ***E\_ac1\_tot, E\_ac2\_tot, E\_ac12mar\_tot\_NM and E\_ac12mar\_tot\_M***

It is often useful in analysing the results of historical and forecasting simulations to have available convenient measures of economy-wide average rates of  $i$ -using technical change. One possibility is  $ac(i)$ . However, this is usually inadequate, even when the "f" variables in  $E\_a1ci$ ,  $E\_a2ci$  and  $E\_a1marg$ , ...,  $E\_a5marg$  are all set exogenously at zero. The difficulty is the movements in  $a1(j)$  and  $a2ind(j)$ , discussed above in connection with  $E\_del\_f\_a1$  and  $E\_del\_f\_a2$ . These impart  $i$ -using technical change in addition to that imparted by  $ac(i)$ .

To meet the need for summary measures of  $i$ -using technical change, we included in MONASH the four equations  $E\_ac1\_tot$ ,  $E\_ac2\_tot$ ,  $E\_ac12mar\_tot\_NM$  and  $E\_ac12mar\_tot\_M$ . The first of these provides a measure [ $ac1\_tot(i)$ ] of the average rate of  $i$ -using technical change in current production. In constructing this measure, we started by defining the rate of  $i$ -using technical change,  $tc1(i,j)$ , in current production in industry  $j$  as the percentage movement in  $j$ 's expenditure on  $i$  excluding the effects of changes in prices and  $j$ 's activity level [ $z(j)$ ]. Next we referred to  $E\_x1csi$  in subsection 18.8b. On making an expenditure-share [ $SOURCE\_SHR1(i,t,j)$ ] weighted average of  $x1csi(i, dom, j)$  and  $x1csi(i, imp, j)$  with  $z(j)$  and all percentage price changes set at zero, we found that

$$\begin{aligned} tc1(i,j) = & a1(j) + a1ci(i,j) + \text{Sum}(s, SOURCE, SOURCE\_SHR1(i,s,j)*a1csi(i,s,j)) \\ & + SOURCE\_SHR1(i, imp,j)*[TRANSERVDUM(i)*f1\_trans(j) \\ & + COMMUNICDUM(i)*f1\_commun(j)] \end{aligned} \quad (31.4)$$

Finally, as can be seen in  $E\_ac1\_tot$ , we arrived at our measure of the average rate of  $i$ -using technical change in current production by making a weighted average of the industry rates defined in (31.4), with the weight given to  $tc1(i,j)$  being industry  $j$ 's share in the basic value of the intermediate usage of commodity  $i$ .

In the second of the four equations, we use  $E\_x2csi$  from subsection 18.8d in constructing a measure [ $ac2\_tot(i)$ ] of the average rate of  $i$ -using technical change

in capital creation. Because this construction is similar to that of  $ac1\_tot(i)$ , it requires no further discussion.

The third and fourth equations define a measure [ $ac12mar\_tot(i)$ ] of the average rate of  $i$ -using technical change over all intermediate, investment and margin uses of  $i$ . In constructing this measure, we weight  $ac1\_tot(i)$  by the share of the basic value of intermediate sales of  $i$  in the basic value of intermediate, investment and margin sales of  $i$ . Similarly, we weight  $ac2\_tot(i)$  by the investment share in the basic value of  $i$ 's intermediate, investment and margin sales. Technical change [ $a1mar(ii,s,j,i)$ ] affecting the margin usage [ $MAR1(ii,s,j,i)$ ] of  $i$  per unit of flow of  $(ii,s)$  to industry  $j$  for current production is weighted by the share in the basic value of intermediate, investment and margin sales of  $i$  accounted for by  $MAR1(ii,s,j,i)$ . In the same way, all other technical changes affecting margin uses of  $i$  per unit of flow facilitated are weighted according to the shares of these uses in the total value of  $i$ 's intermediate, investment and margin sales.

### ***E\_int\_input***

This equation, which defines total usage of intermediate inputs by industry, is sometimes useful in analysing MONASH results for changes in industries' multi-factor productivity.

### ***E\_adj, E\_x5cs\_obs, E\_x4\_obs, E\_x3\_obs, E\_x0imp\_obs, E\_x0dom\_absobs and E\_x3ncom\_obs***

As explained in the discussion of  $E\_x0dom\_abs$ ,  $E\_ffac$ ,  $E\_a1ci$ , ...,  $E\_a5marg$ , our normal method for letting MONASH generate results compatible with an observed value for  $x0dom\_abs(abs)$  is to endogenize  $aq(abs)$ . However, this is unsatisfactory when very little use is made of the commodities in the group  $abs$  for intermediate, investment and margin purposes. Consider, for example, footwear. Assume that our data indicate a 25 per cent increase in the supply of footwear and a 20 per cent increase in the sales of footwear to households, to the public sector and to exports. It is not sensible to assume that the discrepancy represents a change towards the use of footwear as an input to production and capital creation. These purposes account for only one per cent of footwear usage. If we try to absorb a five percentage point demand/supply gap via endogenization of  $aq(\text{footwear})$ , we obtain a result indicating an approximate 500 per cent increase in footwear usage per unit of production and capital creation throughout the economy.

Where intermediate, capital and margin usage of commodity  $abs$  accounts for less than 15 per cent of its sales, we judged the strategy of endogenizing  $aq(abs)$  to be inadequate. Then, as explained in detail in section 47 (steps 9 and 11), in generating results in our historical simulation for 1987 to 1994 consistent with output data [ $x0dom\_abs(abs)$ ], we generally adopted one of the following three approaches: (a) endogenization of inventory demands; (b) endogenization of an additional shift in consumer preferences; and (c) equal percentage adjustment in opposite directions in supply and demand data.

Approach (c) was used for commodities for which we had apparently reliable data on supplies (imports and domestic production) and all non-negligible categories of demand.  $E\_adj$ ,  $E\_x5cs\_obs$ , ...,  $E\_x3ncom\_obs$  were included in MONASH to allow adjustments under this approach to be carried out conveniently. In the historical simulation for 1987 to 1994 we introduced all data on percentage changes in supply and demand items through exogenization of "obs" variables, i.e. we used an exogenous setting of  $x5cs\_obs(i,s)$  rather than  $x5cs(i,s)$  to introduce the observed percentage change in public consumption of good (i,s), an exogenous setting of  $x4\_obs(i)$  rather than  $x4(i)$ , etc. For most of the 104 ABS commodities we set  $adj\_abs(abs)$  in  $E\_adj$  exogenously at zero. For MONASH commodities  $i$  in these ABS categories,  $adj(i)$  was then zero, and  $x5cs(i,s)$  equaled  $x5cs\_obs(i,s)$ , etc. However, for ABS categories where approach (c) applies, we endogenized  $adj\_abs(abs)$ . Then via  $E\_adj$ ,  $E\_x5cs\_obs$ ,  $E\_x4\_obs$ , ...,  $E\_x3ncom\_obs$ , MONASH adjusted supply items of data for all commodities  $i$  in the category  $abs$  by  $adj\_abs(abs)$  and adjusted demand items by  $-adj\_abs(abs)$ . In this way, MONASH resolved incompatibilities between supply and demand data for the ABS category,  $abs$ .

#### ***E\_cap\_at\_t\_s, E\_y\_s, E\_twistlk and E\_x0ind\_26s***

Each of the 113 MONASH industries belongs to precisely one of the 26 sectors in the set INDSAGGTO26. The percentage movements in capital and investment in these 26 sectors [ $cap\_at\_t\_s(s)$  and  $y\_s(s)$ ] are defined in  $E\_cap\_at\_t\_s$  and  $E\_y\_s$ . In generating  $cap\_at\_t\_s(s)$  and  $y\_s(s)$ , we weight the percentage movements in capital and investment in MONASH industry  $j$  [ $cap\_at\_t(j)$  and  $y(j)$ ] by  $j$ 's share in the value of capital and investment in sector  $s$ .

As explained in the discussion of  $E\_f\_r\_inv\_cap$  in subsection 30.2, in the historical simulation for 1987 to 1994 we produced results consistent with observations of investment in the 26 sectors by imposing a uniform shift [ $r\_inv\_cap\_s(s)$ ] in the investment/capital ratios of industries in the same sector  $s$ . To produce results consistent with observations of percentage movements in capital stocks in the 26 sectors, we imposed a uniform twist in the labour/capital ratios of industries in the same sector  $s$ . We did this via  $E\_twistlk$ . By setting  $ff\_twistlk(j)$  and  $f\_twistlk$  exogenously at zero, we assumed that labour/capital twists [ $twistlk(j)$ , discussed in subsection 20.4 in connection with  $E\_labind$  and  $E\_cap\_at\_t$ ] for all industries in sector  $s$  were equal to  $twistlk\_s(s)$ . By allowing  $twistlk\_s(s)$  to be determined endogenously, we gave MONASH the freedom to adjust capital demands in sector  $s$  to be consistent with the observed capital growth in the sector,  $cap\_at\_t\_s(s)$ .

The final equation in this group,  $E\_x0ind\_26s$ , defines the percentage movement in the output of sector  $s$  [ $x0ind\_26s(s)$ ] as a weighted average of the percentage movements in the outputs [ $x0ind(j)$ ] of the industries which constitute sector  $s$ . The weights are industry shares in the total returns to primary factors used in sector  $s$ .

As is apparent from our discussion earlier in this section of  $E_{x0dom\_abs}$ , we have industry (commodity) output data at a considerably finer level of disaggregation than 26-sectors. Thus,  $E_{x0ind\_26s}$  is not used to introduce data into MONASH historical simulations. Instead, its role is simply to generate results for sectoral outputs. In interpreting historical simulations, we often compare these results with our 26-sector data for capital and investment.

#### ***E\_x0ci\_obs and E\_avea0ci\_j***

The first of these equations is useful in eliminating conflicts in data on agricultural outputs. As described in subsection 20.2, the agricultural sector in MONASH consists of seven industries ( $j \in IND\_JP$ ) which produce nine commodities ( $i \in COM\_JP$ ). In our historical simulation, we had data for the percentage changes between 1987 and 1994 in all 63 commodity outputs [ $x0ci\_obs(i,j)$ ,  $i \in COM\_JP$  and  $j \in IND\_JP$ ]. We also had independent data on total commodity outputs [ $x0dom(i)$ ,  $i \in COM\_JP$ ]. With both industry outputs of agricultural commodities and aggregate outputs of these commodities set exogenously at their observed values, there is a conflict. This was resolved in favour of the data on aggregate outputs. By endogenizing the  $f_{x0ci(i)}$ s in  $E_{x0ci\_obs}$ , we imposed a uniform adjustment on the industry data for commodity  $i$ .

The second equation defines the average rate of output-contracting technical change in agricultural industry  $j$  [ $avea0ci\_j(j)$ ] as a weighted average of the output-contracting technical changes [ $a0ci(i,j)$ ] applying to the commodities produced by industry  $j$ . The weights are commodity shares in  $j$ 's revenue. As we will see in section 47 (step 9), in the historical simulation for 1987 to 1994 the  $avea0ci\_j(j)$ s were exogenized. In most MONASH simulations these variables are endogenous and of little interest.

#### ***E\_twist\_src, E\_twist\_eff, E\_impftwist and E\_d\_f\_tw\_forc***

This group of equations allows a variety of treatments of  $twist\_src(i)$ . As we have seen earlier (e.g., in subsection 20.3),  $twist\_src(i)$  is a cost-neutral twist in technologies and preferences in favour of imported good  $i$  and against domestic good  $i$ . For all intermediate, investment, household and government uses of  $i$ ,  $twist\_src(i)$  produces percentage changes in demand for the domestic and imported varieties given by:

$$x(i, dom, k) = - SOURCE\_SHR(i, imp, k) * twist\_src(i) \quad (31.5)$$

$$\text{and } x(i, imp, k) = SOURCE\_SHR(i, dom, k) * twist\_src(i), \quad (31.6)$$

where

$x(i, dom, k)$  and  $x(i, imp, k)$  are the percentage changes in demand for domestic and imported good  $i$  by user  $k$  (i.e., an industry for current production, an industry for capital creation, households and the government); and

SOURCE\_SHR(i, imp, k) and SOURCE\_SHR(i, dom, k) are the import and domestic shares in k's purchases of good i.

One treatment of the twist\_src(i)s made possible by E\_twist\_src and E\_twist\_eff is to set them according to

$$\text{twist\_src}(i) = C\_TWIST\_SRC(i) * [x0\text{dom}(i) - \text{gdpreal}] \quad . \quad (31.7)$$

This equation will apply if twist\_src\_bar, ftwist\_src(i) and ftwist\_eff(i) are all set exogenously at zero. With the coefficients C\_TWIST\_SRC(i) set at positive values (usually 1.0 for all i via a Read statement in subsection 18.4), (31.7) introduces growth-related movements in demands for imports relative to domestic substitutes. We do not have sufficient time-series data to quantify such movements at the 115-commodity level of disaggregation used in MONASH. However, these movements are often observed in data for broader commodity groups. Consequently, we think it reasonable to assume that rapid growth in the output of commodity i relative to GDP is associated with a twist in favour of imports of i and that slow growth in the output of i is associated with a twist against imports of i. The usual explanation for growth-related import/domestic twists is that rapid growth in demand for i produces shortages in the domestic market which increase the likelihood that users of i will look overseas for suppliers. Similarly, during period of slow growth in demand, users of i are unlikely to look far afield for suppliers and are likely to cut overseas orders before cutting domestic orders.

A variant of (31.7) is

$$\text{twist\_src}(i) = \text{twist\_src\_bar} + C\_TWIST\_SRC * [x0\text{dom}(i) - \text{gdpreal}] \quad . \quad (31.8)$$

This specification of the twist\_src(i)s will apply if ftwist\_src(i) and ftwist\_eff(i) are set exogenously at zero and twist\_src\_bar is either endogenous or exogenous. In forecasting, we usually have a macro scenario which includes movements in aggregate imports [impvol]. To produce results consistent with the forecasts for impvol, we introduce a uniform shift in each year in the twist\_src(i)s by endogenizing twist\_src\_bar.

Another possible treatment of the twist\_src(i)s involves endogenization of the ftwist\_src(i)s. We do this in historical simulations where we have observations [x0imp\_obs(i)] of movements in import volumes. In such simulations, twist\_src\_bar and ftwist\_eff(i) are set exogenously at zero. The endogenously determined values of the ftwist\_src(i)s are then differences between the twist\_src(i)s necessary to explain observed movements in imports and the growth-related twists [twist\_eff(i)]. Thus the ftwist\_src(i)s can be interpreted as import/domestic twists arising from changes in technology and preferences.

Provided that d\_f\_tw\_hist(i) is set at zero, the contribution of the technology/preference-related twist, ftwist\_src(i), to growth in domestic, non-inventory, non-margin demand for domestically produced good i is measured in E\_impftwist by impftwist(i). This is a weighted average of terms such as that on

the RHS of (31.5), with  $\text{twist\_src}(i)$  replaced by  $\text{ftwist\_src}(i)$ . The weights are the shares of each user  $k$  in the basic value of the sales of  $(i, \text{dom})$  to intermediate, investment, household and government users.

In forecasting, we usually extrapolate the  $\text{impftwist}(i)$ s determined in an historical simulation, i.e. we assume that twists in preferences and technology in favour of imports of  $i$  in the forecast period will inhibit growth in domestic production to the same extent as in the historical period. The obvious alternative is to extrapolate the  $\text{ftwist\_src}(i)$ s. Assume, for example, that our historical simulation reveals a twist in favour of imported cars of 5 per cent a year beyond that which can be explained by rapid growth in the demand for cars relative to GDP. Then, in forecast simulations we could assume a continuation of the historical rate of twist by setting  $\text{ftwist\_src}(\text{cars})$  exogenously at 5 in each forecast year. However, with this approach we experienced problems with commodities for which there was rapid import growth in the historical period starting from a low base. For such commodities, we find that historical simulations give very high values for  $\text{ftwist\_src}(i)$ . By the beginning of the forecast period, the import shares [ $\text{SOURCE\_SHR1}(i, \text{imp})$ ,  $\text{SOURCE\_SHR2}(i, \text{imp})$ , etc.] for these commodities are considerably higher than their average values in history. Extrapolation of the high historical values of the  $\text{ftwist\_src}(i)$ s then produces for these commodities unrealistically subdued forecasts for domestic production.

Unfortunately, the strategy of extrapolating the  $\text{impftwist}(i)$ s [and leaving the  $\text{ftwist\_src}(i)$ s to be determined endogenously in  $E_{\text{impftwist}}$ ] is not problem free. Difficulties occur with commodities for which imports declined rapidly in the historical period generating in the historical simulation: (a) a non-negligible positive  $\text{impftwist}(i)$  and (b) small import shares [ $\text{SOURCE\_SHR1}(i, \text{imp})$  etc.] at the start of the forecast period. With  $\text{impftwist}(i)$  set exogenously at its historical value, we found in our forecasts that  $\text{ftwist\_src}(i)$  determined in  $E_{\text{impftwist}}$  could be very large and negative, sometimes implying negative import volumes.

Our solution was to add  $E_{\text{d\_f\_tw\_forc}}$  to the model. Apart from having a different shift variable, the main difference between this equation and the previous one is the coefficient  $\text{DUM\_TW}(i)$ . From subsection 18.5p, we see that the value of this coefficient increases from zero to one as the share [ $\text{AVIMPSH}(i)$ ] of imports of good  $i$  in domestic, non-margin, non-inventory sales of  $i$  increases from zero to 0.1 and then remains at one as the import share increases from 0.1 to 1. In forecasting, we activate  $E_{\text{d\_f\_tw\_forc}}$  by exogenizing  $\text{d\_f\_tw\_forc}(i)$  at zero for all  $i$ , and we turn off  $E_{\text{impftwist}}$  by endogenizing  $\text{d\_f\_tw\_hist}(i)$ . This means that the value of  $\text{ftwist\_src}(i)$  in forecast simulations is determined in  $E_{\text{d\_f\_tw\_forc}}$ . Consequently, irrespective of the exogenous values of  $\text{impftwist}(i)$ ,  $\text{ftwist\_src}(i)$  is close to zero if the import share of  $i$  is close to zero. In effect, we fully extrapolate the historically determined  $\text{impftwist}(i)$  only when the import share in domestic usage of  $i$  is large enough for us to assume that twists in import/domestic choices can have similar effects on domestic output as they did in history.

***E\_hist\_cont and E\_f\_forc***

In historical simulations, we set  $f\_hist(i)$  exogenously at zero. Then  $hist\_cont(i)$ , calculated in  $E\_hist\_cont$ , is the percentage point contribution to growth in the output of non-traditional export commodity  $i$  of the difference between growth in exports of  $i$  and growth in non-traditional exports. Assume, for example, that exports of cars (commodity 70) are 10 per cent of output [i.e.,  $BAS4(70)/SALES(70) = 0.1$ ] and that car exports grew at 8 per cent a year [ $x4(70) = 8$ ] compared with growth of all non-traditional exports of 6 per cent a year [ $ntradexpvol = 6$ ]. Then  $hist\_cont(70)$  equals 0.2 and we say that rapid export growth (i.e., growth at a faster rate than that of non-traditional exports as a whole) contributed 0.2 percentage points a year to the growth rate in the output of cars.

In forecasting simulations, we sometimes use historical results for  $hist\_cont(i)$  as a basis for distinguishing between the prospects for different non-traditional exports. Our reluctance to give these commodities separate, cost-sensitive export-demand specifications is explained in section 23 (see the discussion of  $E\_x4\_NTRADEXP$ ). However, we have been prepared to generate separate growth forecasts for different non-traditional exports by extrapolating the historical  $hist\_cont(i)$ s. Thus, for example, if the contribution of rapid export growth to the growth in the output of cars was historically 0.2 percentage points a year, we have assumed that it will continue in the future to be about 0.2 percentage points a year.

Before the historically determined values of the  $hist\_cont(i)$ s could be used in forecasting, we needed to deal with three technical issues.

The first is the problem of commodities  $i$  in  $NTRADEXP$  for which exports declined in history (or grew slowly) producing: (a) non-negligible negative values for  $hist\_cont(i)$ ; and (b) very small export shares at the start of our forecast period. With  $f\_hist(i)$  set exogenously at zero and  $hist\_cont(i)$  set exogenously at its value from history, our forecast results for percentage changes in exports of such commodities tended to be large and negative, sometimes indicating declines in exports of more than 100 per cent. To solve this problem, we added  $E\_f\_forc$  to the model. As can be seen from the definition of  $DUMMY\_HC(i)$  in subsection 18.5p, the LHS of this equation can be written as

$$LHS = \left[ \frac{f(x) - f(0)}{1 - f(0)} \right] * hist\_cont(i) \quad (31.9)$$

where  $x$  is the export share in sales, that is  $BAS4(i)/SALES(i)$ , and

$$f(x) = \frac{e^{58.889*(x-0.05)}}{1 + e^{58.889*(x-0.05)}} \quad (31.10)$$

Thus the LHS of  $E\_f\_forc$  is a fraction of  $hist\_cont(i)$ , with the fraction increasing from zero to almost one as  $x$  increases from zero to one. The form of  $f$  is chosen so

that the fraction increases rapidly (from 0.20 to 0.75) as  $x$  moves from 0.03 to 0.07. In forecasting, we activate  $E\_f\_forc$  by exogenizing  $f\_forc(i)$  at zero for all  $i$ , and we turn off  $E\_hist\_cont$  by endogenizing  $f\_hist(i)$  for all  $i$ . Now when we exogenize  $hist\_cont(i)$ ,  $i \in NTRADEXP$ , we obtain export growth rates for low-share ( $x < 0.03$ ) export commodities close to that of non-traditional exports, even for relatively large negative values of  $hist\_cont(i)$ . For other commodities in  $NTRADEXP$  with non-negligible exports ( $x > 0.07$ ), our export forecasts are influenced, as required, by close to the full historical values of  $hist\_cont(i)$ .

The second technical difficulty with extrapolating  $hist\_cont(i)$  concerns the requirement [ $E\_ntradexpvol$  in subsection 18.8f] that an appropriately weighted sum of the  $x4(i)$ ,  $i \in NTRADEXP$ , must equal  $ntradexpvol$ . With  $hist\_cont(i)$  and  $f\_forc(i)$  set exogenously for all  $i$  in  $NTRADEXP$ , this condition is in danger of being violated. The solution is to include a degree of freedom in  $E\_f\_forc$  by treating  $fhist\_cont$  as an endogenous variable.

The third technical issue concerns closure. In particular, how should we reconcile  $E\_f\_forc$  with  $E\_x4\_NTRADEXP$  in subsection 18.8f? As discussed in section 23, in many MONASH simulations the structure and overall volume of non-traditional exports are determined in  $E\_x4\_NTRADEXP$ . In these simulations, all of the following variables are exogenous:  $fep\_ntrad$ ,  $feq\_ntrad$ ,  $feq\_general$ ,  $fep\_ntradi(i)$  and  $f\_ntrad(i)$ . When we move to a forecasting simulation in which  $fhist\_cont$  is determined endogenously and  $hist\_cont(i)$  and  $f\_forc(i)$  are set exogenously, we see that  $E\_f\_forc$  determines the relative growth rates [ $x4(i) - ntradexpvol$ ] of non-traditional exports. Consequently, we must free up the relative growth rates determined in  $E\_x4\_NTRADEXP$ . This can be done by endogenizing  $f\_ntrad(i)$  and exogenizing  $hs\_ntrad$  appearing in  $E\_hs\_ntrad$  in subsection 18.8f.<sup>45</sup>

#### ***E\_x4\_abare\_RUR, E\_x4\_abare\_MIN, E\_gx4\_abare\_ru and E\_gx4\_abare\_mi***

In most MONASH simulations, these four equations are of little significance. The two scalar variables,  $fx4\_abare\_ru$  and  $fx4\_abare\_mi$  are set exogenously and  $E\_x4\_abare\_RUR$  and  $E\_x4\_abare\_MIN$  are turned off by endogenization of  $x4\_abare(i)$ .  $E\_gx4\_abare\_ru$  and  $E\_gx4\_abare\_mi$  simply define the percentage changes ( $gx4\_abare\_ru$  and  $gx4\_abare\_mi$ ) in aggregate exports of commodities in the sets  $ABARE\_RUR$  and  $ABARE\_MIN$ .

The four equations are valuable only in forecasting simulations where we take advantage of work by the Australian Bureau of Agricultural and Resource Economics. Each year, the Bureau publishes detailed five-year forecasts for exports

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<sup>45</sup>The variable  $hs\_ntrad$  was necessarily endogenous when  $feq\_ntrad$  and the  $f\_ntrad(i)$ s were exogenous. When we exogenize  $hs\_ntrad$ ,  $E\_x4\_NTRADEXP$  continues to determine the overall volume of non-traditional exports. However in most MONASH forecasts,  $hs\_ntrad$  is endogenized to accommodate a forecast for non-traditional exports derived as a residual from exogenous forecasts for total exports, for tourism exports and for traditional exports.

of Australia's rural and mineral products. These forecasts cover the commodities in the set ABARE which is divided into two subsets: ABARE\_RUR for rural products and ABARE\_MIN for mineral products. On a quarterly basis, the Bureau publishes broad revisions of its detailed forecasts. These up-grade or down-grade the outlook for aggregate rural and aggregate mineral exports.

We include the detailed ABARE export forecasts in MONASH forecasting simulations as shocks to  $x4\_abare(i)$ ,  $i \in ABARE\_RUR$  and  $ABARE\_MIN$ . To introduce ABARE's broad revisions to these forecasts, we set  $gx4\_abare\_ru$  and  $gx4\_abare\_mi$  exogenously and endogenize  $fx4\_abare\_ru$  and  $fx4\_abare\_mi$  to scale the export forecasts for individual rural and mineral commodities.

***E\_r\_elec\_cpi***

The set CELECSET contains one commodity, electricity. Thus, by setting  $r\_elec\_cpi(s)$  exogenously, we fix the relationships between consumer prices<sup>46</sup> of electricity [p3cs( electricity,s)] and the consumer price index [xi3]. This is useful when we want to reflect government policy that consumer prices of electricity should increase by, for example, two percentage points a year less than the CPI [ $r\_elec\_cpi(s) = -2$ ]. If  $r\_elec\_cpi(s)$  is exogenized, we usually endogenize the rate of tax on consumer sales of electricity.

***E\_capprod***

This equation defines the percentage change [capprod(j)] in capital productivity in industry j as the difference between the percentage changes in j's output [x0ind(j)] and capital input [cap\_at\_t(j)]. Usually, capprod(j) is endogenous for all industries except ownership of dwellings (industry 104). Under normal conventions, the output of industry 104 is proportional to its capital which is the housing stock. Thus, we project capital productivity for the industry exogenously at zero change. To accommodate an exogenous setting for capital productivity, we endogenize the industry's rate of primary-factor saving technical change [a1prim(104)].

***E\_f\_gdpreal***

In forecast simulations we sometimes use forecasts from macro-econometric models such as TRYM (the Australian Treasury's model). These forecasts are introduced to MONASH as exogenous values for, among other variables, real consumption, real investment, real public expenditure, export volumes, import volumes and real inventory changes. We also exogenize  $gdpreal\_true$  at the TRYM forecast value for the growth in real GDP. The endogenously determined value of  $f\_gdpreal$  then alerts us to discrepancies between the weights used in MONASH and TRYM in deriving the percentage change in real GDP as a sum of the percentage changes in the macro expenditure aggregates.

***E\_f\_oil***

This equation allows us to take advantage of forecasts supplied from outside MONASH of movements in the ratio of Australia's production of oil to its oil imports.

***E\_irtrue***

The derivation of this equation starts from

$$AGGINV\_T = AGGINV + BAS6(\text{construction, dom}) \quad (31.11)$$

where

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<sup>46</sup> Only the price [p3cs( electricity, dom)] of domestic electricity is of any significance. Imports of electricity are negligible.

AGGINV is, as defined in subsection 18.5h, aggregate investment by industries; and

BAS6(construction, dom) is accumulation of inventories of non-residential buildings.

The variable  $ir_{true}$  defined by  $E_{ir_{true}}$  is the effect on  $AGGINV\_T$  of changes in quantities  $[y(j)]$  and  $d_{x6cs}(\text{construction, dom})$  holding prices constant.

We included  $E_{ir_{true}}$  in MONASH to cope with the glut of office space in the early 1990s reflecting overly optimistic growth forecasts made by developers in the late 1980s. In forecasting for the 1990s we recognized that demands for new office space in this period were often satisfied by the occupation of existing unused or under-used buildings. In effect, demands for buildings by industries were satisfied by a rundown of building inventories (negative values for  $X6CS(i, \text{dom})$ ,  $i \in \text{CONSTRUCTION}$ ). In these circumstances  $ir$ , which is an aggregate of investment  $[y(j)]$  by industry (see  $E_{r\_inv\_cap\_u}$  in subsection 18.8l), may differ significantly from  $ir_{true}$ . Thus to take advantage of macro forecasts of investment, which generally refer to  $ir_{true}$  not  $ir$ , it was necessary to include a defining equation for  $ir_{true}$ . In recent MONASH forecasts for the period 1998 onwards we assume there is no building glut. Consequently, in these forecasts  $ir_{true}$  equals  $ir$ .

### **32. Equations for facilitating policy simulations (subsection 18.8p in the TABLO code)**

In MONASH policy simulations we are concerned with the effects on naturally endogenous variables (such as GDP, exports and employment) of changes in naturally exogenous variables (such as tax rates, tariffs, world commodity prices and technology). Many naturally endogenous variables are exogenous in forecast simulations. In policy simulations, these variables must become endogenous. The equations in this section facilitate the endogenization of variables which were forecast exogenously. The aim of the equations is to allow policy simulations to generate results for naturally endogenous variables as deviations from their exogenously given forecast paths. The equations deal with policy-induced deviations in wages, employment and consumer welfare and with the transfer of results from forecast simulations to policy simulations.

Although MONASH is a detailed model, further detail is often added to enhance particular policy applications. In this section we describe some equations which were added to facilitate the policy application given in section 7. Among other things, these equations are concerned with refunds to Australian motor vehicle producers of tariffs paid on their imports of car parts.

#### ***E\_{del\_f\_wage\_c}* and *E\_{del\_f\_wage\_pt}***

In most general equilibrium analyses of the effects of changes in policy instruments and other changes in the economic environment (e.g. shifts in exports demand curves), one of the following two assumptions is made:

- a. real wages adjust so there is no effect on employment; or
- b. real wages remain unaffected and employment adjusts.

In MONASH we can take an intermediate position between a and b. We can assume that real wages are sticky in the short run and flexible in the long run. In this case favourable shocks generate short-run gains in aggregate employment and long-run gains in real wages.

More specifically, in MONASH policy simulations, we usually assume that the deviation in the real wage rate from its basecase forecast level increases at a rate which is proportional to the deviation in aggregate hours of employment from its basecase forecast level. The coefficient of proportionality is chosen so that the employment effects of a shock to the economy are largely eliminated after 5 years. In other words, after about 5 years, the benefits of favourable shocks, such as outward shifts in export demand curves, are realized almost entirely as increases in real wage rates. This labour market assumption is consistent with conventional macro-economic modelling in which the NAIRU is either exogenous or only weakly dependent on real wage rates.

Algebraically, the MONASH employment-wage specification is as follows:

$$\left\{ \frac{W_t}{W_{t,old}} - 1 \right\} = \left\{ \frac{W_{t-1}}{W_{t-1,old}} - 1 \right\} + \alpha_1 \left\{ \frac{E_t}{E_{t,old}} - F \left( \frac{W_{t-1}}{W_{t-1,old}} \right) \right\} . \quad (32.1)$$

In this equation *old* indicates a basecase forecast value, that is, a value in the simulation without the policy or other shock under consideration.  $W_{t,old}$  and  $E_{t,old}$  are the real wage rate and the level of employment in year  $t$  in the basecase forecasts.  $W_t$  and  $E_t$  are the real wage rate and the level of employment in year  $t$  in the policy simulation, that is the simulation with the shock.  $F$  is a long-run supply function of labour (to be discussed below) and  $\alpha_1$  is a positive parameter. In most MONASH simulations we assume that  $F(Y) = 1$  for all  $Y$ , that is, the long-run supply of labour is independent of wage rates. In this case (32.1) simplifies to

$$\left\{ \frac{W_t}{W_{t,old}} - 1 \right\} = \left\{ \frac{W_{t-1}}{W_{t-1,old}} - 1 \right\} + \alpha_1 \left\{ \frac{E_t}{E_{t,old}} - 1 \right\} . \quad (32.2)$$

As indicated earlier, we usually assume that employment effects of shocks applied in year  $t$  are largely eliminated by year  $t+5$ . This is achieved in (32.2) by adopting a suitable value for  $\alpha_1$ .

The operation of the employment-wage specification (32.2) is illustrated in Figure 32.1 for a steady-state case in which the forecasts for technology, consumer tastes, foreign prices and capital availability are unchanged from year to year, leaving the demand curve for labour in each year  $t$  at  $DD$ , employment and the labour supply at  $E_{old}$  and the wage rate at  $W_{old}$ , so that in each year the employment-wage combination is at point  $I$ . In the policy simulation there is an outward movement in export demand curves (say) in year 1. This causes the

demand curve for labour to shift up to  $D'D'$ , where it remains for all future years. The short-run labour supply curve for year 1 in the policy simulation is SS.<sup>47</sup> Together, SS and  $D'D'$  give policy simulation levels for employment and the real wage rate of  $E_1$  and  $W_1$ . In year 2 there is a vertical upward shift in the short-run supply curve reflecting the gap between  $W_1$  and  $W_{old}$ . In our diagram, employment and the real wage rate in year 2 are  $E_2$  and  $W_2$ . Eventually the short-run supply curve for labour stops moving when  $W$  reaches  $W_\infty$ . At this stage employment has returned to  $E_{old}$ .

In some policy simulations, we have assumed that favourable (unfavourable) shocks to the economy can cause long-run increases (decreases) in employment, that is  $E$  remains above (below)  $E_{old}$ . We can do this by specifying  $F$  in (32.1) as

$$F\left(\frac{W_{t-1}}{W_{t-1,old}}\right) = \left(\frac{W_{t-1}}{W_{t-1,old}}\right)^{\alpha_2}, \quad (32.3)$$

with  $\alpha_2$  being a positive parameter. [It is zero in the special case leading to (32.2)]. With  $\alpha_2$  greater than zero, the  $F$  function can be interpreted as an upward-sloping long-run supply curve for labour. It shows how much labour households are willing to supply, relative to the forecast amount, at different wage rates when sufficient time has passed for households to adjust their employment decisions including their working hours. Under this interpretation, (32.1) implies that wages in year  $t$  react to the gap between employment in year  $t$  and the long-run supply of labour which is forthcoming at the wage of year  $t-1$ . Thus, we recognize that there may be no further pressure for wage increases relative to forecast in year  $t$  although employment in year  $t$  is above forecast. This will happen if wages in year  $t-1$  are high enough to make workers happy to supply the above-forecast amount of labour demanded in year  $t$ . In this case both employment and wage rates will settle at levels above their forecasts.

The available econometric evidence on labour supply in Australia indicates that the appropriate value for  $\alpha_2$  is quite low. Estimates by Kalb (1997) can be used to justify values up to 0.15. In the policy application of MONASH reported in section 7, we used a value of zero. Sensitivity analysis not reported in this book indicates that our results are little affected by varying  $\alpha_2$  between 0 and 0.15.

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<sup>47</sup> The short-run supply curve (SS) in year 1 in the policy simulation is given by:

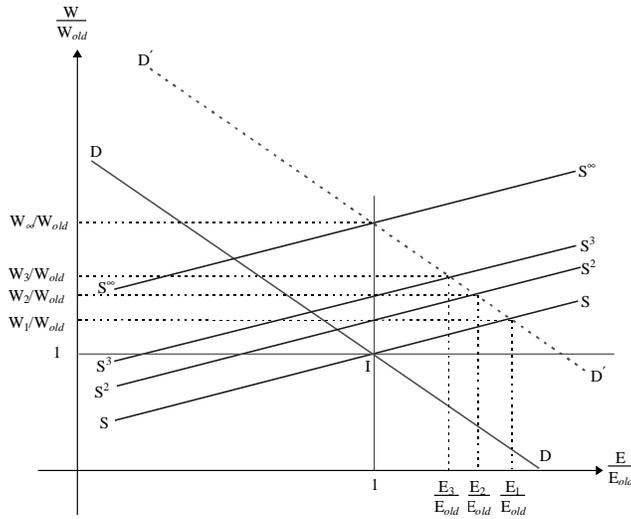
$$W_1/W_{old} - 1 = \alpha_1(E_1/E_{old} - 1).$$

More generally, with a steady-state forecast, the short-run supply curve ( $S^t S^t$ ) in year  $t$  of the policy simulation is given by:

$$W_t/W_{old} - 1 = W_{t-1}/W_{old} - 1 + \alpha_1(E_t/E_{old} - 1).$$

On the assumption that the initial solution for year t is the final solution for year t-1, we must include in the year t computation a change form of (32.1) and (32.3) such as:

**Figure 32.1. Operation of the employment-wage specification in a steady state**



$$\frac{W_t}{W_{t,old}}(w_t - w_{t,old}) = \frac{W_{t-1}}{W_{t-1,old}}(w_{t-1} - w_{t-1,old}) + \alpha_1 \frac{E_t}{E_{t,old}}(e_t - e_{t,old}) - \alpha_1 \alpha_2 \left[ \frac{W_{t-1}}{W_{t-1,old}} \right]^{\alpha_2} (w_{t-1} - w_{t-1,old}) \quad (32.4)$$

where

$w_t$  is the percentage change in the real wage rate between years t-1 and t with the policy shock in place;

$w_{t,old}$  is the percentage change in the real wage rate between years t-1 and t without the policy shock, i.e.,  $w_{t,old}$  is the rate of real wage growth in the basecase forecast;

$w_{t-1}$  and  $w_{t-1,old}$  are the percentage changes in the real wage rate between years t-2 and t-1 with and without the policy shock; and

$e_t$  and  $e_{t,old}$  are the percentage changes in aggregate employment between years  $t-1$  and  $t$  with and without the policy shock.

If we were to use (32.4), then in policy simulations,  $w_{t,old}$ ,  $w_{t-1,old}$  and  $e_{t,old}$  could be treated as exogenous variables, and given the values for real wage and employment growth generated in the relevant forecast simulation.<sup>48</sup> The lagged wage rate,  $w_{t-1}$ , could be handled by a `del_unity` term similar to that used in the equation, `E_d_f_xi3_1`, for the movement in the lagged consumer price index.

However, we did not base the TABLO code for the wage-employment specification on (32.4). Instead we worked on a version involving the lagged value for  $W/W_{old}$  rather than the lagged value for  $W$  and based the TABLO code on

$$\begin{aligned} \frac{W_t}{W_{t,old}}(w_t - w_{t,old}) = & \\ 100 * \left[ \frac{W\_B}{W\_OLD\_B} - \frac{W\_L\_B}{W\_OLD\_L\_B} \right] * del\_unity + \alpha_1 \frac{E_t}{E_{t,old}}(e_t - e_{t,old}) & \\ - 100 * \alpha_1 \left[ \left( \frac{W\_B}{W\_OLD\_B} \right)^{\alpha_2} - \left( \frac{W\_L\_B}{W\_OLD\_L\_B} \right)^{\alpha_2} \right] * del\_unity & \quad (32.5) \end{aligned}$$

where

`del_unity` is a variable which is moved from 0 to 1 in the computation for year  $t$ ;

`W_B` is the level in our initial solution for year  $t$  of the real wage rate with the policy shock in place i.e., `W_B` is the level of the real wage in  $t-1$  in the policy simulation;

`W_OLD_B` is the level in our initial solution for year  $t$  of the real wage rate without the policy shock, i.e., `W_OLD_B` is the forecast level of the real wage rate in  $t-1$ ;

`W_L_B` is the level in our initial solution for year  $t$  of the lagged real wage rate with the policy shock in place, i.e., `W_L_B` is the level of the real wage rate in  $t-2$  in the policy simulation; and

`W_OLD_L_B` is the level in our initial solution for year  $t$  of the lagged real wage rate without the policy shock i.e., `W_OLD_L_B` is the forecast level of real wage rate in  $t-2$ .

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<sup>48</sup> Later in this section, in the discussion of `E_real_wage_c_o`, ..., `E_d_error_o`, we describe a convenient method for transferring results for variables in a forecast simulation into shocks for variables in a policy simulation.

On looking at the TABLO code, we find two versions of (32.5),  $E\_del\_f\_wage\_c$  and  $E\_del\_f\_wage\_pt$ . In the first version, the wage variables and coefficients refer to the economy-wide *pre-tax* wage rate deflated by the CPI. When this version is turned on by exogenization of  $del\_f\_wage\_c$ , we are assuming that wage bargains are made in real, *pre-tax* terms. In the second version, the wage variables and coefficients refer to the economy-wide *post-tax* wage rate deflated by the CPI. When this version is turned on by exogenization of  $del\_f\_wage\_pt$ , we are assuming that nominal wage rates respond not only to movements in the CPI and aggregate employment, but also to changes in rates of income tax. If, for example, there is an increase in income tax rates, then in the second version of the employment-wage specification, workers attempt to maintain their real post-tax wage rates by demanding higher pre-tax wage rates.

Before leaving the employment-wage specification, we consider the evaluation, in the year- $t$  computation of a policy simulation, of the wage and employment coefficients in  $E\_del\_f\_wage\_c$  and  $E\_del\_f\_wage\_pt$ .

In  $E\_del\_f\_wage\_c$  there are three pairs of real wage coefficients and a pair of employment coefficients. The first pair of wage coefficients are  $RWAGE$  and  $RWAGE\_OLD$ , the year- $t$  real wage rates with and without the policy shock. From subsections 18.4 and 18.7, we find that these are read from Header "RWAG" in files with logical names  $EXTRA$  and  $EXTRA3$ , and are updated by  $real\_wage\_c$  and  $real\_wage\_c\_o$  (the percentage movements in the real wage rate between  $t-1$  and  $t$  with and without the policy shock). In a policy simulation for years 2,3, ... $T$ , the particular files that we use in the year  $t$  computation ( $t > 1$ ) to play the roles of  $EXTRA$  and  $EXTRA3$  are the particular files which played the roles of updated file  $EXTRA$  in the policy and forecast computations for year  $t-1$ . Thus, in the computation for year  $t$ ,  $t > 1$ , the initial values for  $RWAGE$  and  $RWAGE\_OLD$  are, as required, the real wage rates projected for year  $t-1$  with and without the policy shock. In the computation for year 1, the initial values of  $RWAGE$  and  $RWAGE\_OLD$  should be the same. Since only the ratio of the initial values is of any significance, both can be read from  $EXTRA$  and  $EXTRA3$  files in which the Header "RWAG" contains the value 1.0.

The second pair of wage coefficients in  $E\_del\_f\_wage\_c$  are  $RWAGE\_B$  and  $RWAGE\_OLD\_B$ . In the year  $t$  computation, these are fixed via Formula (Initial)s in subsection 18.5u at the initial values for  $RWAGE$  and  $RWAGE\_OLD$ . Thus, they are fixed, as required, at the wage rates applying in year  $t-1$ , with and without the policy shocks.

The final pair of real wage coefficients in  $E\_del\_f\_wage\_c$ ,  $RWAGE\_L\_B$  and  $RWAGE\_O\_L\_B$ , are read from Header "RWAG" in files with logical names  $EXTRA4$  and  $EXTRA5$  and are not updated. For  $t > 2$ , we ensure that the particular files playing the roles of  $EXTRA4$  and  $EXTRA5$  in the year  $t$  computation of a policy simulation are the particular files which played the roles of updated file  $EXTRA$  in the year  $t-2$  computations of the policy and forecast simulations. Thus,

in the year- $t$  policy computation,  $t > 2$ , `RWAGE_L_B` and `RWAGE_O_L_B` are fixed, as required, at the real wage rates applying in year  $t-2$ , with and without the policy shock. In the computations for years 1 and 2, the initial values of `RWAGE_L_B` and `RWAGE_O_L_B` should be the same. Again, only their ratio matters. Consequently, they may be read from `EXTRA4` and `EXTRA5` files in which the number in the Header "RWAG" is 1.0.

The evaluation of the pair of employment coefficients in `E_del_f_wage_c`, `EMPLOY` and `EMPLOY_OLD`, is similar to that of `RWAGE` and `RWAGE_OLD`. They are read from Header "EMPT" in `EXTRA` and `EXTRA3`, and are updated by `emp_hours` and `emp_hours_o` (the percentage movements in employment between  $t-1$  and  $t$  with and without the policy shock).

In `E_del_f_wage_pt`, the post-tax wage coefficients are evaluated by formulas in subsection 18.5u. In the computation for year  $t$  of a policy simulation for years  $1, \dots, T$ , these formulas involve the pre-tax wage coefficients (discussed above) together with the following tax coefficients:

`TAX_L_RATE` and `TAX_L_RATE_O`, the tax rates on labour income applying in year  $t$  with and without the policy shock; and

`TAX_L_RATE_L` and `TAX_L_R_O_L`, the tax rates on labour income applying in year  $t-2$  with and without the policy shock.

Notice that we do not need separate coefficients for the tax rates in year  $t-1$ . The post-tax real wage rates for year  $t-1$  are calculated in subsection 18.5u as the initial values of the post-tax real wage rates for year  $t$ .

From subsections 18.4 and 18.7 we find that `TAX_L_RATE` and `TAX_L_RATE_O` are read from Header "TAXL" in the `EXTRA` and `EXTRA3` files, and are updated by `tax_l_r` and `tax_l_r_o` (the percentage changes between years  $t-1$  and  $t$  in the tax rates on labour, with and without the policy shocks). As we have seen already, the files playing the roles of `EXTRA` and `EXTRA3` in the policy computation for year  $t$ ,  $t > 1$ , are the updated `EXTRA` files produced by the policy and forecast computations for  $t-1$ . Thus, as required, when  $t > 1$  the initial values for `TAX_L_RATE` and `TAX_L_RATE_O` in the year  $t$  computation are the tax rates projected for year  $t-1$ , with and without the policy shock. When  $t=1$ , we ensure the initial values for `TAX_L_RATE` and `TAX_L_RATE_O` are the tax rate for year  $t-1$  by using `EXTRA` and `EXTRA3` files in which the entries in the Header "TAXL" are the rate of tax on labour income implied by our data for year 0.

From subsection 18.4, we find that `TAX_L_RATE_L` and `TAX_L_R_O_L` are read from Header "TAXL" in `EXTRA4` and `EXTRA5`, and are not updated. As noted earlier, the particular `EXTRA4` and `EXTRA5` files used in the year- $t$  computation ( $t > 2$ ) of a policy simulation are the updated `EXTRA` files produced in the computations for year  $t-2$  in the policy and forecast simulations. Thus, in the year- $t$  computation ( $t > 2$ ), `TAX_L_RATE_L` and `TAX_L_R_O_L` are fixed, as required, at the tax rates projected for year  $t-2$ . For the year 1 and 2 computations,

we use EXTRA4 and EXTRA5 files in which the entries in the Header "TAXL" are the rates of tax on labour income in our data for years -1 and 0.

### ***E\_real\_wage\_pt***

The employment-wage specifications in the previous two equations include percentage changes in the economy-wide, CPI-deflated, pre- and post-tax wage rates. The pre-tax variable was defined earlier in *E\_real\_wage\_c* (subsection 18.81). The post-tax variable (*real\_wage\_pt*) is now defined in *E\_real\_wage\_pt*. In deriving *E\_real\_wage\_pt*, we started from the levels equation:  $RWAGE\_PT = RWAGE*(1-TAX\_L\_RATE)$ .

### ***E\_d\_f\_empadj and E\_d\_ff\_empadj***

When we use the wage adjustment equations *E\_del\_f\_wage\_c* and *E\_del\_f\_wage\_pt* with  $ALPHA2 = 0$ , we have found that the policy-induced deviation in employment may exhibit a damped cycle and may not show a long-run tendency to adjust back to zero. Typically we have found a long-run tendency to adjust to either a small positive or negative deviation. This is caused by features of our basecase forecast interacting with the policy shock. For example, in a policy simulation of the effects of reducing costs on Australian wharves, we found a long-run tendency to a small positive deviation in employment, despite a gradual increase in real wages. The explanation was that our basecase forecast showed rapid growth in Australia's international trade. Consequently, reduced costs on the wharves provided an ever-increasing benefit to the Australian economy. Under our wage adjustment equations *E\_del\_f\_wage\_c* and *E\_del\_f\_wage\_pt* such a benefit is realized partly in ever-increasing real wage deviations and partly in increased employment

For communicating in the policy debate, we have found that results showing either cycles or small long-run changes in employment require too much explanation, deflecting attention from our main messages. Consequently, we often eliminate cycles and force the long-run employment deviation to zero. We do this by imposing in later years of policy simulations the equation

$$\frac{E_t}{E_{t,old}} - 1 = \left[ \frac{E_{t-1}}{E_{t-1,old}} - 1 \right] * EMPADJ + FEMPADJ \quad . \quad (32.6)$$

with *EMPADJ* at 0.5 (for example) and *EMPADJ* set on zero, ensuring that the percentage deviation in aggregate employment from the basecase forecast must eventually disappear.

In the TABLO version of (32.6), *E\_d\_f\_empadj*, *EMPADJ* is treated as a homotopy variable and shocked each period from zero to 0.5 (say). In early years of a policy simulation *FEMPADJ* is endogenous and movements in aggregate employment are determined elsewhere, in *E\_real\_wage\_pt* for example. In the first

year, say  $t$ , in which (32.6) is used to determine employment, we must move FEMPADJ from its value in  $t-1$  to its forecast value, FEMPADJ\_O.<sup>49</sup> This is done via  $E\_d\_ff\_empadj$  by setting  $d\_emp\_sh$  at one and  $d\_ff\_empadj$  at zero. In year  $t+1$  and subsequent years, we keep FEMPADJ on its forecast value by exogenizing  $d\_f\_empadj$  at its forecast value and endogenizing  $d\_ff\_empadj$ .

***E\_real\_wage\_c\_o, E\_emp\_hours\_o, ..., and E\_d\_error\_o***

All these equations are of the form

$$x\_o = x + fx\_o, \quad (32.7)$$

where

$x$  is a variable such as real wage growth for which we need forecast results in policy simulations;

$fx\_o$  is a shift variable; and

$x\_o$  is the variable which, in policy simulations, is given the forecast simulation value of  $x$ .

The equations have been included in MONASH so that we can use SHOCKTRAN. This is a program which transfers results from forecast simulations to policy simulations. SHOCKTRAN can: (1) read the results generated in a MONASH forecast simulation for year  $t$ ; (2) read the list of exogenous variables to be used in a policy simulation for year  $t$ ; and (3) form a shock file in which exogenous variable  $r$  in the policy simulation is assigned the value,  $r\_f$ , that it had (either endogenously or exogenously) in the forecast simulation, provided only that  $r\_f$  is not zero. A supplementary file of shocks (usually very short) can be prepared manually for variables that are exogenous and shocked in the policy simulation and had zero values in the forecast simulation.

To take advantage of SHOCKTRAN, we must plan our forecast and policy simulations so that the exogenous values required in the policy simulation for variables with non-zero forecast values are precisely those forecast values. SHOCKTRAN would not be applicable if we wanted to give a variable such as  $q$  (the number of households) a different exogenous value in the policy simulation from the non-zero exogenous value it had in the forecast simulation. Similarly, SHOCKTRAN would not be applicable if we wanted to use non-forecast values in the policy simulation for variables such as export demand shifts which have non-zero endogenous values in the forecast simulation but are exogenous in the policy simulation.

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<sup>49</sup> Theoretically, FEMPADJ\_O should be zero because in forecast  $E_t = E_{t,old}$  and  $E_{t-1} = E_{t-1,old}$ . However, small discrepancies can be introduced by the forecast rerun simulation [discussed in connection with (30.25)]. In policy simulations we force FEMPADJ onto its forecast path (not the zero path) to ensure that the policy-induced deviation in  $E_t/E_{t,old}$  does not reflect any deviation between the policy and forecast paths of FEMPADJ.

Returning to (32.7), we see that the use of SHOCKTRAN is facilitated by setting each of the shift variables ( $fx_o$ ) at zero in forecasting simulations. Then the forecast result for  $x_o$  is the same as that for  $x$ . Thus, the forecast result for  $x_o$  is precisely the value required as an exogenous shock for  $x_o$  in policy simulations. With  $x_o$  being exogenous in policy simulations,  $fx_o$  becomes endogenous.

In connection with SHOCKTRAN, it is worth returning briefly to the discussion in subsection 28.1 of  $E\_powtaxm$  (subsection 18.8k in the TABLO code). In forecasting, we exogenize  $fpowtaxm(i)$  and  $ffpowtaxm$  at zero. Consequently the forecast value for  $powtaxmo(i)$  is the forecast value for the percentage change in the power of the tariff on good  $i$ . In policy simulations,  $powtaxmo(i)$  is exogenous and is shocked, via SHOCKTRAN, with its forecast value. Without invalidating the use of SHOCKTRAN, we can adopt different tariff scenarios from those in forecast simulations by attaching to policy simulations supplementary files containing non-zero shocks for  $fpowtaxm(i)$  and/or  $ffpowtaxm$ . Thus, we have the answer to the question posed in subsection 28.1:  $powtaxmo(i)$  is included in MONASH as a computational convenience in the analysis of the effects of tariff changes.

#### ***E\_ev\_over, E\_cv\_under, E\_b3shr and E\_d\_dum\_year1***

This group of equations provides two measures of the effect of policy changes on consumer welfare. Both are simple measures computed without reference to the household utility function. The measures are:

$$EV\_OVER_t = \sum_i P_{it}^f * (X_{it}^p - X_{it}^f) \quad , \quad (32.8)$$

$$\text{and} \quad CV\_UNDER_t = \sum_i P_{it}^p * (X_{it}^p - X_{it}^f) \quad , \quad (32.9)$$

where

$X_{it}^p$  and  $X_{it}^f$  are the consumption of good  $i$  in year  $t$  in the policy and forecast simulations; and

$P_{it}^p$  and  $P_{it}^f$  are the prices to consumers of good  $i$  in year  $t$  in the policy and forecast simulations.

$EV\_OVER$  is sometimes referred to as a Laspeyre cost difference and  $CV\_UNDER$  as a Paasche cost difference (see Ng, 1979, p. 89).  $EV\_OVER_t$  is the amount of money that would need to be given to consumers in the forecast situation in year  $t$  to enable them to just buy the policy consumption bundle. Thus,  $EV\_OVER_t$  is an over-estimate of equivalent variation, that is it over-estimates the amount of money that must be given to consumers in the forecast situation in year  $t$  to enable them to buy a consumption bundle which generates the policy level of utility.  $CV\_UNDER_t$  is the amount of money that could be taken away from

consumers in the policy situation in year  $t$  and leave them just able to buy the forecast consumption bundle. Thus,  $CV\_UNDER_t$  is an under-estimate of compensating variation, that is it under-estimates the amount of money that could be taken away from consumers in the policy situation in year  $t$  and leave them able to buy a consumption bundle which generates the forecast level of utility. In MONASH computations we have usually found that  $EV\_OVER_t$  and  $CV\_UNDER_t$  are close together with  $CV\_UNDER_t$  being less than  $EV\_OVER_t$ . In these circumstances,  $EV\_OVER_t$ ,  $CV\_UNDER_t$  or an average of them are all adequate measures of the welfare effect in year  $t$  of the policy change under consideration.

Expressed in a convenient form, (32.8) and (32.9) can be rewritten as

$$ev\_over_t = 100 * \sum_i BSH_{it}^f * (X_{it}^p - X_{it}^f) / X_{it}^f \quad (32.10)$$

$$\text{and } cv\_under_t = 100 * \sum_i BSH_{it}^p * (X_{it}^p - X_{it}^f) / X_{it}^p \quad (32.11)$$

where

$ev\_over_t$  is the amount of money expressed as a percent of consumer expenditure that must be given to consumers in the forecast situation in year  $t$  to allow them to buy the policy consumption bundle;

$cv\_under_t$  is the amount of money expressed as a percent of consumer expenditure that could be taken away from consumers in the policy situation in year  $t$  and leave them just able to buy the forecast consumption bundle; and

$BSH_{it}^p$  and  $BSH_{it}^f$  are the shares of good  $i$  in household expenditure in year  $t$  in the policy and forecast simulations.

$E\_ev\_over$  is the TABLO representation of (32.10). To understand this representation it is necessary to look at six coefficients:  $LEVX3$ ;  $LEVX3\_O$ ;  $LEVX3B$ ;  $LEVX3B\_O$ ,  $B3SHO$  and  $B3SHBO$ .

The first two,  $LEVX3$  and  $LEVX3\_O$ , are read in subsection 18.4 and updated in subsection 18.7 by  $x3cs$  and  $x3cs\_o$ . In forecast simulations, with  $f\_x3cs\_o$  set at zero (see  $E\_x3cs\_o$ ), the two coefficients are identical. The starting value for the  $(i,s)$ th components of the two coefficients in the year- $t$  forecast computation is a quantity index for the forecast level of consumption of good  $(i,s)$  in year  $t-1$ . In the year- $t$  computation these  $(i,s)$ th components move to the year- $t$  forecast level of consumption of good  $(i,s)$ .

Via Formula(Initial)s in subsection 18.5u,  $LEVX3B$  and  $LEVX3B\_O$  are set in year  $t$  computations at the base values of  $LEVX3$  and  $LEVX3\_O$ . Thus, in a year-to-year forecast simulation, the values of  $LEVX3B$  and  $LEVX3B\_O$  in the year  $t$  computation equal forecast consumption levels in year  $t-1$ . Because  $LEVX3B$  and

LEVX3B\_O are identical in forecast simulations,  $ev\_over$  must be zero in each year.

When we switch to a policy simulation, LEVX3\_O and LEVX3B\_O behave in the same way as in the forecast simulation. This is because LEVX3\_O is updated by  $x3cs\_o$  which continues to reflect forecast movements in consumption. Meanwhile, LEVX3 and LEVX3B move in accordance with the consumption movements ( $x3cs$ ) in the policy simulation. Thus, throughout the year  $t$  computation in a policy simulation, LEVX3B and LEVX3B\_O appearing in  $E\_ev\_over$ , reflect the policy and forecast consumption levels for year  $t-1$ .

The coefficient  $B3SHBO(i,s)$  appearing in  $E\_ev\_over$  in a year- $t$  computation is the share of the consumer budget accounted for by good  $(i,s)$  in the forecast for year  $t-1$ . It is calculated by a formula in subsection 18.5u as the base value of  $B3SHO(i,s)$ . The coefficient  $B3SHO(i,s)$  is read in subsection 18.4, altered by  $Formula(Initial)$  in subsection 18.5u and updated in subsection 18.7 by the percentage movement  $[b3sh\_o(i,s)]$  in the budget share for good  $(i,s)$  in the forecast computation. As will be explained in our discussion of  $E\_d\_dum\_year1$ , the coefficient  $DUM\_YEAR1$  used in the alteration of  $B3SHO(i,s)$  has the value zero in the first year of a simulation and the value one in subsequent years. Thus the alteration by  $Formula(Initial)$  in section 18.5u can affect the value of  $B3SHO(i,s)$  only in the first year of a multi-year simulation. In the first year the alteration by  $Formula(Initial)$  ensures that irrespective of the values that are read for  $B3SHO(i,s)$ , the starting values in the year 1 computation are in fact the budget shares implied by the base data. Our seemingly cumbersome method of evaluating  $B3SHO(i,s)$  is necessary to allow MONASH to generate conveniently the forecast budget shares in a policy simulation.

At this stage we see that the movement in  $del\_unity$  from zero to one in the year- $t$  policy computation generates via  $E\_ev\_over$  the  $ev\_over$  value given by (32.10). It should be emphasised that the year- $t$  policy computation produces the  $ev\_over$  result for year  $t-1$ . To produce the  $ev\_over$  result for year  $t$  we need accurate measures of consumption *levels* in the policy simulation for year  $t$ . These are not available until after the completion of the year  $t$  policy simulation.

$E\_cv\_under$  is the TABLO representation of (32.11). The technicalities underlying this representation are similar to those underlying  $E\_ev\_over$  and require no further explanation.

The next equation defines the percentage movements in budget shares  $[b3shr(i,s)]$  in terms of percentage movements in consumer prices, consumption quantities and the overall budget.

The final equation in this group generates values for  $d\_dum\_year1$ , used in subsection 18.7 to update the coefficient  $DUM\_YEAR1$ . This coefficient has an initial value of zero in computations for year 1 and a value of one for computations for subsequent years. To achieve these values the coefficient is given an initial value of zero in year-1 computations via a read statement. With  $DUM\_YEAR1$  on

zero, a formula in subsection 18.5u ensures that the coefficient `ADJDUMYEAR1` has the value 1. Thus, with `del_unity` moving from zero to one, `d_dum_year1` is one in computations for year 1. Via its update in subsection 18.7, `DUM_YEAR1` moves to one. Thus in year 2 and subsequent years `ADJDUMYEAR1` is zero, `d_dum_year1` is zero and `DUM_YEAR1` remains at one.

***E\_powtax0g, E\_d\_add\_rev, E\_x0dom\_dom and E\_x0***

These are examples of equations added to MONASH to facilitate a specific policy application: the analysis in section 7 of the effects of a reduction in protection on motor vehicles (industry 68 and commodity 70).

The first equation in the group, `E_powtax0g`, was added so that we could handle a particular type of subsidy (negative production tax) which applies to the motor vehicle industry. This takes the form of a partial refund of tariffs paid on imported car parts used as intermediate inputs by the industry. Failure to model this subsidy would lead to underestimation of the damage to the industry of reductions in tariffs because it would cause overestimation of the reduction in the costs to the industry of their imported car inputs.

For each firm in the car industry the tariff refund is paid on imports up to 9.5 per cent of the value of the firm's output. In practice imports by each firm are well in excess of 9.5 per cent of output. Thus, in effect, a typical motor vehicle firm receives a subsidy of 9.5 per cent of the value of its output multiplied by the motor vehicle tariff rate. This can be represented as a (negative) tax on production in the car industry with power:

$$\Pi(68) = [1 - 0.095 * (\text{LEV\_PTAXM}(70) - 1)] + \text{FPOWTAX0G}(68) \quad (32.12)$$

where `LEV_PTAXM(70)` is the power of the tariff on imports of cars and `FPOWTAX0G(68)` is a shift variable which normally has the value zero.

In percentage change form, (32.12) can be written as

$$\begin{aligned} \pi(68) = & - \frac{0.095 * \text{LEV\_PTAXM}(70)}{\Pi(68)} * \text{powtaxm}(70) \\ & + \frac{100}{\Pi(68)} d\_fpowtax0g(68) . \end{aligned} \quad (32.13)$$

By multiplying and dividing on the RHS of (32.13) by the total value of the output of cars or equivalently the total costs [`COSTS(68)`] of the Australian car industry we obtain:

$$\begin{aligned} \pi(68) = & \\ & -0.095 * \left[ \frac{\text{COSTS}(68)}{\text{COSTS}(68) + \text{TAX0G}(68)} \right] * \text{LEV\_PTAXM}(70) * \text{powtaxm}(70) \end{aligned}$$

$$+ \frac{100 * \text{COSTS}(68)}{\text{COSTS}(68) + \text{TAX0G}(68)} d_{\text{fpowtax0g}}(68) \quad (32.14)$$

where TAX0G(68) is the production tax (subsidy if negative) on motor vehicle output.

E\_powtax0g is a generalization of (32.14), written to cover all industries. However for industries other than motor vehicles, it simply allows movements in powers of production taxes to be driven by movements in shift variables.

In simulations of the effects of a reduction in motor vehicle tariffs, the second equation in the group, E\_d\_add\_rev, can be used for introducing revenue replacement policies. For understanding how this is done, it is convenient to assume initially that del\_wealth is set exogenously on zero so that we can ignore the last term. As we will see, the remaining terms (the first three terms) on the RHS of E\_d\_add\_rev are an estimate of the effect on government revenue of the imposition of an additional uniform consumption tax [fpowtax3gu] combined with an additional change in the power of the motor vehicle tariff [fpowtaxm(70)].

In deriving these first three terms we start with the equations

$$\text{NET\_TARIFF\_REV}(70) = \frac{\text{PM}(70)}{E} * \text{QM}(70) * [\text{LEV\_PTAXM}(70) - 1] - 0.095 * (\text{LEV\_PTAXM}(70) - 1) * \text{COSTS}(68) \quad (32.15)$$

$$\text{and} \quad \text{CONS\_TAX\_REV} = \text{BAS3} * (\text{POWTAX3} - 1) \quad (32.16)$$

where

NET\_TAX\_REV(70) is tariff revenue on commodity 70 net of refunds to motor vehicle producers;

QM(70) and PM(70) are the volume of imports of commodity 70 and the foreign currency price;

E is the \$foreign/\$A exchange rate;

CONS\_TAX\_REV is revenue from consumption taxes;

BAS3 is the basic value of household consumption; and

POWTAX3 is the average over commodities of the power of consumption taxes.

Under the assumption that changes in the tariff rate on commodity 70 and changes in the average consumption tax do not affect PM(70), E, QM(70), COST(68) and BAS3, (32.15) and (32.16) give

$$100 * d_{\text{net\_tariff\_rev}}(70) = \text{IMPORTS}(70) * \text{powtaxm}(70) - 0.095 * \text{COSTS}(68) * \text{LEV\_PTAXM}(70) * \text{powtaxm}(70) \quad (32.17)$$

$$\text{and} \quad 100 * d_{\text{cons\_tax\_rev}} = (\text{AGGTAX3} + \text{BAS3}) * \text{powtax3} \quad , \quad (32.18)$$

where

IMPORTS(70) is the landed-duty-paid value of car imports, i.e.,

$$\text{IMPORTS}(70) = [\text{PM}(70)/E] * \text{QM}(70) * \text{LEV\_PTAXM}(70);$$

AGGTAX3 is aggregate consumption taxes; and

d\_net\_tariff\_rev(70), powtaxm(70), d\_cons\_tax\_rev and powtax3 are changes or percentage changes in the variables denoted by the corresponding upper case symbols.

E\_d\_add\_rev with del\_wealth fixed on zero is obtained by adding (32.17) and (32.18) and replacing powtaxm(70) and powtax3 with fpowtaxm(70) and fpowtax3gu.

In the simulation in section 7, fpowtaxm(70) and fpowtax3gu were the additional percentage changes in the power of the tariff on cars and the power of the tax on consumption imposed as the policy. Thus in the policy simulation, the first three terms on the RHS of E\_d\_add\_rev were a first-round estimate of the effect of the policy on net government revenue. They were a first-round estimate because they ignored second-round effects on revenue of policy-induced changes in quantities and prices, PM(70), E, QM(70), etc.

The Australian Treasury makes little use of general equilibrium modelling and we would expect them to ignore second-round effects on revenue of a minor policy change such as reductions in tariffs on cars. By setting d\_add\_rev and del\_wealth exogenously on zero and by endogenizing fpowtax3gu, we simulate the imposition of a revenue-replacing consumption tax set at the rate which would be adopted by Treasury if they used the simplest first-round calculation.

Via the last term on its RHS, E\_d\_add\_rev allows an alternative approach which might be adopted by Treasury in determining fpowtax3gu. Under this alternative, which was applied in section 7, the government sets its revenue-replacing tax in year t with the aim of not only covering the net loss of tariff revenue but also of creating sufficient additional national saving to close any gap apparent in the previous year between the basecase forecast value of real national wealth [defined in subsection 18.8r and discussed in section 34] and its value in the policy simulation. Thus for example, if the estimated net loss in tariff revenue in year t associated with the policy is \$30 million and the policy simulation shows real national wealth in year t-1 to be \$20 million lower than in the forecast simulation, then we assume that the additional consumption tax in year t is designed to raise \$50 million, rather than \$30 million.

To explain how this wealth-sensitive approach is implemented in MONASH, we begin with the equation:

$$\text{WADJ}(t) = [\text{RWEAL\_T\_O} - \text{RWEAL\_T\_B}] \quad , \quad (32.19)$$

where

RWEAL\_T\_O and RWEAL\_T\_B are start-of-year<sup>50</sup> real national wealth in the forecast and policy simulations for year t-1.

Under the wealth-sensitivity assumption, the government sets the consumption tax in year t with the aim of generating sufficient revenue to cover the net loss of tariff revenue and to leave a surplus of WADJ(t). Hence as we move from year t-1 to year t, the change in the consumption tax (fpowtax3gu) must cover the change in WADJ(t) in addition to the change in the estimated net loss of tariff revenue (the first three terms on the RHS of E\_d\_add\_rev). The change in WADJ between years t-1 and t is

$\Delta WADJ(t) =$

$$[RWEAL\_T\_O - RWEAL\_T\_L\_O] - [RWEAL\_T\_B - RWEAL\_T\_L] \quad (32.20)$$

where

RWEAL\_T\_L\_O and RWEAL\_T\_L are start-of-year real national wealth in the forecast and policy simulations for year t-2.

Assuming that the base data for our year t computation is derived from the solution for year t-1,<sup>51</sup> then from (32.20) we can see that the wealth-sensitivity approach can be implemented via E\_d\_add\_rev with del\_wealth set exogenously on one and with d\_add\_rev continuing to be set exogenously on zero.

Our approach to evaluating the four real wealth coefficients in E\_d\_add\_rev is broadly similar to that adopted in the evaluation of the real wage coefficients in E\_del\_f\_wage\_c and E\_del\_f\_wage\_pt, although the details differ. RWEAL\_T\_B is the initial value of RWEAL\_T. As can be seen from the formulas at the end of subsection 18.5w, RWEAL\_T is evaluated in the first year (t = 1) of a simulation (DUM\_YEAR1 = 0) from start-of-year data on industry capital stocks and on net foreign liabilities. In subsequent years (DUM\_YEAR1 = 1), RWEAL\_T is generated by reading (from EXTRA) an updated value created in the simulation of the previous year. RWEAL\_T\_O, RWEAL\_T\_L\_O and RWEAL\_T\_L are also read. For t = 2, 3, ..., we ensure (by reading from EXTRA3) that RWEAL\_T\_O is the updated value of start-of-year real national wealth generated in the forecast simulation for year t-1. For years t = 3, 4, ..., we ensure (by reading from EXTRA5 and EXTRA4) that RWEAL\_T\_L\_O and RWEAL\_T\_L are the updated start-of-year values of real national wealth generated in the forecast and policy simulations for year t-2. This leaves open the evaluation of RWEAL\_T\_O for t = 1 and RWEAL\_T\_L\_O and RWEAL\_T\_L for t = 1 and 2. Remembering that RWEAL\_T\_O for t = 1 is a value at the start of year 0 and is not affected by policy,

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<sup>50</sup> As defined by equations in subsection 18.8r and discussed in section 34, national wealth for year t is measured as the value at the *start of year* t of capital stocks less net foreign liabilities.

<sup>51</sup> If this is not true then E\_d\_add\_rev should be turned off by endogenization of d\_add\_rev.

we ensure that its year 1 value is the same as that of RWEAL\_T\_B via a Formula(Initial) in subsection 18.5w. Similarly, RWEAL\_T\_L\_O and RWEAL\_T\_L for  $t = 1$  and 2 are not affected by policy: they are values at the start of years  $-1$  and 0. For each of these two years we ensure that the difference between the forecast and policy values of these coefficients is zero.<sup>52</sup> Since only these differences matter, this is sufficient to ensure a correct implementation of E\_d\_add\_rev.

The final two equations (E\_x0dom\_dom and E\_x0) added to MONASH to facilitate the tariff-cut experiment define the percentage changes in domestic sales of domestically produced good  $i$  and domestic sales of good  $i$  from both sources. These variables were useful in analyzing the effects of the cuts in motor vehicle tariffs on the share of Australian producers in the Australian car market.

### **33. The government accounts (subsection 18.8q in the TABLO code)**

Australia has three levels of government: federal; state; and local. However in MONASH we simplify reality by treating the public sector as a consolidated entity represented by the flows identified in Table 33.1. The equations in subsection 18.8q allow MONASH to generate results for the consolidated government accounts covering variables such as tax collections, transfer payments and the consolidated budget deficit. Such results are useful in forecasting. Equations for the government accounts are also valuable in policy simulations. In these simulations we often need measures of tax collections and government outlays so that we can implement assumptions such as revenue neutrality or zero impact on the budget deficit. For example, in simulations of the effects of reducing tariffs, we may wish to assume that the government replaces lost tariff revenue by additional income taxes. In this case, we need to be able to exogenize tax revenue and to endogenize the rate of income tax.

#### ***E\_d\_gov\_def, E\_d\_def\_gdp\_r and E\_lev\_def\_gdp\_r***

The first equation is a change form of the government's budget deficit<sup>53</sup> defined as expenditures (AGGOTH, AGGINVG and OTHCAPGOV) minus net tax and other revenue (NET\_TAXTOTG and OTHGOVREV) plus transfers (TRANS). The second and third equations define the change in and the level of the ratio of the

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<sup>52</sup> Because they refer to a pre-simulation year (year  $-1$ ), the EXTRA4 and EXTRA5 files used as inputs to year one computations are identical ensuring that the values of RWEAL\_T\_L and RWEAL\_T\_L\_O in year one are equal. Similarly, because they refer to a pre-simulation year (year 0), the EXTRA4 and EXTRA5 files used as inputs to year two computations are identical ensuring that the values of RWEAL\_T\_L and RWEAL\_T\_L\_O in year two are equal.

<sup>53</sup> The concept of the budget deficit defined here is referred to in Australia as the public sector financing transaction because it is a measure of level of borrowing that the public sector requires to finance its operations.

budget deficit to GDP. The coefficients in the three equations are evaluated either by reads and updates or by simple formulas in subsections 18.5h and 18.5v.

***E\_agginv\_g, E\_agginv\_rg, E\_xi2g, E\_y\_g, E\_f\_gj and E\_d\_othcapgov***

These equations are concerned with movements in public sector capital expenditure (agginv\_g and d\_othcapgov). The first three define: (a) government expenditure on new capital creation as a sum of expenditures over different industries such as public administration, welfare and education; (b) government expenditure in real terms on new capital creation; and (c) a price index for new government capital expenditure.

The next two equations, E\_y\_g and E\_f\_gj, allow movements in government investment by industry to be modelled in a variety of ways. One option is to exogenize both the shift variables in E\_y\_g. Then percentage movements in the ratios of government investment to total investment in each industry can be set exogenously, possibly at zero. A second option is to exogenize only the first shift

**Table 33.1. Government outlays and revenue: 1997 (\$billion)\***

Public consumption (AGGOTH)	90.5	
Public investment (AGGINVG)	24.0	
Transfers (TRANS)	67.1	
<i>made up of:</i>		
Unemployment benefits (UNEMPBEN)		6.9
Age benefits (AGEBEN)		13.4
Other personal benefits (OTHBEN)		25.9
Grants (GRANT)		9.7
Net interest payments (NETINT_G)		11.2
Other capital expenditure (OTHCAPGOV)	-4.4	
<b>Total outlays</b>	<b>177.2</b>	
Indirect taxes (AGGTAXG)	53.0	
<i>made up of taxes on:</i>		
Intermediate inputs (AGGTAX1G)		13.6
Inputs to investment (AGGTAX2G)		3.9
Consumption (AGGTAX3G)		19.2
Exports (AGGTAX4G)		0.4
Public expenditure (AGGTAX5G)		0.0
Production (AGGTAX0G)		10.8
Imports (AGGTAXM)		5.1
Direct taxes (INCTAX + COL_PAYRTOT)	99.3	
<i>made up of taxes on:</i>		
Labour (TAX_LAB + COL_PAYRTOT)		70.9
Capital (TAX_CAP)		27.6
Land (TAX_LND)		0.8
Other revenue (OTHGOVREV)	17.0	
<b>Total revenue</b>	<b>169.3</b>	
<b>Public sector deficit (GOV_DEF)</b>	<b>7.9</b>	

\* Names of MONASH coefficients are shown in parentheses.

variable [ $f_{y_g}(j)$ ] leaving the second shift variable ( $ff_{y_g}$ ) as endogenous. Then we can impose an exogenously given structure for movements in the ratios of government investment to total investment by industry while allowing the percentage movement in real aggregate public investment ( $agginv_{rg}$ ) to be given exogenously. Another option is to use  $E_{f_gj}$  to determine government investment in each industry independently of total investment in the industry. For example, we can impose an exogenous structure on government investment by industry by exogenizing  $f_{gj}(j)$ . If at the same time we endogenize  $f_g$ , then we can achieve an exogenously given movement in real aggregate public investment.

The final equation [ $E_{d_{othcapgov}}$ ] in the group relates growth in other capital outlays/sales by the government to growth in nominal GDP. In recent years this item has been negative and has been dominated by public sector sales of utilities as part of the move to privatization. With  $d_{f_{othcapgov}}$  set exogenously on zero, we ensure that MONASH does not imply an unrealistic movement in the ratio of these sales to GDP.

*$E_{net\_tax\_tot}$ ,  $E_{d\_net\_tax\_gdp}$ ,  $E_{taxrev\_inc}$ ,  $E_{labrevinc}$ ,  $E_{tax\_k\_r}$ ,  $E_{d\_col\_payr}$ ,  $E_{labrev\_j}$  and  $E_{oth\_gov\_rev}$*

This group of equations provides measures of government revenue net of subsidies.

The first equation ( $E_{net\_tax\_tot}$ ) is a change version of the levels form:

$$NET\_TAXTOTG = AGGTAXG + INCTAX + COL\_PAYRTOT \quad (33.1)$$

where

$NET\_TAXTOTG$  is genuine<sup>54</sup> tax revenue net of subsidies;

$AGGTAXG$  is genuine indirect taxes net of subsidies;

$INCTAX$  is income tax collections; and

$COL\_PAYRTOT$  is the collection of payroll taxes.

The coefficient  $AGGTAXG$  in  $E_{net\_tax\_tot}$  is calculated in subsection 18.5g as a sum of sales taxes, production taxes and tariffs.  $INCTAX$  is calculated in subsection 18.5u as the sum of income taxes on labour ( $TAX\_LAB$ ), capital ( $TAX\_CAP$ ) and land ( $TAX\_LND$ ). These income tax collections are calculated in subsection 18.5u by applying average tax rates to labour income net of payroll taxes, to capital income and to land income. We assume that the same tax rate ( $TAX\_K\_RATE$ ) applies to capital and land income. The coefficient  $COL\_PAYRTOT$ , used in the formula for  $NET\_TAXTOTG$ , is calculated in subsection 18.5u according to the formulas

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<sup>54</sup> Phantom tax collections are not included.

$$\text{COL\_PAYRTOT} = \sum_j \text{COL\_PAYROLL}(j) \quad (33.2)$$

and

$$\text{COL\_PAYROLL}(j) = \frac{\text{LABIND\_J}(j)}{\text{POW\_PAYROLL}(j)} * (\text{POW\_PAYROLL}(j) - 1) . \quad (33.3)$$

Thus total payroll tax collection is the sum of payroll-tax collections over industries where the collection [COL\_PAYROLL(j)] in each industry is calculated as the rate of payroll tax [POW\_PAYROLL(j) - 1] multiplied by labour costs net of payroll taxes [LABIND\_J(j)/POW\_PAYROLL(j)].

The next equation (E\_d\_net\_tax\_gdp) defines the change in the ratio of net taxes to GDP.

The third equation (E\_taxrev\_inc) defines the percentage change (taxrev\_inc) in revenue from income taxes. As already indicated, all the coefficients in E\_taxrev\_inc are calculated in subsection 18.5u. Apart from changes in tax rates, income tax collections on labour are driven by labour income net of payroll taxes. This driving variable is defined in the fourth equation, E\_labrevinc. The corresponding driving variables (caprev and Indrev) for income-tax collections on capital and land were defined earlier in subsection 18.8l.

The fifth equation in the group (E\_tax\_k\_r) is useful when we want to assume that tax rates on labour and non-labour (capital and land) income move by the same percentage. This can be done by exogenizing f\_tax\_r at zero.

The sixth equation (E\_d\_col\_payr) is a change version of (33.2) and (33.3). This introduces the percentage change in labour costs by industry [labrev\_j(j)] which is defined in the seventh equation.

The final equation (E\_oth\_gov\_rev) in the group relates growth in other government revenue to growth in nominal GDP. Other government revenue includes income from public sector enterprises and investments, for example dividends from government shares in the Australian telephone company. With privatization, we can expect a reduction in the share of other government revenue to GDP. This could be simulated with negative values for the shift variable f\_oth\_g\_rev.

*E\_transfers, E\_unemp\_ben, E\_unempben\_rat, E\_d\_f\_labsup, E\_age\_ben, E\_oth\_ben, E\_grants, E\_d\_net\_int\_g, E\_d\_int\_psd, E\_d\_rint\_psd, E\_d\_psd\_t1 and E\_d\_f\_psd\_t*

This group of equations models government transfers. The first equation defines total transfers as a sum over different types. All of the coefficients on the RHS are evaluated by reads and updates. The coefficient on the LHS is evaluated by a formula in subsection 18.5v.

The first type of transfer is unemployment benefits, modelled in E\_unemp\_ben and E\_unempben\_rat. The underlying levels forms of these equations are:

$$\text{UNEMPBEN} = \text{ELIGSHARE} * \text{UNEMPBEN\_RATE} * [\text{LAB\_SUP} - \text{EMPLOY}], \quad (33.4)$$

and 
$$\text{UNEMPBEN\_RATE} = \text{CPI} * \text{RWAGE} * \text{F\_UNEMPBEN} , \quad (33.5)$$

where

UNEMPBEN is unemployment benefits;

ELIGSHARE is the proportion of unemployed people who are eligible to receive unemployment benefits;

UNEMPBEN\_RATE is the annual rate of payment to eligible, unemployed people;

LAB\_SUP is the supply of labour;

EMPLOY is aggregate employment;

CPI is the consumer price index;

RWAGE is the real wage rate (CPI deflated); and

F\_UNEMPBEN is a shift variable.

By fixing F\_UNEMPBEN, we assume that the unemployment benefit rate is indexed to the nominal wage rate.

A feature of the Australian labour market is that labour supply responds positively to movements in employment. When the probability of finding a job is low, many people withdraw from the labour force. They do not think that it is worthwhile to undertake the expense and effort involved in job search. When jobs become more plentiful, these people re-enter the labour force. A consequence of this type of behaviour is that payment of unemployment benefits declines rather slowly as employment grows. To take account of this effect in policy simulations, we include E\_d\_f\_labsup in MONASH. This equation is derived from the levels form:

$$\frac{\text{LAB\_SUP}}{\text{LAB\_SUP\_O}} - 1 = \text{LS\_COEFF} * \left( \frac{\text{EMPLOY}}{\text{EMPLOY\_OLD}} - 1 \right) + \text{F\_LABSUP} , \quad (33.6)$$

where

LAB\_SUP is labour supply in year t with the policy shock;

LAB\_SUP\_O is the forecast labour supply, i.e., the labour supply in year t without the policy shock;

EMPLOY and EMPLOY\_OLD are the levels of employment in year t, with and without the policy shock;

LS\_COEFF is a positive parameter, usually set at 0.5; and

F\_LABSUP is a shift variable.

With the shift variable fixed on its forecast value (i.e., zero) and with LS\_COEFF set at 0.5, we assume that if the policy shock under consideration generates a one per cent increase in employment in year  $t$ , then it generates a 0.5 per cent increase in the labour supply in year  $t$ .

In  $E_{age\_ben}$  and  $E_{oth\_ben}$ , we assume that age and other personal benefits (e.g. child support, student allowances, disability allowances) paid by the government are adjusted in line with movements in the overall wage rate ( $xi3 + real\_wage\_c$ ) and with movements in the size of the relevant population. For age benefits we assume that the relevant population is people over 65 ( $pop\_aged$ ). For other benefits we assume that the entire population ( $pop$ ) is relevant. Both equations include a shift variable which can be used to simulate the effects of changes in the rates of benefits.

With the shift variable ( $f\_grants$ ) in  $E\_grants$  set exogenously on zero, we assume that charitable grants, emergency relief grants, foreign-aid grants and other government grants move in line with GDP.

The last five equations in the group are concerned with public sector net interest payments (interest payments less interest receipts) and public sector debt. In  $E\_d\_net\_int\_g$ , the change in public sector net interest payments is derived from:

$$NETINT\_G = INT\_PSD * \frac{(PSDATT + PSDATTPLUS1)}{2} , \quad (33.7)$$

where

$NETINT\_G$  is net interest payments by the government on its accumulated debt;

$INT\_PSD$  is the interest rate on public debt;

$PSDATT$  is the start-of-year level of public debt; and

$PSDATTPLUS1$  is the end-of-year level of public debt.

$E\_d\_int\_psd$  is similar to  $E\_d\_int$  (see subsection 18.8n and the associated explanation in subsection 30.2). It relates the change in the nominal interest rate on public debt ( $d\_int\_psd$ ) to the change in the real interest rate on public debt ( $d\_rint\_psd$ ) and to the change in inflation ( $d\_inf$ ).  $E\_d\_rint\_psd$  is a convenient device for equating the changes in the real interest rates on public debt ( $d\_rint\_psd$ ) and on business borrowing ( $d\_rint$ ). This can be done by exogenizing the shift variable  $d\_f\_rint\_psd$  at zero.

The equation for the change in the end-of-year public sector debt ( $E\_d\_psd\_t1$ ) is derived from the levels form:

$$PSDATTPLUS1 = PSDATT + GOV\_DEF \quad (33.8)$$

where  $GOV\_DEV$  is the level of the budget deficit, that is the level of new borrowing that the government must undertake during the year. In  $E\_d\_psd\_t1$  we also include a shift variable which can be used to allow for data revisions and other discrepancies between the government's deficit and the change across the year in

public sector debt. In year-to-year simulations we can use  $E\_d\_f\_psd\_t$  with its shift variable set exogenously on zero to determine the movement in the start-of-year public sector debt. In simulations spanning more than one year,  $E\_d\_f\_psd\_t$  should be turned off by endogenizing its shift variable. In this case  $d\_psd\_t$  should be set exogenously.

All the coefficients in  $E\_d\_net\_int\_g$ ,  $E\_d\_int\_psd$ ,  $E\_d\_rint\_psd$ ,  $E\_d\_psd\_t1$  and  $E\_d\_f\_psd\_t$  are evaluated either by reads and updates or by formulas in subsections 18.5s and v. The only formula requiring comment is that for end-of-year public sector debt (PSDATTPPLUS1). Rather than the simple (33.8), we are forced to use a formula without GOV\_DEF on its RHS. This is because the value of GOV\_DEF depends on PSDATTPPLUS1 via interest payments (NETINT\_G) and transfers (TRANS). As explained in subsection 17.5, coefficients appearing on the RHSs of formulas must be evaluated by instructions appearing earlier in the TABLO code.

***E\_d\_r\_psdgdp and E\_lev\_r\_psdgdp***

These two equations define the change in and the level of the ratio of start-of-year public sector debt to GDP.

***34. Equations and computational strategy for facilitating decomposition simulations***

This section is divided into two subsections. The first describes a group of equations that played an important role in the decomposition simulation for 1987 to 1994 discussed in subsection 5.3. Through these equations, the effects of each set of exogenous changes (e.g., changes in technology) on private and public consumption were linked to their effects on gross national product (GNP). Underlying our specification of movements in GNP and in related variables such as net foreign liabilities are a series of smooth growth assumptions. As mentioned in subsection 5.3, these assumptions eliminate the need for explicit modelling of intermediate years (1988 to 1993).

The second subsection provides some technical details on decomposition simulations, particularly the minimization of linearization errors through the use of half-way databases.

***34.1. Gross national product, net foreign liabilities, consumption/savings propensities and national wealth (subsection 18.8r in the TABLO code)******E\_gnpnom and E\_cr***

In levels form, these equations are

$$\text{GNP} = \text{GDPEX} - \text{ROIFOREIGN} * \text{NET\_FLTF/EXCH}, \quad (34.1)$$

and 
$$(\text{AGGOTH} + \text{AGGCON}) = (\text{APCGNP}) * \text{GNP} . \quad (34.2)$$

Equation (34.1) defines gross national product as the difference between gross domestic product and income payable to foreigners. In calculating this latter concept, first we multiply the foreign rate of interest or dividend by the foreign currency value of Australia's net foreign liabilities.<sup>55</sup> Then we convert the resulting foreign currency payment into Australian dollars by dividing by the exchange rate. In moving from (34.1) to *E\_gnpnom*, we adopted the simplifying assumption that the foreign rate of interest (*ROIFOREIGN*) is constant. For the decomposition simulation reported in subsection 5.3, *ROIFOREIGN* was fixed at its average value for the period 1987 to 1994.

Equation (34.2) allows consumption (public plus private) to be determined by gross national product. For example, if the percentage change in *APCGNP* (the average propensity to consume out of gross national product), is set exogenously

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<sup>55</sup> Net foreign liabilities are the value of foreign equity in Australian assets net of Australian equity in foreign assets *plus* debts owed by Australian residents (governments, businesses and households) to foreigners net of debts owed by foreigners to Australian residents.

on zero, then the percentage movements in consumption and gross national product will be the same.

### *E\_d\_netflt and E\_aps\_gnp*

The first of these equations generates the change between two years  $t$  and  $t+\tau$  (say, 1987 and 1994) in net foreign liabilities valued in foreign currency. In simplified notation, the underlying theory starts with the equation

$$L_{t+1} = L_t*(1+R) + E_t * \sum_j P_{jt}*(K_{j,t+1} - K_{jt}*(1-D_j)) - E_t*APSGNP_t*GNP_t - E_t*TRNFGNAUS_t, \quad (34.3)$$

where

$L_t$  is net foreign liabilities valued in foreign currency at the beginning of year  $t$  (previously denoted in this section by NET\_FLTF);

$R$  is the foreign rate of interest (or dividend) on Australia's net foreign liabilities (previously denoted by ROIFOREIGN);

$E_t$  is the exchange rate in year  $t$  (previously denoted by EXCH);

$K_{jt}$  is the quantity of capital in industry  $j$  at the beginning of year  $t$ ;

$P_{jt}$  is the average asset price of capital in industry  $j$  in year  $t$ ;

$D_j$  is the depreciation rate in industry  $j$ ;

$GNP_t$  is gross national product in year  $t$ ;

$APSGNP_t$  is the average propensity to save out of gross national product in year  $t$ ; and

$TRNFGNAUS_t$  is the Australian dollar value of net transfers from foreigners to Australian residents (e.g., assets moved into Australia by incoming migrants, net gifts to Australian households from foreign households, and the negative of aid given by the Australian government to international organisations and foreign countries).

In (34.3), we assume that the foreign currency value of Australia's net foreign liabilities at the beginning of year  $t+1$  is: net foreign liabilities at the beginning of the previous year augmented by interest/dividend payments *plus* investment in Australian industries during year  $t$  converted to its foreign currency value by the average exchange rate for the year *minus* the foreign currency value of saving during year  $t$  by Australian residents *minus* the foreign currency value of transfers from foreigners to Australian residents.

The last two items, savings and transfers, need some further explanation. In (34.3), Australian savings in year  $t$  are calculated as a fraction ( $APSGNP_t$ ) of  $GNP_t$ . As can be seen from a formula in subsection 18.5w,  $APSGNP_t$  is one minus  $APCGNP_t$ . This identity is preserved in *E\_aps\_gnp*. By including  $TRNFGNAUS_t$  as a separate item on the RHS of (34.3), we are treating these transfers as additional saving (or dis-saving). For studies in which  $TRNFGNAUS_t$  (a minor

item, worth about 0.4 per cent of GDP) is not the central focus, this treatment seems reasonable. The dominant component in  $TRNFGNAUS_t$  is assets brought to Australia by incoming migrants. We would expect these assets to be largely preserved rather than consumed. As will be described in section 35, movements ( $d\_trn\_fgn\_a$ ) in  $TRNFGNAUS$  are modelled in subsection 18.8s.

From (34.3) we obtain

$$\begin{aligned} L_{t+\tau} &= L_t * (1+R)^\tau \\ &+ \sum_{s=0}^{\tau-1} E_{t+s} * (1+R)^{\tau-s-1} * \sum_j P_{j,t+s} [K_{j,t+s+1} - K_{j,t+s} * (1-D_j)] \\ &- \sum_{s=0}^{\tau-1} E_{t+s} * (1+R)^{\tau-s-1} * [APSGNP_{t+s} * GNP_{t+s} + TRNFGNAUS_{t+s}] . \end{aligned} \quad (34.4)$$

Next, we introduce smooth growth assumptions for the foreign-currency value of national savings (including net foreign transfers), for the foreign-currency value of capital in each industry and for the quantity of capital in each industry:

$$\begin{aligned} E_{t+s} * (APSGNP_{t+s} * GNP_{t+s} + TRNFGNAUS_{t+s}) &= \\ E_t * (APSGNP_t * GNP_t + TRNFGNAUS_t) & \\ * \left( \frac{E_{t+\tau} * (APSGNP_{t+\tau} * GNP_{t+\tau} + TRNFGNAUS_{t+\tau})}{E_t * (APSGNP_t * GNP_t + TRNFGNAUS_t)} \right)^{s/\tau} &\text{ for } s = 1, \dots, \tau-1 ; \end{aligned} \quad (34.5)$$

$$\begin{aligned} E_{t+s} * P_{j,t+s} * K_{j,t+s} &= E_t * P_{jt} * K_{jt} * \left( \frac{E_{t+\tau} * P_{j,t+\tau} * K_{j,t+\tau}}{E_t * P_{jt} * K_{jt}} \right)^{s/\tau} \\ &\text{for } s = 1, \dots, \tau-1 ; \end{aligned} \quad (34.6)$$

$$\text{and } K_{j,t+s} = K_{j,t+s-1} * \left( \frac{K_{j,t+\tau}}{K_{jt}} \right)^{1/\tau} \text{ for } s = 1, \dots, \tau-1 . \quad (34.7)$$

These assumptions allow us to eliminate variables for intermediate years (i.e., between  $t$  and  $t+\tau$ ) from (34.4), giving

$$\begin{aligned}
L_{t+\tau} &= L_t * (1+R)^\tau + \\
&\sum_{s=0}^{\tau-1} (1+R)^{\tau-s-1} \\
&* E_t * \sum_j P_{jt} * K_{jt} * \left( \frac{E_{t+\tau} * P_{j,t+\tau} * K_{j,t+\tau}}{E_t * P_{jt} * K_{jt}} \right)^{s/\tau} \left[ \left( \frac{K_{j,t+\tau}}{K_{jt}} \right)^{1/\tau} - (1-D_j) \right] \\
&- E_t * (\text{APSGNP}_t * \text{GNP}_t + \text{TRNFGNAUS}_t) \\
&* \sum_{s=0}^{\tau-1} (1+R)^{\tau-s-1} * \left[ \frac{E_{t+\tau} * (\text{APSGNP}_{t+\tau} * \text{GNP}_{t+\tau} + \text{TRNFGNAUS}_{t+\tau})}{E_t * (\text{APSGNP}_t * \text{GNP}_t + \text{TRNFGNAUS}_t)} \right]^{s/\tau}.
\end{aligned} \tag{34.8}$$

As explained in subsection 5.3(a), smooth accumulation relationships such as (34.8) cause a difficulty in decomposition and historical simulations with respect to initial solutions. In performing these simulations for the period  $t$  to  $t+\tau$  (e.g., 1987 to 1994) we regard MONASH as a model for year  $t+\tau$  of the form

$$F(X, Q) = 0 \tag{34.9}$$

where

$X$  is the vector of variables for year  $t+\tau$ ; and

$Q$  is a vector of values for year  $t$  of net foreign liabilities, capital stocks and other year  $t$  variables appearing in smoothed accumulation relationships such as (34.8).

In computing solutions for (34.9) we like to use year  $t$  values,  $X_t$ , as our initial solution for  $X$ . However, this violates (34.8). With  $X$  equal to  $X_t$

$$\text{LHS}(34.8) = L_t \tag{34.10}$$

and

$$\begin{aligned}
\text{RHS}(34.8) &= L_t * (1+R)^\tau + \sum_{s=0}^{\tau-1} (1+R)^{\tau-s-1} * E_t * \left( \sum_j P_{jt} * K_{jt} * D_j \right) \\
&- E_t * (\text{APSGNP}_t * \text{GNP}_t + \text{TRNFGNAUS}_t) * \sum_{s=0}^{\tau-1} (1+R)^{\tau-s-1}.
\end{aligned} \tag{34.11}$$

In general the expressions in (34.10) and (34.11) will not be equal. Hence, if (34.8) were part of our model, year  $t$  values for variables would not constitute a valid initial solution.

In subsection 5.3(a) we showed that such difficulties can be overcome by using homotopy variables ( $U$ ). In homotopy form, (34.8) can be written as:

$$\begin{aligned}
 L_{t+\tau} - L_t = & \\
 & \left\{ L_t * (1 + R)^\tau + \sum_{s=0}^{\tau-1} (1 + R)^{\tau-s-1} * E_t * (\sum_j P_{jt} * K_{jt} * D_j) \right. \\
 & - E_t * (\text{APSGNP}_t * \text{GNP}_t + \text{TRNFGNAUS}_t) * \sum_{s=0}^{\tau-1} (1 + R)^{\tau-s-1} - L_t \} * U \\
 & + \left\{ \sum_{s=0}^{\tau-1} (1 + R)^{\tau-s-1} * E_t * \sum_j P_{jt} * K_{jt} * \left( \frac{E_{t+\tau} * P_{j,t+\tau} * K_{j,t+\tau}}{E_t * P_{jt} * K_{jt}} \right)^{s/\tau} * \right. \\
 & \left. \left[ \left( \frac{K_{j,t+\tau}}{K_{jt}} \right)^{1/\tau} - (1 - D_j) \right] - \sum_{s=0}^{\tau-1} (1 + R)^{\tau-s-1} * E_t * \sum_j P_{jt} * K_{jt} * D_j \right\} \\
 & - \left\{ E_t * (\text{APSGNP}_t * \text{GNP}_t + \text{TRNFGNAUS}_t) \right. \\
 & * \sum_{s=0}^{\tau-1} (1 + R)^{\tau-s-1} * \left[ \frac{E_{t+\tau} * (\text{APSGNP}_{t+\tau} * \text{GNP}_{t+\tau} + \text{TRNFGNAUS}_{t+\tau})}{E_t * (\text{APSGNP}_t * \text{GNP}_t + \text{TRNFGNAUS}_t)} \right]^{s/\tau} \\
 & \left. - E_t * (\text{APSGNP}_t * \text{GNP}_t + \text{TRNFGNAUS}_t) * \sum_{s=0}^{\tau-1} (1 + R)^{\tau-s-1} \right\} \quad (34.12)
 \end{aligned}$$

where U is a variable having an initial value of 0, moving to a final value of 1. Notice that when U is at its initial value of zero and all variables are set at their year t values, then

$$\text{LHS}(34.12) = 0 = \text{RHS}(34.12). \quad (34.13)$$

When U is moved to one as part of a year-t/year-(t+τ) simulation, (34.8) is re-established.

In terms of the discussion in subsection 5.3(b), (34.12) presents the change in net foreign liabilities between years t and t+τ in three parts. The first is momentum, the U term on the RHS of (34.12). The movement in U from 0 to 1 generates the change in net foreign liabilities that would have occurred in the absence of changes in GNP *plus* transfers, capital stocks, the exchange rate and prices. The second part is the excess accumulated cost of investment, denoted in subsection 5.3(b) and Figure 5.1 by  $I_{87/94}$ . This is the difference between the value of investment over the period t to t+τ and the value investment would have had in the absence of changes in capital stocks, the exchange rate and prices. The final part is accumulated excess saving, denoted in subsection 5.3(b) and Figure 5.1 by  $S_{87/94}$ . This is the difference between the value of accumulated saving over the period t to t+τ and the

value accumulated saving would have had in the absence of changes in GNP *plus* transfers, the exchange rate and the average propensity to save.

$E\_d\_netflt$  is the change version of (34.12) used in the MONASH model. Apart from obvious differences in notation, readers wishing to check the derivation of  $E\_d\_netflt$  from (34.12) should keep five points in mind.

First, we have included a shift variable ( $d\_f\_netflt$ ) on the RHS of  $E\_d\_netflt$ . By endogenizing this shift variable, we can turn  $E\_d\_netflt$  off, allowing the change in net foreign liabilities to be determined by other equations, for example those discussed in section 35.

Second, only  $U$  and year  $t+\tau$  concepts are treated as variables. Year  $t$  (or base-year concepts denoted in  $E\_d\_netflt$  by  $\_B$ ) are treated as parameters. They are part of the  $Q$  vector in (34.9).

Third, in  $E\_d\_netflt$ , we use the expression:

$$\sum_{s=0}^{\tau-1} (1+R)^{\tau-s-1} = [(1+R)^{\tau} - 1]/R. \quad (34.14)$$

Fourth, in  $E\_d\_netflt$  we handle expressions involving  $s$  and summations over  $s$  from 0 to  $\tau-1$  by using COUNTSET, COUNT( $s$ ) and DUM\_COUNT( $s$ ). For example, we represent

$$\sum_{s=0}^{\tau-1} s * \{ \dots \} \quad (34.15)$$

$$\text{as } \text{Sum}(s, \text{COUNTSET}, \text{DUM\_COUNT}(s)*\text{COUNT}(s)*\{ \dots \} \quad (34.16)$$

As can be seen from subsections 18.2a and 18.5w: COUNTSET is a set containing the components CS1, CS2, ..., CS20; DUM\_COUNT( $s$ ) is a coefficient with value 1 for the first TAU components of COUNTSET and 0 for the remaining components; and COUNT( $s$ ) is a coefficient with value  $s-1$  for the  $s$ th component of COUNTSET. Thus (34.16) reduces to (34.15). The advantage of seemingly clumsy expressions such as (34.16) is that they allow us to treat TAU as a coefficient, evaluated by a read statement in subsection 18.4. In the MONASH application in subsection 5.3, TAU is 7 (1987 to 1994). For other applications, the value of TAU can be changed by changing a data file. Provided that TAU is less than 20 (the number of components in COUNTSET), no alteration is required to the TABLO representation of our model.

The final noteworthy point associated with  $E\_d\_netflt$  concerns the role of DUMMY\_DEC in the evaluation of year- $t$  coefficients such as NET\_FLTF $\_B$ , GNP $\_B$ , APSGNP $\_B$ , EXCH $\_B$ , PCAP $\_J\_B(j)$ , QCAPATT $\_B(j)$ , etc. This is discussed in the next subsection.

### ***E\_d\_netflt***

The levels form of this equation is

$$\text{NET\_FLT} = \text{NET\_FLTF}/\text{EXCH\_T} , \quad (34.17)$$

i.e., net foreign liabilities in Australian dollars at the beginning of year  $t$  equals net foreign liabilities in foreign dollars divided by the exchange rate.

***E\_wealth\_at\_t, E\_rwealth\_at\_t and E\_xi2\_t***

The first of these equations defines national wealth at the beginning of year  $t$  as the difference between the value of industry capital stocks and the \$A value of net foreign liabilities. The second defines real national wealth at the beginning of year  $t$  as national wealth deflated by the index of start-of-year prices of capital goods. The third defines this index as an average over industries of start-of-year capital goods prices.

**34.2. Computational strategy for decomposition simulations**

As explained in subsection 2.2(a), in decomposition simulations we use a Johansen (or one-step Euler) computation of the form

$$x(\bar{D}) = B * x(D) \quad (34.18)$$

where

$x(\bar{D})$  and  $x(D)$  are vectors of percentage changes (or changes) in the endogenous and exogenous variables in the decomposition closure, and

$B$  is the matrix of partial derivatives relating the movements in the endogenous variables to those in the exogenous variables.

To reduce linearization errors, that is to ensure that  $x(\bar{D})$  computed via (34.18) is close to the true solution obtainable in a multi-step computation, we evaluate  $B$  at a "half-way" point between our initial solution (reflecting variable values for year  $t$ , e.g. 1987) and our final solution (reflecting variable values for year  $t+\tau$ , e.g. 1994).

In making the halfway evaluation, we conduct an historical simulation using half-sized shocks. If the full shocks for the period  $t$  to  $t+\tau$  are  $x_{t,t+\tau}(H)$ , in the half-way simulation they are  $\alpha * x_{t,t+\tau}(H)$  where  $\alpha$  is fixed (as discussed below) at approximately 0.5. At the end of this computation, we have a half-way database reflecting half-way values for the exogenous variables.

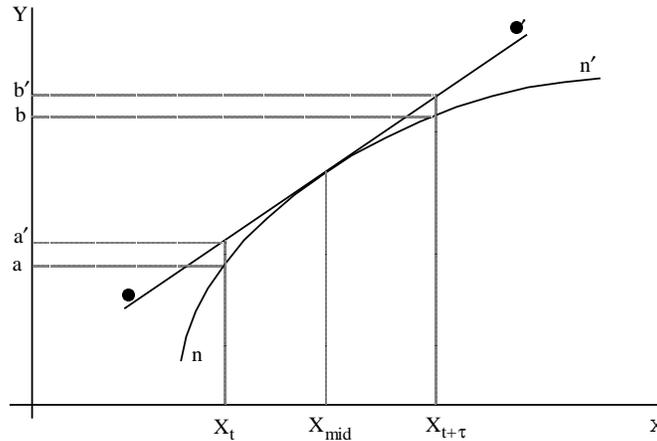
Using this database as the input to a MONASH simulation we form the linear system set out in section 18, with the coefficients approximately half-way between their values in years  $t$  and  $t+\tau$ . Then we conduct a 1-step historical simulation, giving the exogenous variables their full changes<sup>56</sup> for the period  $t$  and  $t+\tau$ . In light of the mean value theorem, we would expect this 1-step historical simulation off the half-way database to generate accurately the full changes in the endogenous variables (see Figure 34.1). We found this to be the case for the historical

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<sup>56</sup> Care is needed with percentage change variables. For example, assume that the foreign currency value of exports (a percentage change variable which is exogenous in the historical closure) increased by 78 per cent between  $t$  and  $t+\tau$ . Then if  $\alpha = 0.5$ , the appropriate percentage shock for this variable in an historical simulation off the half-way database is 56.12 per cent [= 78/(1+0.5\*0.78)].

simulation reported in section 5, with the most accurate results being obtained when the half-way database was generated with  $\alpha = 0.45$ .

**Figure 34.1. Using a half-way database to reduce linearization error**



The true non-linear relationship between  $X$  and  $Y$  is depicted by  $nn'$ , giving an increase in  $Y$  of  $ab$  when  $X$  moves from  $X_t$  to  $X_{t+\tau}$ . By linearizing around the mid point ( $X_{mid}$ ) we obtain an approximate (linear) relationship between  $X$  and  $Y$  depicted by  $ll'$ . This gives an increase in  $Y$  of  $a'b'$ . Unless  $nn'$  is an unusual shape,  $a'b'$  will be close to  $ab$ .

Having obtained a linear system which accurately reproduces the historical results, we switch to the decomposition closure and conduct the computation in (34.18) with the  $x(D)$  vector reflecting values (endogenous and exogenous) from the 1-step historical simulation off the half-way database. With this approach, the components of the decomposition simulation (e.g. the results in columns 1 to 10 of Tables 5.4 and 5.5) add precisely to results or exogenous settings in the 1-step historical simulation. Thus we obtain decomposition results that add very closely to results or settings in a full non-linear historical computation.

A final technical problem to be resolved in relation to simulations off half-way databases concerns the  $Q$  variables in (34.9). Consider for example a particular component of  $Q$ , namely  $GNP_t$  in (34.12). As can be seen from  $E\_d\_netfltf$ , the role of  $GNP_t$  in our TABLO implementation of MONASH is played by  $GNP\_B$ . However, in most simulations  $GNP\_B$  is simply the base value of  $GNP$ . When we are using a half-way database for analysis of the period  $t$  to  $t+\tau$ , the base value of  $GNP$  is approximately half-way between the values of  $GNP$  in years  $t$  and  $t+\tau$ . This is not the value we require for  $GNP\_B$  in simulations using smooth growth assumptions between periods  $t$  and  $t+\tau$ , that is simulations in which  $E\_d\_netfltf$  is turned on. In such simulations  $GNP\_B$  should be the value of  $GNP$  in year  $t$ .

We ensure this via the coefficient DUMMY\_DEC. Notice from subsection 18.4 that GNP\_B is read. This is true of all other components of the Q vector, NET\_FLTF\_B, QCAPATT\_B, etc. In most simulations the read value of these coefficients has no impact. In these simulations DUMMY\_DEC is set at one, allowing the read value to be overruled by a Formula(Initial). For example, from subsection 18.5w we see that with DUMMY\_DEC set on one, GNP\_B is reset at the base value of GNP. Similarly, NET\_FLTF\_B is reset at the base value of NET\_FLTF. In simulations off the half-way database, DUMMY\_DEC is set at zero. Then GNP\_B, NET\_FLTF\_B, etc, retain their read values. These read values were generated in the historical simulation with half-way shocks and with DUMMY\_DEC set on one. Thus, as required, they reflect year t (1987) values for GNP, NET\_FLTF, etc.

### **35. *The balance of payments (subsection 18.8s in the TABLO code)***

In recent years Australia's current account deficit (CAD) has varied between 3 and 6 per cent of GDP, and the level of net foreign liabilities (NFL) has reached about 50 per cent of GDP. Both CAD and NFL are major political statistics. CAD numbers are published monthly by the Australian Bureau of Statistics. High numbers inevitably generate media questioning of the direction of Australian economic policy, while low numbers lead the government of the day to an outbreak of self congratulation. Although published less frequently, the statistics on net foreign liabilities attract a similar amount of attention.

Economists in Australia [most notably Pitchford, e.g. 1990] have questioned the appropriateness of having CAD and NFL as targets of macro policy. Nevertheless, results for these variables are of great interest to users of MONASH simulations. Consequently, we include in MONASH (subsection 18.8s) equations giving a detailed account of CAD and NFL. These equations are concerned largely with the concepts in Table 35.1.

Unlike the equations for NFL discussed in section 34, the CAD and NFL equations discussed in this section are suitable for tracing out year-to-year movements.

#### ***E\_d\_cad, E\_d\_newfl and E\_d\_balitem***

The first equation in subsection 18.8s, E\_d\_cad, defines the change in the current account deficit. As can be seen from Table 35.1, Australia's trade is approximately balanced and the current account deficit is dominated by interest/dividend payments and receipts on foreign liabilities and assets. Consequently MONASH gives these items relatively detailed treatment.

In representing interest and dividend payments we divide Australia's liabilities into three parts: debt repayable in foreign currency (about 36 per cent of Australia's foreign liabilities); debt repayable in domestic currency (about 23 per cent); and foreign-owned equity in Australian industries (about 41 per cent). By distinguishing between foreign- and domestic-currency debt, MONASH captures

valuation effects of exchange rate changes, including exchange-rate-induced changes in the value of Australia's foreign debt relative to the value of exports. By identifying foreign-

**Table 35.1. Calculation of the current account deficit: 1997 (\$billion)\***

IMPORTS (AGGIMP)	98.8	
– EXPORTS (AGGEXP)	-99.6	
+ SERVICING OF AUSTRALIA'S FOREIGN LIABILITIES	27.9	
<i>MADE UP OF:</i>		
INTEREST ON \$F FOREIGN DEBT (INTFDFC)		8.9
+ INTEREST ON \$A FOREIGN DEBT (INTFDDC)		5.7
+ DIVIDENDS (DIV_FE_A)		13.3
– INCOME FROM AUSTRALIA'S FOREIGN ASSETS	-8.6	
<i>MADE UP OF:</i>		
– INTEREST ON \$F LOANS (INTFCFC)		-2.1
– INTEREST ON \$A LOANS (INTFCDC)		-0.6
– DIVIDENDS (DIV_AE_F)		-5.9
– TRANSFERS FROM FOREIGNERS TO AUSTRALIANS	-4.4	
<i>MADE UP OF:</i>		
– UNREQUITED FLOWS FROM FOREIGNERS (TRNFGNHH)		-3.4
– INCOME TAXES PAID BY FOREIGNERS (TAXFGNGOV)		-1.0
+ TRANSFERS TO FOREIGNERS (TRNOTHFGN)	2.7	
<b>CURRENT ACCOUNT DEFICIT (CADEF)</b>	<b>16.8</b>	
CURRENT ACCOUNT DEFICIT AS PERCENT OF GDP	3.4 %	

\*Names of MONASH coefficients are shown in parentheses.

owned equity, MONASH recognizes that increases in the profitability of Australian industries generate capital gains and additional dividends for foreigners.

Similarly, in representing interest and dividend receipts, we divide Australia's foreign assets into three parts: credits payable in foreign currency (about 34 per cent of Australia's foreign assets); credits payable in domestic currency (about 10 per cent); and Australian equity in other countries (about 56 per cent). Thus MONASH can capture the effects on receipts from Australia's foreign assets of changes in the exchange rate and in the profitability of foreign industries.

The levels version of  $E_d\_cad$  is

$$\begin{aligned}
 CADEF = & AGGIMP - AGGEXP\_ADJ + INTFDFC \\
 & + INTFDDC - INTFCFC - INTFCDC \\
 & + DIV\_FE\_A - DIV\_AE\_F - TRNFGNAUS \quad , \quad (35.1)
 \end{aligned}$$

where

CADEF is the \$A value of the current account deficit;

AGGIMP is the c.i.f. value of imports of goods and services;

AGGEXP\_ADJ is the f.o.b. value of exports of goods and services (AGGEXP) adjusted, as discussed below, by the addition of the term  $(1-DUMF)*AGGTAX4F$ ;

INTFDFC is the interest paid on foreign-currency debt;

INTFDCC is the interest paid on domestic-currency debt;

INTFCFC is the interest received from foreign-currency credits;

INTFCDC is the interest received from domestic-currency credits;

DIV\_FE\_A is dividends and retained profits on equity held by foreigners in Australian industries;

DIV\_AE\_F is dividends and retained profits on equity held by Australians in foreign countries; and

TRNFGNAUS is net transfers from foreigners to Australians.

With the exception of the adjusted value of exports, none of the coefficients in  $E\_d\_cad$  raise any new issues. They have either been discussed in connection with earlier equations or are evaluated by simple reads and updates.

If DUMF is one then there is no adjustment of the value of exports. However, usually we set DUMF at zero. In a year-t computation, this has the effect of zeroing out phantom taxes from the database generated in the year-(t-1) computation (see subsection 28.2). For calculating the change in the current account deficit ( $d\_cad$ ) in the year t computation we re-include year t-1's phantom taxes (AGGTAX4F) in the base value of exports for year t. If phantom taxes in year t-1 are positive, then leaving them out of the base value of exports in the year t calculation of  $d\_cad$  will lead to an underestimate of the improvement in the current account deficit associated with any given growth ( $expvald$ ) in the value of exports. For example, if the aggregate value of exports in year zero (the data year) is \$100, phantom export taxes in year zero are \$2 and export growth ( $expvald$ ) in year one is 10 per cent, then the exclusion of year zero's phantom export taxes from the calculation of  $d\_cad$  in year one would cause an under-estimate of \$0.2 in the improvement in the current account deficit. By updating AGGEXP4F by  $expvald$  (see subsection 18.7) we ensure in a year-t computation of  $d\_cad$  that all of the exports in the final solution for year t-1 are moved by  $expvald$ . However, as is apparent from the discussion of CADEF at the end of this section, the re-inclusion of year t-1's phantom export taxes ensures a completely accurate valuation of  $d\_cad$  only for year one. This is because the initial value of AGGEXP in a year t calculation excludes not only phantom taxes from year t-1 but also from years t-2, t-3, etc.

The second equation in subsection 18.8s,  $E\_d\_newfl$ , equates the change in foreign lending and equity investment in Australia to the change in the current

account deficit *plus* the change in Australia's lending and equity investment abroad *minus* the change in the balancing item. The change in lending and equity investment abroad ( $d\_newfa$ ) is modelled later in subsection 18.8s. The balancing item (which reflects differences in published estimates of the current account deficit from the current and capital sides of the balance of payments) can be modelled via  $E\_d\_balitem$  as a fixed share of GDP.

The remainder of the equations in subsection 18.8s are concerned mainly with the movements in: (a) the interest and dividend flows on the RHS of (35.1) and related asset and debt variables, and (b) transfers between foreigners and Australian residents.

***E\_int\_fdfc, E\_int\_fddc, E\_int\_fcfc and E\_int\_fcdc***

The theory underlying each of these equations is:

$$\text{INTEREST} = \text{ROI} * (\text{DatT1} + \text{DatT}) / 2 \quad , \quad (35.2)$$

that is we relate interest payments (receipts) to a rate of interest (ROI) and the average level of debt (credit) through the year computed as the value at the start of the year ( $\text{DatT}$ ) plus the value at the end of the year ( $\text{DatT1}$ ) divided by 2. Interest rates in MONASH are normally treated as exogenous variables. More elaborate treatments would require integration of MONASH with a financial model.

The coefficients in these four equations are start-of-year and end-of-year debt and credit levels ( $\text{DatT}$  and  $\text{DatT1}$ ). These are calculated in subsection 18.5x as shares ( $\text{SHT\_FDFC}$ ,  $\text{SHT1\_FDFC}$  etc.) of Australia's total start-of-year and end-of-year foreign liabilities and assets. The share coefficients are read in subsection 18.4 and updated in subsection 18.7.

***E\_div\_fea, E\_div\_fea\_j and E\_div\_aef***

$E\_div\_fea$  is derived from

$$\text{DIV\_FE\_A} = \sum_j \text{DIV\_FE\_A\_J}(j) \quad (35.3)$$

where  $\text{DIV\_FE\_A}$  has been defined earlier in connection with (35.1) and  $\text{DIV\_FE\_A\_J}(j)$  is dividends and retained profits on equity held by foreigners in Australian industry  $j$ .

Movements in  $\text{DIV\_FE\_A\_J}(j)$  are modelled in  $E\_div\_fea\_j$ . In simplified notation, the levels form of this equation is

$$\text{DIV\_FE\_A\_J}(j) = \text{R}(j) * \text{K}(j) * (1-T) * \{\text{FE\_A\_T\_J}(j) / \text{VCAP\_AT\_T}(j)\} * \text{F}(j) * \text{FF} \quad (35.4)$$

where

$\text{R}(j)$  is the rental per unit of capital in industry  $j$ ;

$\text{K}(j)$  is the quantity of capital in industry  $j$  at the start of the year;

T is the rate of tax applying to rental income;

$FE\_A\_T\_J(j)/VCAP\_AT\_T(j)$  is the share of the capital in industry j that is owned by foreigners; and

F(j) and FF are shifters allowing dividend payments to foreigners to move independently of after-tax rentals in industry j and of the foreign-ownership share.

The coefficients in  $E\_div\_fea$  and  $E\_div\_fea\_j$  are  $TAX\_K\_RATE$ ,  $DIV\_FE\_A$  and  $DIV\_FE\_A\_J$ . The first two are read in subsection 18.4 and updated in subsection 18.7. The treatment of the third coefficient is more complicated. Whereas there are published data for aggregate dividend payments ( $DIV\_FE\_A$ ), there are no published data on foreign-owned dividends by industry ( $DIV\_FE\_A\_J$ ). In the first year of a simulation (year 1), preliminary estimates of foreign-owned industry dividends are made in subsection 18.5x by a version of (35.4) using a Formula(Initial) which draws on estimates, discussed later, of foreign equity [ $FE\_A\_T\_J(j)$ ] in each industry in the data year (year 0). The shift coefficients ( $FGN\_SHD\_J$  and  $FGN\_SHD$ ) in this Formula(Initial) are read in subsection 18.4. In the year 0 data their values are one. Following the Formula(Initial) for the preliminary estimates of the  $DIV\_FE\_A\_J$ s, there are two further Formula(Initial)s. The first calculates the sum of the industry dividends ( $DIV\_FEA\_ADD$ ) implied by the preliminary industry estimates. The second adjusts the value of  $FGN\_SHD$ . With this adjusted value, the next formula re-estimates the  $DIV\_FE\_A\_J$ s. These re-estimates add to the observed value for aggregate dividends ( $DIV\_FE\_A$ ). In multi-year simulations, the computations for year 2 draw on data for year 1. In the year 1 data there is no inconsistency between the read value of  $DIV\_FE\_A$  and the values of the  $DIV\_FE\_A\_J$ s calculated via the preliminary formula in subsection 18.5x. Consequently, beyond year 1, the Formula(Initial)s in subsection 18.5x have no effect on the evaluation of the  $DIV\_FE\_A\_J$ s.

Because MONASH is a one-country model, its treatment of dividends on Australian equity in foreign countries contains no country/industry detail. In  $E\_div\_aef$  the percentage movement in dividend receipts on foreign equity ( $div\_aef$ ) is the percentage movement in the average rate of dividend ( $rodiv\_aef$ ) plus the percentage movement in the value of Australia's foreign equity holdings ( $aef\_t$ ). The average dividend rate is normally set exogenously.

#### ***E\_p1cap\_ave and E\_p1cap\_ave\_f***

These two equations define the economy-wide average movement in the rental rate of capital and the average movement in the rental rate of capital owned by foreigners. Comparisons of results for  $p1cap\_ave$  and  $p1cap\_ave\_f$  are useful in explaining movements in dividends paid to foreigners ( $div\_fea$ ) relative to movements in the overall profitability of Australian capital (measured by  $caprev$  for example).

$E_d_f_fdfc_t$ ,  $E_d_f_fddc_t$ ,  $E_d_f_fea_t_j$ ,  $E_d_f_fcf_t$ ,  $E_d_f_fcdc_t$ ,  
 $E_d_f_aef_t$ ,  $E_{ff\_shfeat}$ ,  $E_{fea_t}$ ,  $E_{aef_t}$ ,  $E_{flt}$ ,  $E_{fdfc_t}$ ,  $E_{fddc_t}$ ,  
 $E_{fea_t_j}$ ,  $E_{fcfc_t}$ ,  $E_{fcdc_t}$  and  $E_{fat}$

This group of sixteen equations ties down the start-of-year debt, credit and equity values introduced in the equations just described concerned with interest and dividends.

The first six are homotopy equations. With their shift variables exogenous and unshocked, they are used in year-to-year simulations to generate movements in  $fdfc_t$ ,  $fddc_t$ ,  $fea_t_j$ ,  $fcfc_t$ ,  $fcdc_t$  and  $aef_t$ . In solutions spanning a time period of more than one year, these six equations are turned off by endogenizing their shift variables.

The next four equations define: start-of-year aggregate foreign equity as a sum across industries; start-of-year foreign liabilities as a sum of debt and equity; start-of-year foreign assets as a sum of credit and equity; and net foreign liabilities as a difference between liabilities and assets.

In year-to-year simulations, the final six equations in the group can be thought of as determining the movements in six start-of-year shares: the share of foreign-currency debt in total foreign liabilities ( $shtfdfc$ ); the share of domestic-currency debt in total foreign liabilities ( $shtfddc$ ); the foreign-ownership shares in industry capital stocks [ $shfeat_j(j) + ff\_shfeat$ ]; the share of foreign-currency credits in total foreign assets ( $shtfcfc$ ); the share of domestic-currency credits in total foreign assets ( $shtfcdc$ ); and the ratio of total foreign assets to GDP ( $f\_fat$ ). Notice that the movements in the foreign-ownership shares in industry capital stocks are split into an industry-specific shifter [ $shfeat_j(j)$ ] and a general shifter ( $ff\_shfeat$ ). In year-to-year simulations  $ff\_shfeat$  is exogenous.

The variable  $ff\_shfeat$  plays an endogenous role in simulations spanning more than one year. In such simulations  $shtfdfc$ ,  $shtfddc$ ,  $shfeat_j$ ,  $shtfcfc$ ,  $shtfcdc$  and  $f\_fat$  are exogenous. In this case the last six equations in this group take over from the homotopy equations in determining start-of-year debt, credit and equity values. As explained in section 34, in simulations spanning more than one year, the change in net foreign liabilities ( $d\_net\_flt$ ) is determined mainly by comparison of capital and GNP growth [see  $E_d\_netfltf$  and  $E_d\_netflt$ ]. Exogeneity of  $f\_fat$  ties down  $fat$ , leaving  $flt$  to be determined in  $E\_flt$ . Then exogeneity of  $shtfdfc$  and  $shtfddc$  allows  $fdfc_t$  and  $fddc_t$  to be determined in  $E\_fdfc_t$  and  $E\_fddc_t$ , leaving  $fea_t$  to be determined as a residual in  $E\_fea_t$ . With the start-of-year movement in aggregate foreign equity ( $fea_t$ ) determined in this way, endogeneity of  $ff\_shfeat$  is required to avoid conflict with the movement implied by aggregating over the industry variables ( $fea_t_j$ ) determined in  $E\_fea_t_j$ .

In the sixteen equations being considered here, the only coefficients requiring explanation are  $FE\_A\_T\_J\_B$  and  $FE\_A\_T1\_J\_B$ . These are the base values of  $FE\_A\_T\_J$  and  $FE\_A\_T1\_J$ . The treatment of  $FE\_A\_T\_J$  and  $FE\_A\_T1\_J$  in subsection 18.5x is similar to that of  $DIV\_FE\_A\_J$ . We make preliminary

estimates of FE\_A\_T\_J and FE\_A\_T1\_J from base values of industry capital stocks [VCAP\_AT\_T, read, and VCAP\_AT\_T1, calculated in subsection 18.5x] and from foreign-ownership shares by industry [SHFEA\_T\_J and SHFEA\_T1\_J, both read]. The shares are adjusted by Formula(Initial)s to ensure that the totals across all industries of the FE\_A\_T\_Js and the FE\_A\_T1\_Js are consistent with the aggregate base values of start-of-year and end-of-year foreign equity (FE\_A\_T and FE\_A\_T\_1) deduced earlier in subsection 18.5x from base values of foreign liabilities and foreign debt.

In year-to-year simulations users of MONASH will notice that the percentage changes in some start-of-year stock and share variables computed in year t+1 are not identical to the percentage changes in the corresponding end-of-year variables computed in year t. For example, the percentage changes in start-of-year foreign equities by industry (fea\_t\_j) computed in the simulation for year t+1 are not identical to the percentage changes in end-of-year foreign equities by industry (fea\_t1\_j) computed in year t. This is a minor problem and disappears as we increase the number of steps in Euler computations. In the case of foreign equities, equality between fea\_t\_j in year t+1 and fea\_t1\_j in year t would be achieved if our code ensured that:

$$FE\_A\_T1\_J\_B(\text{year } t) = FE\_A\_T\_J\_B(\text{year } t + 1) \quad (35.5)$$

and

$$FE\_A\_T1\_J\_B(\text{year } t) * \left( 1 + \frac{fea\_t1\_j(\text{year } t)}{100} \right) = FE\_A\_T1\_J\_B(\text{year } t + 1), \quad (35.6)$$

where

the LHS of (35.5) is the base-value of end-of-year foreign equity in the year-t computation;

the RHS of (35.5) is the base-value of start-of-year foreign equity in the year-(t+1) computation;

the LHS of (35.6) is end-of-year foreign equity implied in the year-t computation; and

the RHS of (35.6) is the base-value of end-of-year foreign equity in the year-(t+1) computation.

In combination with  $E\_d\_f\_fea\_t\_j$ <sup>57</sup>, (35.5) and (35.6) imply that

$$fea\_t1\_j(\text{year } t) = fea\_t\_j(\text{year } t + 1) \quad (35.7)$$

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<sup>57</sup> We assume that  $d\_f\_fea\_t\_j(j)$  is exogenous and unshocked.

However, (35.5) and (35.6) are not satisfied in finite-step Euler computations. This is easy to see in the case of (35.6). The RHS of (35.6) is evaluated at the beginning of the year  $t+1$  computation by formulas rather than by reads and updates in keeping with the LHS. With four Euler steps (our usual number in year-to-year simulations), the violation in MONASH of (35.7) is small and of no practical importance.

***E\_fdfc\_t1, E\_fddc\_t1, E\_fea\_t1, E\_fea\_t1\_j, E\_ff\_shfeat1 and E\_shfeat1\_j***

These six equations determine end-of-year values for foreign debt and equity.

The levels equations underlying  $E\_fdfc\_t1$ ,  $E\_fddc\_t1$  and  $E\_fea\_t1$  are

$$FDFCATT\_1 = SHT1\_FDFC * FL\_T1 \quad , \quad (35.8)$$

$$FDDCATT\_1 = SHT1\_FDDC * FL\_T1 \quad (35.9)$$

$$\text{and } FE\_A\_T\_1 = FL\_T1 - FDFCATT\_1 - FDDCATT\_1 \quad , \quad (35.10)$$

where

$FDFCATT\_1$ ,  $FDDCATT\_1$  and  $FE\_A\_T\_1$  are end-of-year Australian dollar values of: foreign debt repayable in foreign currency; foreign debt repayable in domestic currency; and foreign equity in Australian industries;

$FL\_T1$  is total foreign liabilities at the end of the year; and

$SHT1\_FDFC$  and  $SHT1\_FDDC$  are the shares of  $FDFCATT\_1$  and  $FDDCATT\_1$  in  $FL\_T1$ .

$E\_fea\_t1\_j$  is a percentage change version of

$$FE\_A\_T1\_J(j) = SHFEA\_T1\_J(j) * VCAP\_AT\_T1(j) \quad (35.11)$$

where

$FE\_A\_T1\_J(j)$  is the end-of-year value of foreign equity in industry  $j$ ;

$SHFEA\_T1\_J(j)$  is the end-of-year foreign ownership share in industry  $j$ ; and

$VCAP\_AT\_T1(j)$  is the end-of-year value of capital in industry  $j$ .

The movements in end-of-year foreign equities by industry are added in  $E\_ff\_shfeat1$  to form the movement in total end-of-year foreign equity.

Movements [ $shfeat1\_j(j)$ ] in end-of-year foreign-ownership shares are given in  $E\_shfeat1\_j$  by movements in start-of-year foreign-ownership shares [ $shfeat\_j(j) + ff\_shfeat$ ] and by movements in general [ $ff\_shfeat1$ ] and industry-specific [ $f\_shfeat1\_j(j)$ ] shifters. The general shifter is normally endogenous to eliminate conflicts between movements in the aggregate value of end-of-year foreign-owned equity determined at the macro level (via  $E\_fea\_t1$ ) and determined by summation across industries (via  $E\_ff\_shfeat1$ ). The industry-specific shifters are normally exogenous.

***E\_d\_new\_fdfc, E\_d\_new\_fddc, E\_d\_new\_fea\_j, Eflt1 and E\_d\_new\_fea***

The five equations allow us to deduce new foreign liabilities by comparing end-of-year liability values with start-of-year values. In  $E\_d\_new\_fdfc$  and  $E\_d\_new\_fddc$ , the changes in foreign borrowing (new foreign debt) are determined by changes in the start- and end-of-year \$A values of foreign debt. If foreign debt is incurred (repayable) in foreign currency, in evaluating new foreign debt we need to take account of exchange rate changes. Thus, exchange rate variables appear in  $E\_d\_new\_fdfc$  but not in  $E\_d\_new\_fddc$ . Whereas the levels form of  $E\_d\_new\_fddc$  is simply

$$NEWFDDC = FDDCATT\_1 - FDDCATT \quad , \quad (35.12)$$

the levels form of  $E\_d\_new\_fdfc$  is

$$\begin{aligned} FDFCATT\_1 = FDFCATT * (EXCH\_T / EXCH\_T\_1) \\ + NEWFDFC * (EXCH / EXCH\_T\_1) \end{aligned} \quad (35.13)$$

In (35.13) we evaluate the end-of-year foreign debt repayable in foreign currency as the sum of two terms. The first is the start-of-year \$A value of foreign debt repayable in foreign currency revalued according to the movement in the exchange rate from the start of the year ( $EXCH\_T$ ) to the end of the year ( $EXCH\_T\_1$ ). The second is the end-of-year \$A value of new foreign debt repayable in foreign currency. We assume that this new foreign debt is incurred at the average exchange rate through the year ( $EXCH$ ).

The change in new foreign equity [ $d\_new\_fea\_j(j)$ ] in industry  $j$  is deduced in  $E\_d\_new\_fea\_j$ . This involves a similar approach to that in (35.13), requiring revaluations of starting stocks and through-the-year flows. The levels equation underlying  $E\_d\_new\_fea\_j$  is

$$\begin{aligned} FE\_A\_T1\_J(j) = FE\_A\_T\_J(j) * (1 - DEP(j)) * (PCAP\_AT\_T1(j) / PCAP\_AT\_T(j)) \\ + NEW\_FE\_A\_J(j) * (PCAP\_AT\_T1(j) / PCAP\_J(j)) \quad . \end{aligned} \quad (35.14)$$

In (35.14), the end-of-year foreign equity in industry  $j$  has two components. The first is the start-of-year value of foreign equity in industry  $j$  depreciated and revalued according to the movement in  $j$ 's asset price from the start of the year [ $PCAP\_AT\_T(j)$ ] to the end of the year [ $PCAP\_AT\_T1(j)$ ]. The second is the end-of-year value of new foreign equity. We assume that new foreign investments in industry  $j$  are made at the average asset price [ $PCAP\_J(j)$ ] through the year.

The change in total new foreign equity investment is defined in  $E\_flt1$  by summing changes over all industries.

In  $E\_d\_new\_fea$ , changes in new foreign debt repayable in foreign currency, new foreign debt repayable in domestic currency and new foreign equity are aggregated to give the total change in new foreign liabilities.

Finally, it is useful to check through the five equations in this group and the six in the last group to see how, in combination, they determine the variables for which they are named. (As explained in subsection 17.8, each equation is named

E\_xxx where xxx can be thought of as the variable determined by the equation in decomposition simulations.)

We start by guessing a value for  $flt1$ . Then, with their share variables treated exogenously,  $E\_fdfc\_t1$  and  $E\_fddc\_t1$  can be thought of as determining  $fdfc\_t1$  and  $fddc\_t1$ . From  $E\_fea\_t1$  we can now determine  $fea\_t1$ . Notice that  $fdfc\_t1$ ,  $fddc\_t1$  and  $fea\_t1$  are increasing functions of our guess of  $flt1$ .

From  $E\_d\_new\_fdfc$  and  $E\_d\_new\_fddc$  we determine  $d\_new\_fdfc$  and  $d\_new\_fddc$ . With  $d\_newfl$  known from  $E\_d\_newfl$ , we can determine  $d\_new\_fea$  from  $E\_d\_new\_fea$  as a decreasing function of our guess of  $flt1$ .

Now we guess a value for  $ff\_shfeat1$ . With  $f\_shfeat1\_j$  and  $shfeat\_j$  exogenous and  $ff\_shfeat$  determined in  $E\_ff\_shfeat$ ,  $E\_shfeat1\_j$  determines  $shfeat1\_j$ . From here we can find  $fea\_t1\_j$  from  $E\_fea\_t1\_j$ . We choose  $ff\_shfeat1$  so that the outcome for  $fea\_t1$  in  $E\_ff\_shfeat1$  is compatible with our earlier determination of  $fea\_t1$  based on our guess of  $flt1$ . In this way we can think of  $E\_ff\_shfeat1$  as determining  $ff\_shfeat1$  as an increasing function of  $flt1$ . Thus,  $E\_fea\_t1\_j$  determines  $fea\_t1\_j$  as an increasing function of our guess of  $flt1$ .

From  $E\_d\_new\_fea\_j$  we can now determine  $d\_new\_fea\_j$  as an increasing function of our guess of  $flt1$ . Thus,  $E\_flt1$  gives  $d\_new\_fea$  as an increasing function of our guess of  $flt1$ . The value of  $d\_new\_fea$  deduced from  $E\_flt1$  must be made compatible with the earlier value deduced as a decreasing function of our guess of  $flt1$ . At this stage we can think of  $flt1$  as being determined by varying our guess until  $E\_flt1$  is satisfied, that is we think of  $flt1$  as being determined by the inclusion in our model of  $E\_flt1$ .

***$E\_fat1$ ,  $E\_fcfc\_t1$ ,  $E\_fcdc\_t1$ ,  $E\_aef\_t1$ ,  $E\_d\_new\_fcfc$ ,  $E\_d\_new\_fcdc$ ,  $E\_d\_new\_aef$  and  $E\_d\_newfa$***

These equations are concerned with Australia's lending and investment in foreign countries during the year and with end-of-year values of Australia's foreign assets.

With  $f\_fat1$  exogenous (the usual treatment), the first equation in the group fixes the end-of-year value of Australia's holdings of foreign credits and equity as a share of GDP.

The remaining equations in the group correspond closely to equations in the previous group concerned with funds flowing into Australia and with end-of-year foreign debt and equity. Only  $E\_d\_new\_aef$  needs further explanation. The levels version of this equation is

$$AE\_F\_T\_1 = AE\_F\_T * (WPTPLUS1/WPT) * (EXCH\_T/EXCH\_T\_1) \\ + NEW\_AE\_F * (WPTPLUS1/WP) * (EXCH/EXCH\_T\_1) . \quad (35.15)$$

In (35.15) the \$A value of Australia's end-of-year equity in foreign countries ( $AE\_F\_T\_1$ ) is the sum of two terms. The first is the \$A value of start-of-year equity ( $AE\_F\_T$ ) revalued to reflect foreign inflation ( $WPTPLUS1/WPT$ ) and movements in the exchange rate ( $EXCH\_T/EXCH\_T\_1$ ). The second is the \$A

value at the end of the year of equity investment made during the year (NEW\_AE\_F). In calculating the end-of-year value, we assume that this investment was made at the average foreign prices (WP) and average exchange rate through the year.

None of the coefficients appearing in this group of equations present any new difficulties. As can be seen by working through their descriptions in subsection 18.3 and the formulas in subsection 18.5x, our broad approach to evaluating the coefficients relating to Australia's foreign assets is to use data on total foreign assets and on shares of each type of asset in the total.

***E\_d\_f\_pcapatt, E\_pcapatt, E\_pcapatt1, E\_d\_ff\_pcapatt1, E\_d\_f\_excht, E\_excht, E\_excht1, E\_d\_ff\_excht1, E\_d\_f\_xiworldt, E\_xiworld\_t, E\_xiworld\_t1 and E\_d\_ff\_xiworldt1***

This group of equations imposes relationships between start-, average and end-of-year asset prices [pcapatt(j), pi(j) and pcapatt1(j)], exchange rates [excht, phi and excht1] and world price indexes [xiworld\_t, xiworld and xiworld\_t1]. All of these variables were used in equations appearing earlier in this section.

The first four equations in the group specify movements in the start- and end-of-year asset prices. Movements in mid-year asset prices [pi(j)] were handled by E\_pi in subsection 18.8d.

E\_d\_f\_pcapatt is used in year-to-year simulations (with its shift variable exogenous and unshocked and del\_unity shocked by one) to ensure that start-of-year asset prices in the computation for year t equal end-of-year asset prices in the base year, that is year t-1.

If the base year for the year t computation is not t-1, then E\_d\_f\_pcapatt is turned off by endogenizing its shift variable. In this case we exogenize d\_ff\_pcapatt and determine pcapatt via E\_pcapatt. In simplified notation the theory underlying E\_pcapatt is given by

$$P0 = PM * \left( \frac{PM}{PM\_B} \right)^{-1/2\tau} + (P0\_B - PM\_B) * (1 - U) \quad (35.16)$$

where

P0 and PM are start-of-year and average (or mid-year) asset prices in year t;

P0\_B and PM\_B are start-of-year and average asset prices in the base year;

$\tau$  is the number of years from the base year to year t (for example, in our 1987 to 1994 simulations,  $\tau$  is 7); and

U is the homotopy variable. It is zero in the initial solution for year t and one in the final solution.

With U on zero, (35.16) is satisfied with P0 and PM at their base values. With U on one we impose the condition that start-of-year asset prices in year t equal

middle-of-year prices less six months growth at the average rate established between the middle of the base year and the middle of year t.

In determining end-of-year prices our approach is the same in both year-to-year simulations and in simulations spanning several years. We assume that end-of-year asset prices in year t are middle-of-year prices plus six months growth at the average rate established between the middle of the base year and the middle of year t. In implementing this assumption we start with

$$P1 = PM * \left( \frac{PM}{PM\_B} \right)^{1/2\tau} + (P1\_B - PM\_B) * (1 - U) \quad (35.17)$$

where P1\_B and P1 are end-of-year asset prices in the base year and in year t. Then converting to a change form and adding a shift variable we obtain E\_pcapatt1. E\_d\_ff\_pcapatt1 is the special case of E\_pcapatt1 in which TAU is one. The inclusion of E\_d\_ff\_pcapatt1 is a convenience. In switching from historical simulations (TAU equals seven for example) to year-to-year simulations it is more convenient to change closures (exogenize d\_ff\_pcapatt1 and endogenize d\_f\_pcapatt1) than to change the value of TAU.

The theory underlying the other equations in this group is the same as that for E\_d\_f\_pcapatt, E\_pcapatt, E\_pcapatt1 and E\_d\_ff\_pcapatt1. Consequently no further discussion is required.

#### ***E\_d\_trn\_fgn\_a, E\_trn\_fgn\_hh, E\_tax\_fgn\_gov and E\_trnoth\_fgn***

The first equation in this group sets out the movement in net transfers from foreigners to Australians (TRNFGNAUS) as a combination of three components. Movements in these three components are described in the subsequent three equations.

The first component is unrequited transfers to Australians from foreigners (trn\_fgn\_hh). This includes money brought into Australia by migrants and pensions paid to Australian residents from foreign governments. We model the percentage movement in this component as the sum of the percentage movements in the Australian population (pop) and in the \$A value of world GDP (world\_gdp + xiworld - phi).

The second component is income taxes paid by foreigners to the Australian government (tax\_fgn\_gov). It includes income taxes on wages, dividends, interest and royalties earned by non-residents in Australia. We model this component as proportional to total income taxes.

The final component is miscellaneous transfers from Australian residents to foreigners (trnoth\_fgn). This includes: foreign aid and social security payments to non-residents; and gifts, alimony, inheritances and labour income received by foreigners from Australians net of similar flows from foreigners to Australians. We relate this agglomeration to nominal GDP.

*E\_ximf, E\_xiworld, E\_d\_nfl\_gdp, E\_d\_nfl\_vcap, E\_aggvcap, E\_lev\_nfl\_gdp, E\_lev\_nfl\_vcap, E\_d\_r\_cadgdp and E\_lev\_r\_cadgdp*

The first equation in this group defines the overall percentage movement (ximf) in the foreign-currency price of imports. Then the second equation allows us to assume that the world price level (xiworld) moves with the foreign-currency price of imports. Other assumptions can be introduced via the shift variable f\_xiworld.

The third and fourth equations define the changes in the ratios of net foreign liabilities to GDP and to the value of Australia's capital stock. The percentage change in the value of the capital stock is defined in the fifth equation. The sixth and seventh equations define the levels of the ratios of net foreign liabilities to GDP and to the capital stock.

The final two equations define the change in the ratio of the current account deficit to GDP and the level of this ratio. The two equations include the coefficient R\_CADGDP and its base value R\_CADGDP\_B. The evaluation of R\_CADGDP is via a formula in subsection 18.5x involving the coefficient for the current account deficit, CADEF.

The evaluation of CADEF is convoluted. The most obvious approach is to use a formula based on (35.1). However, we rely on a formula only for the initial value in the computation for year 1. This can be seen from subsection 18.5x where CADEF is reset by a Formula(Initial) to reflect (35.1) if and only if DUM\_YEAR1 is zero. For subsequent evaluations of CADEF in year 1, we rely on updates via d\_cad (see subsection 18.7) and in all evaluations in later years we rely on reads and updates.

The difficulty with simply using a formula for evaluating CADEF relates to the exclusion of phantom taxes on exports from the starting database for each year's computation (DUMF = 0). This exclusion has little effect on the year t results for the changes and percentage changes in most variables, including d\_cad. Consequently, by ensuring that the initial value of CADEF in the year 1 computation accurately reflects the value of the current account deficit in the data year (year 0), we can be confident of generating satisfactory evaluations of CADEF for the rest of our simulation via reads and updates. If, on the other hand, we rely on (35.1) throughout our computations, then the exclusion of phantom export taxes at the beginning of each year's computation may lead to relatively serious errors in the evaluation of CADEF. These arise from errors in the evaluation of aggregate exports (AGGEXP). For example, at the beginning of our computation for year three [after the application of Formula(Initial)s], the value of AGGEXP will reflect the value of exports in year zero plus the changes in exports in years one and two but will exclude phantom export taxes in years zero, one and two. Formulas such as (35.1) applied at the beginning of the year three computation would re-include the phantom export taxes for year two but not for years zero and one. In a simulation in which the phantom export taxes for a string of years were significantly different from zero and of the same sign, there would be significant

errors in the evaluation of AGGEXP which would lead to significant errors in formula-generated values of CADEF. While we are usually content with reporting growth rates for aggregate exports so that errors in AGGEXP of the size normally encountered are of no concern, for the current account deficit we need to report levels. Thus for the current account it is important to adopt a valuation method that avoids errors in levels.

**36. Household disposable income, household saving and national saving (subsection 18.8t in the TABLO code)**

***E\_hdy, E\_housav, E\_real\_housav, E\_natsav, E\_govsav, E\_natsav\_r, E\_govsav\_r and E\_apc***

In *E\_hdy* we define household disposable income as GDP *plus* transfers to households from the government and from foreigners *plus* net capital income from foreigners *minus* government revenue excluding income taxes paid by foreigners. All of these concepts have been discussed in sections 33 and 35. Consequently no further discussion of *E\_hdy* is required beyond noting that the coefficient HOUS\_DIS\_INC (in common with the other coefficients introduced in this group of equations) is evaluated by a formula in subsection 18.5y.

Household saving is defined in *E\_housav* as the difference between disposable income and private consumption. In *E\_real\_housav*, real household saving is defined as household saving deflated by the investment price index, that is, we define real saving in terms of its command over investment goods.

National saving is given in *E\_natsav* as the sum of household and government saving. Government saving is defined in *E\_govsav* as government revenue minus public consumption and transfers. It can be calculated as the negative of the government deficit excluding public sector investment [= - (GOV\_DEF - AGGINVG - OTHCAPGOV), see *E\_d\_gov\_def* in subsection 18.8q]. To obtain real national saving and real government saving, we deflate national and government saving by the price index for investment goods (see *E\_natsav\_r* and *E\_govsav\_r*).

*E\_apc* allows us to relate consumption to household disposable income. For example, if we set *apc* exogenously on zero, then nominal consumption will move by the same percentage as household disposable income.