Australia's Carbon Pricing Strategies in a Global Context

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1. Introduction

While Australia's greenhouse gas emissions are high per capita, they are a small part of total global emissions. That does not mean Australian action on climate change is unimportant, but suggests that moral suasion effects are likely to be the main source of influence of Australian climate policy on global climate policy settings. These moral suasion effects are important for wealthy industrialised countries with high per capita emissions since, if such countries do not mitigate, this provides a negative reciprocity message to poorer countries with lower per capita emissions. The emissions growth of relatively poor countries (China, India, Indonesia and Brazil) is important since it will dominate global emissions growth over coming decades. Emulation effects can be motivated by positive reciprocity from those who see wealthy countries mitigating just as an enhanced motivation to 'free ride' can be motivated by negative reciprocity and the desire to 'punish' (Fehr and Gächter, 2004, p. 514-518). Finally, there is a strenuous global political campaign being launched by politically conservative groups who assert that the core implications of climate science are false and who seek to undo efforts to mitigate. If countries such as Australia are observed to take costly actions to address climate change, that should help, at least in a limited way, to counterbalance the effects of this misinformation in influencing views both of politicians and the public.

The important global implications for Australia, however, are the effects of the presence or absence of mitigation policies in other countries on Australia's desired carbon pricing policies rather than the reverse. How do global policy settings drive Australia's carbon pricing regime and its choice of base on which such charges should be levied? Section 2, below, discusses how Australian carbon prices should be set in a global setting and Section 3 discusses the selection of an appropriate carbon charge base. There are interdependencies between these issues since higher carbon charges increase incentives to protect the traded goods sector of the Australian economy from competitiveness losses. These interdependencies are also discussed. A commonly preferred charge base is a *destination base* where charges are levied only on carbon emissions associated with output consumed or used as a productive input in Australia. Initially, in discussing charge levels the base is assumed to be a destination base although this is subsequently discussed.

Global policy settings may potentially have important implications for the international competitiveness of Australian energy-intensive and trade-exposed sectors (EITES) if Australia implements a carbon pricing regime. For example, a carbon tax can be expected to increase the relative price of energy-intensive goods in Australia. If other countries do not levy a carbon tax or some other equivalent policy, Australian energy-intensive exports will face a competitive disadvantage due to Australia's carbon pricing regime. Import-competing energy-intensive goods in Australia can be expected to suffer reduced competitiveness with respect to imports of carbon-intensive goods from overseas when these imports are sourced in countries without mitigation policies. A number of studies (notably Daley and Edis (2010)) have argued that some Australian EITES (including cement, iron and steel) should receive compensation upon implementation of carbon pricing in Australia. Section 4 discusses how competitiveness protection for the EITES should best be provided. Section 5 uses a computable general equilibrium model of the Australian economy to analyze the effects of a carbon charges on key Australian industries. Contrary to Daley and Edis (2010), we find no case for compensating the Australian non-metallic minerals (including cement) and iron-and-steel sectors. We find that protection is warranted only for the Australian non-ferrous metals sector, since leakage and competitiveness concerns in other sectors are negligible. But protection for the metals sector should only be made for direct carbon emissions, since compensation based on embodied carbon emissions results in a dramatic increase in the equilibrium carbon charge and economy-wide welfare loss. This highlights the crucial role played by the existence or absence of a system whereby carbon emissions permits can be internationally traded. Commonwealth of Australia (2008) find that the cost of shielding some Australian producers is minimal in an environment where carbon permits can be imported at a fixed price. Without such a global market for carbon permits, the cost of compensating Australian producers for an erosion in competitiveness after the introduction of carbon charges rises dramatically. Section 6 summarizes conclusions. An Appendix summarizes the issue of setting proximate emission targets to maximize the present value of emissions reduction.

2. Setting carbon charges

How should Australia devise carbon taxes given greenhouse gas emission control policies in the rest of the world? Alternatively, how large should Australia's carbon emission quotas be? In a deterministic setting a carbon tax is equivalent to the price at which the market for carbon emissions quotas would clear, so these alternatives are equivalent. Since our analysis is deterministic, make things specific by thinking of determining a tax. This amounts to setting an initial carbon price p(0) and a subsequent time path for prices p(t) defined over some policy time horizon [0, T] with $T < \infty$.

How should this be done? One criterion for setting Australian carbon charges might be sought in terms of 'international equity' or 'justice' criteria. Australia then must do its 'share' of the global mitigation task. Given that different countries have different capacities to mitigate and that mitigation reductions stem from a complex mix of direct actions and pricing policies, defining the appropriate share on the basis of such a normative theory is not simple despite the compelling ethical case for the policy. The theory should correctly prescribe some targeted net addition to the emissions stock by Australia over [0,T].

International climate negotiations target certain atmospheric emission stocks such as 450 ppm CO_2E. However, individual countries such as Australia use a more proximate targeting procedure in calibrating national actions. A base level of emission flows e_0 is observed and a policy proposed that reduces emission flows to a fraction of that base level, αe_0 with $0 \leq \alpha < 1$ at T. This does *not* pin down achievement of a stock target. Thus if p_{max} is the price that restricts flows at T to αe_0 the complete time profile of pricing policies up to T could be: (i) to set $p(t) = p_{max}$ for all t; or (ii) set p(t) = 0 for all t < T and switch to $p(T) = p_{max}$ at T. Each of these policies hits the desired emissions flow target at T even though policy (ii) has a negligible impact on emission stocks. Indeed, ignoring adjustment costs and climate externalities, if output is positively associated with emissions flows, choosing policy (ii) is optimal for maximizing the present value of a country's output.

It therefore seems somewhat unsatisfactory to begin by targeting emissions flows e(t) at time t, when it is the atmospheric stock of emissions, S(t), that have the damaging effects on climate. Australia should pursue a cumulative net change in additional emissions so it releases only S(0)-S* over its policy horizon. The Appendix – Proposition 1 – shows in a Hotelling optimizing framework how correct emissions flow targets can be derived from national stock reduction targets. Even with a correctly specified emissions flow objective there are various possible approach paths to this desired emissions level, depending on discount rate choice. Consider the flow paths illustrated in **Figure 1** and the associated respective emissions pricing paths in **Figure 2.** As the Appendix shows – Proposition 2 – these are consistent with achieving the same stock targets at different discount rates when the policy objective is to maximize the present value of emissions over a time horizon T.

Emissions path (1) involves using a higher social discount rate than path (2). Emissions path (1) is a gradual 'ramping up' or *Nordhaus path* (after Nordhaus, 2007). Emissions are gradually cut, with the bulk of deep cuts deferred to the future but with initially moderate carbon prices increasing strongly to higher levels. Path 2 involves a more immediate move to cut emissions – a *Stern path* (after Stern, 2007) – and an immediate much higher jump in carbon prices followed by slower growth in emissions prices. Both paths hit desired stock targets, although the Nordhaus path defers doing the bulk of the work in cutting emissions to the future whereas the Stern path involves larger upfront cuts given higher carbon prices and lower longer-term cuts with more moderate future price growth.

[Figure 1 here]

[Figure 2 here]

With concern about current low levels of mitigation globally – both through carbon charging and direct interventions – and consequent potential adverse competitiveness effects, it is plausible to suppose Nordhaus–type pricing paths will prove attractive in Australia. The Nordhaus path involves *postponing* intense mitigation policies and has intrinsic appeal for procrastinating politicians who are reluctant to act as policy 'first-movers' given uncertainties in the extent of policy responses in other countries. This suggests a preference for low initial carbon prices followed by rapid growth in subsequent charges.

As is shown below, issues of competitiveness become less pressing if destination accounting is adopted in the sense that impacts on the traded goods sector are reduced or eliminated. But then, because the tax base narrows, the size of required carbon taxes on the non-traded sector will be higher so that greater tax efficiency issues arise for that sector.

3. Carbon charge bases

Australia is a relatively open economy, with both imports and exports amounting to a little over 20 per cent of GDP. Thus, depending on how carbon charges are configured, there will be policy impacts on the competitiveness of import-competing and export sectors if Australia mitigates by charging for carbon emissions while its main trading partners do not. There are competitiveness concerns linked to carbon leakages[1] if outputs of non-mitigating countries expand while those of Australian firms contract because Australia unilaterally levies a carbon charge. These effects reduce Australian welfare. Competitiveness losses that arise because of a degree of unilateralism in adopting carbon emission controls are serious concerns, but their seriousness is amplified by leakages since then targeted emission reductions are offset by increased emissions elsewhere. Both competitiveness and carbon leakage concerns can be addressed by appropriately designing the carbon tax base or, equivalently, by appropriately deciding which economic sectors should be required to purchase carbon emission quotas under an emissions trading scheme.

One suggestion (Carmody, 2009, Clarke, 2010a, 2011) is to levy the Australian carbon tax on a destination basis. Charges would be levied on goods that directly or indirectly generate carbon emissions in Australia, with exports that experience adverse competitiveness effects receiving rebates on the carbon charges levied directly or indirectly on inputs. Similarly imports from non-mitigating countries would be subject to border tax adjustments (BTAs) so importers would pay an equivalent carbon charges to that levied in Australia. Effectively, then, carbon charges would fall on that portion of Australian produced output utilized in Australia or on carbon-intensive Australian imports. Such adjustments both address competitiveness concerns and reduce carbon leakages. The key empirical issue is to determine if these concerns are significant enough to warrant intervention.

[1] Carbon leakage from Australia is defined here as the ratio of the change in the carbon emissions of other countries that occur in response to a policy-induced reduction in Australian emissions. For example, if Australian mitigation efforts lead to a reduction in Australian emissions of 200 tonnes, but leads to some Australian firms relocating to other countries because of the policy and emitting 40 tonnes of extra emissions there, then a leakage of 20 per cent has occurred.

Use of a destination base eliminates carbon leakages associated with a unilateral local mitigation decision that results in:

(i) Lost competitiveness from a switch to imports rather than local products.
(ii) Lost competitiveness of Australian exports in international markets because exports are subject to carbon charges whereas competing products are not and,
(iii) 'Footloose' Australian firms relocating to countries with less stringent restrictions on carbon emissions.

However a destination-based carbon charge would not address competitiveness concerns created by terms-of-trade changes induced by Australian policy. Given the generally small share of most Australian traded products in world output, such effects are likely to be small. A reduced Australian demand for carbon-based fuels will have only a small impact in reducing the world price of such fuels, thereby stimulating the use of such fuels in non-mitigating countries. However, such leakages are likely to be empirically important only for larger countries that consume a significant fraction of the world's carbon-based fuels. In the CGE model developed below these terms of trade effects are therefore ignored.

There are also strategic advantages from utilizing destination-based pricing in helping to drive an international consensus on climate change. It can be shown that the incentive issues that make 'non-mitigation' a dominant strategy in these global settings become less demanding if carbon leakages are eliminated using BTAs (Clarke, 2010b). Thus mitigation becomes a more sensible – although still not inevitable – unilateral response with BTAs. Moreover, countries faced with the threat of such policies have increased propensities to mitigate their own emissions, if only to recoup the tax revenues that otherwise accrue to export destination countries. As discussed below the strength of this effect depends precisely on how the BTAs are configured.

Destination accounting is designed to offset the disadvantages of taxing emissions production or *origin-based* accounting. Origin accounting involves taxing the production of all carbon emissions in an economy irrespective of whether output is consumed locally or is exported. It implies all the adverse competitiveness and carbon leakage effects that destination accounting seeks to avoid since carbon-intensive exports are taxed and carbon-intensive imports are not. Many actual carbon tax bases have elements of both a destination and origin base and one strand of literature advocates intermediate regimes. Metcalf and Weisbach (2009), for example, argue for a modified destination basis for the US economy with BTAs but without tax exemptions for exports.

It would be misleading to overstate without strong evidence the potential policy advantages from Australian BTAs. Such taxes will impact only on a small fraction of the value of production that delivers Australia's major imports. These incentives, as well as moral suasion impacts on the policies of other countries, are unlikely to be important for small countries such as Australia unless they are part of a global policy response.

4. Devils in the detail

The precise way tax rebates for exporters and border taxes on imports are levied matters.

Consider timing. If the objective of a BTA is primarily to protect the competitiveness of the local traded goods sector then BTAs and export rebates should be introduced contemporaneously with any move to price carbon. The higher the *initial* carbon price in Australia and the broader the carbon tax base the greater is the need to immediately address competitiveness concerns among EITES. If, however, a primary objective of the measures is also to help induce non-mitigating countries to mitigate then measures might be introduced with a lag to allow a gradual development of carbon emissions policies in other countries, particularly developing countries. This approach was enshrined in the United States' *Waxman-Markey* proposal. In its 2009 formulation this legislation did not propose introducing BTAs on US imports until 2020.

Furthermore, rebates to exporters under the *Waxman-Markey* proposals were viewed as *transitional* not ongoing. US import-competing, carbon-intensive industrial sectors were to be offered tax rebates from 2012-2025 with rebates phased out from 2025-2035.

Furthermore, problems arise from particular approaches to levying trade-related measures. *Ad valorem* rebates on exports create incentives to divert output into international markets where carbon is untaxed. This is the primary reason Metcalf and Weisbach (2009) opposed them. Such rebates involve carbon leakages associated with the diverted output even if competitiveness concerns for Australian firms are addressed. Lump-sum handouts to exporters that compensate them for emissions charges paid on the exported portion of their output do not alter the incentive to divert output. At best such measures compensate firms for lost profits caused by mitigation policy. Moreover, lump-sum measures lose relevance through time if trade patterns change.

These are conceptually simple issues that have received comparatively little attention. How is competitiveness among exporters to be *sustained* through time? An alternative approach, discussed below, relies on issuing marketable free emission permits.

Most importantly the size of the BTA as well as the eligibility criteria for tariff exemptions need to be determined. In the absence of foreign mitigation actions a BTA should reflect the cost of an emissions permit in Australia given the implied carbon content of the imports. Exemptions from BTA liability should be based on a demonstration that the import was produced using a non-carbon based fuel such as hydroelectric power or that a 'comparable' emissions target has been pursued in the country of origin by non-pricing means. The *Waxman-Markey Bill* also gave exemptions to very poor countries reflecting international income distribution objectives.

The notion of 'comparability' is ambiguous. It might mean that carbon control measures have been levied with respect to a specific good or class of goods in question (for example a specific export tax) or it might mean that comparable general measures to control emissions have been devised across the whole economy. The measures need not involve direct charging but could involve for example direct interventions such as the promotion of renewable technologies or regulated emission controls. BTAs reflecting an economy's *overall* failure to mitigate have more bite in attempting to elicit a mitigation response in other countries but face problems of WTO legality[2]. In addition, countries exporting specific products – for example Chinese steel – typically provide most of their output to their domestic market. A specific BTA on Chinese steel exports because no carbon tax operated will have limited incentive effects on Chinese steel producers even if the importing country is a significant source of demand. If the countries applying the BTAs on Chinese steel exports are small like Australia the effects will be negligible.

Free quotas. An objection to BTAs is that their use can be corrupted by industry pressure groups that make them degenerate into unwarranted protectionism. If competitiveness costs and carbon leakages in key Australian traded goods sectors are limited – as argued in Section 5, this is largely so – then this fear is justifiable. An approach to avoiding such difficulties is to write the regulations for setting BTAs into global climate agreements themselves. If they are implemented as VAT-style consumption taxes they are likely to be consistent with the rules of the General Agreement of Tariffs and Trade (GATT) so legality is probably not a concern (Tamiotti et al., 2009).

Alternatively, as the Australian Trade Minister Craig Emerson has argued, there is a case for issuing marketable emission quotas to local firms rather than BTAs to protect import-competing products (Franklin, 2011). This scheme is avoids the risk of BTAs being misused and degenerating into protectionism although there will be competition to gain the quotas.

The case for free quotas is related to the argument that an optimal Pigovian tax is equivalent to a subsidy on reducing pollution to desired levels except that the subsidy involves an income transfer to the polluter (Mas Colell et al. (1995, pp. 355-356)).

To illustrate, suppose both foreign and local firms supply output in Australian markets. In a 'first-best' world where all carbon emitted by *any* firm (local or foreign) is correctly priced, the carbon use by Australian firms would decline from an untaxed, inefficient level c(0) to a lower efficient level c*. If carbon charges can *only* be applied to local firms then they will lose competitiveness, reducing their output and delivering increased market share to foreign firms who will provide extra output onto the Australian market as well as creating carbon leakages that offset the carbon reductions achieved by Australian firms.

BTAs stop such leakages and restore local firm competitiveness. If foreign firms are not subject to adequate carbon charges at home, they must pay additional charges, for example, by buying local carbon emission permits that cover their carbon costs. This prevents the carbon leakages and holds local emissions to c*.

The free quota proposal involves instead providing Australian import-competing firms with free permits which can be sold if unused at the prevailing carbon charge. The policy would deliver a free quota of c(0)–c* to import-competing firms. If these firms were originally willing to abate by this amount given a carbon charge p it would have been the case that the costs of cutting emissions over this range were less than the cost of buying a carbon permit. Hence given this quota for free the firms will earn more by reselling the quota than from using it to accommodate emissions. Firms would again drive emissions to c*. Thus the

[2] Winchester et al. (2011, Section 2) provides a useful discussion of the compatibility of provisions in the Waxman-Markey Bill with international trade rules implied by the World Trade Organisation.

proposal restores desired emission levels by providing the firm with a transfer of income p(c(0)-c*) rather than by requiring it to pay an additional charge of the same amount.

There are problems with this proposal:

- It is costly because the quota is given away. This has an opportunity cost because it can be auctioned and used as public revenue. Political economy considerations might suggest its hypothecation to providing carbon-reducing R&D or income compensations and tax cuts to consumers. Indeed revenue neutrality might be sought to promote the political acceptability of the carbon policy package. BTAs yield revenue rather than opportunity costs.
- For given emissions control, targets providing extra free quotas increase the required charges on producers who remain subject to carbon charges.
- Incorrect pricing signals continue to be provided to foreign firms that over-supply from the viewpoint of the global social optimum. Compared to using BTAs local markets are overprovided with socially damaging imports.
- Difficult judgments are required in determining the free allocations. This requires cost information provided by firms with incentives to exaggerate impacts. Our subsequent analysis shows this exaggeration has occurred in Australia. Fewer problems arise when equivalent BTAs are used.
- Judgment is also required as to assessing cross price elasticities of demand. If a firm is subject to almost no foreign competition the quota transfer has no compensatory rationale in terms of promoting efficiency. Local polluting firms that produce largely non-traded goods *should* reduce output. The difficulty with assessing the extent of competition faced by local firms is that they, again, have incentives to exaggerate their competitive plight.
- Both BTAs and free quota provisions must be set conditionally based on the type of technology used by the foreign firm. If foreign firms export aluminum using non-polluting hydropower there is no case for offering free entitlements (or BTA protection) to Australian firms. This specific instance is examined subsequently.
- The measure might provide barriers to new Australian-sourced competition in industries where incumbents receive a free quota. This is unlikely to be a major issue in many of Australia's EITES. It is unlikely entry would be attempted in the ferrous or non-ferrous metal sectors for example.

The costs of potential protectionism from exaggerated claims for compensation must be greater than the costs of providing the required free quotas for the latter policy to prove a better option. This is an issue since BTAs yield government revenue. The possibility of exaggerated claims suggest the need for investing resources in accurately estimating entitlements to free quotas – in estimating c(0)-c* – to avoid wasteful transfers. Leaving local firms with *some* incentives to reduce emissions is preferable to giving undeserved subsidies. Subsidies should accrue only to firms in the EITES which face strong competition from foreign firms utilizing carbon-intensive technology.

If the scale of assistance to be provided to key Australian industrial segments is low the comparatively lower transaction costs of implementing the 'free quota' proposal might address a ‘low-order’ problem more cheaply than an elaborate range of BTAs. The proposal has practicality in a political-economy sense given that it ‘buys’ support from those sectors of Australian industry that will oppose most strongly the argument that Australia needs to effectively price carbon.

5. Empirics

While there are strong *a priori* arguments for protecting the traded goods sector, particularly in the absence of a comprehensive global agreement to address climate change, there are important concerns as to whether the scale of carbon leakages and competitiveness effects justify the complexity that would be introduced into policy settings by protective measures. The quantitative impacts of carbon charges on EITES in Australia – and not only *a priori* judgments – must be determined, so that those sectors where protection and/or compensation is warranted can be properly identified. It is important to both articulate the form and scale of such protection or compensation, and to evaluate the costs and benefits.

These empirical questions are now examined using a computable general equilibrium (CGE) model to simulate the economics of introducing carbon charges in Australia. The starting point for the CGE model is the GTAP7 dataset, described in Hertel (1997). This depicts a global general equilibrium of production, consumption, and trade for 113 regions and 57 commodities that are produced using 5 primary factors of production and intermediate inputs for the year 2004 – the most recent year for which comprehensive data is available. To isolate the effects of carbon charges in Australia, a single-country CGE model is constructed using GTAP7 data for Australia. This adapts the GTAP-EG model of Rutherford and Paltsev (2000) and the GTAP-E model of Burnieaux and Truong (2002). Since the objective is to examine only the effects of carbon charges imposed in Australia, it is assumed Australia faces fixed world terms of trade and fixed world relative output prices. All domestic input and output markets are perfectly competitive. The model is static so investment activity, technical progress and international capital flows are exogenous. The use of a static CGE model rather than a dynamic CGE model has advantages and disadvantages. A comparable dynamic CGE model would require assumptions about growth of GDP growth and endowments of factors of production such as labour, capital and natural resources. Such assumptions would have important implications for the baseline to which the results of any policy on carbon charges are compared. More contentious features of such dynamic CGE models involve making assumptions regarding technological change in the production of energy goods and associated reductions in emission intensities. Using a static CGE model means such assumptions are unnecessary, so conclusions will not need to be qualified against contentious presumptions about the emergence and cost-effectiveness of new technologies like wind and solar power. The results from our static CGE model *overstate* the costs of emissions abatement policies since they ignore technological innovations reducing emissions intensities. The results *understate* abatement costs since increased emissions arising from economic growth are ignored.

Production. The structure of production of good y_i for generic industry i is represented by a series of nested CES production functions, as illustrated in **Figure 3.** At the uppermost level, production of y_i is represented by the CES production function:

$$y_i = [\sum_j \alpha_{ij} v_{ij}^{\sigma-1/\sigma} + \alpha_{vae} \text{vae}_i^{\sigma-1/\sigma}]^{\sigma/\sigma-1}$$

where v_{ij} is the amount of non-energy intermediate input j used in production of good i, vae_i is the aggregate of value-added and energy inputs used in production of good i, and σ is the elasticity of substitution between inputs. Non-energy intermediate inputs include all GTAP commodities except coal, gas, petrol, electricity and gas distribution. The substitution elasticity σ in this uppermost nest is assumed zero for all industries i, so goods are produced using a fixed coefficients (Leontief) production technology. The aggregate energy input is produced as a CES aggregate of energy and value-added, as shown in the second-highest nest. As is common in such CGE models, value-added is modeled as a CES aggregate of primary factors of production, where the CES substitution elasticity between primary factors in industry i is assumed equal to that in the GTAP7 dataset. Assuming fixed coefficients production technology in the uppermost nest exaggerates the effects of introducing carbon charges since it restricts the ability of firms to adjust.

To accommodate substitutability between different energy inputs (coal, gas, petroleum, electricity, gas distribution), the nesting structure used by Rutherford and Paltsev (2000) and Fischer and Fox (2007) along with their assumed elasticities of substitution between energy inputs is adopted to model production of the aggregate energy input. Beginning in the bottom-most nest of **Figure 3**, producers can substitute between liquid fuels (gas and petroleum) at a substitution elasticity $\sigma_{lqd} = 2$. This CES aggregate of liquid fuels can then be combined with coal in the next-higher nest at a substitution elasticity $\sigma_{nel} = 0.5$. Ultimately, an aggregate energy input is produced in the next-higher nest by combining the CES aggregate of coal and liquid fuels with electricity and gas distribution in a CES function with a substitution elasticity $\sigma_e = 0.1$.[3] This aggregate energy input is then combined with value-added at a substitution elasticity $\sigma_{vae} = 0.5$ to produce the energy which is ultimately combined with other non-energy inputs in the fixed-coefficients upper-level production function. This technology for usage of energy inputs is adopted for all industries except the three primary energy sectors coal, oil, and gas, for which all substitution elasticities in the energy nests are assumed to equal zero ($\sigma_{lqd} = \sigma_{nel} = \sigma_e = \sigma_{vae} = 0$). Virtually all primary energy input oil is used as an input into the production of petroleum. Note that oil does not

[3] While other studies like Rutherford and Paltsev (2000) and Burnieaux and Truong (2002) aggregate the two GTAP industries gas and gas distribution together into a single industry, we maintain these as separate industries. The primary energy industry gas is traded and natural resources make up a large share of value added, while the intermediate energy industry gas distribution uses only labour and capital as primary inputs. Gas distribution (pipeline gas) is not imported into Australia, and only 2.9 per cent is exported according to the GTAP7 dataset.

enter the production process through the energy nests at the bottom of **Figure 3**, but rather is used in fixed coefficients in the top-most nest, reflecting the fact that it cannot be substituted in the production of petroleum. While we are adopting the substitution elasticities used in Rutherford and Paltsev (2000), note that the sample-size-weighted mean elasticity of substitution between oil and gas reported in Stern (2010) is 2.022 compared to our estimate of 2. While it is difficult to compare our other energy substitution elasticities to those in Stern (2010), he finds that the industry-level coal-gas and coal-electricity elasticities are insignificantly different from unity. Thus the other elasticities in our energy nests should not be regarded as being too high, implying again that the costs of the introduction of carbon charges in our CGE model should be interpreted as worst-case results.

[Figure 3 here]

Representative Consumer. A representative Australian consumer owns the fixed endowment of all primary factors of production (land, labour, capital, and natural resources) supplied to the production sector. Land is a specific factor that produces primary agricultural commodities, and natural resources are specific to production of forestry, fishing, minerals, and the three primary energy industries: coal, oil and gas. Assume that labour and capital are perfectly mobile between production sectors. Further, suppose that all tax revenue is costlessly redistributed to the representative consumer, who maximizes utility subject to the constraint that expenditure equals income earned from factors of production and taxes. Following Rutherford and Paltsev (2000) suppose the representative consumer's utility function is a CES function of aggregate energy goods and aggregate non-energy goods, where the substitution elasticity between the aggregate energy good and the aggregate non-energy good is 0.5. Each of these aggregates is itself a Cobb-Douglas function of energy and non-energy goods, respectively.

International trade. Trade is accommodated using the so-called Armington assumption so domestic and imported varieties of the same good are treated as differentiated products. This is accomplished by aggregating domestic and imported varieties of the same good using a CES function, where the CES substitution elasticity determines the degree to which domestic and imported varieties are differentiated. The CES substitution elasticities in the GTAP7 model are adopted. Homogeneous traded goods like Oil and Gas[4] have a much higher CES substitution elasticity (10.4 and 17.2, respectively), while more heterogeneous goods like Iron-and-Steel and Metals have a smaller CES substitution elasticity (2.95 and 4.2, respectively). These CES substitution elasticities are approximately equal to the elasticity of demand for imports, so a 1 per cent decrease in the price of imported Metals relative to Metals produced in Australia will lead to a 4.2 per cent increase in demand for imported Metals.

[4] Capitalised product descriptions refer to industry categories in GTAP.

The literature provides many estimates of carbon leakages associated with the Kyoto Protocol. Paltsev (2001) finds a leakage rate of 10 per cent whereas Babiker (2005) finds rates exceeding 100 per cent – indeed as high as 130 per cent – so a unilateral carbon tax in one country raises global emissions. Typical of more recent estimates, Elliot et al. (2010) find leakages of 20 per cent for Annex B Kyoto countries. Earlier work on Australian carbon leakages – the Garnaut Review (Garnaut, 2008, pps. 232-234, 341-349), the Treasury (Commonwealth of Australia, 2008) and the Grattan Institute (Daley and Edis (2010)) – is discussed below.

Garnaut (2008) provides conditional support for correctly imposed BTAs as part of an international agreement on climate change and admits the possibility of providing special assistance to S. The report includes 'sheep and cattle products' among the EITES but includes no empirical analysis of any specific sector. The Commonwealth of Australia (2008, 31) found, with a range of carbon prices, that there was "little evidence of carbon leakage" but, somewhat inconsistently, argued that the distribution of free permits to EITES eased their transition towards use of low-carbon technologies at what were claimed to be modest costs to other economic sectors. Indeed, with a $35 per tonne carbon price, Daley and Edis (2008:4) found that free carbon permits were "often unnecessary" and that "alumina refining, LNG production and most coal mining, will be less profitable but still internationally competitive" without such free permits. They found that free permits to limit leakage effects were justified for steel and cement since a "carbon price could force these industries offshore". Again these findings are discussed below.

In the CGE model, carbon emissions are attached to use of energy goods (coal, oil, gas, petrol, gas distribution) using fixed coefficients. Whenever a unit of energy is used as an intermediate input in production or by consumers, a fixed amount of carbon is emitted, consistent with the GTAP7 CO_2 emissions data in Lee (2008). That is, for each energy good used in production, another nest is added at the bottom of **Figure 3** which includes the energy good and the CO_2 emitted, where the substitution elasticity between the energy good and CO_2 emitted is zero. A similar nest below energy goods consumed by the representative consumer accounts for CO_2 emissions from consumption by households. Carbon emissions (in megatonnes) and emissions intensities (in gm/USD or tonnes/million USD) of the more energy-intensive industries in Australia are reported in **Table 1**.

[Table 1 here]

Initially the economy is assumed to have an endowment of carbon permits which is exactly equal to total carbon emissions in Australia, so the price per unit of carbon equals zero. As the availability of carbon permits decreases, the price of carbon emissions increases. The number of permits available is reduced by from 0-30 percent, simulating the effects of CO_2 emissions abatement of 0-30 percent. These permits are freely traded between sectors up to the point where the marginal cost of abatement between sectors is equalized at the prevailing price per unit of CO_2. In this sense, the effects of this carbon abatement exercise are somewhat analogous to a Rybczynski experiment where the effects of an exogenous reduction in the endowment of a factor of production – carbon – are simulated. Abatement leads to a contraction in the economy as a whole but these effects spread asymmetrically through the economy. Those sectors using carbon most intensively contract the most, so the effects of the carbon price are greatest where emissions intensities are highest.[5]

It is difficult to compare results of this abatement exercise to those reported in dynamic models such as Commonwealth of Australia (2008). The latter report that ``… an absolute reduction of 5 per cent (in the CPRS-5 scenario) by 2020 corresponds to a 27 per cent reduction in per capita emissions'' (Commonwealth of Australia (2008, 10)). This is accomplished with an initial carbon price of $23 per tonne in 2010 ($20 in 2005 dollars), rising to $35 per tonne in 2020 (Commonwealth of Australia (2008, 19)). Daley and Edis (2010) use a static model to evaluate the effects of a carbon tax of $35AU per tonne which reduces Australian emissions by 5 per cent below 2000 levels by 2020, to reflect modeling in Commonwealth of Australia (2008). It is important to note that in these studies, the carbon price is *exogenous*. In our CGE model, selecting a level of abatement of 27 per cent results in an endogenously determined carbon price of US$26.41 per tonne, equivalent to AU$36.68 using an exchange rate of US$0.72/AU for 2004. Thus our static simulation of a 27 per cent carbon emissions abatement without BTAs or compensation for EITES are broadly comparable to those in Commonwealth of Australia (2008) and Daley and Edis (2010). To correctly evaluate the effects of policies like BTAs to deal with carbon leakage or compensation for EITES whose international competitiveness is adversely affected by the introduction of carbon charges, it is essential that the price of carbon be determined endogenously given the level of abatement. It is impossible for the same price of carbon to clear the market for carbon permits for a given level of abatement with and without BTAs, or with and without compensation to exporters, since the introduction of compensation in any of the EITES must result in higher emissions from that sector compared to an equilibrium without compensation. To achieve abatement of 27 per cent other sectors must achieve a higher abatement than they would in a scenario without compensation, resulting in a higher carbon price.

With abatement of 27 per cent and without either BTAs or compensation for EITES sectors, our CGE model suggests an overall static welfare loss of 0.39 per cent of base period national economic welfare.[6] By comparison Commonwealth of Australia (2008) predicts a reduction in GDP of 1.1 per cent relative to baseline (in CPRS-5 and Garnaut-10 scenarios by 2020). Decomposing this welfare change, the largest effect on income is through a 14.3 per cent decrease in the real return to natural resources in Australia. The most adversely affected natural resources are those which are specific to production of Coal and Gas, whose real return falls by 12.5 per cent and 28.8 per cent respectively. The carbon charge will increase costs and decrease the producer price of carbon-intensive primary energy goods. Through the magnification effect[7] this decreases the real return to specific factors in production of primary energy goods. On the other hand, the reduction in the real return to the mobile factors labour and capital is a much more modest 1.1 per cent and 1.6 per cent,

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[5] The analogy to a Rybczynski experiment is not perfect, since input prices and domestic output prices will be changing, though we are holding world output prices fixed in all simulations.

[6] All welfare changes are measured as Hicksian equivalent variations.

[7] As described in Jones (1965:561), in a general equilibrium model with specific factors of production, a decrease in an output price will have a magnified effect on factors of production which are specific to that sector, causing a decrease in the real return to those specific factors which is larger than the output price change.

respectively. By comparison Commonwealth of Australia (2008:147) predicts a reduction in real wages of 2.6 to 4.2 per cent relative to baseline (in CPRS-5 and Garnaut-10 scenarios by 2020). Finally, the carbon charge results in a 7.5 per cent increase in real government revenue.

Specific sectoral effects due to the imposition of carbon charges on the Australian economy are now provided. The effects of the carbon charge will be greatest in those sectors with the highest emissions intensity. Our discussion begins with the electricity sector which accounts for most emissions and then continues with the EITES.

Electricity. As shown in **Table 1**, the electricity industry is by far Australia's largest carbon emitter, with 2004 emissions of 193 Mt or 54 per cent of total emissions in 2004. The Productivity Commission (2011, 75) lists 2009 CO_2 emissions in this sector at 196 Mt, so that there has been negligible growth in emissions from electricity production in Australia since 2004. Electricity is non-traded, so there is no scope for carbon leakages to affect its international competitiveness. The value of Australian electricity production in 2004 (GTAP sector 15) was $US17.3b, accounting for 1.5 per cent of total Australian output.

The carbon tax falls more heavily on the electricity industry than any other in Australia. With abatement of 27 per cent the effective tax on electricity production is 17.2 per cent, leading to an increase in electricity prices of 21.9 per cent and a decrease in production of 18 per cent. By comparison Commonwealth of Australia (2008:34) predicts increased electricity prices of 17-24 per cent. Electricity production in Australia is coal-intensive, with coal inputs initially accounting for 12.7 per cent of the value of electricity production and gas inputs accounting for only 2.4 per cent. The ability to substitute between energy inputs will lead this sector to substitute away from coal, whose usage falls by 40.2 per cent by volume, towards gas, whose usage decreases by only 23.2 per cent. Impacts on electricity production for various abatement targets are given in **Figure 4**. While carbon charges have a direct effect on costs and competitiveness of EITES in Australia, the large increase in the price of electricity due to carbon charging means it is important to account for indirect effect of carbon charges through increased electricity prices.

[Figure 4 here]

Coal and Gas. Now consider the effects of a carbon tax on the primary energy industries that are most important to electricity production in Australia. **Table 1** provides data for the Australian coal and gas industries in 2004. The value of production in GTAP sector 15 Coal in 2004 was $US12b, accounting for about 1 per cent of Australian output by value. Of this 79 per cent was exported, primarily to Japan (42 per cent), Korea (14), Taiwan (7) and India (8). Coal imports were zero. Carbon emissions associated with mining coal were 2.4 million tonnes, about 0.7 per cent of total emissions in Australia in 2004. Gas production was $US3.3b, or about 0.3 per cent of output by value. Of this, 47 per cent was exported, primarily to Japan (90 per cent), Korea (3) and the United States (5). Gas imports were zero. Carbon emissions were 0.8 million tonnes, accounting for 0.2 per cent of total emissions in 2004. The carbon emissions identified here are the 'fugitive' emissions associated with extracting and transporting these resources in Australia – including other greenhouse gas emissions such as methane these comprised about 7 per cent of Australia's total emissions in 2007 (DCC, 2009, 20). Emphatically emissions embodied in coal exported from Australia are *not* part of the carbon tax base.

Trends in output, domestic demand and exports in the coal and gas sectors are presented in **Figure 5**. Virtually all non-exported coal is used in the domestic production of electricity, while gas is also an input in production of gas distribution (pipeline or utility gas). Through the aforementioned effects of the carbon tax on the electricity industry, there is a larger drop in domestic demand for coal than for gas.

[Figure 5 here]

A carbon charge causes a decrease in demand for coal and gas in the electricity industry. But coal has an emission factor (tonnes of carbon per Terajoule) which is more than 60 per cent higher than that of gas (Lee, 2008, 41), so the demand for coal by the electricity industry falls by much more than the demand for gas. Since virtually all coal demanded in Australia is employed in the electricity industry, a charge on carbon results in a much larger drop in domestic demand for coal than for gas. With abatement of 27 per cent, domestic demand for coal and gas fall by 37.5 and 22.7 per cent, respectively. The decrease in domestic demand for coal and gas causes their price to fall, making it more advantageous for firms to export coal and gas, leading to an increase in coal and gas exports of 7.0 and 14.8 per cent, respectively. Since such a large share of Australian coal is exported, this 7 per cent increase in coal exports almost completely offsets the 38 per cent decrease in domestic demand for coal, so the overall decrease in coal production is only 1.5 per cent. Since a smaller share of gas is exported, overall gas production falls by 4.3 per cent.

It is difficult for the coal and gas industries to argue for compensation to offset the effects of the imposition of carbon charges on international competitiveness. There is no scope for leakage through imports since Australia imports no coal or gas, and coal and gas exports increase. Carbon charging will lead to a decrease in domestic demand for coal and gas, which will put downward pressure on the price of Australian coal and gas, making them more competitive on world markets.[8] With 27 per cent abatement the carbon tax of US$26.41 per tonne implies an effective *ad valorem* carbon tax in the coal and gas sectors of 0.5 per cent and 0.7 per cent respectively**.**

It is also worth noting that these results contradict many industry-based predictions of the effects of carbon charges on the competitiveness of and carbon leakage from the Australian coal industry. For example, in Korporaal and Hepworth (2011), Macarthur Coal chairman Keith De Lacy argues that ``… a substantial carbon tax in Australia would actually lead to a rise in global carbon emissions, as it would cut back the production of Australian coal and increase the production of coal from other countries that had less stringent environmental standards.'' Maher (2011b) cites modeling by the Australian Coal Association which argues that a carbon tax could lead to the loss of 4000 coal jobs. While our results suggest there will be a small decrease in Australian coal production of 1.5 per cent, we find that coal exports will increase by 7 per cent, which will decrease coal production other countries. The effect on global emissions will depend upon leakage arising from Australia's imposition of

[8] Recall that we have assumed that Australia is a small open economy facing fixed world prices.

carbon charges and the behaviour of other coal-producing nations. To illustrate, consider the regional comparison of emissions intensities in coal production in **Table 2**. If increased Australian exports supplants production which would have come from China (where the emissions intensity in coal production is 1.73 kg/US$), then global emissions should decrease. But if the supplanted production came from the United States (where the emissions intensity in coal production is 0.03 kg/US$), global emissions could increase.

Now consider the effects of the carbon tax on processed EITEs in Australia. **Table 1** suggests that GTAP sectors 34 (Mineral Products including cement), 35 (Ferrous Metals – iron and steel) and 36 (Metals nec including aluminum) all have high carbon intensities. On *a priori* grounds all could potentially be strongly affected by emission charges. These sectors face competition through imports which make up 11-13 per cent of industry output in the initial equilibrium, so leakage through imports may be a concern. Daley and Edis (2008) conclude that the Australian cement and steel sectors should both qualify for compensation after the introduction of carbon charges, and that the Australian aluminum sector will face a considerable loss in international competitiveness resulting in the closure of some smelters.

Analysis begins with GTAP sector 36 (Metals nec including aluminum), since it is the EITE which relies most heavily on export markets.

Metals nec. GTAP sector 36 `Metals nec' includes aluminum, nickel, copper, zinc and other metals. **Table 1** indicates that the value of Australian output in 2004 was $US23b, accounting for 2 per cent of total output by value. Almost two-thirds of production was exported, primarily to China (12 percent), Japan (11), Korea (9), Taiwan (6), Thailand (6) and India (21), while $US2.6b was imported. Carbon emissions were 11.9 million tonnes, about 3.4 per cent of total 2004 emissions.

The effects of carbon taxes on exports and imports as well as the level of domestic demand are given in **Figure 6**. As abatement increases, the carbon price increases, making Australian Metals exports less competitive internationally. With 27 per cent abatement, a charge of US$26.41 per tonne of carbon is equivalent to a tax of 1.09 per cent on production of aluminum and other metals. But much more important to these industry outcomes is the 21.9 per cent increase in the price of electricity, since electricity represents 15.8 per cent of the value of Metals output initially. A carbon charge resulting in abatement of 27 per cent leads to an overall increase in the domestic price in the Metals sector of 11 per cent. The implied loss of competitiveness of Australian Metals on world markets leads to a drop in exports of 38 per cent and increased imports of 17 per cent.

[Figure 6 here]

Since 66 per cent of Metals produced in Australia are exported, the leakage through decreased exports and increased imports results in a large drop in Metals production of 33 per cent. The impact of carbon pricing on the Metals sector is the largest of the EITES, due to the higher export levels and the large share of electricity used in production. This sector suffers significantly reduced international competitiveness due to imposition of a carbon tax, and could qualify for compensation to deal with the negative effects of carbon leakage.

In discussing compensation, we begin with Daley and Edis' (2010) assessment of the effects of carbon charges on the Australian aluminum industry. They conclude that ``... without exemptions, most producer's costs would increase by around US$450-620/t Al.'' Australian production of aluminum in 2004 was about 1900 thousand tonnes. If production fell by 33 per cent (as is suggested in our CGE model with abatement of 27 per cent), the costs of aluminum producers implied by Daley and Edis (2010) would rise by 1900·1000·(2/3) ·[450-620], or US$570-785 million. Our CGE model suggests that carbon charges of US$26.41 per tonne would imply a direct carbon charge on the entire Australian Metals sector of US$174 million, or about 1.1 per cent of the value of production, while electricity costs would increase by US$401 million, or about 2.5 per cent of the value of production. These cost increases result in a loss in international competitiveness reflected in the large decrease in exports and increase in imports in this sector.

To compensate producers in this sector, a BTA can be introduced into the CGE model which adjusts endogenously to increase the cost of imported Metals by the implied cost of direct carbon emissions associated with production of those imports. In equilibrium:

$$pm(nfm) \cdot qm(nfm) \cdot bta = carbon(nfm) \cdot imp\_share(nfm) \cdot p\_carb$$

where pm(nfm) and qm(nfm) are the price and quantity of Australian Metals imports, respectively, carbon(nfm) is total direct carbon emissions in the Metals sector (equal to 11.9Mt in the initial equilibrium), imp_share(nfm) is the share of total demand for Metals in Australia accounted for by imports, and p_carb is the price per tonne of carbon. With abatement of 27 per cent, this BTA is equivalent to an import tariff of 2.2 per cent. At the same time Australian producers/exporters of Metals are compensated by introducing an endogenous production subsidy prod_sub which adjusts so that its value equals the cost of direct carbon emissions from production of Metals destined for export:

$$py(nfm) \cdot qy(nfm) \cdot prod\_sub = carbon(nfm) \cdot exp\_share(nfm) \cdot p\_carb$$

where py(·) and qy(·) are the price and quantity of Metals produced in Australia, respectively, and exp_share(·) is the share of production of Metals exported. With abatement of 27 per cent, this production subsidy is equal to 0.75 per cent. Together these two policy tools improve the international competitiveness of Australian Metals so with abatement of 27 per cent, exports fall by 33 per cent (compared to 38 percent without compensation for exporters) and imports increase by 10 per cent (compared to 17 per cent without BTAs). Overall production of Metals falls by 29 per cent, compared to a drop in production of 33 per cent without compensation. This increased production means that, to achieve the same 27 per cent level of abatement, other industries must reduce emissions by more than would be the case without the compensations. But for the economy as a whole, the cost of this compensation is small. The price per tonne of carbon rises from US$26.41 to US$27.39 with compensation, and the overall welfare loss in the economy rises from 0.3932 per cent of benchmark welfare to 0.3941 per cent.

It is more likely that Australian producers in the Metals sector will argue for compensation not only for the higher cost of direct emissions, but also for the higher cost of emissions embodied in the intermediate inputs used in their production. Recall that without compensation, the increase in costs in the Metals sector due to the higher cost of electricity was more than double the cost of direct emissions. Suppose that producers in this sector were compensated for embodied carbon emissions. Now the BTA adjusts to equate receipts from the endogenous import tariff with the implied cost of embodied carbon in imports of Metals, and the production subsidy adjusts to equate the value of the production subsidy to the implied cost of embodied carbon in exports. The embodied carbon emissions intensity in the Metals industry is the solution to:

$$mc(nfm) = \sum_j mc_j \cdot x_j(nfm) + dc(nfm)$$

where x_j is the number of dollars of intermediate input j used in producting Metals, and mc(nfm) and dc(nfm) are embodied and direct carbon emissions per dollar of output in the Metals sector. To solve for the embodied carbon emissions intensity, write this equation in matrix form:

$$mc' = mc'X + dc'$$

where mc' (dc') is a row-vector, the i'th element of which is the embodied carbon (direct carbon) emissions intensity in industry i, and the ij'th element of matrix X is the number of dollars of intermediate input i used in production of good j. The vector of embodied emissions intensities mc' is found by post-multiplying the row-vector of direct emissions dc' by the inverse of the matrix [I-X]:

$$mc' = dc'[I-X]^{-1}.$$

Total embodied carbon in any industry i is the product of that industry's embodied emissions intensity and the value of total output in industry i. Thus for the Metals industry:

$$emb\_carbon(nfm) = mc(nfm) \cdot py(nfm) \cdot qy(nfm).$$

In the initial equilibrium for the Australian Metals sector, while direct carbon emissions are 11.9Mt, embodied carbon emissions are 79.3Mt. Compensating producers in this sector on the basis of embodied carbon emissions rather than direct carbon emissions alone, results in much higher compensation, leading to a much larger shift in competitiveness in favour of Australian Metals. This results in a much smaller decrease in production, and a much smaller reduction in emissions from the Metals sector. Now to achieve abatement of 27 per cent, other sectors must achieve much larger abatement. This is compounded by the fact that the Metals sector is the largest user of electricity. Thus in the initial equilibrium, it used almost 21 per cent of all electricity produced in Australia. Since the Metals sector will abate less when compensated on the basis of embodied carbon emissions, it will be using more electricity, so abatement efforts by other sectors must be even stronger so that the carbon price must be much higher. This feeds back again through the Metals sector in the form of even higher levels of compensation for embodied carbon emissions which become much more valuable as the carbon price increases.

These effects all combine to produce a level of compensation for the Metals sector that is so strong, exports actually increase by 20 percent and imports fall by almost 57 per cent. With abatement of 27 per cent, the BTA with compensation based on embodied carbon in imports is equivalent to an import tariff of 37.9 per cent and the production subsidy is 8.6 per cent. Overall production in the Metals sector increases by almost 24 per cent. To achieve the same 27 per cent abatement, the market price of carbon must rise from US$27.39 when producers in this sector are compensated only on the basis of direct carbon emissions to US$40.26 when compensation is on the basis of embodied carbon emissions. The overall economy-wide welfare cost of abatement of 27 per cent rises from 0.39 per cent of benchmark welfare when this sector is compensated for direct carbon emissions to 0.58 per cent when this sector is also compensated for embodied carbon emissions.

We should also stress that this result contrasts strongly to that presented in Commonwealth of Australia (2008:169-70), which argues that there will be only minimal costs of shielding some Australian sectors (including aluminum) for the cost of direct carbon emissions and the higher price of electricity upon introduction of carbon charges. Their result is dependant upon the assumption that the extra permits required to shield Australian producers can be imported at a fixed price per tonne of carbon. If this global market for tradable carbon permits does not exist, then these permits much come from other non-shielded sectors in Australia, which results in the dramatic increase in the price per tonne of carbon when compensation is based on embodied carbon. With the continuing failure of negotiations through the UNFCCC to conclude a successor agreement to the Kyoto Protocol, it becomes increasingly difficult to justify the assumption of the existence of a system of internationally traded carbon emission permits.

Providing such compensation should only occur if other countries that export products such as aluminum are generating comparable carbon emissions and are not addressing these emissions by carbon taxes. Garnaut (2011, 84) questions this:

> "Australian aluminum is among the most emissions intensive as it is based on coal. The expansion of this sector elsewhere is likely to generate much lower (or even zero) emissions."

It is straightforward to test this claim using data on emissions intensities derived from GTAP. Are there likely to be significant carbon leakages? **Table 2** shows that Australia's emissions intensity in production of Metals (0.52 kg/US$) is lower only than that in the Former Soviet Union (0.54 kg/US$). So without BTAs in the Metals sector, the scope of leakages through an increase in Metals imports depends upon where imports are sourced. If most of this increase in imports comes from the Former Soviet Union or China (where the emissions intensity in production of Metals is 0.51 kg/US$), then leakage will be considerable and compensation could be warranted. If most increased imports come from the EU (where the emissions intensity is only 0.10 kg/US$), leakage through imports will not be a problem and compensation should not be pursued. Given that China (16.8Mt) and Russia (3.85Mt) accounted for half of global aluminum production in 2009, while Australia's production was 1.95Mt, Garnaut's claim is questionable.

Ferrous metals (iron and steel). GTAP sector 35 `Ferrous Metals' comprises mainly iron and (stainless and alloy) steel. The value of output in 2004 was $US13b, accounting for 1.1 per cent of total Australian output by value. Most of this was sold domestically, with $US1.85

billion exported, primarily to New Zealand (9 per cent), China (11), Korea (14), Thailand (12) and the US (15), while $US1.9b of iron and steel products were imported. Carbon emissions were about 5 million tonnes or 1.4 per cent of the total carbon emitted by Australia in 2004.

[Figure 7 here]

The effects of carbon charges on output in this sector, exports and imports as well as the level of domestic demand are given in **Figure 7**. In contrast to the Metals sector, the effects of carbon charging on the iron and steel sector are more modest. With abatement of 27 per cent, the price of carbon is equivalent to a tax of 0.85 per cent on Australian production of iron and steel. Electricity represents only about 4 per cent of the value of output in the iron and steel sector, so increased electricity prices have a much smaller effect on the international competitiveness of the iron and steel industry than for Metals. The overall increase in the domestic price is only 1 per cent, so the implied loss of competitiveness of Australian iron and steel on world markets is small, leading to a drop in exports of only 1.9 per cent and an increase in imports of 3.4 per cent. Since only 14 per cent of iron and steel produced in Australia is exported, the leakage through decreased exports and increased imports results in a drop in production of iron and steel of only 0.12 per cent. The large impacts on the Australian steel industry suggested recently in the press from carbon pricing **(**see e.g. Maher, 2011a) are not borne out by these findings. Daley and Edis (2010:48) find that charges on carbon emissions have the effect of a carbon tax on the iron and steel sector of 2.5-8.5 percent. They argue that in the electric arc (blast furnace) steel industries, electricity makes up 10 (25) per cent of total costs, respectively, which seems very high. In the GTAP7 dataset the corresponding figure for Australia is 3.8 per cent, while the corresponding figure for the US and the EU15 is 4.7 and 4.9 per cent, respectively. On the other hand, Daley and Edis (2010) argue that labour and capital account for 8 (15) per cent of total costs in the electric arc (blast furnace) steel industries. These figures seem very low, since in the GTAP7 dataset, labour and capital account for 32 per cent of total costs in the Australian iron and steel sector. The overstatement of the share of electricity and the understatement of the share of labour and capital in Daley and Edis (2010) would both contribute towards an overestimate of the effects of a given carbon charge on competitiveness of the Australian iron and steel sector.

Finally consider the potential impact of leakage on global emissions in the iron and steel sector. As noted above, we find that leakage due to the introduction of carbon charges in Australia will be very limited, with Australian exports falling by only 1.9 per cent and imports increasing by only 3.4 per cent. But as evidenced by the emissions intensity figures for the iron and steel sector in **Table 2**, Australia is a relatively clean producer of iron and steel. If Australia's reduced exports and increased imports are met by an increase in production in other developed economies like the US or Europe, the effects of leakage on global emissions will be negligible. But if this leakage leads to increased production in developing countries like China and India, leakage in this sector will lead to increased global emissions, since emissions intensities in the iron and steel sector in China and India are about three times those in Australia.

Mineral Products. GTAP sector 34 `Mineral Products' includes cement and glass. The value of output in 2004 was $US11b, accounting for 0.9 per cent of total Australian output by value. Most of this was sold domestically, with only 2.5 per cent exported, primarily to New Zealand (30 per cent), Japan (15), the Rest of Oceania (9), Korea (6) and the United States (5), while imports accounted for 11 per cent of the value of Minerals consumption. Carbon emissions were 5.7 million tonnes, about 1.6 per cent of total emissions in 2004.

[Figure 8 here]

The effects of carbon taxes on output, on exports and imports as well as domestic demand are given in **Figure 8**. Carbon taxes have a very small effect on the volume of production and trade in the Mineral Products sector. With 27 per cent abatement, the implied carbon price is equivalent to a tax of 1.1 per cent on production of Australian iron and steel. Electricity accounts for only 2.8 per cent of the value of production, so increased electricity prices have only a small effect on competitiveness. Finally, while labour and capital accounted for 22 and 31 per cent of production value in the Metals and iron and steel sectors, they account for 37 per cent in Mineral Products, so the decrease in the real return to labour and capital has a more pronounced effect here. Overall there is a negligible decrease in the price of Australian Mineral Products which fall by 0.2%, leading to a decrease in exports of less than one-hundredth of one per cent and a decreased imports of 0.8 per cent. Total Australian production of Mineral Products falls by 0.33 per cent. It is difficult to justify compensation for this sector.

Daley and Edis (2010, 19) argue that ``there is a real possibility that Australia would substitute cement clinker produced offshore for locally produced cement clinker as a result of carbon pricing,'' suggesting that competitiveness losses through imports could significantly damage Australia's cement sector. Daley and Edis (2010, 61) suggest that a carbon charge in on Australian cement of AU$35 per tonne of CO_2 would increase the average cost of cement production by AU$23.67 per tonne. Using their price of AU$160-170 per tonne of cement, this implies a carbon tax of 14.3 per cent, which is much larger than the effective carbon tax of 0.85 per cent implied by the carbon charge of US$26.41 per tonne of CO_2 (equivalent to AU$36.56 at an average 2004 exchange rate of US$0.722/AU$) at the 27 per cent abatement level of our analysis. It is difficult to understand the calculations in Daley and Edis (2010) since CO_2 emissions in the GTAP dataset for this sector *as a whole* are 5.65Mt while CO_2 emissions for the cement industry alone in Daley and Edis (2010, 57) are 7.14Mt.

6. Conclusion

It is becoming increasingly unlikely that a successor Agreement to the Kyoto Protocol will emerge from negotiations between countries at the UNFCCC in the short-term. In the absence of a multilateral agreement which binds the greenhouse gas (GHG) emissions of countries, it is important to understand the implications of unilateral policies to abate GHG emissions. There is a large literature which compares different mechanisms to achieve a carbon abatement target, but virtually all conclude that the most efficient policy is to introduce a charge on carbon emissions. The objective of this paper was to investigate the implications for Australia of the unilateral imposition of a charge on carbon emissions. We argue that in the absence of mitigation in other countries, it is best for Australia to identify some target level of emissions consistent with a given stock of atmospheric CO_2, and then to levy a carbon charge consistent with achieving this targeted level of emissions.

To achieve a targeted abatement level the carbon price must be determined endogenously. The price which clears the market for carbon permits will be different when the volume of permits differs. The carbon price will also differ when compensation schemes are introduced since those compensated will emit more, forcing other firms to abate more. A given level of abatement cannot be achieved by the same carbon price in scenarios with and without compensation. While other models which have evaluated the effects of carbon charges in Australia (Commonwealth of Australia (2008) and Daley and Edis (2008)) these have assumed that the carbon price was exogenous. We use a CGE model where the price of carbon is endogenous and consistent with a targeted level of abatement.

From the viewpoint of competitiveness concerns and the reasonable desire to reduce carbon leakages, there is a strong presumptive case for seeking to insulate the most emissions-intensive trade exposed EITES from the effects of a carbon tax. However, there remains the empirical question of whether such insulation policies – in the form of BTAs and export rebates – are necessary given the scale of the underlying problems. To address this question, we used a CGE model of the Australian economy, and investigated the effects of implementing a charge on carbon emissions in an environment where Australia was a small open economy facing fixed world terms of trade. While other studies have concluded that many industries in Australia (including coal, cement, steel and aluminum) should qualify for compensation after the introduction of carbon charges, we find that compensation is only warranted for the Australian metals sector which includes aluminium production. We find that carbon charges without the insulating properties of BTAs and compensation for exporters do not result in significant cost impacts and do not impact adversely on competitiveness in any sectors. Even here the case for compensation is conditional on the leakage-induced increase in world Metals exports being sourced from countries or regions where the emissions intensities are higher than those in Australia. If the increase in Australian Metals imports is sourced from regions where electricity used to produce Metals is generated with clean technology, then there is no case for compensating Australian Metals producers or for applying BTAs. In fact, in contrast to many arguments warning of strong adverse effects of carbon charges on the competitiveness of the Australian coal industry, we do not find a justification for compensation.

Redefining the tax base to operate on a destination basis will address limited competitiveness concerns which reduce concerns about Australia moving unilaterally towards carbon charging. Such policies increase the required charges required elsewhere to hit emissions targets. These issues help drive the initial carbon charge set and hence the required subsequent growth in pricing necessary to hit emissions targets. They are also important when considering the question of how to compensate sectors which have been identified as requiring compensation to address lost international competitiveness upon unilateral introduction of carbon charges. We illustrate by contrasting two forms of compensation for the Australian Metals industry, the only sector identified as potentially warranting compensation. A BTA is introduced to increase the price of Metals imported into Australia by the value of either direct or embodied carbon emissions associated with those imports, and a production subsidy which compensates Australian Metals exporters for either direct or embodied carbon emissions associated with Metals exports. When compensation is based on direct carbon emissions, the BTA and production subsidy are relatively small (2.2 and 0.75 per cent, respectively). Since this compensation effectively restricts the tax base on which carbon charges are applied, the equilibrium price of carbon must rise. But with compensation based on direct carbon emissions, this increase in the carbon price is small.

On the other hand, when Australian Metals producers are compensated for embodied carbon, the tax base is more restricted, since embodied carbon emissions are greater than direct emissions in this sector by a factor of 7. The BTA and production subsidy are now much larger, and the carbon price required to achieve the same economy-wide level of abatement rises to US$40.26. The economy-wide welfare cost of abatement increases by almost 50 per cent when compensation is based on embodied rather than direct carbon emissions alone.

Suggestions for using free emissions quotas instead of BTAs for the import competing sector are equivalent to policies which tax the sector but provide a lump-sum rebate to the sector. There are a host of problems with such policies but if the scale of policy intervention is not large then these policies provide an effective ‘second best’ policy option.

Appendix: **Optimal Carbon Pricing Trajectories and Proximate Emission Flow Targets.**

Suppose a government seeks to price carbon so that over a time horizon [0,T] the emissions stock at time t, S(t) grows by no more than $\Delta s \equiv S^*-S(0)$ where S(0) is the initial stock. Suppose the demand for emissions $\varepsilon(t)$ is $\varepsilon(t) = A - Bp(t)$ where p(t) is the price of carbon at t and A, B are positive numbers with A equal to emissions flows with zero pricing of carbon. Since CO_2 has a long half-life of over 100 years and the T envisaged is of the order of 10-20 years it is reasonable as a first approximation to ignore the reabsorption of CO_2 by the oceans and biosphere. Given this emissions add to the emissions stock in the atmosphere. Then for an initial carbon price p(0), the time path of prices that maximizes the present value of emissions will take the form of a Hotelling price path $p(t)=p(0)\, e^{\delta t}$ where δ is the discount rate. Thus the demand for emissions is:

$$\varepsilon(t) = A - Bp(0)\, e^{\delta t}.$$

Thus at T, $\varepsilon(T) = A - Bp(0)\, e^{\delta T}$ so that $p(0) = e^{-\delta T}\,(A - \varepsilon(T))/B$ which means $\varepsilon(t) = A - (A - \varepsilon(T))\, e^{\delta(t-T)}$.

Since emissions yield positive present value it is reasonable to suppose the stock constraint holds with equality. The requirement that growth in the emissions stock over [0,T] be equal to Δs requires:

$$\int_0^T \left\{A - \left(A - \varepsilon(T)\right) e^{\delta(t-T)}\right\} dt = \Delta s\ .$$

On integration:

$$AT - (A-\varepsilon(T))(1-e^{-T\delta})/\delta = \Delta s.$$

So :

$$\varepsilon(T) = A + \delta(\Delta s - AT)/(1-e^{-T\delta}). \qquad (1).$$

For given T and δ this defines the terminal sought after emissions flow, ε(T), given the stock target objective Δs provided that $\Delta s > 0$. This operationalises the *ad hoc* procedure of setting emissions flow targets when the objective should be to restrict growth in the emissions stock. To summarize:

Proposition 1. With a Hotelling objective of maximizing the present value of emissions an emissions stock reduction objective can be targeted by a correctly calibrated constraint on emissions flows.

Then, given ε(T), the initial desired carbon price is

$$p(0) = e^{-\delta T}\,(A - \varepsilon(T))/B. \qquad (2).$$

Equations (1) and (2) jointly determine the initial price and the terminal emission rate target and, given the Hotelling rule, the entire profile of prices and extraction rates. Differentiating (1) and (2) respectively with respect to the discount rate it is easy to show that

Proposition 2. The higher the discount rate the lower must be the final emissions flow target and the higher must be future emissions prices. Similarly an increased discount rate reduces the initial required carbon price but increases the required terminal carbon price.

Thus postponing decisive policy action means more intense future policy actions.

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Tables

GTAP Sector Number	GTAP Sector Code	Sector Description	Carbon (Mt)	Emissions Intensity (gm/USD)	Industry Share of Total Output (%)	Exports as Share of Industry Output (%)	Imports as Share of Industry Output (%)
15	COA	Coal	2.40	202.80	1.01	78.78	0.00
16	OIL	Oil	3.25	417.14	0.67	26.64	48.11
17	GAS	Gas	0.83	248.93	0.29	46.70	0.00
18	OMN	Minerals nec	5.44	222.55	2.10	41.04	1.91
32	P_C	Petroleum coal products	2.68	189.90	1.21	4.54	15.38
33	CRP	Chemical rubber plastic prods	3.74	120.37	2.67	15.97	45.83
34	NMM	Mineral products (incl. cement)	5.65	539.56	0.90	2.49	12.79
35	I_S	Ferrous metals (iron and steel)	4.82	372.58	1.11	14.32	13.26
36	NFM	Metals nec (incl. aluminum)	11.88	520.40	1.96	66.39	11.17
37	FMP	Metal products	0.17	9.89	1.49	3.65	13.25
43	ELY	Electricity	192.50	11098.03	1.49	0.00	0.00
44	GDT	Gas manufacture distribution	2.58	1938.89	0.11	2.93	0.00
		Households	38.41				
		Total	353.66				

Table 1: Emission Intensive Industries in Australia

Country/Region	COA	OIL	GAS	NMM	I_S	NFM	ELY	GAS
Australia	0.20	0.42	0.25	0.54	0.37	0.52	11.10	1.94
Japan	0.00	0.00	0.00	0.30	0.25	0.05	2.58	0.02
India	0.34	0.36	1.11	3.58	1.28	0.28	11.78	0.65
Canada	0.55	0.52	1.48	0.42	0.59	0.17	4.25	0.06
United States of America	0.03	0.32	0.16	0.66	0.40	0.19	8.15	0.40
China and Hong Kong	1.73	0.90	5.70	3.91	1.19	0.51	20.82	21.41
Carbon Exporters	0.03	0.22	0.91	0.94	0.91	0.15	10.02	1.05
Carbon Importers	0.39	0.39	0.33	1.45	0.48	0.23	5.04	0.50
European Union - 15	0.02	0.26	0.04	0.34	0.24	0.09	3.39	0.40
European Union - 2004	0.25	0.86	0.93	0.49	0.63	0.10	6.92	1.78
Rest of Europe & EFTA	0.03	0.15	0.61	0.50	0.52	0.03	2.57	0.32
Former Soviet Union	0.20	0.21	0.87	2.92	1.68	0.54	11.95	0.11
OPEC	0.04	0.11	0.71	2.24	1.70	0.43	9.74	0.90

Table 2: Emissions Intensity (kg/US$)

Figures

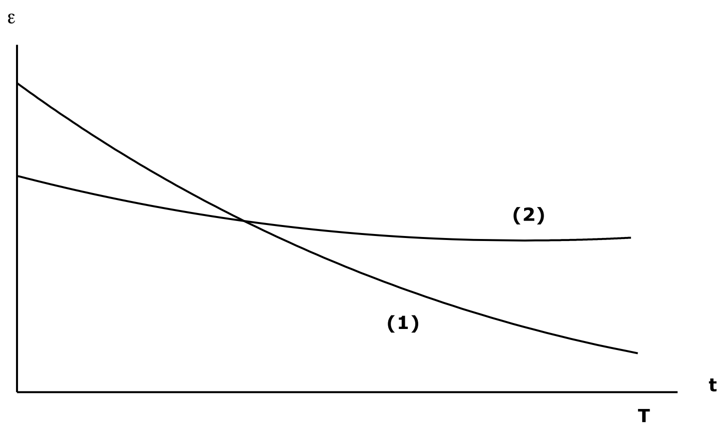


Figure 1: Emissions reduction paths (1) and (2).

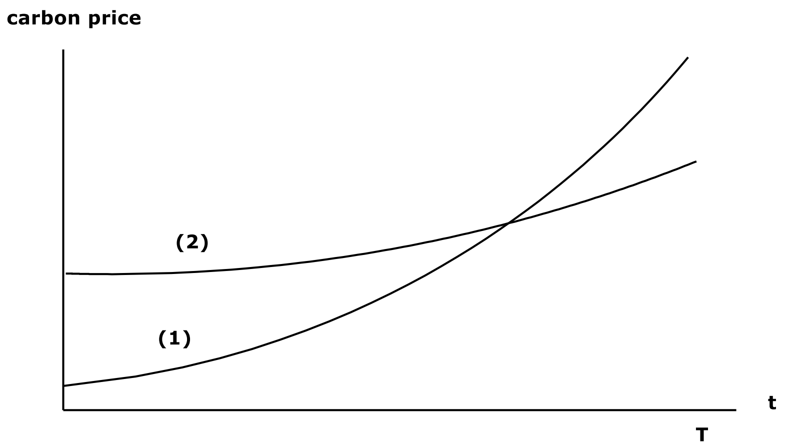


Figure 2: Emissions pricing paths (1) and (2).

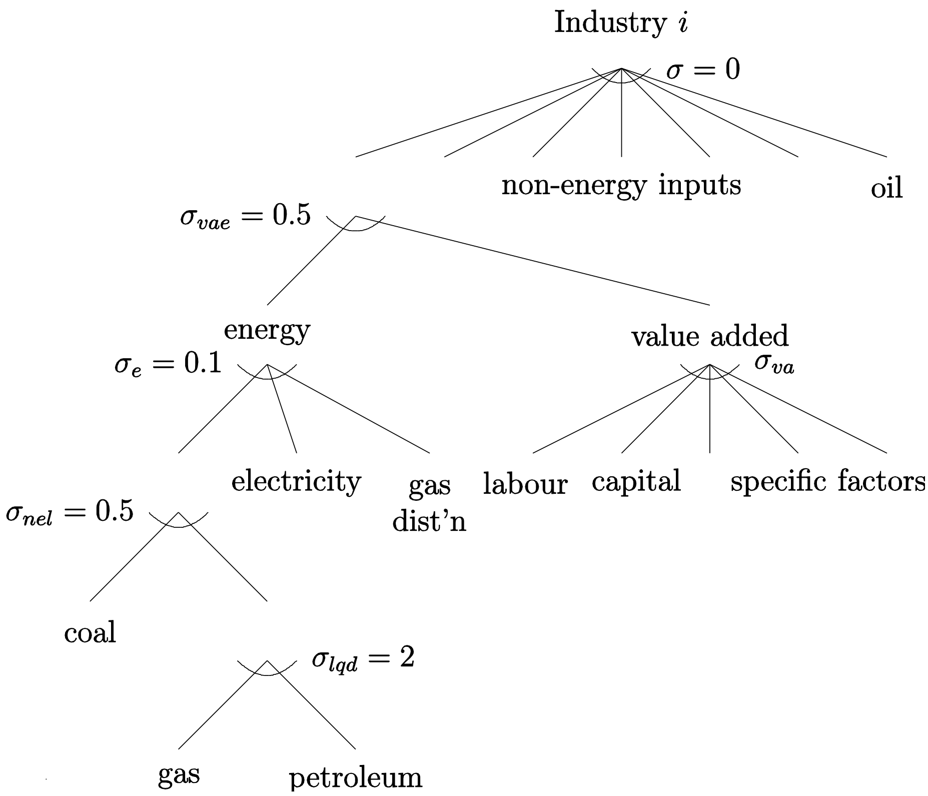


Figure 3: Structure of Production in the CGE Model

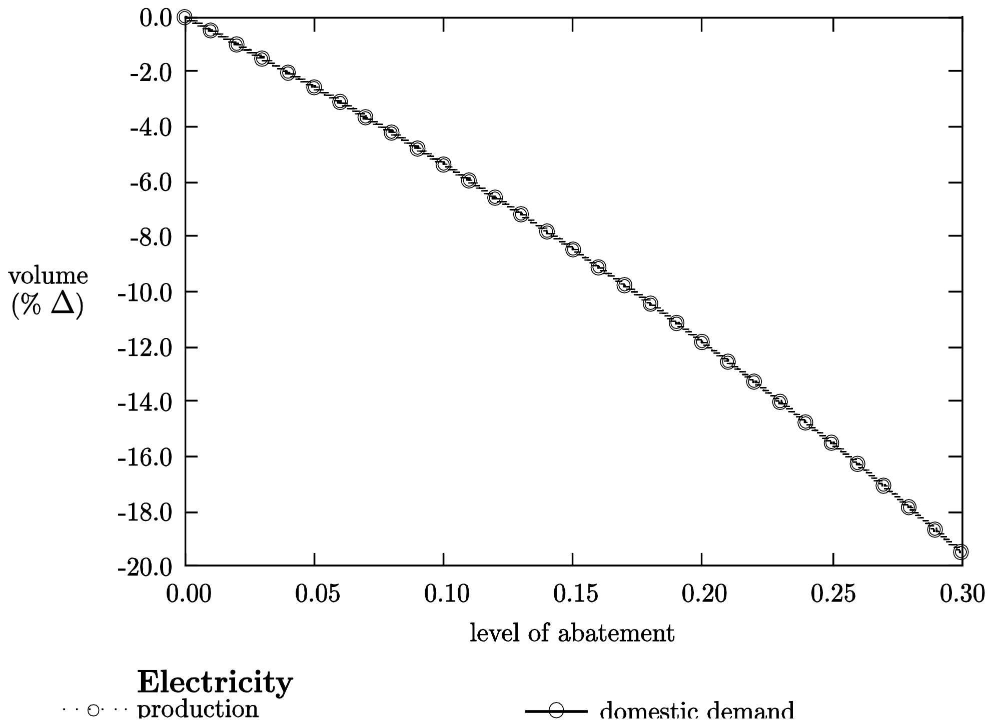
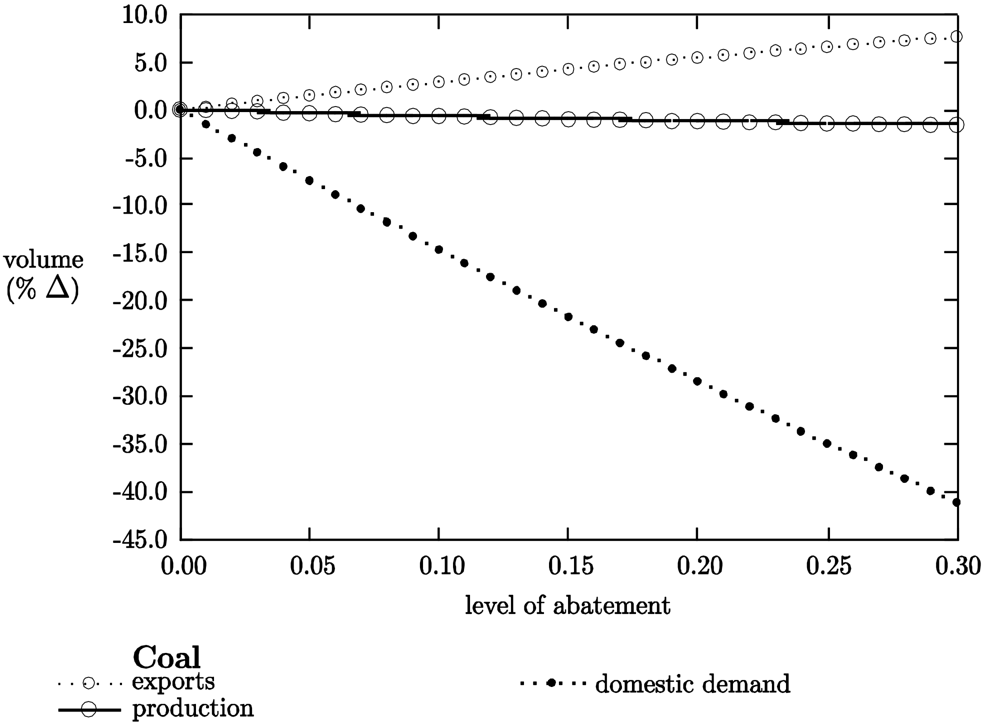


Figure 4: Carbon taxes and the electricity sector



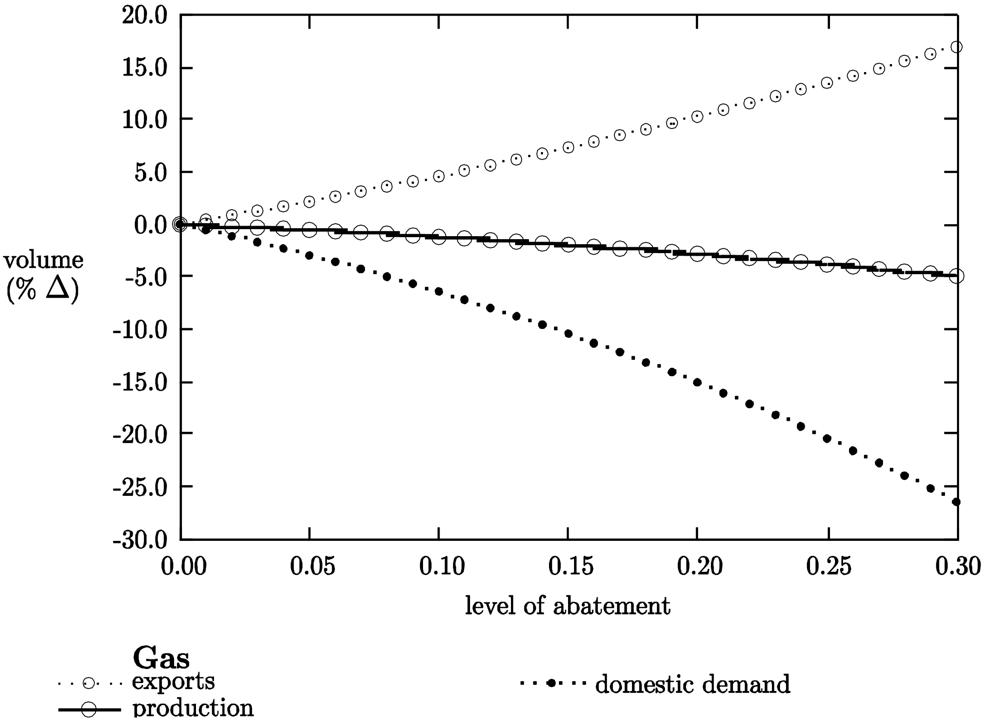


Figure 5: Carbon taxes and the coal and gas sectors

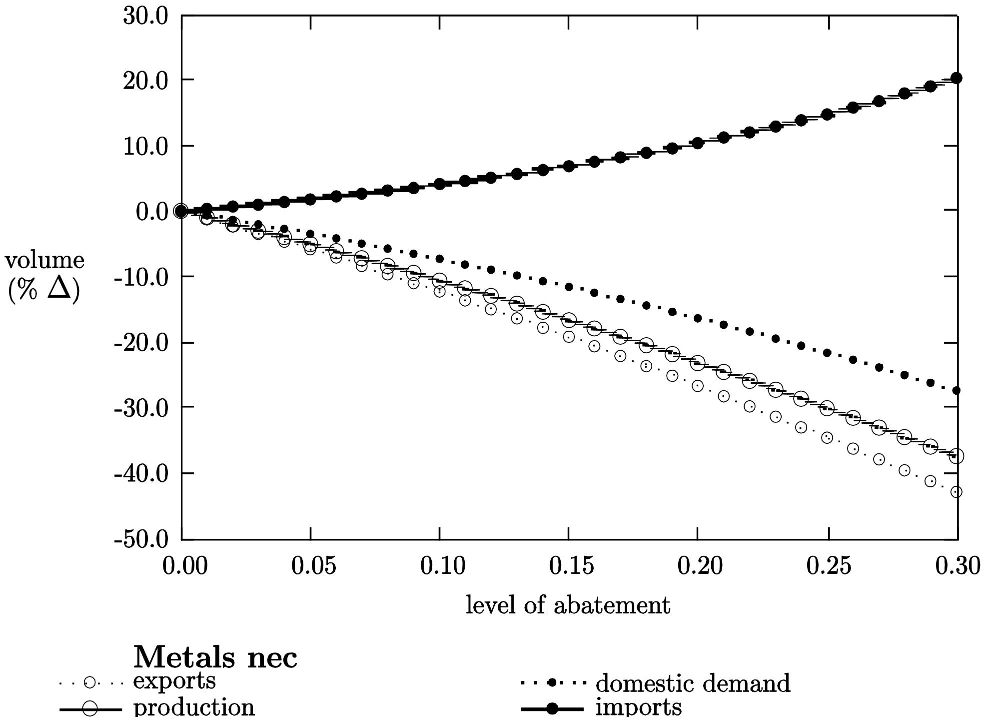


Figure 6: Carbon taxes in the Metals (incl. aluminum) sector

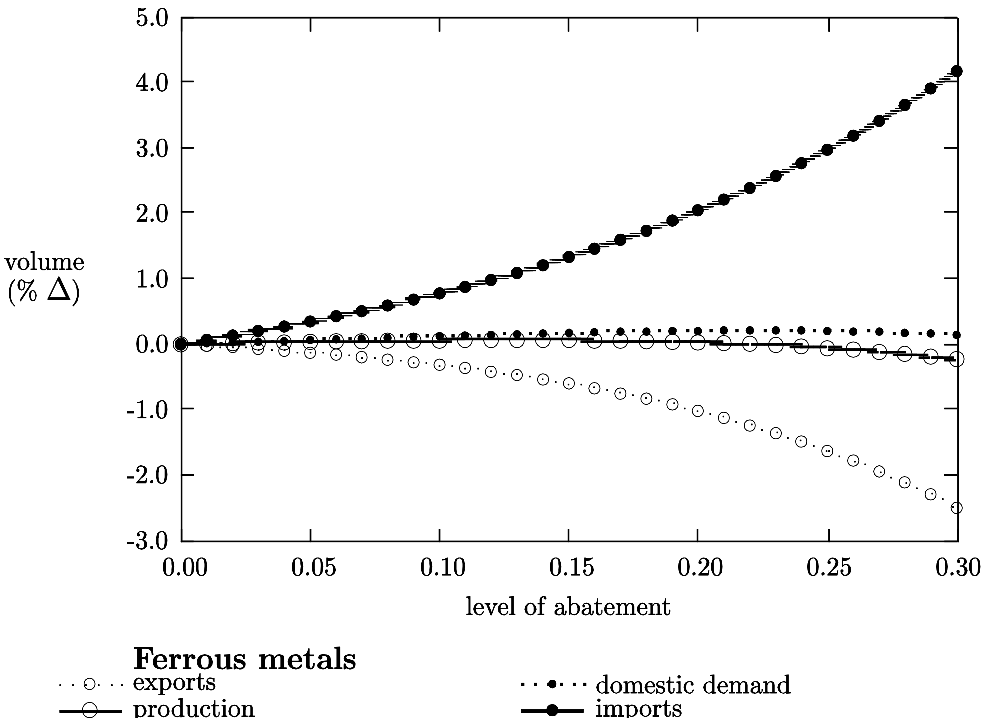


Figure 7: Carbon taxes in the Ferrous Metals (iron and steel) sector

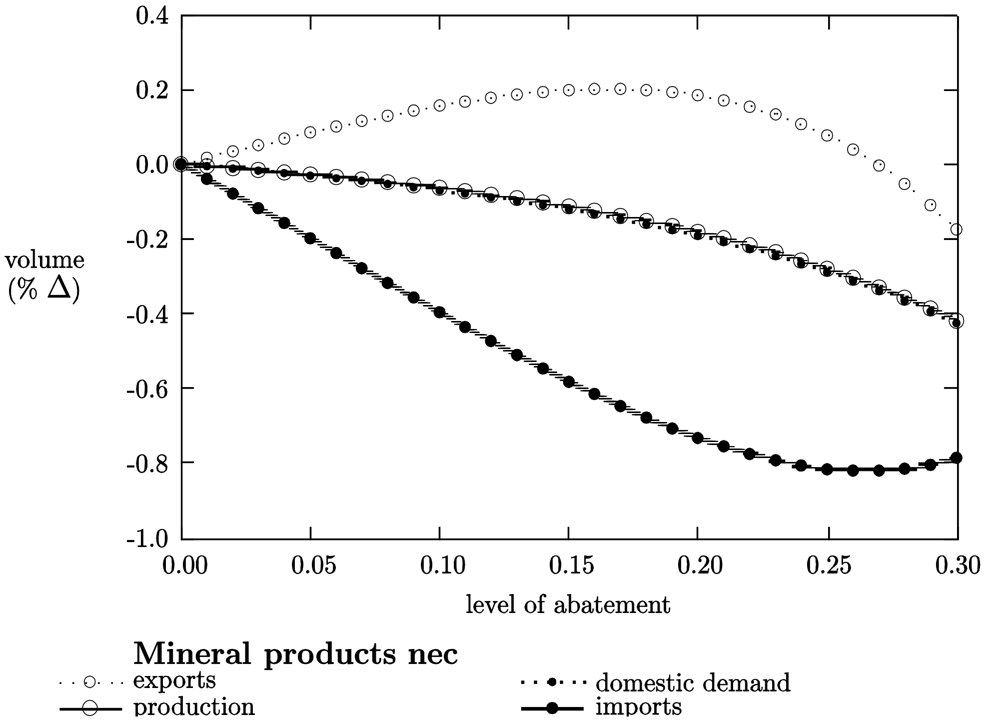


Figure 8: Carbon taxes in the Mineral Products (incl. cement) sector