Analysis of Greenhouse Policy using MMRF-GREEN

by

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

Centre of Policy Studies, Monash University

1. INTRODUCTION

This paper describes modelling work that uses an enhanced version of the Monash Multi-Regional Forecasting Model[1] (called MMRF-GREEN, see section 2) to project business-as-usual baselines for Australia's greenhouse-gas emissions and to analyse the effects of emissions-trading schemes designed to limit emissions with a view to meeting Australia's emissions-reduction commitments under the Kyoto protocol.

Table 1 illustrates the dimensions of the policy problem that motivates the project. Column A gives official data on Australia's greenhouse-gas emissions for 1990. Emissions are broken into those accounted for by land clearing and those due to all other sources (primarily the combustion of fossil fuels, fugitive emissions from mining, emissions from the production of cement, and agricultural emissions). Gases included are CO_2, CH_4 and N_20, all expressed in CO_2-equivalent units of global warming potential. MMRF-GREEN includes all forms of emissions except those from land clearing. Data on emissions from land clearing are very uncertain. The entries for land-clearing emissions in columns other than column A are informal projections, not model-based.

Column B of Table 1 shows emissions for 1997, the base year for our projections. For emissions excluding land clearing two figures are given, the first from MMRF-GREEN data and the second from official sources (NGGI, 1997, Table 6, p.xxii). These accord closely with each other. Column C shows Australia's commitment under the Kyoto protocol, which is to limit emissions in the period 2008-12 to 1.08 times 1990 levels. Assuming that emissions from land clearing will be 60 m.t., this requires emissions from other sources to be limited to 471 m.t. Column D shows emissions for 2010 according to MMRF-GREEN business-as-usual baseline projections (Section 3). Assuming that emissions from land clearing remain at 60 m.t., the policy problem is to reduce emissions from other sources by 95 m.t. (=566 – 471).

In Section 4, we report detailed results for a simulation of a comprehensive domestic cap-and-trade permits system with auctioned permits and a cap set to meet the Kyoto commitment. Revenue from the auction is recycled as an across-the-board cut in taxes on consumption. Ignoring transactions costs, this is equivalent to a comprehensive carbon tax set at a rate that meets the Kyoto target (i.e., a rate per tonne of carbon equal to the equilibrium permit price), with tax revenue returned as an across-the-board cut in taxes on consumption.

Our conclusion in Section 5 includes a brief discussion of a second policy simulation in which permits are allocated via grandfathering, rather than at auction. This shows that the permit-allocation method has some implications for macroeconomic variables but does not have much effect on the allocative outcome, i.e., on where the permits are used.

---

[1] An earlier version of MMRF is documented in Matthew Peter, Mark Horridge, G. Meagher, F. Naqvi and B. Parmenter (1996), "The Theoretical Structure of MONASH-MRF", *Centre of Policy Studies Preliminary Working Paper*, No. OP-85, August.

2. THE MMRF-GREEN MODEL

2.1 Overall structure and dynamics

MMRF-GREEN is an enhancement of CoPS' MMRF model. MMRF distinguishes eight regions (six States and two Territories) and, for this study, 37 commodities/industries. The model recognises:

- domestic producers classified by industry and domestic region;
- investors similarly classified;
- eight region-specific household sectors;
- an aggregate foreign purchaser of the domestic economy's exports;
- eight state and territory governments;
- the Federal government;
- intra-regional, inter-regional and international trade based on regional input-output data developed at CoPS;
- greenhouse gas emissions from each of the 37 industries and eight regions;
- inter-fuel substitution in electricity generation; and
- mechanisms that allow for the endogenous take-up of abatement measures in response to greenhouse policy measures.

MMRF-GREEN produces sequences of annual solutions connected by accumulation relationships for capital stocks. It incorporates most of the dynamic features of the MONASH model. These include:

- equations relating investment to capital in year-to-year simulations, equations explaining the relationship between year-to-year capital growth and rate-of-return expectations, and equations that facilitate the running of forecasting and dynamic policy simulations; and
- regional data for industry investment/capital ratios, for industry rates of return and for dynamic adjustment parameters.

2.2 Modelling emissions

MMRF-GREEN breaks down emissions according to emitting agent (37 industries and residential), emitting state or territory (8) and emitting activity. Most of the emitting activities are the burning of fuels (*Black coal*, *Natural gas*, *Brown coal* or *Petroleum products*). The other category, named *Activity*, covers emissions such as fugitives and agricultural emissions not arising from fuel burning. The resulting 38×8×5 matrix includes all emissions except those arising from land clearing. Emissions are measured in kiloTonnes of CO_2-equivalent.

The emissions matrix refers to 1994. A national total of this matrix is shown in Table 2. The first four columns show the contributions made by burning fuels. *Black coal* contributes the most. The first 37 rows correspond to the MMRF-GREEN industries. The industry *ElectBlack* is the largest burner of *BlackCoal*. Electricity generators have been divided according to fuel used (into *ElectBlack*, *ElectBrown*, *ElectGas*, *ElectOil* and *ElectOther* [hydro and renewables]). Each of these sells to the *ElectSupply* 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 the matrix is in the *Agriculture* row of the *Activity* column. This shows emissions caused by livestock digestion, soil disturbance, and fertiliser use. There is negative entry for *Forestry*, which we treat it as a sink.

The first four columns of Table 2 are based on data from the National Greenhouse Gas Inventory (1996). The fifth is derived from a 1999 NGGI summary table. Value flows from the standard MMRF database were used to apportion the emissions of Table 2 between regions.

Fuel-burning emissions (columns 1-4 of Table 2) are modelled as proportional to fuel usage. We do not allow for any invention, which might, say, allow the *ElectBlack* industry to release less CO_2 per tonne of *BlackCoal* burned. On the other hand, we do allow for exogenous input-saving technical progress, e.g., for changes in the amount of *BlackCoal* burned per kilowatt-hour generated by the *ElectBlack* industry.

In MMRF-GREEN, price-induced substitution effects generate emission reduction. For example, the *ElectSupply* industry might source less of its power from *ElectCoal* and more from *ElectGas*, resulting in a drop in emissions. The elasticity of substitution between the types of electricity has been set equal to 5. For other energy-intensive commodities (namely *Agriculture*, *Forestry*, *BlackCoal*, *NatGas*, *BrownCoal*, *Food*, *WoodPaper*, *Chemicals*, *Petrol*, *Cement*, *Steel*, *Aluminium*, *OthMet_prods*, *ElectSupply*, *UrbanGasDis*, *RoadTrans*, *OthTrans*) used in industry, MMRF-GREEN allows for abatement possibilities by including a similar, but weaker, form of input substitution. In most cases, we have imposed a substitution elasticity of 0.1 between the commodities and other inputs. For *Petroleum Products*, *ElectSupply*, and *Urban Gas*, the substitution elasticity is 0.25.

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 related to the price of emissions permits (or the level of the CO_2 tax). 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 assumed that if the tax reached \$100 (93-4 dollars) per tonne CO_2, non-fuel-burning emissions from:

- *Agriculture* would drop by 60%,
- *BlackCoal* would drop by 70%,
- *Oil* would drop by 40%,
- *Aluminium* would drop by 25%,
- *NaturalGas*, *BrownCoal*, *Chemicals*, *Cement* and *OtherServices* would all drop by 10%.

We should emphasise that these estimates are speculative, but only really important in the case of *Agriculture*, which makes such a large initial contribution to activity-related emissions. In all these cases the abatement response is assumed to raise the requirement for other inputs by a value, *at the margin*, equal to the tax saved. That means a net saving, to the industry, of about half of the tax avoided by abatement.

We have treated the sink potential of *Forestry* conservatively, connecting it to *Forestry* activity as a whole, which includes logging, rather than to the rate of planting. If *Forestry* is growing rapidly, as it does in our policy scenarios, we should expect it to be devoting a high fraction of effort to planting, rather than felling. This would, at least temporarily, increase the sink effect beyond what we have estimated.

3. BASECASE PROJECTION

In assessing the impact of any policy designed to reduce greenhouse gas emissions, we first use MMRF-GREEN to produce a basecase projection excluding the policy change. Then we produce a second (deviation) projection with the change in place. The effects of the policy change are measured by the differences between the deviation and basecase projections.

3.1. Inputs to the basecase projection

For the forecast years, 1996-97 to 2007-08, we include in our basecase forecasts:

- macroeconomic forecasts from Access Economics and State Treasury departments;
- national-level forecasts of inbound tourism numbers from the Tourism Forecasting Council (TFC) and forecasts of real foreign-tourist expenditure by region from Access Economics;
- assumptions for changes in industry production technologies and in household preferences from CoPS; and
- forecasts for the quantities of agricultural and mineral exports, and estimates of capital expenditure on major minerals and energy projects from the Australian Bureau of Agricultural and Resource Economics (ABARE).

For the remainder of the forecast period, 2007-08 to 2019-20, we use, in the main, trend annual growth rates from the preceding ten years.

3.1.1 Macroeconomic inputs

In our basecase macro scenario, real GDP is assumed to grow at an average annual rate of 2.8 per cent. The regions with the best GSP growth potential are WA (3.3 per cent per annum annual growth) and QLD (3.2 per cent). The states with the worst growth potential are TAS (2.0 per cent) and SA (2.3 per cent). For QLD and WA these forecast growth rates are below the average rates of the last five years, while for TAS and SA they are higher than recent experience. Factors such as the Asian financial crisis, the prospect of a prolonged period of slow growth in Japan and a forecast slowdown in the US economy, make it unlikely that the foreign-export-oriented states like QLD and WA can sustain their recent strong performance. On the other hand, we are assuming that some of the negative factors underlying the recent poor performance of SA and ACT, such as declining population growth and the stagnation of some foreign-import-competing industries, will gradually be reversed.

3.1.2 Assumptions for changes in technology and tastes

Table 3 shows our assumptions for changes in the preferences of households and in the production technologies of industries. These are applied uniformly across regions. They are based on trends extrapolated from a MONASH simulation for the period 1986-87 to 1996-97.

Assumptions for the household tastes are summarised in the first column of Table 3. For example, we assume that consumption of *Financial and business services* will increase at a rate 1.1 per cent a year faster than can be explained on the basis of changes in prices and changes in the average budget of households.

The second column of Table 3 shows our initial[2] assumptions for the average annual rates of change in the usage of commodities as intermediate inputs per unit of production in the using industries, and as inputs per unit of capital creation. For example, we assume initially that in each year industries will increase their usage of *Communication* services by 5.0 per cent more than their outputs.

---

[2] Results from our simulation imply annual changes in input-output coefficients that are slightly different from those in the second column of numbers in Table 3. The entries in this column are entered as exogenous shocks applied in each year of the forecast. Where the shocks called for an increase in use of commodity i by industry j, we endogenously scaled down all other inputs used by j to leave unit costs unchanged. Similarly, we scaled up all inputs to industry j if the initial shock called for reduced usage of commodity i.

Our initial[3] assumptions for each industry concerning average annual changes in primary-factor usage per unit of output are shown in the final column of Table 3. For example, our initial assumption for *Electricity* is that output will increase on average by 3.1 per cent a year relative to the industry's overall usage of primary factors.

3.1.3 Assumptions for Exports, Production and Capital Expenditure

Forecasts for these are taken from ABARE. The forecasts for export volumes reflect ABARE projections to 2004-05, and long-term trends for the years 2004-05 to 2019-20. The forecasts for production reflect ABARE estimates to 2014-15, followed by five years of trend growth. Most of our basecase forecasts for real gross investment in the mining and energy industries are endogenous in MMRF-GREEN. However, in some years between 1999-00 and 2009-10, for some of the industries in some regions, investment is exogenously set in light of data provided by ABARE. For example, in the period 2000-01 to 2009-10, investment in the QLD aluminium industry reflecst the construction of the Gladstone Alumina plant. Allowance is also made for the construction of the PNG-QLD natural gas pipeline.

3.2. Basecase projections for industry output

Table 4 gives base forecasts for the 37 industries distinguished in the model. At the Australia-wide level, *Communication services* is the fastest growing industry. This reflects the assumptions that changes in technology will favour intermediate usage of these services strongly (column 2 of Table 3) and that rapid productivity growth (column 3 of Table 3) will reduce their prices relative to consumer prices in general. Similar factors explain the strong growth forecast for *Financial and business services*. Other industries with strong growth forecasts include *Other transport services* and *Other metal products*. These participate heavily in the growth forecast for international tourism and manufactured exports. In addition, changes in technology are assumed to favour intermediate usage of *Other metal products* (column 2 of Table 3). Forecasts for agriculture and mining are based on the current views of the ABARE. These include slow growth for *Crude oil*, reflecting the run down of the Bass Straight reserves. Other industries with relatively weak growth forecasts include *Textiles, clothing and footwear*, which is restricted by import competition, and *Cement*, which is restricted by adverse shifts in technology in the construction sector.

For most industries, especially services, regional differences in growth forecasts mirror regional differences in the GSP forecast. Hence, growth tends to be relatively strong in Western Australia and Queensland and relatively weak in Tasmania and South Australia.

Table 4 includes our base forecasts for sectors that are likely to be especially affected by policy responses to Australia’s Kyoto commitments. Electricity generation is the most important case. In all regions, forecast growth of *Electricity supply* lags behind forecast GSP growth. This reflects assumptions about electricity-saving technical change that are imposed on the forecasts. For all regions in which it is relevant, we assume that growth in *Electricity generation – gas* will be strong. This restricts growth prospects for other types of electricity generation, especially *Electricity generation – black coal* in Queensland and South Australia.

---

[3] Results from our simulation imply annual changes in primary factor usage per unit of output in each industry different from those shown in Table 4. Apart from the endogenous adjustments described in the previous footnote, we also allow for endogenous adjustments to reconcile the industry results with the region-wide forecasts for real value added, aggregate employment and aggregate capital.

3.3 Emissions in the base scenario

Table 5 presents data about CO_2-equivalent emissions in our base scenario. Total emissions are projected to grow at an average annual rate of 1.7 per cent, considerably less than the projected GDP growth rate of 2.8 per cent. Some reasons are:

- the slow growth of *Agriculture* (a major contributor);
- the shift towards *Natural Gas* for electric power generation;
- *Electricity*-saving technical change; and
- faster-than-average growth of the service sectors, which do not emit much.

Nevertheless, the national total for all emissions (excluding land clearing) in 2009-10 is 566 megaTonnes. This is 20% above the Kyoto target (see column C of Table 1).

For Tasmania, we do not show the rate of growth of emissions. Tasmania has a large forest sector and relies on hydroelectricity, which emits nothing. In 1996-7, Tasmania's gross emissions (predominantly from *Agriculture*) just outweighed its *Forestry* sink, leaving it with small net emissions. Through the projection period, *Agriculture* grows more slowly than *Forestry* (Table 4), turning Tasmania into a net sink. Since total emissions change sign, we cannot compute a sensible growth rate.

4. A POLICY SIMULATION

This policy scenario differs from the base case in that from 2005 a uniform tax is imposed on all the emissions covered in MMRF-GREEN. The tax rate ($44.33 per tonne of CO_2 equivalent emissions) is chosen to yield a total emission level in 2009-10 that, given our assumption about emissions from land clearing, is consistent with Australia's Kyoto target[4]. (An alternative interpretation is that, in order to be able to emit a tonne of CO_2 equivalent emissions, emitters must buy a permit the price of which is $44.33.) The tax applies to the usage of fuels that release greenhouse gases and to the output of industries that release gases in other ways. The tax revenue (alternatively, the proceeds of the sale of permits) is used to make a uniform reduction in *ad valorem* taxes on household consumption. The effect of the tax is to make fuels more expensive to users, and to increase the prices of commodities produced by industries that cause non-fuel-related emissions. The increased prices reduce emissions by bringing into play the substitution mechanisms mentioned in Subsection 2.2.

The main effects of the emissions-reduction policy on economic variables and on emissions are shown in Charts 1a-9a. These show, for the period 2003-04 to 2011-12, percentage deviations of a range of variables in the policy simulation from their values in the base case. For example, Chart 1a shows that the imposition of the policy in 2004-05 would reduce real GDP at factor cost in 2011-12 by about 0.6 per cent relative to its basecase value.

Our explanation of the results is given in a series of numbered points. The italicised headings to the numbered points outline the main structure of the explanation.

i. *In the short run, the imposition of the policy reduces employment. With the capital stock fixed, this leads to a decrease in real GDP at factor cost (Chart 1a).* The emissions policy substitutes a carbon tax for a consumption tax. In the short run, this increases the investment price index, reducing rates of return and discouraging investment (Chart 2a). Because of its

[4] With the emissions charge in place, emissions in 2009-10 from sources other than land clearing are projected to be 469 m.t., very close to the target of 471 m.t., set out in Table 1.

large *Construction* component, investment is relatively labour intensive. Hence, the reduction in investment tends to reduce employment.

ii. *The costs of abatement cause the decline in real GDP at factor cost to exceed the decline in factor inputs (Chart 1a)*. This is especially evident in the early years of the projection period, in which the path of real GDP at factor cost lies below the paths of employment and the capital stock. Our specification recognises that to reduce their emissions of greenhouse gases per unit of output producers must use more inputs per unit output.

iii. *The percentage fall in real GDP at market prices relative to its base case value exceeds the percentage fall in real GDP at factor cost (Chart 1a).* The percentage change in real GDP at market prices is a weighted average of percentage changes in real GDP at factor cost and the real indirect-tax base. The fact that real GDP at market prices declines more than real GDP at factor cost indicates that the real indirect-tax base is declining more than real GDP at factor cost. The main factor contributing to this in the short run is the decline in domestic usage of petroleum products. Taxes on petroleum products account for almost 25 percent of aggregate indirect tax revenue.

iv. *The reduction in investment causes real gross national expenditure (GNE) to decline relative to real GDP in the short run, moving the trade balance towards surplus* (Charts 2a and 3a). Public consumption is assumed to be unaffected by the policy. Real private consumption declines less than real GDP because the cut in the consumption tax reduces the CPI relative to the GDP deflator, increasing real disposable income relative to real GDP. Overall, GNE declines in 2004-05 by about 0.7 per cent, whereas real GDP at market prices falls by about 0.5 per cent (Chart 2a). This implies that the trade balance must move to surplus. Hence, in 2004-05 aggregate exports rise relative to aggregate imports (Chart 3a). Because energy intensive exports are inhibited by the carbon tax, a significant depreciation of the real exchange rate is required.

v. *After 2004-05, the capital stock declines but employment moves back towards its base case level (Chart 1a).* According to the labour-market specification in MMRF-GREEN, if employment is above (below) its basecase level, labour demands an increase (allows a decrease) in the consumer real wage. Hence, the consumer real wage moves below its basecase value (Chart 4a). Out to 2011-12, the wage reduction is not strong enough to return aggregate employment to its basecase value. Hence, the wage continues to decline relative to base. This strengthens producers' incentive to substitute labour for capital. Hence, the capital stock continues to move below base (Chart 1a) and investment remains below base (Chart 2a)[5]. With capital falling further below base and with employment failing to make a significant return towards base, real GDP continues to fall relative to base (Chart 1a).

vi. *The decline in GDP eventually outstrips the decline in GNE, moving the trade balance back towards deficit.* With investment recovering towards base, the deviation of real GNE from its base value stabilises but real GDP continues to decline relative to base. By 2007-08, real GDP has moved further from base than real GNE (Chart 2a). Correspondingly, the trade balance has to be in deficit relative to base by 2006-08. This is reflected in Chart 3a by the crossing of the paths of aggregate exports and aggregate imports.

vii. *At the national level, there are three industries for which the emissions policy significantly raises output relative to base in the long run.* Chart 5a shows percentage deviations of

[5] The distance below base of the investment line in Chart 2a is related to the slope of the capital line in Chart 1a. If the capital line is getting steeper (less steep) the investment line will be moving further away from (closer towards) base.

industries' outputs from their basecase levels for the industries that in the long run gain most from the introduction of the emissions policy. Two of the three most favourably affected industries, *ElectGas* and *ElectOil*, are low-emissions electricity generators. The emissions tax causes substitution in their favour at the expense of the high-emissions coal generators. The third favourably affected industry is *Forestry*. Because it is a net sink, the emissions tax acts as a subsidy for this industry.

viii. *With the exception of Agriculture, adversely affected industries are in the energy or energy-intensive sectors (Chart 6a)*. Prominent among the industries most adversely affected by the introduction of the emissions policy are *ElectBlack* and *ElectBrown*, the two high-emissions electricity generators, which lose share in the national electricity market. Also included are the two coal industries. *BrownCoal* is the more severely affected, with its output declining more relative to base than does the output of *ElectBrown*. This is because local electricity generation is the only use for *BrownCoal* and because the abatement possibilities included in MMRF-GREEN allow *ElectBrown* to reduce its usage of *BrownCoal* per unit of electricity generated. *BlackCoal* is affected much less seriously than is *ElectBlack* because a large share of the output of *BlackCoal* is exported. The imposition of the policy has two offsetting effects on these exports. The adverse effect is the tax on fugitive emissions associated with coal mining. The favourable effect is the induced depreciation of the real exchange rate (Chart 3a). Overall, exports of *BlackCoal* decline but not as severely as the domestic demand for black coal.

Aluminium is an energy-intensive export industry. The rise in electricity prices induced by the policy increases its costs significantly and reduces its exports. Exports of *Agriculture* are also restricted by the policy because of the tax imposed on the emissions related to agricultural activity.

Oil and *NatGas* are relatively low-emissions fuels. *ElectOil* and *ElectGas* both increase their shares in the local electricity market (Chart 5a) but the abatement possibilities built into the model allow them, in response to the policy-induced rise in fuel prices, to reduce the amount of fuel used per unit of electricity generated. This restricts local demand for *Oil* and *NatGas*. In addition, their exports decline in response to the cost increases imposed by the tax on *Activity*-related emissions involved in their extraction.

The prices of the output of the remaining three industries in Chart 6a (*UrbanGasDis*, *ElectSupply* and *Petrol*) are all raised directly by the imposition of the emissions tax. Hence, they are all subject to adverse substitution effects in their local markets.

ix. *Tasmania and the ACT both gain from the imposition of the policy. WA, Queensland, Victoria and NSW are the main losers* (Chart 7a) Tasmania and the ACT are the only regions in which gross product is stimulated by the policy change in the long run. Relying as it does on hydroelectricity, Tasmania does not experience a rise in its electricity costs when the policy is imposed. This allows it to expand its international exports following the depreciation of the Australian real exchange rate (Chart 3a). It also puts Tasmania in a favourable position to compete with other states in domestic markets, especially for energy-intensive commodities. The ACT depends heavily on public-sector activities, which are assumed unaffected by the emissions-reduction policy.

WA, Queensland and Victoria are the three states most adversely affected by the policy. For WA and Queensland the explanation is their heavy dependence on emissions-intensive mining and related industries, and on *Agriculture*. The key factor for Victoria is its reliance on brown coal (the most emission-intensive of the fuels included in the model) for the generation of electricity.

x. *In the long run, the policy induces a reduction in total emissions of about 17.5 per cent relative to the basecase level*. Chart 8a shows that the largest percentage reductions are for

Activity-related emissions and for emissions related to the combustion of coal. Chart 9a shows that for all regions except Tasmania and the ACT, long-run percentage reductions in emissions lie within the range 13-20 per cent. Through the projection period, Tasmania switches from being a small net emitter to a net sink. Hence, *percentage* reductions in its emissions are not very meaningful. Percentage emissions reductions are small for the ACT primarily because it does not generate any electricity.

xi. *The aggregate emissions reduction can be decomposed into the contributions of sources, industries and regions.* For 2009-10, the middle of the Kyoto commitment period, Charts 8a and 9a are supplemented by Tables 6a-8a. Note that the individual elements of each of these tables sum to –97334 kilotonnes, the aggregate reduction in emissions produced by the policy. (Assuming that emissions from land clearing are 60 megatonnes, this is enough to limit emissions in 2009-10 to 529 megatonnes, just slightly below the Kyoto target.)

The last column of Table 6a shows that agriculture, mining and electricity generation make the largest contributions to the aggregate reduction in emissions. The first two of these are heavy emitters of *Activity*-related emissions (see Table 2). The third accounts for the bulk of combustion-related emissions. The result for agriculture is heavily dependent on our rather optimistic assumptions about the scope for abatement of *Activity*-related emissions. The table shows, not surprisingly, that the two largest regional economies, NSW and Victoria, make the two largest regional contributions to the emissions reduction. Queensland also makes a large contribution, notably *via* agriculture, mining and manufacturing. Tasmania's contribution comes almost entirely from agriculture, which includes forestry at this broad-sector level.

Consistent with Table 6a, the last row of Table 7a shows that *Activity*-related emissions, mainly in agriculture and mining, account for more than half of the total emissions reduction. Reductions in emissions from the burning of coal, mainly in electricity generation, contribute another 40 per cent.

Table 8a presents the most detailed picture for 2009-10. If we compare the contributions in Table 8a with the data on the distribution of emissions in Table 2, we see that, on the whole, the contributions are roughly proportional to the data. An exception is the household (*Residential*) sector, which contributes relatively little to emissions reduction. Among the things confirmed by the table are:

- the importance of black coal electricity generation in the contribution of NSW;
- the importance of brown coal electricity generation in the contribution of Victoria;
- the importance of emissions from aluminium production in the manufacturing contribution in Queensland;
- the dominance of the expansion of the forestry sink in accounting for Tasmania's contribution; and
- the absence of reductions in electricity generation in the ACT.

5. CONCLUSION: ALTERNATIVE PERMIT-ALLOCATION MECHANISMS

In this paper we have reported the results of one of a number of studies of greehouse-policy issues that we have made using MMRF-GREEN. Among the other issues that we have investigated is the implications of alternative permit-allocation methods – grandfathering rather than auctioning, for example.

A comprehensive domestic cap and trade with grandfathered permits is equivalent to a comprehensive carbon tax with revenue recycled lump sum to the shareholders of the industries responsible for the emissions in the base case. To the extent that the shareholders are domestic residents, this increases domestic nominal disposable income but it does not directly influence the production or investment decisions of the relevant industries. In MMRF-GREEN, if it is not profitable for an industry to buy a permit at the going price, then it will be more profitable for it to sell a permit at that price than to retain it for its own use.

The main differences between the results of the grandfathering and auctioning simulations are macroeconomic. In the short run, employment and real GDP fall further with grandfathering than with auctioning of permits. The principal reason is that with grandfathering the emissions charge raises puts a wedge between the market price of output (the CPI, for example) and the return to primary factors (the deflator for GDP at factor cost). With the real wage rate from the employee's point of view assumed to be sticky in the short run, the nominal wage diverges only slowly from the CPI. Hence the nominal wage rises relative to the factor cost deflator. That is, the real wage rises from the employers' point of view. In the auctioning case, the revenue raised from the emissions charge is used to reduce taxes on consumption. Hence, the CPI declines relative to the factor cost deflator.

Table 1: CO2-equivalent emissions, million tonnes

	A	B	C	D
	1990 (official)	1997 (MMRF-GREEN)	2010 (Kyoto target)	2010 (MMRF-GREEN baseline)
Total emissions exclg land clearing	389	442 (official = 431)	471	566
Land Clearing *	103	65	60	60
Total	492	507	531 (= 1.08*492)	626

* Land clearing data are uncertain. Entries in columns B-D are informal estimates, not model-based.

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

Industry	Emissions category					
	1 BlackCoal	2 NatGas	3 BrownCoal	4 Petrol	5 Activity*	Total
1 Agriculture	0	113	0	5161	94200	99474
2 Forestry	0	44	0	757	-26500	-25699
3 IronOre	375	38	0	194	0	607
4 NonIronOre	430	260	0	1522	0	2212
5 BlackCoal	8944	78	0	431	11852	21305
6 Oil	75	971	0	16	9070	10132
7 NatGas	82	1063	0	18	3468	4631
8 BrownCoal	20	259	0	4	5110	5393
9 Food	2017	522	0	916	0	3455
10 TCF	215	42	0	91	0	347
11 WoodPaper	1390	213	0	758	0	2362
12 Chemicals	1772	1242	0	1187	484	4686
13 Petrol	126	0	0	11170	0	11296
14 Nmet_prods	504	314	0	286	0	1104
15 Cement	633	984	0	126	5078	6821
16 Steel	4745	1412	0	405	0	6561
17 Aluminium	1965	261	0	484	3482	6192
18 OthMet_prods	6259	983	0	5908	0	13150
19 CarsParts	126	111	0	50	0	287
20 Other_man	580	208	0	286	0	1073
21 ElectBlack	71083	0	0	0	0	71083
22 ElectBrown	0	0	44968	0	0	44968
23 ElectGas	0	4220	0	0	0	4220
24 ElectOil	0	0	0	253	0	253
25 ElectOther	0	0	0	0	0	0
26 ElectSupply	0	0	0	0	0	0
27 UrbanGasDis	55	14860	0	64	0	14979
28 Water	25	0	0	672	0	697
29 Construction	110	274	0	2912	0	3297
30 TradeHotels	1415	728	0	6341	0	8485
31 RoadTrans	0	174	0	4992	0	5167
32 OthTrans	211	327	0	10605	0	11144
33 Communic	0	710	0	960	0	1670
34 FinBusServ	0	396	0	4258	0	4655
35 Dwelling	0	0	0	117	0	117
36 PublicServ	832	2356	0	5296	0	8484
37 OthServ	106	142	0	1121	15563	16932
38 Residential	192	2162	0	25401	0	27756
Total	104287	35469	44968	92762	121807	399293

Sources: Fry (1997), NGGI (1996)). The *Activity* column uses a 1999 NGGI summary report.

* The *Activity* column shows: for *Coal*, *Oil* and *Gas*, fugitives; for *Agriculture*, animal gas, soil disturbance and fertilizer use; for *Other Services*, mainly rubbish dumps. *Forestry* is a net sink. Production of *Cement* and *Aluminium* also release non-combustion gases.

Table 3: Industry Technology and Household Taste Assumptions: MMRF-GREEN Basecase (average annual percentage changes)

Industry	Household	Technology:	
	preferences[(a)]	Intermediate input-using[(b)]	Primary-factor using[(c)]
Agriculture	0.8	0.1	-2.3
Forestry	-0.9	1.7	0.0
Iron ore	-1.3	-0.3	-4.1
Non-iron ore	-0.3	-1.8	-2.4
Black coal	-3.7	0.0	0.0
Crude oil	-1.3	0.0	0.0
Natural gas	1.0	0.5	0.0
Brown coal	-1.3	0.0	0.0
Food, beverages and tobacco	0.7	0.2	-1.3
Textiles, clothing and footwear	0.2	-0.4	-1.7
Wood and paper products	1.4	0.1	-0.2
Chemical products excl. Petrol	4.9	2.8	-0.1
Petroleum products	-2.7	-0.5	0.0
Non-metal construction materials excl. Cement	-1.4	0.6	-1.1
Cement	0.2	-1.2	-0.4
Iron and steel	5.2	2.3	-1.4
Alumina and aluminium	6.7	3.0	-2.5
Other metal products	-1.6	2.0	-0.1
Motor vehicles and parts	1.0	4.3	-0.4
Other manufacturing	2.0	-3.5	-1.8
Electricity generation – black coal	0.3	-0.3	-3.1
Electricity generation – brown coal	0.3	0.0	-3.1
Electricity generation – gas	0.3	1.0	-3.1
Electricity generation – petroleum products	0.3	-0.3	-3.1
Electricity generation – other (mainly hydro)	0.3	0.3	-3.1
Electricity supply	0.3	-0.5	-3.1
Urban gas distribution	0.3	0.6	-2.7
Water and sewerage services	-0.5	-0.2	-2.4
Construction services	6.3	1.8	0.0
Wholesale trade, retail trade, accommodation	-3.1	-1.8	0.0
Road transport services	-1.6	0.5	-0.8
Other transport services	-0.2	-0.2	-2.2
Communication services	0.0	5.0	-4.5
Financial and business services	1.1	3.2	-1.8
Dwelling ownership	0.0	0.0	0.3
Public services	-1.3	0.0	-0.4
Other services	0.6	1.6	0.0

(a) Annual rate of shift of consumption function.

(b) Annual rate of change of use of the commodity identified on the left-hand panel per unit of output of industries using the commodity.

(c) Annual rate of change of use of all primary factors (labour, capital and agricultural land) per unit of production of the industry identified on the left.

Table 4: Basecase Forecasts: Industry Output (average annual growth rates, 1996-97 to 2019-20)

Industry	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Agriculture	1.7	1.7	2.5	2.0	2.5	1.6	1.1	1.4	2.0
Forestry	2.6	2.8	3.2	2.9	3.5	2.4	5.3	4.6	2.9
Iron ore	2.0	1.7	1.7	2.8	2.6	1.5	1.0	0.9	2.5
Non-iron ore	2.1	0.0	2.5	0.3	2.1	2.6	1.1	0.3	2.0
Black coal	2.4	-0.3	2.6	-0.7	2.5	0.9	0.6	0.3	2.5
Crude oil	0.0	-0.5	-1.0	-1.4	0.8	0.0	1.0	0.0	-0.4
Natural gas	1.0	3.7	-0.6	-2.4	3.8	0.0	11.6	0.0	3.3
Brown coal	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Food, beverages and tobacco	1.6	2.2	3.4	2.8	3.2	1.6	4.1	4.5	2.5
Textiles, clothing and footwear	0.6	1.6	1.5	1.7	3.2	1.4	5.8	6.9	1.4
Wood and paper products	1.2	1.7	1.6	2.2	2.7	0.8	7.7	5.3	1.7
Chemical products excl. Petrol	2.8	3.3	3.8	4.6	5.3	3.5	8.1	7.7	3.5
Petroleum products	1.0	1.3	1.6	0.9	1.9	-0.4	2.0	2.1	1.3
Non-metal construction materials excl. Cement	2.1	2.1	3.0	2.2	3.4	1.4	3.5	3.2	2.5
Cement	0.1	0.3	1.2	1.1	1.3	0.2	2.7	2.3	1.0
Iron and steel	3.1	3.9	3.6	4.8	4.5	3.6	9.3	8.7	3.5
Alumina and aluminium	3.4	3.3	5.0	0.0	3.8	3.4	3.4	0.0	3.8
Other metal products	3.6	4.5	4.3	4.6	6.0	2.8	5.9	6.1	4.5
Motor vehicles and parts	0.7	2.2	2.5	3.6	4.3	1.5	9.2	7.6	2.6
Other manufacturing	2.6	2.7	2.6	2.3	3.8	2.0	4.9	4.7	2.7
Electricity generation – black coal	1.1	0.0	-0.7	-5.1	1.6	0.0	2.3	0.0	0.8
Electricity generation – brown coal	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	1.6
Electricity generation – gas	5.9	3.1	11.3	3.5	2.8	0.0	3.1	0.0	6.9
Electricity generation – petroleum products	-0.6	-1.8	-1.8	-5.7	-0.3	-2.7	2.1	3.1	2.6
Electricity generation – other (mainly hydro)	2.3	2.8	0.9	-5.5	3.6	1.1	2.8	3.2	1.9
Electricity supply	1.7	1.7	2.2	1.4	2.3	1.0	2.4	2.3	1.8
Urban gas distribution	2.8	2.8	4.6	2.6	3.7	2.2	3.6	3.1	3.1
Water and sewerage services	2.3	2.3	2.7	1.8	2.9	1.5	2.6	2.8	2.4
Construction services	2.9	2.5	3.6	1.9	3.9	1.4	1.8	1.5	2.9
Wholesale trade, retail trade, accommodation	1.7	1.8	2.8	1.5	2.6	2.0	1.9	1.7	2.0
Road transport services	2.7	2.8	3.4	2.9	3.8	2.4	3.1	2.7	3.0
Other transport services	4.0	5.2	4.8	4.1	4.6	6.9	6.7	8.5	4.7
Communication services	8.0	8.3	7.9	7.4	8.1	6.8	7.7	6.9	8.0
Financial and business services	4.8	4.6	5.3	4.4	5.6	4.4	5.7	5.6	4.9
Dwelling ownership	3.0	3.4	3.0	2.1	3.4	1.6	3.0	3.4	3.0
Public services	2.2	2.0	2.9	1.8	3.1	1.6	2.6	2.9	2.3
Other services	3.1	2.9	3.7	2.8	3.9	2.9	3.4	3.0	3.2

Table 5: Basecase Forecasts: Gas Emissions

Fuel/Activity	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Average annual growth rates (1996-97 to 2019-20)									
Total	1.4	1.4	1.9	1.4	2.6	na.	2.2	1.7	1.7
Black coal	0.7	2.2	-0.2	-0.9	2.4	1.3	1.8	2.0	0.7
Natural gas	3.1	2.7	5.8	3.3	3.3	2.1	3.5	3.0	3.5
Brown coal	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Petrol	1.3	1.4	1.9	1.0	2.5	1.6	2.2	1.2	1.6
Activity	1.9	1.4	2.5	1.4	2.6	3.3	2.1	1.8	2.0
Levels (kT = Gg) (1996-97)									
Total	153109	122934	84368	24160	49513	323	4580	2977	441964
Black coal	64743	5928	30018	4023	11592	609	593	133	117639
Natural gas	10749	12492	5400	3933	6973	647	347	584	41125
Brown coal	0	47369	0	0	0	0	0	0	47369
Petrol	36750	24217	18530	5744	11741	2029	991	1679	101681
Activity	40867	32928	30420	10460	19207	-2962	2649	581	134150
Levels (kT = Gg) (2009-10)									
Total	187833	152246	113796	29042	73253	-159	6293	3998	566302
Black coal	73553	8365	33584	3672	16677	714	815	183	137563
Natural gas	16876	18671	11442	5920	11548	848	567	944	66816
Brown coal	0	55862	0	0	0	0	0	0	55862
Petrol	43483	29063	24756	6622	17327	2504	1370	2094	127219
Activity	53921	40285	44014	12828	27701	-4225	3541	777	178842

Tabe 6a: (Broad Industry Sectors + Residential) by Region: levels changes in emissions (kT = Gg) at 2009-10 relative to base

Sector/Residential	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1. Agriculture	-11293	-7205	-8712	-3645	-5921	-3305	-340	-55	-40476
2. Mining	-2705	-3045	-3163	-261	-1211	-22	-220	-6	-10632
3. Manufacturing	-2358	-1684	-2058	-365	-2048	-66	-99	-1	-8678
4. Electricity generation	-10083	-9439	-6040	-701	-2969	1	-85	12	-29303
5. Transport services	-263	-168	-175	-24	-83	-16	-9	-3	-740
6. Construction	-100	-64	-62	-13	-46	-1	-3	-3	-291
7. Community services	-1522	-1632	-878	-282	-434	-38	-34	-143	-4963
8. Residential	-741	-633	-445	-90	-262	-29	-17	-33	-2250
Total	-29064	-23871	-21532	-5381	-12973	-3476	-807	-230	-97334

Table 7a: (Broad Industry Sectors + Residential) by Fuel and Activity: levels changes in emissions (kT = Gg) at 2009-10 relative to base

Sector/Residential	Black coal	Natural gas	Brown coal	Petrol	Activity	Total
1. Agriculture	0	-12	0	-650	-39814	-40476
2. Mining	-1058	-464	0	-112	-8999	-10632
3. Manufacturing	-4381	-783	0	-1468	-2046	-8678
4. Electricity generation	-21287	1698	-9785	71	0	-29303
5. Transport services	-37	-30	0	-674	0	-740
6. Construction	-20	-26	0	-245	0	-291
7. Community services	-361	-2385	0	-1106	-1111	-4963
8. Residential	-56	-673	0	-1522	0	-2250
Total	-27200	-2675	-9785	-5704	-51970	-97334

Table 8a: (Industry + Residential) by Region: levels changes in emissions (kT = Gg) at 2009-10 relative to base

Industry/Residential	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Agriculture	-10934	-6536	-8378	-3146	-5651	-1260	-340	-28	-36274
Forestry	-358	-670	-333	-499	-270	-2044	0	-28	-4202
Iron ore	0	0	0	0	-71	-2	0	0	-73
Non-iron ore	-6	-13	-19	-2	-75	-3	-12	0	-130
Black coal	-2696	-12	-3062	-58	-295	-18	-5	-6	-6151
Crude oil	-3	-1399	-81	-194	-320	0	-192	0	-2189
Natural gas	0	-223	-1	-7	-449	0	-11	0	-692
Brown coal	0	-1398	0	0	0	0	0	0	-1398
Food, beverages and tobacco	-105	-115	-114	-35	-40	-8	-1	0	-419
Textiles, clothing and footwear	-8	-14	-2	-4	-5	-1	0	0	-34
Wood and paper products	-76	-86	-24	-9	-31	20	-1	0	-205
Chemical products excl. Petrol	-122	-189	-51	-40	-90	-11	0	0	-503
Petroleum products	-191	-163	-105	0	-32	0	0	0	-490
Non-metal construction materials excl. Cement	-35	-34	-21	-4	-18	-1	0	0	-114
Cement	-127	-73	-143	-136	-139	-42	-70	0	-729
Iron and steel	-510	-199	-133	-53	-59	0	0	0	-955
Alumina and aluminium	-455	-417	-851	0	-806	-24	-28	0	-2581
Other metal products	-687	-355	-591	-67	-812	1	1	0	-2509
Motor vehicles and parts	-2	-8	-2	-5	-1	0	0	0	-19
Other manufacturing	-41	-31	-22	-12	-16	0	0	-1	-122
Electricity generation – black coal	-10616	0	-6359	-957	-3262	0	-93	0	-21287
Electricity generation – brown coal	0	-9785	0	0	0	0	0	0	-9785
Electricity generation – gas	510	337	304	250	291	0	7	0	1698
Electricity generation – petroleum products	23	10	16	5	3	1	2	12	71
Electricity generation – other (mainly hydro)	0	0	0	0	0	0	0	0	0
Electricity supply	0	0	0	0	0	0	0	0	0
Urban gas distribution	-526	-868	-370	-123	-112	-15	-2	-25	-2040
Water and sewerage services	-15	-12	-9	-2	-5	-1	0	-1	-44
Construction services	-100	-64	-62	-13	-46	-1	-3	-3	-291
Wholesale trade, retail trade, accommodation	-190	-137	-116	-27	-75	-4	-4	-4	-557
Road transport services	-120	-90	-86	-23	-59	1	-3	-3	-383
Other transport services	-143	-78	-89	-1	-24	-17	-7	1	-357
Communication services	-60	-59	-34	-2	-20	0	-1	-3	-179
Financial and business services	-143	-96	-62	-17	-47	0	-3	-5	-372
Dwelling ownership	-2	-1	-1	0	0	0	0	0	-4
Public services	-169	-137	-93	-33	-51	-6	-10	-61	-559
Other services	-417	-322	-195	-79	-123	-12	-15	-45	-1207
Residential	-741	-633	-445	-90	-262	-29	-17	-33	-2250
Total	-29064	-23871	-21532	-5381	-12973	-3476	-807	-230	-97334

Chart 1a: National Real GDP and Factor Inputs
(percentage deviations from control)

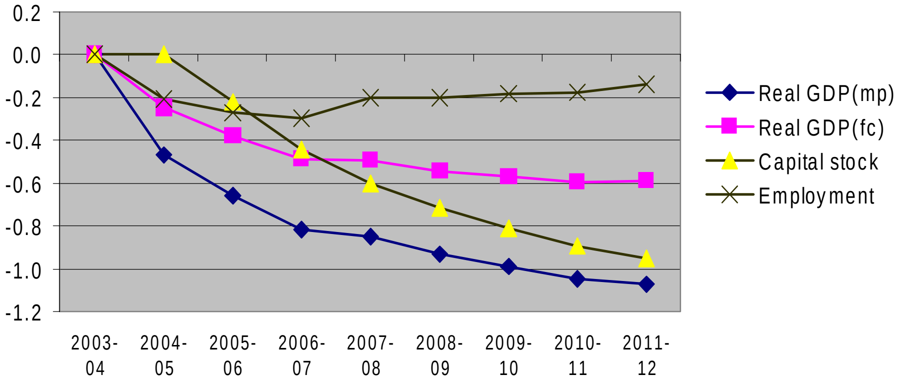

Chart 2a: National Real Domestic Expenditure
(percentage deviations from control)

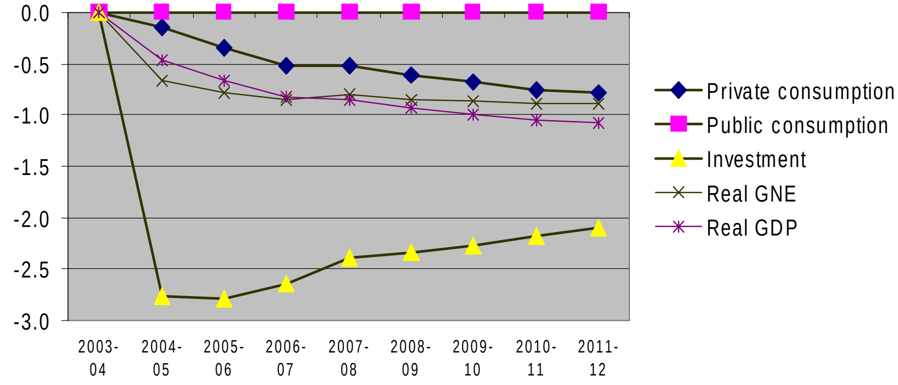

Chart 3a: Trade and the Real Exchange Rate
(percentage deviations from control)

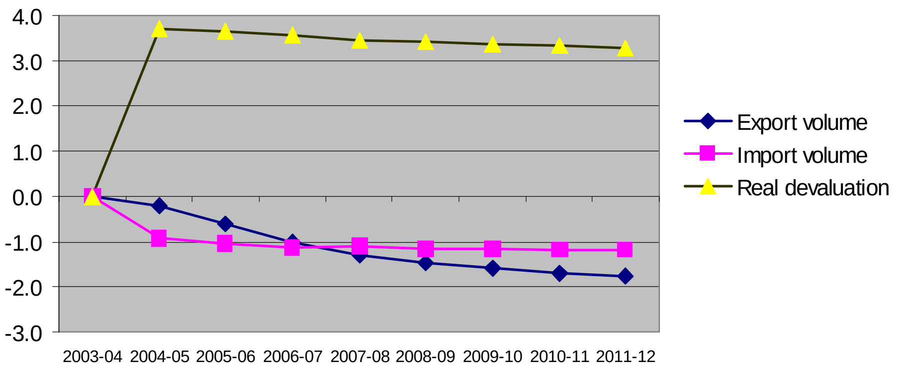

Chart 4a: Real wages and Employment
(percentage deviations from control)

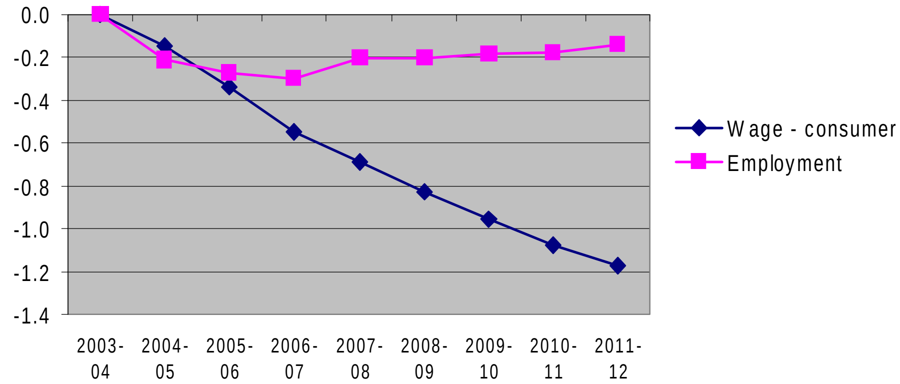

Chart 5a: Industry Production: Winners (percentage deviations from control)

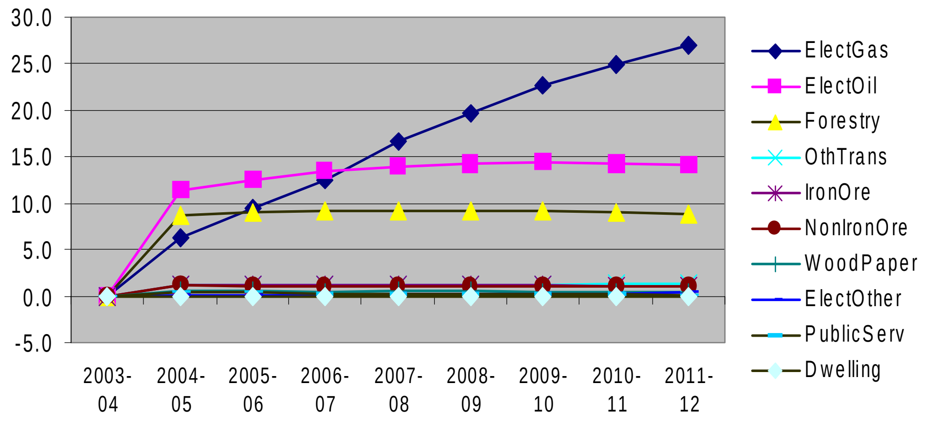

Chart 6a: Industry Production: Losers (percentage deviations from control)

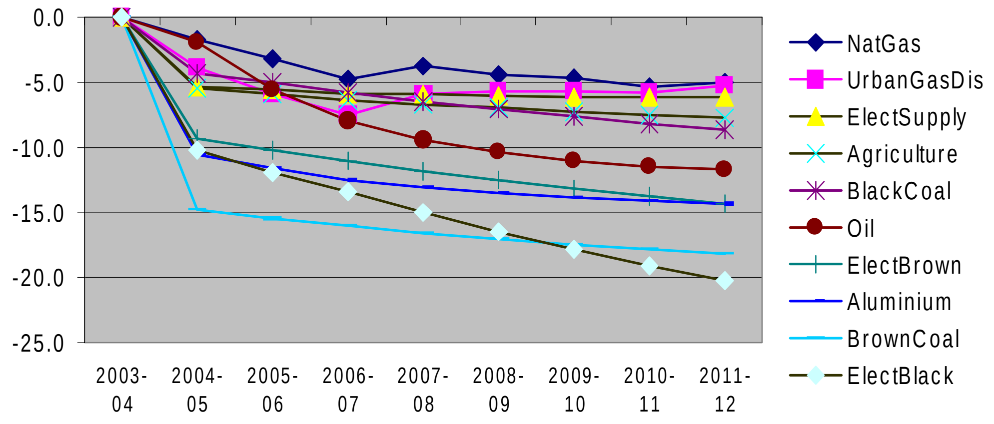

Chart 7a: Real GSP by Region (percentage deviations from control)

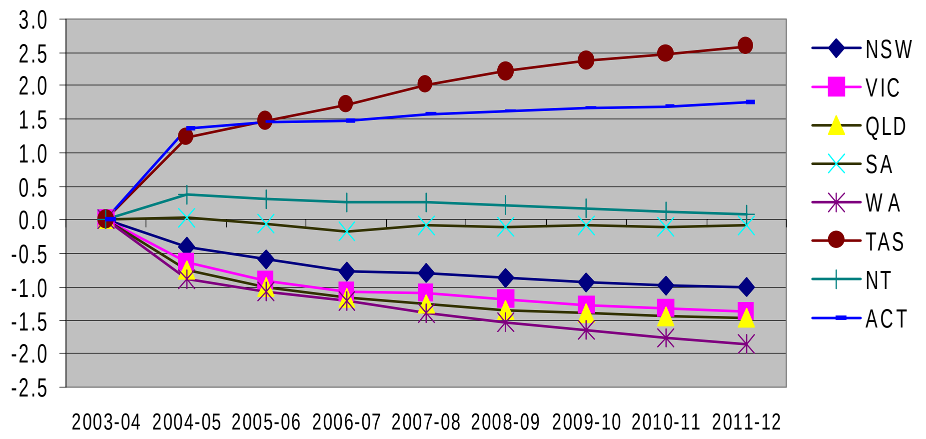

Chart 8a: National Gas Emissions by Fuel/Activity (percentage deviations from control)

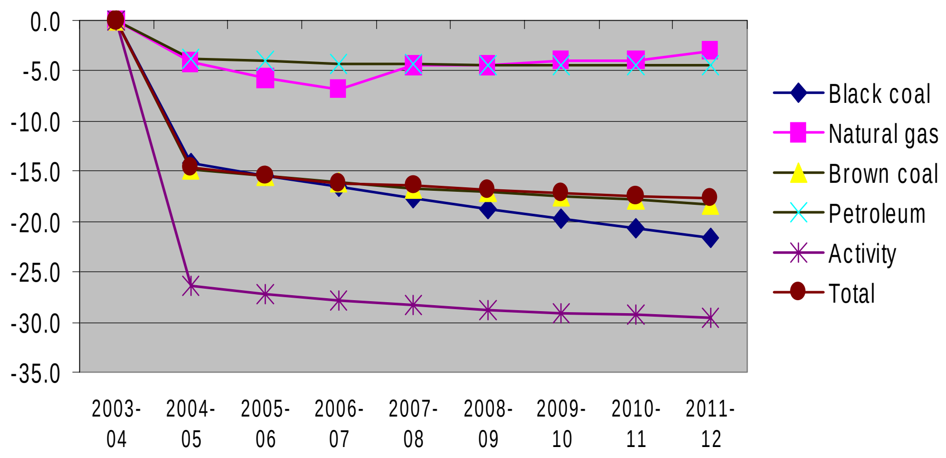

Chart 9a: Gas Emissions by Region
(percentage deviations from control)