CENTRE of POLICY STUDIES and the IMPACT PROJECT

Eleventh Floor
Menzies Building
Monash University Wellington Road
CLAYTON Vic 3800 AUSTRALIA

Telephone:
(03) 9905 2398, (03) 9905 5112 | 61 3 990 52398 or 61 3 9905 5112
Fax: (03) 9905 2426 | from overseas: 61 3 9905 2426

e-mail | impact@vaxc.cc.monash.edu.au

web site | http://www.monash.edu.au/policy/

MMRF-GREEN: A DYNAMIC, MULTI-SECTORAL, MULTI-REGIONAL MODEL OF AUSTRALIA

by

Philip D. Adams, J. Mark Horridge and Brian R. Parmenter

Centre of Policy Studies and IMPACT Project

Monash University

Preliminary Working Paper No. OP-94 October 2000

ISSN 1 031 9034 ISBN 0 7326 1524

The Centre of Policy Studies and Impact Project is a research centre at Monash University devoted to quantitative analysis of issues relevant to Australian economic policy.

ABSTRACT

This paper presents an overview of the Monash Multi-Regional Forecasting-Green (MMRF-Green) model. MMRF-Green is a multi-regional, multi-sectoral model of the Australian economy. It is founded on the MMR model. MMR is a comparative-static model. MMRF-Green, in contrast, is a dynamic model; capable of producing sequences of annual solutions connected by dynamic relationships. MMRF-Green also includes enhanced capabilities for environmental analysis, and a regional disaggregation facility that allows results for the eight states/territories to be disaggregated down to 57 sub-state regions.

Keywords: multiregional, CGE, environmental, dynamics

JEL classification numbers: C68, R10, R13.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

MMRF-GREEN:

A DYNAMIC, MULTI-SECTORAL, MULTI-REGIONAL MODEL OF AUSTRALIA

by

Philip D. Adams, J. Mark Horridge and Brian R. Parmenter

Centre of Policy Studies, Monash University

1. Introduction

This paper gives an overview of the Monash Multi-Regional Forecasting-Green (MMRF-Green) model. MMRF-Green is a dynamic, multi-sectoral, multi-regional model of Australia, with enhanced capabilities for analysis of environmental policies such as carbon permits.[1]

MMRF-Green is founded on the MMR model.[2] Unlike MMRF-Green, MMR is a comparative-static model. It shows for a single year the differences produced in the Australian economy by changes in taxes, tariffs and other exogenous variables. MMRF-Green, on the other hand, is a dynamic model. It produces sequences of annual solutions connected by dynamic relationships such as physical capital accumulation. Policy analysis with MMRF-Green involves the comparison of two alternative sequences of solutions, one generated without the policy change, the other with the policy change in place. The first sequence, called the basecase projection, serves as a control path from which deviations are measured in assessing the effects of the policy shock.

The version of MMRF-Green described here was built in three stages. In the first stage, MMR was transformed into a dynamic system by the inclusion of dynamic mechanisms taken from the MONASH model.[3] These were added as self-contained blocks, allowing MMRF-Green to include MMR as a special case. The second stage involved development of the model's capacity for environmental analysis. In the third stage, a regional disaggregation facility was added, which allows results to be disaggregated down to sub-state regions.

Overall, MMRF-Green represents a considerable advance over MMR in the areas of dynamics, closure options, environmental capabilities and regional detail. These aspects are reviewed in the third section of this paper. This follows a description of the MMR system in Section 2.

2. The MMR model

MMR divides Australia into the six states and two Territories. There are five types of agents in the model: industries, capital creators, households, governments, and foreigners. The

---

[1] Recent applications of MMRF-Green have included investigations of the regional impacts of a global trading scheme in carbon permits (Adams, Parmenter and Horridge, 2000a) and of a proposed efficiency measures in electricity generation (Adams, Parmenter and Horridge, 2000b).

[2] A progress report on the development of the MMR model is given in Meagher and Parmenter (1993). In 1996 MMR was adapted for forecasting by the inclusion of enough dynamics to accumulate variables such as capital stocks and foreign debt over medium-run periods. This version was called the MMR Forecasting (MMRF) model. A detailed description of MMRF is given in Peter *et al* (forthcoming, 2001).

[3] MONASH is a very detailed dynamic single-region model of the Australian economy under development at the Centre of Policy Studies. Documentation of the model is in progress. The latest version is Dixon and Rimmer (2000).

number of industries is limited by computational constraints. Currently, MMRF-Green identifies 37 sectors (see Table 1). These are aggregates of the 116 individual industries recognised in the primary database developed for the MMRF model (see Peter *et. al.*, forthcoming 2001). For each sector in each region there is an associated capital creator. The sectors each produce a single commodity and the capital creators each produce units of capital that are specific to the associated sector. Each region in MMR has a single household and a regional government. There is also a federal government. Finally, there are foreigners, whose behaviour is summarised by export demand curves for the products of each region and by supply curves for international imports to each region.

MMR determines regional supplies and demands of commodities through optimising behaviour of agents in competitive markets. Optimising behaviour also determines industry demands for labour and capital. Labour supply at the national level is determined by demographic factors, while national capital supply responds to rates of return. Labour and capital can cross regional borders so that each region's stock of productive resources reflects regional employment opportunities and relative rates of return.

The specifications of supply and demand behaviour co-ordinated through market clearing equations comprise the general equilibrium (GE) core of the model. There are two blocks of equations in addition to the core. They describe regional and federal government finances and regional labour markets. In the remainder of this section, we provide further details on MMRF, starting with the GE-core equations, followed by comments on the additional two blocks of equations, on data requirements and on the computational technique.

2.1 The GE core

The general equilibrium core of MMR is based on ORANI, a single-region model of Australia.[4] Each regional economy in MMR looks like an ORANI model. However, unlike the single-region model, MMR includes inter-regional linkages. In MMRF, changes in economic conditions in any one regional economy affect the other seven via inter-regional flows of commodities and factors of production. The basic theoretical assumptions made in the GE-core of MMR are as follows.

The nature of markets

The commodity markets in MMR are assumed to be competitive, implying equality between the producer's price and marginal cost in each regional sector. Demand is assumed to equal supply in all markets other than the labour market (where excess supply conditions can hold). The government intervenes in markets by imposing ad valorem sales taxes on commodities. This places wedges between the prices paid by purchasers and prices received by the producers. The model recognises margin commodities (e.g., retail trade and road transport freight) which are required for each market transaction (the movement of a commodity from the producer to the purchaser). The costs of the margins are included in purchasers' prices.

Demands for inputs to be used in the production of commodities

MMR recognises two broad categories of inputs: intermediate inputs and primary factors. Firms in each regional sector are assumed to choose the mix of inputs which minimises the costs

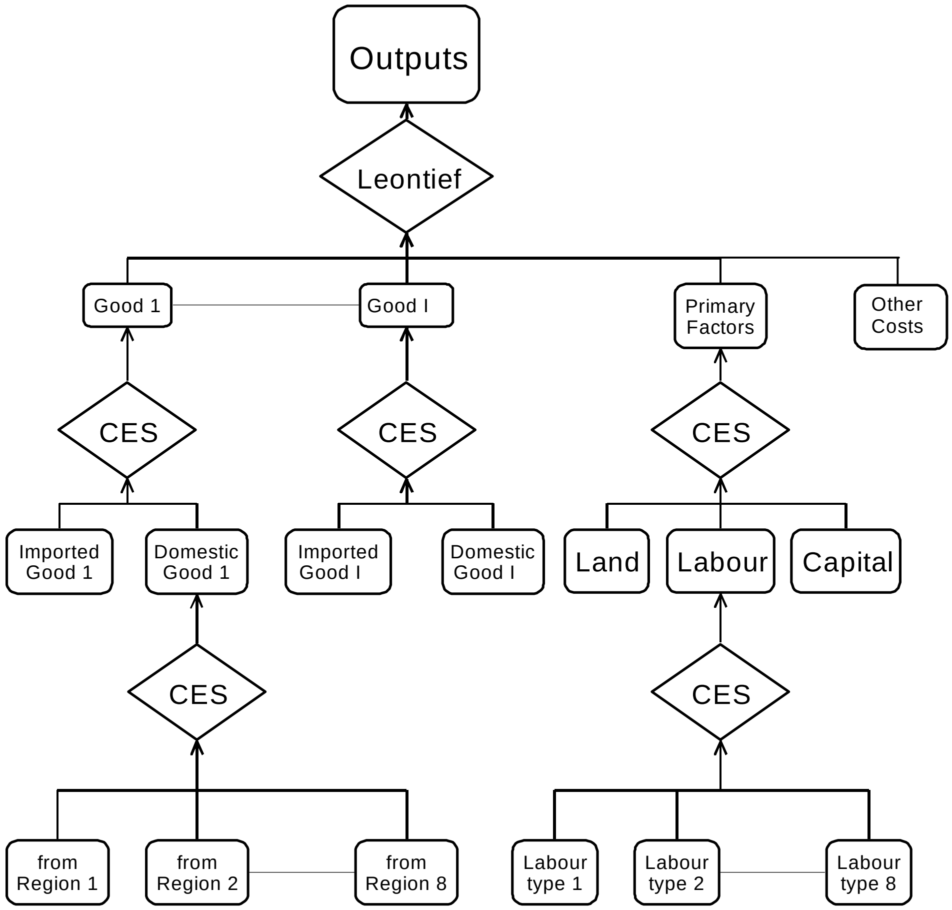
[4] A full description of the ORANI model is given in Dixon *et al* (1982).

Table 1: Sectors Recognised in MMRF-Green

Name	Description
1. Agriculture	All primary agricultural activities plus fishing
2. Forestry	All forestry activities, including logging and management
3. Iron ore	Mining of iron ore
4. Non-iron ore	Mining of non-iron ores, including gold and base ores
5. Black coal	Mining of black coal - thermal and metallurgical
6. Crude oil	Production of crude oil
7. Natural gas	Production of natural gas at well
8. Brown coal	Mining of brown coal
9. Food, beverages and tobacco	All secondary agricultural activities
10. Textiles, clothing, footwear	Manufacture of textiles, clothing and footwear
11. Wood and paper products	Manufacture of wood (including pulp) and paper products
12. Chemical prods. excl. petrol	Manufacture of basic chemicals and paints
13. Petroleum products	Manufacture of petroleum products
14. Building prods (not cement & metal)	Manufacture of non-metallic building products excluding cement
15. Cement	Manufacture of cement
16. Iron and steel	Manufacture of primary iron and steel.
17. Alumina and aluminium	Manufacture of alumina and aluminium
18. Other metal products	Manufacture of other metal products
19. Motor vehicles and parts	Manufacture of motor vehicles and parts
20. Other manufacturing	Other manufacturing including electronic equipment
21. Electricity – black coal	Electricity generation from black coal thermal plants
22. Electricity – brown coal	Electricity generation from brown coal thermal plants
23. Electricity – gas	Electricity generation from natural gas thermal plants
24. Electricity – oil prods.	Electricity generation from oil products thermal plants
25. Electricity – other	Electricity generation from other sources (mainly hydro)
26. Electricity supply	Distribution of electricity from generator to user
27. Urban gas distribution	Urban distribution of natural gas
28. Water and sewerage services	Provision of water and sewerage services
29. Construction services	Residential building and other construction services
30. Trade services	Provision of wholesale and retail trade services
31. Road transport services	Provision of road transport services
32. Other transport services	Provision of water, air and rail transport services
33. Communication services	Provision of communication services
34. Financial/business services	Provision of financial and business services
35. Dwelling ownership	Services of dwellings
36. Public services	Provision of public services
37. Other services	Provision of all other services

of production for their level of output. They are constrained in their choice of inputs by a three-level nested production technology (see Figure 1). At the first level, intermediate-input bundles and primary-factor bundles are used in fixed proportions to output. These bundles are formed at the second level. Intermediate input bundles are CES combinations of international imported goods and domestic goods. The primary-factor bundle is a CES combination of labour, capital and land. At the third level, inputs of domestic goods are formed as CES combinations of goods from

Figure 1: Input Technology for Current Production in MMRF



each of the eight regions, and the input of labour is formed as a CES combination of inputs of labour from eight different occupational categories.

Household demands

In each region, the household buys bundles of goods to maximise a Stone-Geary utility function subject to a household expenditure constraint. As in Figure 1, the bundles are CES combinations of imported and domestic goods, with domestic goods being CES combinations of goods from each region. A Keynesian consumption function determines household expenditure as a function of household disposable income.

Demands for inputs to capital creation and the determination of investment

Capital creators for each regional sector combine inputs to form units of capital. In choosing these inputs, they cost minimise subject to technologies similar to that in Figure 1; the only difference being that they do not use primary factors. The use of primary factors in capital creation is recognised through inputs of the construction commodity (service).

Determination of the number of units of capital to be formed for each regional sector (i.e., determination of investment) depends on whether we are looking at the short- or long-run effects of a shock. In short-run experiments (where the year of interest is one or two years after the shock), capital stocks in the regional sectors and national aggregate investment are exogenously determined. Aggregate investment is distributed between the regional industries on the basis of relative rates of return.

In long-run experiments (where the year of interest is five or more years after the shock), it is assumed that the economy-wide aggregate capital stock adjusts to preserve an exogenously determined economy-wide rate of return, and that the allocation of capital across regional sectors adjusts to satisfy exogenously specified relationships between relative rates of return and relative capital growth rates. Investment in the year of interest in each regional sector is then determined via exogenously specified investment/capital ratios.

Governments' demands for commodities

Commodities are demanded from each region by regional governments and by the Federal government. In MMR there are several ways of handling these demands, including: (i) endogenously, by a rule such as moving government expenditures with household consumption expenditure or with domestic absorption; (ii) endogenously, as an instrument which varies to accommodate an exogenously determined target such as a required level of government deficit; and (iii) exogenously.

Foreign demand (international exports)

MMR adopts the ORANI specification of foreign demand. Each export-oriented sector in each state faces its own downward-sloping foreign demand curve. Thus a shock that improves the price competitiveness of an export sector will result in increased export volume, but at a lower world price. By assuming that the foreign demand schedules are specific to product and region of production, the model allows for differential movements in world prices across domestic regions.

2.2 Additional blocks of equations

Government finances

For each of the eight regional governments and for the Federal government, MMR includes revenue equations for income taxes, sales taxes, excise taxes, taxes on international trade and for receipts from government-owned assets. As described already, the model accounts for public expenditures on commodities (or services). It also contains outlay equations for each government for transfer payments to households (e.g., pensions, sickness benefits and unemployment benefits). Transfers from the Federal to the regional governments are modelled, appearing on the outlay side of the Federal budget and on the revenue sides of the regional budgets.

The specification in MMR of government finances makes the model a suitable tool for (a) analysing the effects of changes in the fiscal policies of both the Federal government and of the regional governments, and (b) analysing the impact on the budgetary situation of the nine governments of a wide range of shocks.

Regional labour markets

This block of equations relates: regional population and population of working age; and regional population of working age and regional labour supply. It also defines regional unemployment rates in terms of regional demands and supplies of labour.

There are three main possible treatments in MMR for regional labour markets: (i) regional labour supply and unemployment rates are exogenous and regional wage differentials are endogenous, (ii) regional wage differentials and unemployment rates are exogenous and regional labour supply is endogenous or (iii) regional labour supply and wage differentials are exogenous and regional unemployment rates are endogenous.

2.3 Data requirements

The GE core of MMR requires a multi-regional input-output table together with values for the elasticities of substitution in the CES nests of the specifications of technologies and preferences. The government finance block requires data on regional and Federal government revenues and outlays. The regional labour market block requires regional demographic, employment and labour force data.

The Australian Bureau of Statistics (ABS) (see Peter *et. al*, forthcoming 2001) publishes suitable regional data for the government finance and labour market blocks. However, it does not compile multi-regional input-output (IO) tables. Disaggregating the national IO table used in the national GE model, MONASH, created IO data for the GE core[5]. The regional disaggregation of the national IO table involved three steps: (i) splitting of columns using regional proportions of industry outputs and final demands; (ii) splitting of rows using inter-regional trade data available from published sources (e.g., Quinlan, 1991); and (iii) application of RAS procedures to ensure equality in the multi-regional input-output table between the outputs and sales of regional sectors.

For values of primary-factor and domestic-import substitution elasticities, MMR relies on the MONASH national database. We have no estimates of substitution elasticities between domestic products from different regional sources. We assume that high numbers are appropriate, five times the values for domestic/import substitution elasticities. That is, we assume that different domestic varieties of a good are closer substitutes than are domestic and imported varieties.

2.4. Computing solutions for MMRF

MMR is a system of non-linear equations. These are solved using GEMPACK, a suite of programs for implementing and solving economic models. A linear, differential version of the MMR equation system is specified in syntax similar to ordinary algebra. GEMPACK then solves the system of non-linear equations as an Initial Value problem, using a standard method, such as Euler or midpoint. For details of the algorithms available in GEMPACK, see Harrison and Pearson (Pearson (1996).

3. From MMR to MMRF-Green

In this section we review the enhancements embodied in MMRF-Green in the areas of dynamics, closure options, environmental capabilities and regional detail.

3.1 Dynamics

There are two main types of inter-temporal links incorporated into MMRF-Green: physical capital accumulation and lagged adjustment processes.

---

[5] See Dixon and Rimmer (2000) for a description of the MONASH IO data.

Physical capital accumulation

It is assumed that investment undertaken in year t becomes operational at the start of year t+1. Under this assumption, capital in industry i in state/territory s accumulates according to:

$$K_{t+1}^{S}(i) = (1 - DEP^{S}(i)) \times K_{t}^{S}(i) + I_{t}^{S}(i) \quad (1)$$

where:

$K_t^s(i)$ is the quantity of capital available in industry i located in s at the start of year t;

$I_t^s(i)$ is the quantity of new capital created for industry i during year t; and

$DEP^s(i)$ is the rate of depreciation in industry i, treated as a fixed parameter.

Given a starting point value for capital in t=0, and with a mechanism for explaining investment through time, equation (1) can be used to trace out the time paths of industry capital stocks.

Investment in industry i in state/territory s in year t is explained via a mechanism of the form

$$\frac{K_{t+1}^{s}(i)}{K_{t}^{s}(i)} - 1 = F_{it}^{s}[EROR_{t}^{s}(i)] \quad (2)$$

where

$EROR_t^s(i)$ is the expected rate of return on investment in industry i in s in year t; and

$F_{it}^s[\ ]$ is an increasing function of the expected rate of return with a finite slope.

As in MONASH, we justify finite positive slopes for the function on the right side of (2) by reference to investor caution and risk aversion. The values of the slopes vary with the values of the capital growth rates in a way that prevents the model from implying unrealistically large short-run investment responses to small changes in expected rates of return.

The expected rate of return in year t can be specified in a variety of ways. As in MONASH, we allow for two possibilities, static expectations and forward-looking model-consistent expectations. Under static expectations, we assume that investors take account only of current rentals and asset prices when forming current expectations about rates of return. Under rational expectations we set the expected rate of return equal to the present value in year t of investing $1 in industry i in region r, taking account of both the rental earnings and depreciated asset value of this investment in year t+1 as calculated in the model.

A practical advantage of static specifications is that they allow a recursive solution method. As noted in Dixon and Rimmer (2000), with static expectations the solution for year 1 can be computed from assumptions for year 1 and data from year 0 and possibly earlier years. Then the solution for year 2 can be computed from assumptions for year 2 and data from year 1 and so on.

With rational specifications the recursive approach breaks down. Investment in year 1 depends on rental rates and other variables in year 2. Consequently, the solution for year 1 cannot be computed before the solution for year 2. Similarly, the solution for year 2 cannot be computed before the solution for year 3, and so on. In MONASH, adopting an iterative algorithm solves the problem. The same solution is adopted in MMRF-Green.

Lagged adjustment processes

MONASH contains a number of lagged adjustment processes. We include just one in MMRF-Green. This relates to the operation of the labour market in year-to-year policy simulations.

In comparative static analysis, one of the following two assumptions is made about the national real wage rate and national employment:

1. the national real wage rate adjusts so that any policy shock has no effect on aggregate employment; or
2. the national real wage rate is unaffected by the shock and employment adjusts.

MONASH's treatment of the labour market allows for a third, intermediate position, in which real wages can be sticky in the short run but flexible in the long-run and employment can be flexible in the short-run but sticky in the long-run. We adopt the same idea for MMRF-Green. Thus, for year-to-year policy simulations it is assumed that the deviation in the national real wage rate increases through time in proportion to the deviation in aggregate employment from its basecase-forecast level. The coefficient of adjustment is chosen so that the employment effects of a shock are largely eliminated after about ten years. This labour market is consistent with macroeconomic modelling in which the NAIRU is exogenous.

3.2 Closures of MMRF-Green

Algebraically, models like MONASH and MMRF-Green take the form

$$F(X) = 0 \quad , \qquad (3)$$

where F is an m-vector of differentiable functions of n variables X, with n>m. In simulations with (3), given an initial solution for the n variables that satisfies (3), we compute the movements in m variables (the endogenous variables) away from their values in the initial solution caused by movements in the remaining n – m variables (the exogenous variables). In year-to-year simulations the changes in the values of the exogenous variables are measured from one year to the next. If the initial solution is for year t then our first computation creates a solution for year t+1. This solution can in turn become an initial solution for a computation that creates a solution for year t+2. In such a sequence of annual computations, links between one year and the next are recognised by ensuring, for example, that the quantities of closing capital stocks in the year t-1 computation are the quantities of opening stocks in the year t computation.

A choice of the n-m variables to be made exogenous is called a closure. Dixon and Rimmer (2000) refer to four classes of closure for the MONASH model. For MMRF-Green, we identify three classes:

1. comparative-static closures;
2. forecasting closures; and
3. policy or deviation closures.

Comparative static closures are used in single-computation comparative-static analyses of the type that could be undertaken with MMRF. Forecasting and policy closures are used in year-to-year simulations.

Comparative-static closures

In a comparative-static closure, we include in the exogenous set all naturally exogenous variables in a GE model. These may be observable variables such as tax rates or unobservable variables such as technology and preference variables. We also include in the exogenous set all variables that are naturally endogenous in a dynamic model, but which are naturally exogenous in a static model. These will typically include one of the capital stock (in a short-run comparative-static closure) or rate of return (in a long-run comparative-static closure) for each industry.

Forecasting and policy closures

Forecasting and policy closures utilise the dynamic features of the model. Thus for both classes of closure we include in the endogenous set all variables that are naturally endogenous in a dynamic model, but naturally exogenous in a static model.

In forecasting with MONASH and MMRF-Green we often want to take on board forecasts and information available from outside sources. Typical examples include macro forecasts made by specialist private or public-sector groups and prospects for agriculture and mining. To accommodate this information, numerous naturally endogenous variables are typically exogenised. These might include macro variables and the volumes of agricultural and mineral exports.

To allow such naturally endogenous variables to be exogenous, an equal number of naturally exogenous variables must be made endogenous. For example, to accommodate forecasts for macro variables, we would endogenise various macro coefficients, such as the average propensity to consume.. To accommodate forecasts for the volumes of agricultural exports we would endogenise variables that locate the positions of foreign demand curves.

In forecasting closures, tastes and technology are exogenous and normally set to reflect historical trends. With MONASH, these trends are deduced in historical simulations. At this stage, we do not plan to conduct historical simulations with MMRF-Green. Thus, in using MMRF-Green for forecasting we generally draw on national values for taste and technology variables deduced in the MONASH work and assume that these apply at the state/territory level. Policy variables are also generally exogenous in forecasting closures. In forecasting values for these variables we can draw on information from extraneous sources such as government departments.

The policy closure reflects natural closure assumptions. Technology, the positions of foreign demand curves and various macro coefficients (propensities) are set exogenously to the values revealed in the forecasts. Correspondingly, export volumes and macro aggregates respond endogenously to the policy change under consideration.

In a policy simulation, most, but not all, of the exogenous variables have the values they had in the associated forecast solution. The exceptions are the exogenous variables via which we impose the policy shock(s). The policy simulation, therefore, generates deviations from the corresponding forecast simulation in response to the exogenously imposed shocks.

3.3 Environmental capabilities

MMRF-Green has been enhanced in a number of areas to improve its capability for environmental analysis. These enhancements include:

- an energy and gas emission accounting module, which accounts explicitly for each of the 37 industries and eight regions recognised in the model;
- equations that allow for inter-fuel substitution in electricity generation by region; and
- mechanisms that allow for the endogenous take-up of abatement measures in response to greenhouse policy measures.

These are now reviewed.

Emissions accounting

MMRF-Green tracks emissions of greenhouse gases at a detailed level. It breaks down emissions according to:

- emitting agent (37 industries and residential);
- emitting state or territory (8); and
- emitting activity (5).

Most of the emitting activities are the burning of fuels (black coal, natural gas, brown coal or petroleum products[6]). A residual category, named Activity, covers emissions such as fugitives and agricultural emissions not arising from fuel burning.

The resulting 38 x 8 x 5 matrix of emissions is designed to include all emissions except those arising from land clearing. Emissions are measured in terms of carbon dioxide equivalents, $C0_2$-e.

The MMRF-Green emissions matrix refers to 1994, and is summarised in Table 2. The first four columns of Table 2 show the contributions made by burning fuels. Black coal contributes the most. The first 37 rows correspond to the MMRF-Green industries. We see that the Electricity-black coal industry (industry 21) is the largest burner of black coal. Electricity generators have been divided according to the fuel used. Each of the generators sells to the Electricity supply sector, which distributes electricity to users.

The last, *Activity*, column represents emissions that do not arise from fuel burning. It accounts for more emissions than any of the fuel columns - but is also the most speculative. The largest single cell in Table 2 is in the Agriculture row of the Activity column. This cell shows emissions caused by livestock digestion, by soil disturbance, and by fertiliser use. Some more notes on this column appear below the table. Note the negative entry for Forestry, which we treat as a sink.

The first four columns of Table 2 are based on data from Fry (1997) and the National Greenhouse Gas Inventory (1997). The fifth column is derived from a NGGI summary table. Value flows from the standard MMR database were used to apportion the emissions of Table 2 between states.

---

[6] Each of these fuels is identified as a separate commodity within the model (see Table 1).

Table 2: 1993-94 Data: Emissions, CO_2-e, kT (=Gg)

Emitting agent	1 Black Coal	2 Natural Gas	3 Brown Coal	4 Petrol	5 Activity*	Total
1. Agriculture	0	113	0	5161	94200	99474
2. Forestry	0	44	0	757	-26500	-25699
3. Iron ore	375	38	0	194	0	607
4. Non-iron ore	430	260	0	1522	0	2212
5. Black coal	8944	78	0	431	11852	21305
6. Crude oil	75	971	0	16	9070	10132
7. Natural gas	82	1063	0	18	3468	4631
8. Brown coal	20	259	0	4	5110	5393
9. Food, beverages and tobacco	2017	522	0	916	0	3455
10. Textiles, clothing, footwear	215	42	0	91	0	347
11. Wood and paper products	1390	213	0	758	0	2362
12. Chemical prods. excl. petrol	1772	1242	0	1187	484	4686
13. Petroleum products	126	0	0	11170	0	11296
14. Building prods (not cement & metal)	504	314	0	286	0	1104
15. Cement	633	984	0	126	5078	6821
16. Iron and steel	4745	1412	0	405	0	6561
17. Alumina and aluminium	1965	261	0	484	3482	6192
18. Other metal products	6259	983	0	5908	0	13150
19. Motor vehicles and parts	126	111	0	50	0	287
20. Other manufacturing	580	208	0	286	0	1073
21. Electricity – black coal	71083	0	0	0	0	71083
22. Electricity – brown coal	0	0	44968	0	0	44968
23. Electricity – gas	0	4220	0	0	0	4220
24. Electricity – oil prods.	0	0	0	253	0	253
25. Electricity – other	0	0	0	0	0	0
26. Electricity supply	0	0	0	0	0	0
27. Urban gas distribution	55	14860	0	64	0	14979
28. Water and sewerage services	25	0	0	672	0	697
29. Construction services	110	274	0	2912	0	3297
30. Trade services	1415	728	0	6341	0	8485
31. Road transport services	0	174	0	4992	0	5167
32. Other transport services	211	327	0	10605	0	11144
33. Communication services	0	710	0	960	0	1670
34. Financial/business services	0	396	0	4258	0	4655
35. Dwelling ownership	0	0	0	117	0	117
36. Public services	832	2356	0	5296	0	8484
37. Other services	106	142	0	1121	15563	16932
38 Residential	192	2162	0	25401	0	27756
Total	104287	35469	44968	92762	121807	399293

Emissions category: columns 1–5.

Sources: Fry (1997), NGGI (1997)). The *Activity* column uses a 1999 NGGI summary report.

* The *Activity* column shows: fugitives for coal, oil and gas; animal gas, soil disturbance and fertiliser use for agriculture; and emissions mainly from rubbish dumps for other services. Forestry is a net sink. Production of Cement and Alumina/aluminium also release non-combustion gases.

Inter-fuel substitution

Fuel-burning emissions (columns 1-4 of Table 2) are modelled as directly proportional to fuel usage. We do not allow for any invention, which might, say, allow Electricity-black coal to release less CO_2 per tonne of coal burned. So far as we know, no advance of this type is likely to be widely adopted within the next 20 years.

On the other hand MMRF-Green does allow for input-saving technical progress. For example, the black coal electricity industry may reduce the amount of coal that it burns per kilowatt-hour of output. This sort of technical progress is imposed exogenously and in our simulations is the same for both the basecase and the emission-policy scenarios.

Other, indirect, forms of substitution offer the main scope, within MMRF-Green for emission reduction. For example, the Electricity supply industry might reduce the amount of power sourced from coal-using generators and increase the amount sourced from gas-fired plants. Such substitution is price-induced; the elasticity of substitution between the various types of electricity used by the Electricity supply industry in each state has been set equal to 5.

For other energy-intensive commodities used in industry, MMRF-Green allows for substitution possibilities by including a similar, but weaker, form of input-substitution specification. If the price of say, Cement (industry 15), rises by 10 per cent relative to other inputs to construction, the Construction industry (industry 29) will use 1 per cent less Cement (and, to compensate, a little more of labour, capital and other materials). In most cases, as in the Cement example, we have imposed a substitution elasticity of 0.1. For three important goods, Petroleum products (industry 13), Electricity supply (26), and Urban gas distribution (27), the substitution elasticity in industrial use is 0.25. This input substitution is driven by price changes, and so is especially important in emission-policy scenarios, which makes outputs of emitting industries more expensive.

Endogenous take-up of abatement measures in response to greenhouse policy measures

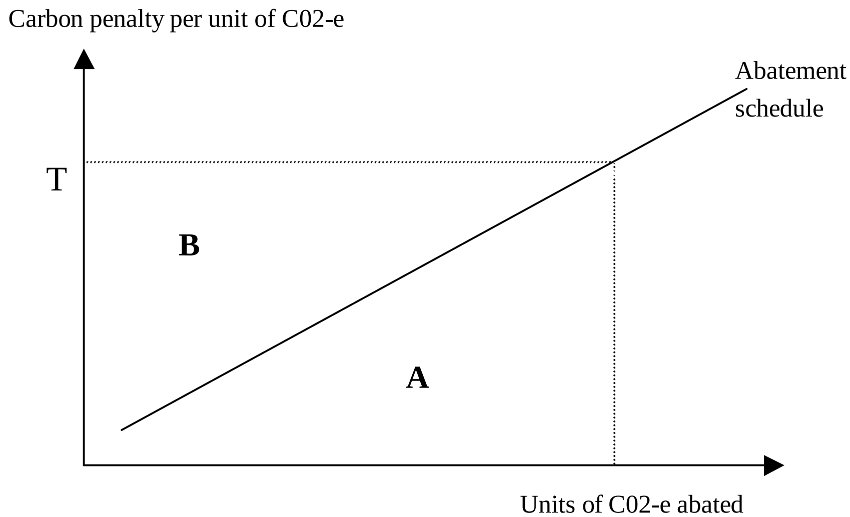
In our base MMRF-Green simulations, we model non-combustion emissions as directly proportional to the output of the related industries. In the policy scenarios, we allow for abatement of these emissions. The amount of abatement is directly related to the price of emissions permits (or the level of the carbon penalty). The constants of proportionality are derived from point estimates, from various sources, of the extent of abatement that might arise at a particular tax level. In particular, we assume that if the tax reached \$100 (93-4 dollars) per tonne CO_2-e, non-fuel-burning emissions from:

- Agriculture would drop by 60 per cent,
- Black coal would drop by 70 per cent,
- Crude oil would drop by 40 per cent,
- Alumina/aluminium would drop by 25 per cent,
- Natural gas, Brown coal, Chemicals (excl. petrol), Cement and Other services would all drop by 10 per cent.

We should emphasise that the estimates above are quite speculative, but are only really important in the case of Agriculture, which makes a very large contribution to activity-related emissions (see Table 2).

Figure 2 shows the linear relation between the quantity of gas abated (horizontal axis) and the level of the carbon penalty (vertical axis) associated with an industry's non-combustion emissions. In our modelling we assume that the abatement response raises the requirement for other inputs by a value, at the margin, equal to the tax saved. Thus the area under the abatement schedule gives the cost of abatement in terms of the value of additional inputs required. At a rate of tax, T, the value of tax saved by abatement (the area A+B) is around twice the cost of abatement

Figure 2: Net Savings to an Industry from Abatement



(area A). In other words, net saving to the industry (area B) is about half of the tax avoided by abatement.

We have treated the sink potential of Forestry (industry 2) conservatively. In our carbon-tax scenarios, Forestry grows rapidly, since it is in effect subsidised (could sell emission permits). One might expect that the carbon sequestered by Forestry should be related to the rate of planting; we connect it to Forestry activity as a whole, which includes logging. If Forestry is growing rapidly we should expect the industry to be devoting an abnormally high fraction of effort to planting, rather than felling. This would, at least temporarily, somewhat increase the sink effect beyond what we have estimated.

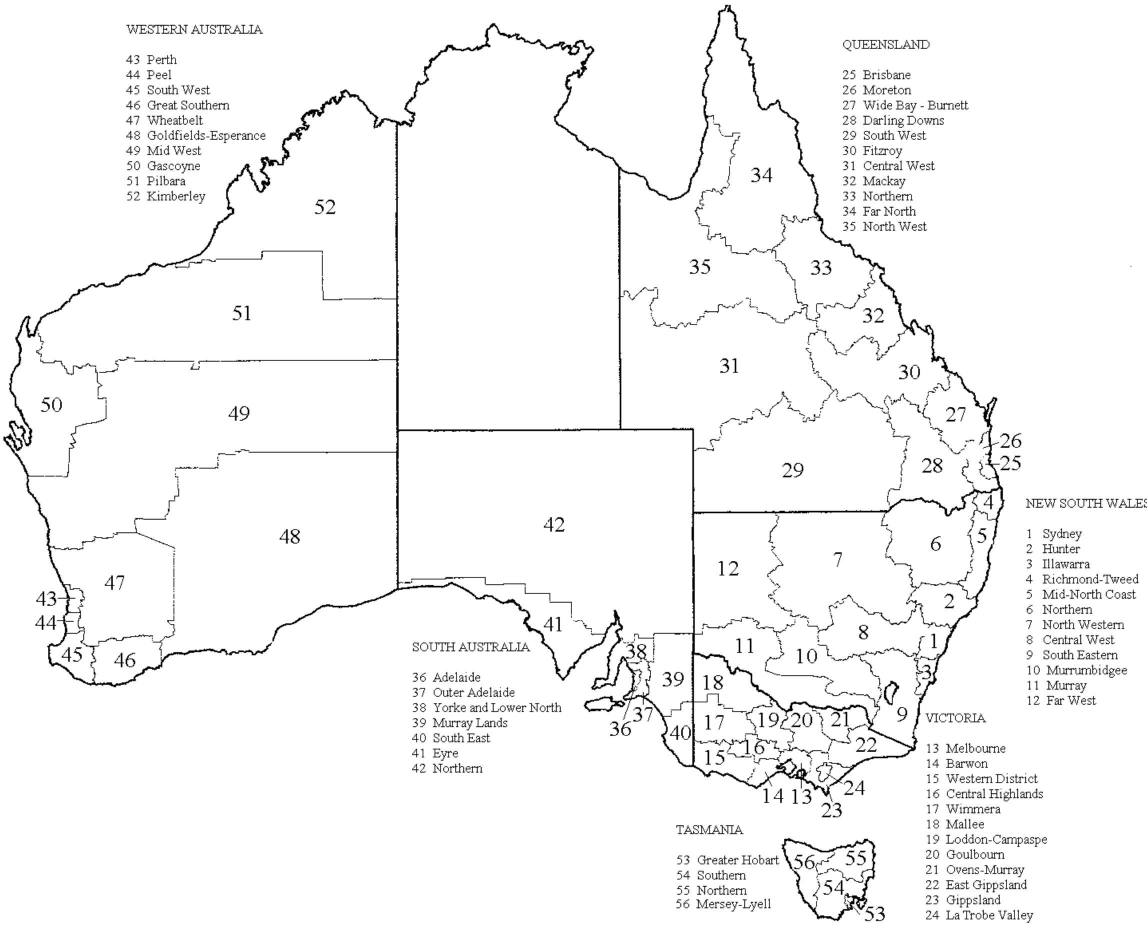
3.4 Disaggregation to Sub-state Regions

Few multi-regional models of the Australian economy have the level of sectoral detail supported by MMRF. This detail is usually more than adequate for contributions to public discussions on the effects of changes in policies concerning taxes, trade and the environment. However, people wanting to use MMR in business and public sector planning are often frustrated by the lack of relevant regional detail. This applies especially to people interested in regional adjustment issues. Often, they are disappointed when all they get from the model are projections for Victoria and New South Wales when they know that the policy under examination will have sharply differential impacts at a sub-state level.

It is with these people in mind that we have incorporated into MMRF-Green a tops-down method that enables disaggregation of state-level results for output, employment and greenhouse-gas emissions down to projections for 56 sub-state regions. The method is an adaptation of the regional disaggregation method first devised by Leontief *et al* (1965), in the context of an input-output model, and first applied to sub-state regions in Australia by Adams and Dixon (1995).

The geographic boundaries of the sub-state regions recognised in the MMRF-Green disaggregation facility are shown in Figure 3. These regions are based on the Statistical divisions defined in the Australian Standard Geographical Classification (ABS catalogue number 1216.0). Our division structure differs slightly from that of the ABS. We combine the ABS's Darwin and *Northern Territory — balance* divisions into one division, Northern Territory. Similarly, Canberra and *ACT—*

Figure 3: Sub-state Regions Identified in MMRF-Green



balance are combined into one division, Australian Capital Territory. Note that both territories are distinguished as separate regions in MMRF-Green. Hence, the tops-down disaggregation facility provides no additional detail for them. We also adopt a slightly different regional classification for WA than that defined by the ABS. Our WA regions are based on the classification used by the WA department of Commerce. Finally, we identify the energy intensive La Trobe Valley in Victoria as a separate region (region 24), with 23 Gippsland defined to include all areas in the ABS statistical division *Gippsland* other than the La Trobe Valley.

Methodology

The methodology for tops-down regional disaggregation involves firstly classifying each of MMRF-Green's industries (see Table 1) into one of two categories: state and local. State industries produce commodities that are readily traded across sub-state regional boundaries. Examples are most agricultural and mining industries. The regional outputs of industries producing state commodities are assumed to move in line with the state-wide percentage rates of change calculated by MMRF-Green.

Local industries produce commodities for which demand within each sub-state region is satisfied mainly from production in that region. Examples include perishable items and services like wholesale and retail trade. The outputs in each region of industries producing local commodities are modelled as depending mainly on demand within the region. In calculating the local demand for the output of local industry j, MMRF-Green takes account of: intermediate and investment demands both by local industries and by the parts of the state industries located in the sub-state region; the region's household demands, which are a function of population and employment changes and of the change in consumption at the state level; government demand; and (if industry j's output is a margin commodity like transport) the usage of industry j's product in facilitating the flow of local and state commodities within the sub-state region and international export flows out of the region. This gives our regional calculations a multiplier property: the effect on a sub-state region's overall level of activity of a favourable mix of state industries is multiplied through induced effects on the output and employment of the region's local industries.

In the regional disaggregation we allow for the possibility of some demand for local commodities outside the region of their production, but not from outside the state in which the region is located. This is because our data imply that for almost all commodities there is at least some imbalance at the sub-state regional level between demand and supply.

Our treatment of inter-region (but intra-state) trade in local commodities starts with the definition:

$$T(i,r) = Q(i,r) - D(i,r) \text{ for all i = local commodity and r = sub-state region,} \tag{4}$$

where:

T(i,r) is net intra-state exports of i from r;

Q(i,r) is production of i in r; and

D(i,r) is demand for i in r.

If *T(i,r)* is negative, region r is a net intra-state importer of i. From our regional database we can calculate values for *Q(i,r)* and *D(i,r)*, and hence infer values for *T(i,r)*. If r is identified as a net intra-state importer of i then in our calculations we set

$$m(i,r) = q(i,r) \tag{5}$$

where *m(i,r)* and *q(i,r)* are percentage changes in r's intra-state imports of i and r's output of i, i.e., we assume that in region r the ratio of intra-state imports of i to production of i remains constant. On the other hand, if r is identified as a net intra-state exporter of i, then we set:

$$e(i,r) = etot(i, s(r)) \tag{6}$$

where:

e(i,r) is the percentage change in r's intra-state exports of i; and

etot(i,s(r)) is the percentage change in total intra-state exports of i in state s which contains r.

Equation (6) fixes, for commodity i, the share of region r in the total intra-state exports of i in the state s which contains r.

Data requirements

An attractive feature of the disaggregation to sub-state regions is that its data requirements are modest. They are satisfied by having base-year data for value added by industry in each sub-state region. Since for state commodities we assume that the regional pattern of production is independent of the pattern of demand, no data are required for these commodities on their sales patterns across sub-state regions. For local commodities, it is assumed that the state-wide input-output coefficients relating to their usage apply at the sub-state level. Thus we do need information on sub-state technologies.

Many primary sources were used to compile the database for value-added by industry and sub-state region. The two main sources were Kenderes (1993) and Enzinger (2000). Table 3 summarises the sub-state data in terms of industry shares in state value added.

Table 3: Industry Shares (per cent) in Value Added by Sub-state Region

Industry	1. Sydney (NSW)	2. Hunter (NSW)	3. Illawarra (NSW)	4. Richmond-Tweed (NSW)	5. Mid-North Coast (NSW)	6. Northern (NSW)	7. North Western (NSW)	8. Central West (NSW)	9. South Eastern (NSW)	10. Murrumbidgee (NSW)
1. Agriculture	0.5	2.3	1.4	7.8	6.3	19.5	21.1	14.4	11.7	18.2
2. Forestry	0.0	0.1	0.1	0.2	0.6	0.3	0.2	0.4	0.5	0.5
3. Iron ore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4. Non-iron ore	0.1	0.3	0.2	0.3	0.3	0.4	3.0	0.6	0.6	0.2
5. Black coal	0.1	8.7	2.6	0.0	0.0	0.4	1.4	5.2	0.0	0.0
6. Crude oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7. Natural gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8. Brown coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9. Food, beverages and tobacco	1.7	1.9	0.9	4.2	3.1	3.2	2.3	4.0	2.2	5.2
10. Textiles, clothing, footwear	1.0	0.5	0.7	0.6	0.6	0.2	0.1	0.6	0.5	0.4
11. Wood and paper products	2.7	1.0	1.7	2.3	3.3	1.4	1.3	1.5	2.2	2.6
12. Chemical prods. excl. petrol	2.0	1.0	0.7	0.4	0.2	0.2	0.2	0.2	0.2	0.1
13. Petroleum products	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0
14. Building prods (not metal)	0.5	0.4	0.7	0.4	0.7	0.4	0.3	0.3	0.6	0.4
15. Cement	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.3	0.0	0.0
16. Iron and steel	0.2	2.3	7.7	0.2	0.1	0.1	0.1	0.0	0.1	0.1
17. Alumina and aluminium	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18. Other metal products	1.3	1.7	1.3	0.6	1.0	0.5	0.5	0.8	0.6	0.6
19. Motor vehicles and parts	0.2	0.1	0.2	0.2	0.5	0.4	0.1	0.1	0.1	0.1
20. Other manufacturing	2.2	1.4	1.5	0.8	1.0	0.5	0.5	1.8	0.5	0.6
21. Electricity – black coal	0.0	10.0	0.0	0.0	0.0	0.0	0.0	9.6	0.0	0.0
22. Electricity – brown coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23. Electricity – gas	0.0	0.3	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0
24. Electricity – oil prods.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25. Electricity – other	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26. Electricity supply	0.3	0.0	0.4	0.4	0.7	0.7	0.5	0.1	1.0	0.7
27. Urban gas distribution	0.2	0.2	0.5	0.0	0.0	0.1	0.2	0.3	0.2	0.5
28. Water and sewerage services	0.8	1.3	1.3	0.9	0.7	1.2	1.3	0.9	1.2	2.2
29. Construction services	7.3	6.3	8.4	8.2	8.1	4.8	5.4	4.6	7.3	5.2
30. Trade services	17.0	14.5	16.3	19.5	20.3	15.6	15.7	12.5	18.1	15.6
31. Road transport services	2.7	2.5	2.6	3.1	3.0	3.1	3.0	2.7	3.4	3.3
32. Other transport services	4.2	2.6	3.2	1.5	1.8	2.2	2.3	2.5	2.4	2.3
33. Communication services	2.5	1.2	1.7	1.9	2.0	1.8	1.5	1.4	2.0	1.4
34. Financial/business services	21.4	10.6	13.1	11.4	10.9	8.5	7.4	6.8	10.6	8.5
35. Dwelling ownership	11.7	10.1	11.8	12.2	12.3	12.2	12.1	10.7	12.3	12.1
36. Public services	17.0	15.6	18.5	21.2	20.1	20.9	17.9	16.4	19.4	17.8
37. Other services	2.1	1.4	1.8	1.8	1.8	1.4	1.4	1.2	2.1	1.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 3 (continued): Industry Shares (per cent) in Value Added by Sub-state Region

Industry	11. Murray (NSW)	12. Far West (NSW)	13. Melbourne (VIC)	14. Barwon (VIC)	15. Western District (VIC)	16. Central Highlands (VIC)	17. Wimmera (VIC)	18. Mallee (VIC)	19. Loddon-Campaspe (VIC)	20. Goulbourn (VIC)
1. Agriculture	18.9	9.1	0.5	3.4	16.4	7.3	33.4	25.3	8.3	14.1
2. Forestry	0.4	0.1	0.0	0.1	0.4	0.3	0.1	0.2	0.1	0.3
3. Iron ore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4. Non-iron ore	0.1	4.8	0.3	0.3	0.2	0.7	1.2	0.4	0.7	0.3
5. Black coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6. Crude oil	0.0	0.0	0.6	0.3	0.1	0.1	0.0	0.0	0.0	0.0
7. Natural gas	0.0	0.0	0.3	0.1	0.0	0.1	0.0	0.0	0.0	0.0
8. Brown coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9. Food, beverages and tobacco	3.8	1.3	1.7	1.9	3.2	3.7	2.1	2.9	4.1	5.1
10. Textiles, clothing, footwear	0.4	0.0	1.7	2.3	0.4	1.1	1.0	0.1	1.3	0.8
11. Wood and paper products	2.3	0.8	3.2	2.0	1.4	2.0	1.0	0.8	2.2	1.9
12. Chemical prods. excl. petrol	0.2	0.1	2.7	2.0	1.0	0.9	0.0	0.4	0.6	0.7
13. Petroleum products	0.0	0.0	0.1	0.9	0.0	0.0	0.0	0.0	0.1	0.0
14. Building prods (not metal)	0.3	0.1	0.7	0.8	0.3	1.1	0.2	0.2	0.7	0.5
15. Cement	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
16. Iron and steel	0.4	0.1	0.4	0.6	0.0	0.5	0.3	0.1	0.2	0.4
17. Alumina and aluminium	0.0	0.0	0.0	1.5	6.9	0.0	0.0	0.0	0.0	0.0
18. Other metal products	1.1	0.3	1.2	1.8	2.2	0.9	0.4	0.3	1.2	1.4
19. Motor vehicles and parts	1.0	0.0	1.3	3.2	0.1	1.8	0.1	0.1	0.6	0.3
20. Other manufacturing	0.8	0.3	2.4	1.0	0.4	1.2	0.5	0.5	2.0	0.9
21. Electricity – black coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22. Electricity – brown coal	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0
23. Electricity – gas	0.0	3.4	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
24. Electricity – oil prods.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25. Electricity – other	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
26. Electricity supply	1.0	0.7	0.3	0.7	0.0	0.6	0.5	0.6	0.7	0.2
27. Urban gas distribution	0.1	0.0	0.5	0.4	0.2	0.4	0.0	0.0	0.4	0.3
28. Water and sewerage services	2.3	5.2	0.6	1.9	1.1	1.9	2.4	4.4	1.6	3.6
29. Construction services	4.7	6.5	6.2	6.8	4.8	5.7	3.4	4.2	6.1	5.8
30. Trade services	15.5	16.9	16.1	15.9	14.5	15.4	11.5	16.1	15.1	15.8
31. Road transport services	3.6	3.0	2.7	2.7	2.9	2.9	2.8	3.4	3.1	4.1
32. Other transport services	0.8	2.9	3.0	2.2	1.3	2.9	2.0	1.5	2.9	1.7
33. Communication services	1.1	1.5	3.0	2.0	1.7	2.4	1.4	1.4	2.8	1.7
34. Financial/business services	7.4	7.4	18.7	11.2	6.8	9.4	5.5	6.8	10.1	7.9
35. Dwelling ownership	11.4	12.1	9.1	9.1	8.9	9.3	9.7	9.6	9.4	9.3
36. Public services	14.6	21.4	20.5	22.5	21.4	25.2	19.2	19.6	23.6	20.2
37. Other services	1.2	1.9	2.1	1.9	1.5	2.2	1.2	1.2	2.1	1.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 3 (continued): Industry Shares (per cent) in Value Added by Sub-state Region

Industry	21. Ovens-Murray (VIC)	22. East Gippsland (VIC)	23. Gippsland (VIC)	24. La Trobe Valley	25. Brisbane (QLD)	26. Moreton (QLD)	27. Wide Bay - Burnett (QLD)	28. Darling Downs (QLD)	29. South West (QLD)	30. Fitzroy (QLD)
1. Agriculture	6.9	8.6	12.8	0.8	1.0	5.2	14.1	19.7	27.5	6.3
2. Forestry	0.7	1.4	0.9	0.1	0.1	0.2	0.7	0.3	0.3	0.1
3. Iron ore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4. Non-iron ore	0.2	3.6	0.6	0.2	0.4	0.4	0.6	0.5	1.0	0.6
5. Black coal	0.0	0.0	0.0	0.1	0.1	1.1	5.4	0.1	0.0	22.4
6. Crude oil	0.0	14.0	0.0	8.2	0.1	0.2	0.1	0.2	2.7	0.1
7. Natural gas	0.0	7.4	0.0	4.3	0.1	0.1	0.1	0.1	1.5	0.1
8. Brown coal	0.0	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0
9. Food, beverages and tobacco	5.9	1.1	1.8	0.7	2.7	2.2	3.3	5.6	0.8	2.3
10. Textiles, clothing, footwear	2.6	0.1	1.0	0.3	0.6	0.8	0.2	0.2	0.1	0.1
11. Wood and paper products	2.6	2.0	3.2	1.2	2.4	2.2	2.4	1.6	0.9	0.7
12. Chemical prods. excl. petrol	0.5	0.0	0.6	0.2	1.2	0.5	0.3	0.4	0.0	0.6
13. Petroleum products	0.0	0.3	0.5	0.2	0.3	0.0	0.0	0.0	0.1	0.1
14. Building prods (not metal)	0.5	0.4	0.4	0.1	0.6	0.7	0.7	0.3	0.0	0.3
15. Cement	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.4
16. Iron and steel	0.3	0.1	0.0	0.1	0.5	0.3	0.4	0.1	0.0	0.1
17. Alumina and aluminium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.2
18. Other metal products	0.9	0.6	1.1	0.4	2.6	1.5	1.3	1.2	0.6	-5.9
19. Motor vehicles and parts	0.3	0.1	0.3	0.1	0.5	0.2	0.1	0.2	0.0	0.1
20. Other manufacturing	1.6	0.5	0.7	0.2	1.7	1.1	1.2	1.3	0.4	0.7
21. Electricity – black coal	0.0	0.0	0.0	0.0	0.0	1.5	4.7	0.0	0.0	8.4
22. Electricity – brown coal	0.0	0.0	0.0	44.4	0.0	0.0	0.0	0.0	0.0	0.0
23. Electricity – gas	0.0	0.1	0.0	0.6	0.0	0.1	0.0	0.2	1.5	0.0
24. Electricity – oil prods.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25. Electricity – other	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
26. Electricity supply	1.2	0.7	0.4	1.3	0.5	0.1	0.2	0.7	0.8	0.1
27. Urban gas distribution	0.2	0.1	0.1	0.2	0.2	0.1	0.1	0.2	1.0	0.1
28. Water and sewerage services	2.2	2.1	0.5	1.0	0.9	0.9	1.2	0.3	1.1	0.9
29. Construction services	5.7	5.1	6.7	3.0	7.8	10.6	6.3	5.9	4.1	6.0
30. Trade services	16.0	12.8	13.8	6.1	18.1	21.1	15.3	15.2	11.9	11.6
31. Road transport services	3.5	2.3	3.4	0.9	3.2	3.1	3.0	3.8	2.9	2.1
32. Other transport services	1.3	0.9	1.3	0.3	3.9	2.1	2.4	1.9	4.3	5.8
33. Communication services	1.7	1.2	1.6	0.8	2.8	2.1	1.5	1.7	1.8	1.2
34. Financial/business services	9.1	6.7	9.2	4.7	14.5	12.3	7.0	6.9	5.0	5.8
35. Dwelling ownership	9.4	7.3	16.7	7.7	10.5	10.6	9.4	10.2	9.2	7.6
36. Public services	24.9	19.1	20.6	8.1	20.9	16.3	16.9	20.0	19.0	13.2
37. Other services	1.7	1.5	1.9	0.7	1.9	2.4	1.1	1.3	1.2	1.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 3 (continued): Industry Shares (per cent) in Value Added by Sub-state Region

Industry	31. Central West (QLD)	32. Mackay (QLD)	33. Northern (QLD)	34. Far North (QLD)	35. North West (QLD)	36. Adelaide (SA)	37. Outer Adelaide (SA)	8. Yorke and Low North (SA)	39. Murray Lands (SA)	40. South East (SA)
1. Agriculture	26.3	7.8	7.5	9.6	6.7	0.8	9.7	27.2	23.7	15.3
2. Forestry	0.0	0.1	0.1	0.2	0.0	0.0	0.3	0.0	0.1	2.6
3. Iron ore	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
4. Non-iron ore	0.4	0.8	3.1	2.7	28.7	0.2	0.6	1.0	0.2	0.3
5. Black coal	0.0	15.0	0.5	0.0	0.1	0.0	0.0	0.0	0.0	0.0
6. Crude oil	0.0	0.1	0.0	0.0	0.0	0.7	0.7	0.8	0.4	0.1
7. Natural gas	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.5	0.2	0.1
8. Brown coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9. Food, beverages and tobacco	1.0	4.5	4.4	3.2	0.5	2.5	8.4	3.1	10.4	6.4
10. Textiles, clothing, footwear	0.0	0.1	0.2	0.1	0.0	1.1	0.5	0.3	0.1	0.8
11. Wood and paper products	0.4	0.9	1.0	1.2	0.3	2.2	1.9	0.9	0.9	8.9
12. Chemical prods. excl. petrol	0.0	0.3	0.3	0.1	0.2	1.5	1.2	3.8	0.5	0.4
13. Petroleum products	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14. Building prods (not metal)	0.0	0.5	0.2	0.3	0.1	0.3	0.3	0.2	0.1	0.2
15. Cement	0.0	0.0	0.2	0.0	0.0	0.1	0.6	0.1	0.0	0.0
16. Iron and steel	0.0	0.1	0.2	0.4	0.0	0.2	0.1	0.0	0.0	0.0
17. Alumina and aluminium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18. Other metal products	0.5	1.7	3.1	1.4	2.0	1.7	1.4	1.1	0.6	0.7
19. Motor vehicles and parts	0.0	0.0	0.1	0.1	0.1	3.1	1.0	0.3	0.1	0.1
20. Other manufacturing	0.1	0.8	1.0	0.7	0.4	3.0	1.8	0.5	1.6	0.5
21. Electricity – black coal	0.0	2.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22. Electricity – brown coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23. Electricity – gas	2.5	0.2	0.0	1.4	3.4	0.0	3.1	0.5	0.0	0.4
24. Electricity – oil prods.	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25. Electricity – other	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
26. Electricity supply	1.1	0.2	0.8	0.4	0.6	0.1	0.1	0.2	0.1	0.1
27. Urban gas distribution	0.0	0.1	0.1	0.1	0.0	0.4	0.2	0.1	0.0	0.2
28. Water and sewerage services	0.0	0.8	1.7	1.0	0.3	0.6	0.7	0.6	2.3	0.9
29. Construction services	7.5	7.4	7.2	7.8	6.2	6.5	7.5	5.0	5.2	6.8
30. Trade services	13.4	16.0	17.1	18.7	10.6	15.2	13.3	13.1	14.0	14.8
31. Road transport services	2.8	3.0	3.1	3.4	2.3	3.0	3.1	3.2	3.6	4.4
32. Other transport services	4.6	7.4	4.6	5.8	5.4	3.5	2.3	2.4	1.5	1.2
33. Communication services	1.4	1.3	1.9	1.5	1.0	2.1	2.0	1.8	1.4	1.3
34. Financial/business services	5.2	6.8	8.7	8.3	3.9	16.1	9.7	5.4	5.6	7.1
35. Dwelling ownership	9.9	8.9	10.1	10.1	8.6	9.4	9.4	10.0	10.1	9.9
36. Public services	21.8	11.9	20.4	19.5	17.8	22.8	18.0	16.9	15.6	15.2
37. Other services	1.0	1.1	1.7	1.7	0.9	2.4	2.0	1.0	1.5	1.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 3 (continued): Industry Shares (per cent) in Value Added by Sub-state Region

Industry	41. Eyre (SA)	42. Northern (SA)	43. Perth (WA)	44. Peel (WA)	45. South West (WA)	46. Great Southern (WA)	47. Wheatbelt (WA)	48. Goldfields-Esperance (WA)	49. Mid West (WA)	50. Gascoyne (WA)
1. Agriculture	28.1	7.7	1.3	2.1	9.1	30.8	34.9	6.6	16.7	19.0
2. Forestry	0.1	0.1	0.1	0.2	0.9	0.5	0.3	0.0	0.2	0.1
3. Iron ore	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4. Non-iron ore	0.9	2.0	3.3	2.3	9.6	1.4	5.8	39.4	19.4	5.7
5. Black coal	0.0	0.0	0.0	0.4	1.8	0.0	0.1	0.3	0.0	0.0
6. Crude oil	0.3	2.9	0.5	0.0	0.2	0.0	0.2	0.2	0.2	0.1
7. Natural gas	0.1	1.6	2.9	0.2	0.8	0.0	1.0	1.0	0.9	0.3
8. Brown coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9. Food, beverages and tobacco	3.0	1.5	1.6	1.1	2.8	4.0	1.6	0.6	0.9	1.3
10. Textiles, clothing, footwear	0.1	0.1	0.5	0.0	0.1	0.6	0.1	0.0	0.0	0.0
11. Wood and paper products	0.6	0.6	2.1	0.9	2.3	1.0	0.5	0.3	0.5	0.6
12. Chemical prods. excl. petrol	0.2	0.9	0.9	0.5	1.4	0.6	0.2	0.7	0.4	0.5
13. Petroleum products	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14. Building prods (not metal)	0.1	0.1	0.9	0.2	0.4	0.4	0.2	0.2	0.5	0.7
15. Cement	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16. Iron and steel	0.0	4.5	0.3	0.0	0.1	0.0	0.2	0.1	0.0	0.0
17. Alumina and aluminium	0.0	0.0	0.0	8.8	7.2	0.0	0.0	0.0	0.0	0.0
18. Other metal products	0.3	5.6	5.0	38.6	25.6	1.9	1.3	2.3	1.5	2.0
19. Motor vehicles and parts	0.0	0.1	0.2	0.0	0.1	0.3	0.1	0.0	0.0	0.0
20. Other manufacturing	0.5	0.5	1.5	0.2	0.4	0.3	0.3	0.4	0.4	0.5
21. Electricity – black coal	0.0	0.0	0.0	2.1	4.8	0.0	0.0	0.0	0.0	0.0
22. Electricity – brown coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23. Electricity – gas	0.2	0.3	0.0	0.0	0.0	0.0	7.9	3.7	5.6	0.0
24. Electricity – oil prods.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25. Electricity – other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26. Electricity supply	0.2	0.1	0.4	0.2	0.9	0.6	0.3	0.2	0.4	0.7
27. Urban gas distribution	0.1	0.3	0.3	0.1	0.1	0.0	0.0	0.1	0.1	0.1
28. Water and sewerage services	1.1	1.0	0.9	0.6	0.4	1.4	1.5	0.4	1.0	1.3
29. Construction services	5.5	6.2	11.1	7.5	5.3	8.3	4.9	7.5	7.8	10.4
30. Trade services	12.5	12.6	18.4	9.7	6.9	14.3	9.2	10.8	12.6	16.8
31. Road transport services	2.5	2.8	3.5	2.0	1.4	2.7	2.3	3.0	2.8	3.7
32. Other transport services	4.7	7.3	2.8	1.0	0.7	1.6	2.7	2.6	2.4	3.2
33. Communication services	1.5	1.4	2.5	1.0	0.7	1.6	1.4	1.2	1.3	1.7
34. Financial/business services	6.0	7.9	17.1	5.5	3.9	6.7	4.8	6.2	6.0	8.0
35. Dwelling ownership	10.5	9.6	8.6	4.2	4.7	8.5	7.2	6.0	6.7	7.9
36. Public services	19.5	20.9	20.3	9.7	6.8	14.6	13.0	9.7	13.5	17.9
37. Other services	1.3	1.6	2.2	0.9	0.6	1.8	0.7	0.9	1.0	1.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 3 (continued): Industry Shares (per cent) in Value Added by Sub-state Region

Industry	51. Pilbara (WA)	52. Kimberley (WA)	53. Greater Hobart (TAS)	54. Southern (TAS)	55. Northern (TAS)	56. Mersey-Lyell (TAS)	Total
1. Agriculture	1.0	7.2	1.5	17.3	6.6	8.2	4.2
2. Forestry	0.0	0.0	0.8	4.6	2.1	1.9	0.2
3. Iron ore	21.3	0.0	0.0	0.0	0.0	0.7	0.1
4. Non-iron ore	7.2	5.7	0.7	1.3	0.9	2.6	1.1
5. Black coal	0.0	0.0	0.0	0.0	0.4	0.0	1.0
6. Crude oil	2.6	0.0	0.0	0.0	0.0	0.0	0.4
7. Natural gas	13.6	0.0	0.0	0.0	0.0	0.0	0.5
8. Brown coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9. Food, beverages and tobacco	0.2	0.8	2.2	2.4	2.2	3.5	2.3
10. Textiles, clothing, footwear	0.0	0.0	1.0	0.6	0.7	0.9	0.9
11. Wood and paper products	0.1	0.4	3.3	4.0	5.0	6.3	2.4
12. Chemical prods. excl. petrol	0.0	0.0	0.8	0.7	0.7	0.6	1.4
13. Petroleum products	0.1	0.0	0.0	0.0	0.0	0.0	0.1
14. Building prods (not metal)	0.3	0.1	0.6	0.4	0.4	0.3	0.5
15. Cement	0.0	0.0	0.0	0.0	0.0	1.3	0.1
16. Iron and steel	0.2	0.0	0.1	0.0	1.5	0.0	0.5
17. Alumina and aluminium	0.0	0.0	0.0	0.0	2.1	0.0	0.4
18. Other metal products	1.3	1.3	0.7	0.3	1.3	0.4	1.3
19. Motor vehicles and parts	0.0	0.0	0.1	0.0	1.8	0.2	0.7
20. Other manufacturing	1.8	0.2	1.1	0.5	0.7	1.2	1.7
21. Electricity – black coal	1.0	0.0	0.0	0.0	0.0	0.0	0.7
22. Electricity – brown coal	0.0	0.0	0.0	0.0	0.0	0.0	0.4
23. Electricity – gas	9.5	0.0	0.0	0.0	0.0	0.0	0.2
24. Electricity – oil prods.	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25. Electricity – other	0.0	0.0	0.0	11.8	0.3	6.6	0.1
26. Electricity supply	0.3	0.4	1.0	1.3	0.3	0.2	0.4
27. Urban gas distribution	0.2	0.0	0.0	0.0	0.0	0.0	0.3
28. Water and sewerage services	0.9	1.8	1.9	0.1	1.7	1.3	1.0
29. Construction services	7.4	8.4	7.7	6.3	6.5	6.5	7.1
30. Trade services	8.2	14.9	17.4	12.7	17.9	16.2	16.2
31. Road transport services	1.6	2.8	2.2	2.7	2.8	3.0	2.9
32. Other transport services	3.0	3.5	1.9	1.1	3.3	3.4	3.2
33. Communication services	0.9	1.3	2.4	1.4	1.7	1.3	2.2
34. Financial/business services	4.3	6.4	11.6	4.8	8.4	7.0	14.9
35. Dwelling ownership	5.4	8.6	10.2	9.1	9.9	9.5	10.1
36. Public services	9.6	36.0	28.5	15.2	19.0	15.8	18.8
37. Other services	0.7	2.7	2.2	1.3	1.6	1.1	1.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

References

Adams, P.D. and P.B. Dixon (1995), "Prospects for Australian Industries, States and Regions: 1993-94 to 2001-02", *Australian Bulletin of Labour*, Vol. 21, No. 2, June, pp. 87-108.

Adams, P.D., J.M. Horridge and B.R. Parmenter (2000a), "Report on Modelling for a Consultancy Examining the Microeconomic Impacts of an Efficiency Standards Measure", for Allen Consulting and the Australian Greenhouse Office, May, 29 pages.

Adams, P.D., J.M. Horridge and B.R. Parmenter (2000b), "Report on Modelling for a Consultancy Examining the Microeconomic Impacts of Global Emissions Trading", for Allen Consulting and the Australian Greenhouse Office, August, 24 pages.

Dixon, P.B. and M. Rimmer (2000), *MONASH: A Dynamic Multi-sectoral Model of the Australian Economy*, mimeo. Current draft can be obtained by writing to Peter Dixon, Centre of Policy Studies, PO Box 11E, Monash University, Victoria 2800, Australia.

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

Enzinger, S. (2000), "Estimates of Value-added by Industry and Sub-state Region, with Special Emphasis on Energy-related Activities", *mimeo*. Current draft can be obtained by writing to Sharn Enzinger, Centre of Policy Studies, PO Box 11E, Monash University, Victoria 3800, Australia.

Fry, J.M. (1997), "Calculating Implied $C0_2$-Equivalent Emissions Factors for Greenhouse Gases", *mimeo*, March. Can be obtained by writing to Philip Adams, Centre of Policy Studies, PO Box 11E, Monash University, Victoria 3800, Australia.

Harrison W. Jill and K.R. Pearson (1996) "Computing solutions for Large General Equilibrium Models Using GEMPACK", *Computational Economics*, Vol. 9, pp. 83-127.

Kenderes, M. (1993), 'Updating of the ORANI Regional Model: Estimates of Employment by ORANI Industry and Statistical Division — 1991 Census', *ORANI Research Memorandum*, Archive No. OA-611, August.

Leontief, W., A. Morgan, K. Polenske, D. Simpson and E. Tower (1965), 'The Economic Impact — Industrial and Regional — of an Arms Cut', *Review of Economics and Statistics*, XLVII, August, pp. 217-41.

Meagher, G.A. and Brian R. Parmenter (1993), "Monash-MR: A Multiregional CGE Model of Australia", *mimeo*, paper presented to the Venice Workshop on Transportation and Spatial CGE Models, Venice, 18-20 May, pp. 25.

National Greenhouse Gas Inventory (1997), *National Greenhouse Gas Inventory, 1997*, Australian Greenhouse Office, Canberra.

Pearson, K.R. (1998), "Automating the Computation of Solutions of Large Economic Models", *Economic Modelling*, Vol. 7, pp. 385-395.

Peter, M.W., J.M. Horridge, G.A. Meagher, F. Naqvi, B.R. Parmenter and P.D. Adams (forthcoming, 2001) MONASH-MRF: A Multi-sectoral, Multi-regional Model of the Australian Economy, *mimeo in preparation*. Current draft can be obtained by writing to Philip Adams, Centre of Policy Studies, PO Box 11E, Monash University, Victoria 3800, Australia.

Quinlan, H. (1991), *Australia's Domestic Freight, 1986-87*, Centre for Transportation Policy Analysis, Wollongong University, Wollongong.