REPORT

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Notes on 'Strong Growth, Low Pollution'

Modelling and related issues

Prepared for AIGN

Centre for International Economics
Canberra & Sydney

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1 Introduction

This report provides some review commentary of the model based analysis contained in *Strong Growth, Low Pollution: Modelling a Carbon Price* (referred to as *SGLP*) published in 2011 by the Commonwealth Treasury[1]. In doing so, a number of comparisons are made with the previous 2008 Treasury analysis (*Australia's Low Pollution Future*, or *ALPF*)[2].

Modelling is an essential component of any policy analysis, and it is difficult to contemplate how the risks, costs and benefits of particular policies could be understood without detailed modelling analysis. Australian policy making has a long history of detailed analysis of policy proposals, often using complex models developed over many years.

There are different ways of going about modelling. A major concern of the Treasury report appears to be to demonstrate that economic growth will continue even in the presence of a carbon price (or, equivalently, in the presence of a well defined target for carbon abatement). This is a valid, but in some ways limited, approach to modelling the full implications and risks associated with carbon mitigation policy.

Models can also be used to understand the risks involved in particular policies and to compare the effectiveness and costs and benefits of different policy configurations. In this case, the question is not so much whether growth will continue in the presence of a carbon price, but the trade-off between income foregone under different policy configurations and the relative benefits that arise from those configurations. While the Treasury modelling does not measure the *benefits* of mitigation, that these benefits are the ultimate objective of policy must be keep in mind when interpreting overall results.

A general comment

A key comment on the Treasury modelling developed throughout this report relates to the limited use of sensitivity analysis and the limited exploration of alternative policy scenarios (both domestic and international) within the Treasury analysis. Models are not necessarily particularly good at forecasting (particularly so far into

[1] The report, data from charts and tables as well as associated consultants reports are available at http://www.treasury.gov.au/carbonpricemodelling/content/default.asp

[2] Full details of this report are available at: http://www.treasury.gov.au/lowpollutionfuture/

the future) but they are good at comparative scenario analysis — particularly in order to reveal risks, costs and benefits of particular policy measures.

Results flow from international assumptions

The price pathway, the availability of international abatement to mitigate Australian costs, and the competiveness implications for individual Australian industries all depend on the simulation configuration, data and parameters embedded in the international model (GTEM) used by Treasury. The reported analysis provides one particular scenario for global action based around one set of parameters. Unfortunately this provides little understanding of the overall sensitivity or risks associated with Australian policy making in the context of global action.

Further, the simulation configuration has a number of implicit assumptions about how a world market for abatement may ultimately work. There is limited reported information to understand the effect of changes to these implicit assumptions.

No consideration of trade-offs in domestic policy

On the domestic side, the Treasury analysis provides relatively little insight into one of the more pressing issues in policy design: the optimal combination of tax and subsidy (especially RD&D subsidy) measures in mitigation policy. The proposed *Securing a Clean Energy Future* (SCEF) package has elements of both, however the overall package (particularly the subsidy elements) is not explicitly modelled in the Treasury analysis.

The modelling also provides little insight into the appropriate balance of different mitigation measures (the interaction of the renewable energy target and the carbon price, for example). A clear implication of the recent analysis by the Productivity Commission[3] is that the best mitigation policy is a uniform economywide price and that the inclusion of other measures only serves to increase the cost of abatement. But this is not the policy mix that is actually proposed. The question of the trade-offs involved in the implementation of the actual policy package is not addressed in the Treasury modelling.

Summary of key issues

Table 1.1 summarises some of the key review themes that emerge. These are essentially around:

- risks relating to the significant purchase of international abatement, and

[3] *Carbon Emission Policies in Key Economies* Productivity Commission Research Report, May 2011. (http://www.pc.gov.au/projects/study/carbon-prices/report)

- some specific issues related to the domestic modelling of the carbon price.

1.1 Summary of review issues

Issues related to 'international' aspects of the modelling	***Issues related to 'domestic' aspects of the modelling***
The overall framing of the policy simulations is limited (only 2 scenarios, both with coordinated international action, are considered). Simulations assume Australia joins *existing* global action.	Exclusion of agriculture and other sectors (in early years) in the simulations...
Apparent higher marginal cost of abatement for Australia (than in previous analysis)....	...appears to lead to a higher cost of abatement in Australia than in the 2008 analysis....
....leads to very high proportion Australian abatement being met through the purchase in international abatement. This in turn leads to a number of questions that could be resolved through additional scenario and sensitivity analysis.	..but apparently to lower average costs per Mt than in the scenarios considered in the 2008 Treasury analysis.
In particular, there are a number of implicit assumptions underlying the results for international trade in abatement which could be made more explicit and tested.	There are a large number of economic mechanisms operating the models used by Treasury. The key mechanisms in the economywide (CGE) model are changes in real wages and the real exchange rate. This is in sharp contrast to the very limited economic mechanisms in the input-output pricing model used to estimate price effects of the carbon price.
This includes sensitivity analysis of various risks related to international trade in abatement including delayed emergence of an international market, different timing of commitments by countries and the challenges involved in combined capped and uncapped trading schemes.	Industry level results within the CGE model follow understandable patterns given the real wage and exchange rate mechanisms. Overall effects are smaller in the current analysis compared with 2008. This may be due to the choice of a different baseline. These results also flow directly from the international assumptions and are likely to vary as those assumptions vary.
	The Australian abatement trajectory does not appear to be met in early years of the simulations, raising questions about Australia's cumulative abatement with the introduction of a flexible carbon price.

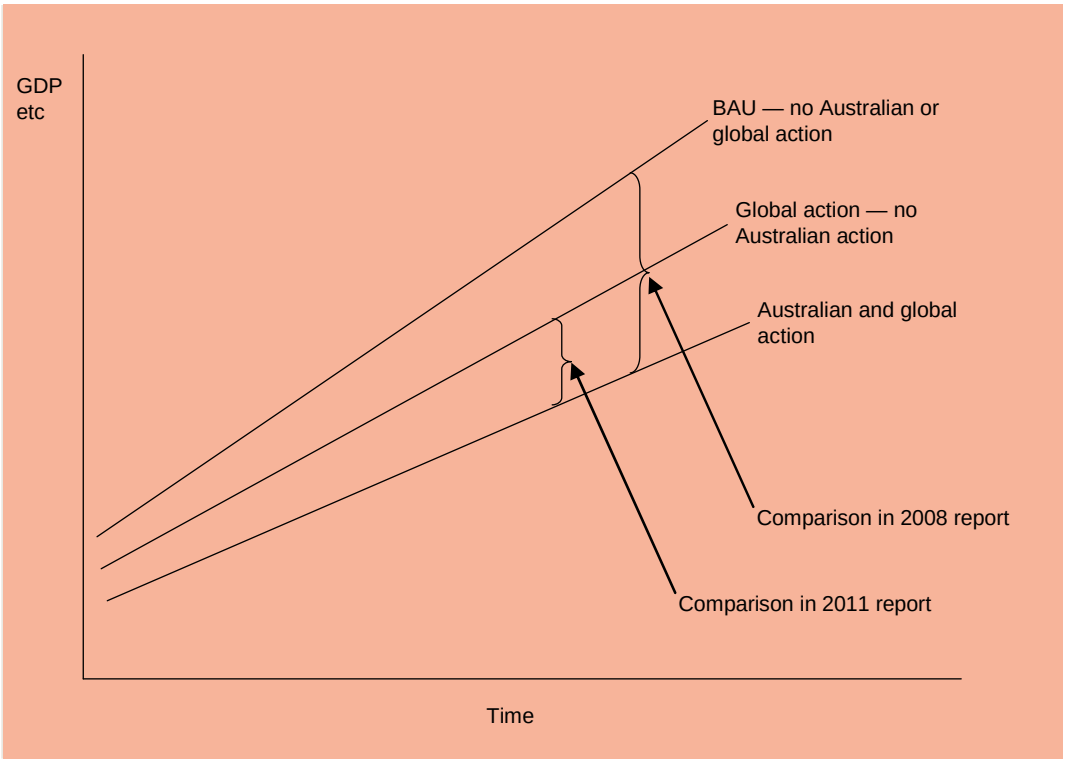
2 *The policy frame*

It is hard to overstate the importance of the framing of the policy problem in determining both the approach to modelling and the interpretation of model results and sensitivities.

Treasury's framing

From the perspective of Australia, the policy frame established within the Treasury modelling is that of Australia joining into *existing global action*. That is, most of the simulations consider the incremental effect of Australia joining in with international action that is, in effect, already taking place. In particular, the analysis compares the two lower lines illustrated in chart 2.1. This differs to the comparison made in the 2008 Treasury analysis of the CPRS.

2.1 **The policy comparison in the Treasury modelling** [a]



[a] Magnitude of differences between lines is entirely illustrative

Data source: Derived from SGLP and ALPF.

A standard convention in policy related modelling is to include in the base (or business as usual) case those elements of the world that are outside of policy control and to compare this with outcomes under the alternative 'with policy' scenario, where this scenario contains elements that are within policy control. The policy frame established by Treasury implies that the pathway of international abatement — and any particular response to this abatement — is outside Australian policy control and effectively that the only trade-off is whether or not to act given international action has already taken place.

This particular policy frame is in contrast to a frame that suggests that Australian policy must make decisions within an uncertain and evolving international policy environment. The two different frames suggest different sorts of sensitivity and risk analysis.

The issue here is not so much whether a particular framework is 'correct', but rather what modelling design can best be used to gain insights about the challenges and opportunities facing Australia as it embarks on carbon pricing policies.

Sensitivity analysis within Treasury's frame

Within the policy framework proposed by Treasury, it is reasonable to consider the sensitivity of model results — especially in the path for the world price of carbon — to changes in uncertain model parameters and datasets. This is particularly true given the importance of purchasing international abatement discovered by Treasury in their work. This is, in a sense, the minimum sensitivity analysis that should be undertaken.

Modelling outside Treasury's frame

Outside of Treasury's frame, a crucial question is one of risk management in an uncertain and evolving world of abatement policies and commitments. Under this frame, the issue becomes more than sensitivity analysis (although this remains important), but rather it is one of simulating different scenarios for the evolution of global policy. Modelling this extended framework should be well within the capabilities of the models used by Treasury.

This broader modelling framework would take advantage of the relative strengths of simulation modelling and would lead to greater understanding of the impact of a key uncertain factor (relative international action) that will influence outcomes for the Australian economy. Again, this is not necessarily a matter of arguing which future outcome is 'correct', but simply a matter of understanding the implications of different outcomes.

3 International abatement issues

Establishing the world price of carbon

To estimate the global emissions price (given assumptions about targets and country participation), Treasury adopts a straightforward procedure that involves imposing an annual price increase and then finding the starting price (and by implication price path) that leads to the required global abatement.

Implicit in the solution to this problem is the abatement cost of all participants in global trading[4]. Higher cost of abatement requires a higher price, and vice versa. Importantly, it is the entire future path for the cost of abatement that determines the starting price (and therefore the price path, and therefore abatement in each year).

This price path feeds into all the subsequent results from the Treasury modelling, so it is important to understand how sensitive prices are to changes in underlying model parameters and assumptions including:

- 'global' cost of abatement;
- the composition of participation in global abatement;
- underlying BAU growth of emissions.

None of these factors is known with certainty. Without access to the GTEM model as used by Treasury it is difficult to estimate how sensitive the price path is to these assumptions, but some insight can be gained from a simple 'back of the envelope' reproduction of Treasury's price path, and then using this to understand the sensitivity of prices to changes in the aggregate costs of abatement at various points in time[5].

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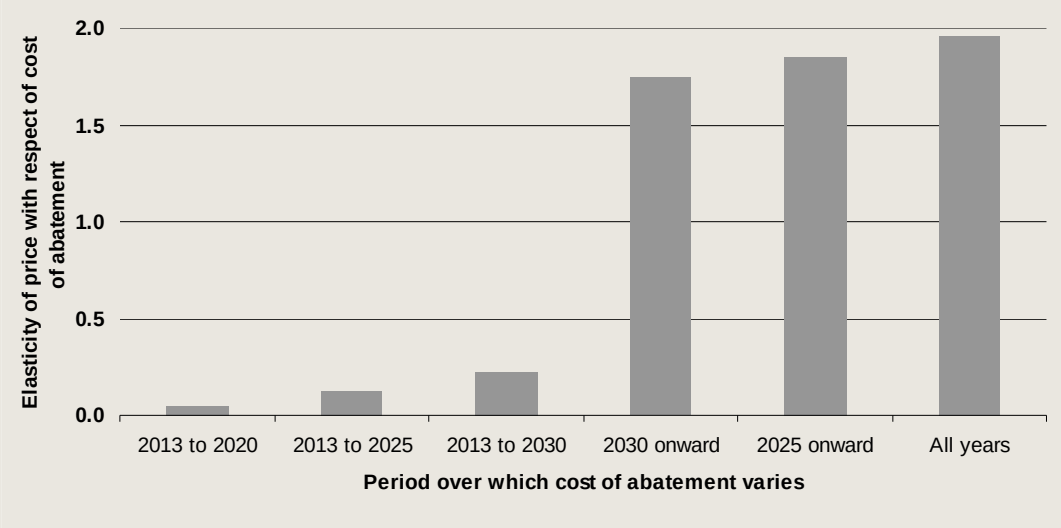
[4] Strictly speaking, Treasury does not assume global trading as such, but that abatement is available for exchange in some form so that an effective global carbon price can emerge. This point is discussed further below.

[5] The procedure adopted is as follows. First, the aggregate global cost of abatement can be derived from the Treasury results by applying a log linear model to the published results for global abatement under different prices. The model is of the form $Ln(Price) = a + b*Ln(Abatement)$ where Ln is the natural logarithm. This model provides a good fit with an R^2 of 0.92, and an estimate of b (the marginal cost of abatement) of 0.52 with a standard error of 0.02. Second, this reduced form global cost of abatement is applied in each year (clearly an approximation) in order to estimate the price path that satisfies the global

Approximate sensitivities of the global carbon price to changes in the cost of abatement are illustrated in chart 3.1.

3.1 **Sensitivity of carbon price to changes in cost of abatement** [a]



[a] Results expressed as an 'elasticity', that is, percentage change in price for a 1 per cent change in cost of abatement.
Data source: CIE estimates based on results from SGLP.

A key result that emerges from this is that the *future* cost of abatement has a greater effect on the price path than the *near term* cost of abatement. This is important as the future cost of abatement is presumably considerably more uncertain than the near term cost of abatement.

Further, the future cost of abatement is amenable to policy interventions, particularly RD&D style interventions. In all, what this relatively simple sensitivity analysis suggests is that risks (in terms of an uncertain price path) are mostly driven by unknown costs in the future and that there is an unknown (from the modelling reported) relationship between RD&D actions today and the cost of abatement in the future.

An aside: global borrowing from the future

A consequence of the price estimation method used by Treasury is that global abatement targets are not necessarily met in each year. In the early years, excess abatement (banking) takes place in order to provide a surplus for lower abatement in later years. This is shown in chart 3.2. In the latest Treasury results, by 2050 there is net borrowing from the future of around 100Gt (or around 8 per cent of the total

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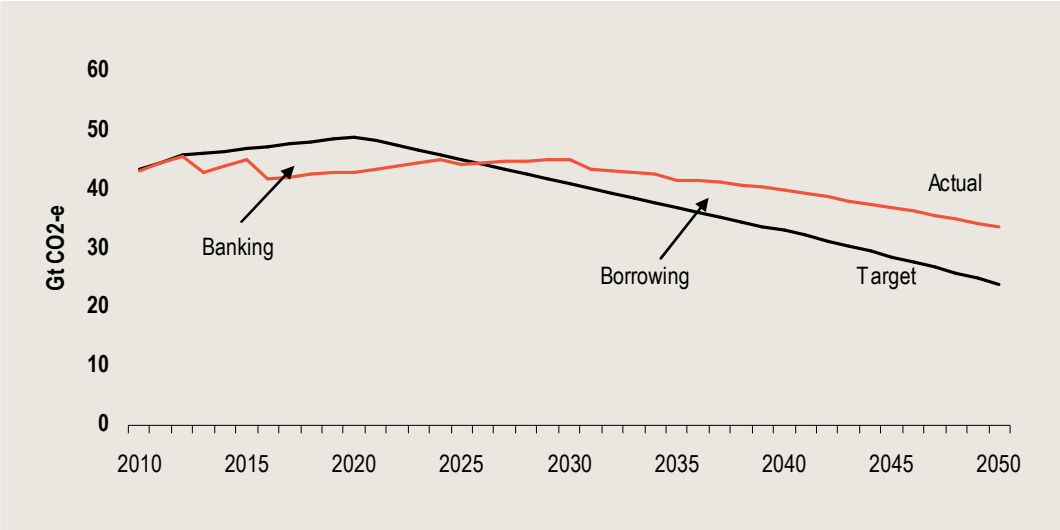
abatement target. The resulting price path is very close to that published by Treasury (the error is around 1 per cent in most years).

abatement task between 2013 and 2050). It is not clear from the Treasury analysis how this deficit is resolved.

3.2 **Banking and borrowing for global abatement**



Data source: SGLP, chart B1.

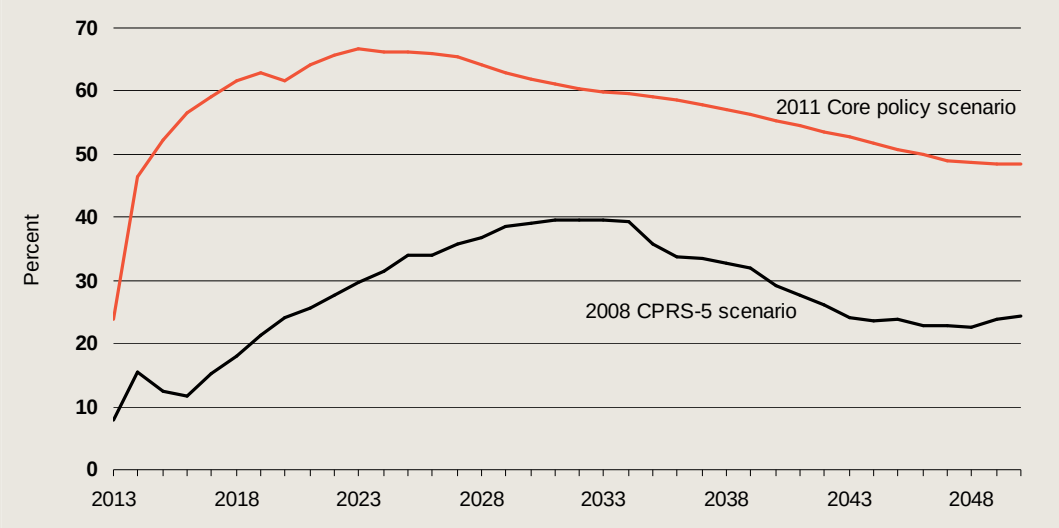
Further, while in principle a carbon market may effectively allow borrowing from the future, it is not clear how such a mechanism would be established in practice, particularly from a monitoring and enforcement perspective where borrowing is over a long period of time. It would be useful to understand the sensitivity of global prices to constraints on borrowing behaviour.

In addition, the pattern of banking and borrowing appears counterintuitive. If the cost of abatement is expected to decline over time, then one reasonable outcome would be to borrow initially (when the cost of abatement is relatively high) and bank increasingly over time (when the cost of abatement is relatively low). Presumably there is a combination of factors that determine the result discovered by Treasury.

Australian abatement and international abatement purchases

Comparing the 2008 and 2011 Treasury reports indicates that in the more recent analysis Australia purchases a higher proportion of international abatement to meet its target than previously (see chart 3.3)

3.3 Proportion of abatement undertaken through international purchases



a The two policy scenarios are not identical, but nevertheless the magnitude of the difference is telling.

Data source: SGLP chart 5.2. ALPF charts 6.2 and 6.4.

This very high reliance on the purchase of international abatement is a crucial feature of the Treasury analysis and flows through to all aspects of the results. That is, the industry results and the price results in particular depend upon particular outcomes in the international market for abatement.

It is natural, therefore, to ask how sensitive the results are to changes in cost of abatement in different countries (as well as to the changing composition of policies in different countries) and to any restrictions in abatement trade between countries.

Without access to the original model, it is difficult to undertake this analysis. However, postulating a simple linear model of abatement and trade in abatement provides some useful insights.[6]

A couple of points emerge from this simple model.

- First, the world price (and by implication the outcomes for Australia) is most sensitive to the marginal cost of abatement of the lowest cost abating country. Thus, in terms of sensitivity analysis, the countries we need to be concerned with understanding are those expected to sell abatement (by implication, these are the lowest cost abating countries).

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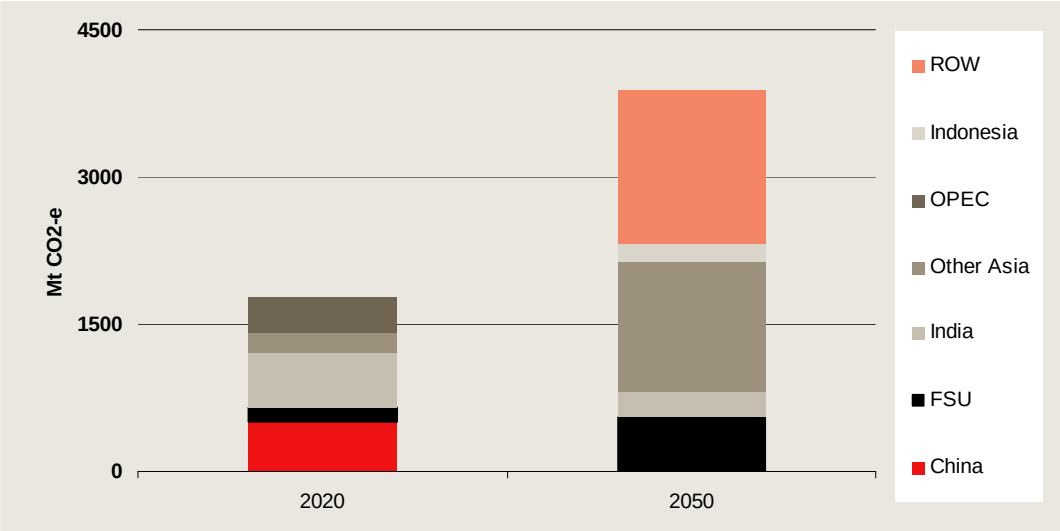
[6] A simple model of trade in abatement can be developed as follows. Let $P_i = \alpha_i A_i$ be the marginal cost of abatement curve for country i. Here P_i is the carbon price and A_i is the amount of abatement (defined relative to BAU). With global commitment to abatement, $\Sigma A_i = T$ where T is the aggregate target for abatement. A world carbon price is defined as $\tau = P_i$. From the global carbon constraint $\tau = T/(\Sigma(1/\alpha_i))$. The elasticity of τ with respect to α_i (that is, the sensitivity of τ to changes in α_i) is $= 1/(\alpha_i(\Sigma(1/\alpha_i)))$. The smaller is α_i, the greater is this elasticity.

- An implication of this is that under the hypothesis of international trade in abatement, Australian outcomes may be more sensitive to uncertain costs in China, India and South East Asia than they are to the Australian cost of abatement[7].
- Assessing risk and uncertainty in this world therefore requires some understanding of the cost of abatement of those countries that are presumed to sell abatement on the international market.

Chart 3.4 summarises the (net) sales of abatement reported in the Treasury analysis.

The question that naturally arises is the empirical basis for the cost of abatement for net selling countries as it is uncertainties about this cost of abatement that will have a significant influence on outcomes for Australia. This cost of abatement is presumably a function of a number of aspects of the GTEM model including a variety of parameter and base data choices. It is unlikely that any of these is known with certainty — particularly given that these are countries where data reliability is an issue.

3.4 **Sale of abatement** [a]



[a] Regions in the GTEM model are defined in SGLP table A1. Other Asia here refers to Other South and East Asia and includes Brunei, Malaysia, Philippines, Thailand, Cambodia, Maldives, Korea, Timor-Leste, Laos, Myanmar, Singapore and Vietnam.

Data source: SGLP table 3.8

Implicit assumptions underlying international results

There are a large number of implicit assumptions in the configuration of the international side of the Treasury modelling.

[7] In the linear model, the ratio of elasticity is equal to the ratio of the cost of abatement (α_i) parameter. Thus if China has half the marginal cost of abatement of Australia, then the world price will be twice a sensitive to the Chinese α as it is to the Australian α.

Formation of an international market

First, that an international market of some form (perhaps on offset market) is established. Second, within this market, prices reflect the marginal cost of abatement of participants. Third, the global cap is met. In the case of a full quota constrained market, the cap will be met. In the case of an offset market this is not as clear as the countries supplying offsets have no ultimate constraint on emissions.

If assumptions about country participation are relaxed or changed, then clearly this will have implications both for the global carbon price, and total global abatement, and of course, outcomes of Australia.

Country decisions to participate

Treasury notes that if other countries don't act, this will lower the global carbon price. This is a conditional result — it depends on what is meant by countries not acting.

First, it is true that factors that reduce the demand for abatement will lower the market price. If countries choose not to participate, then the price will be lower from demand side effects. At the same time, the outcome for global abatement may also be reduced.

If countries remove themselves from any form of constraint (and from the offset market) the effect on prices will depend on which countries don't act — whether they would otherwise be buyers or sellers of abatement. If all the high cost countries act, but the low cost ones don't, then presumably the carbon price will be higher — and global abatement will be lower.

The effect of distortions to trade

The Productivity Commission recently noted that most countries are not implementing carbon policies in the most cost effective way[8]. This means that as policy is currently emerging, it is unlikely that the true cost of abatement will be revealed in international markets. This is similar to having distortions to the ideal market (as simulated by Treasury).

The effect of these distortions is similar to increasing the marginal cost of abatement so that distortions in the lowest cost abating countries will be most important from a risk perspective. Within a global trading framework, the costs to Australia are as much a function of the efficiency of other country policies as they are a function of domestic Australian policy.

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[8] *Carbon Emission Policies in Key Economies* Productivity Commission Research Report, May 2011. (http://www.pc.gov.au/projects/study/carbon-prices/report)

The effect of combining capped and uncapped systems

Recent reviews of the Clean Development Mechanism (CDM) suggest that there are significant issues associated with combining capped and uncapped trading systems[9]. This is something worthy of examination in the models used by Treasury. There is an analogue for this within Australia when looking at agricultural outcomes. Overall, agriculture is projected to expand as a consequence of the carbon price (this is in addition to anything related to the Carbon Farming Initiative (CFI), as the CFI is included in the baseline). This expansion implies an increase in emissions. Thus despite the fact that agriculture provides some form of abatement, because it is uncapped its emissions are still able to increase.

An offset market

The offset market (such as the CMD) does not involve applying a price to the whole economy — only the offset components. While in some cases it may have the effect of transmitting a price throughout the economy, it will not necessarily do so, so there is no guarantee that an overall cap will be met if there are offsetting increases in emissions elsewhere (outside activities covered in the offset market). In this sense, the Treasury analysis does not model an offset-style market (as the cap is met in the Treasury analysis) even though CDM style mechanisms are suggested as one way of establishing an international market.

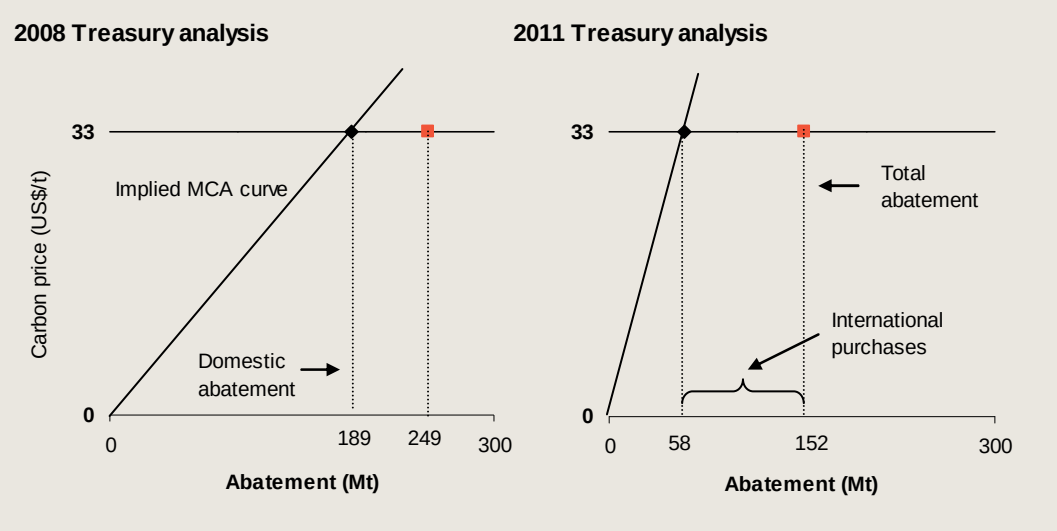
[9] See for example Maslin and Scott 'Carbon trading needs a multi-level approach' in *Nature*, 28 July 2011, Vol 475, pp445-447. See also Campbell, Klaes and Bignell *After Copenhagen: The Impossibility of Carbon Trading*, LSE Law Society and Economy Working Papers 22/2010 (www.lse.ac.uk/collections/law/wps/wps.htm)

4 Domestic modelling issues

Higher cost of abatement for Australia

The very high purchase of international abatement implies that the marginal cost of abatement for Australia is higher in the current modelling than previously. This is illustrated in chart 4.1 which shows an implied cost of abatement curve (on the same scale) for the 2008 and 2011 analyses. The 2011 curve is clearly steeper than that in 2008.

4.1 **Implied marginal cost of abatement in 2020** [a]



[a] 2008 analysis refers to the CPRS-5 scenario. 2011 analysis refers to the core policy scenario. International prices are put on a common (2010) basis and turn out to be very similar between both sets of modelling.

Data source: CIE derivation from SGLP chart 5.2. ALPF charts 6.2 and 6.4

This is likely to be due to a number of factors, particularly the exclusion of agriculture and some parts of transport (in initial years).

This illustrates an important point: *policy design affects the cost of abatement and therefore the cost effectiveness of the policy*.

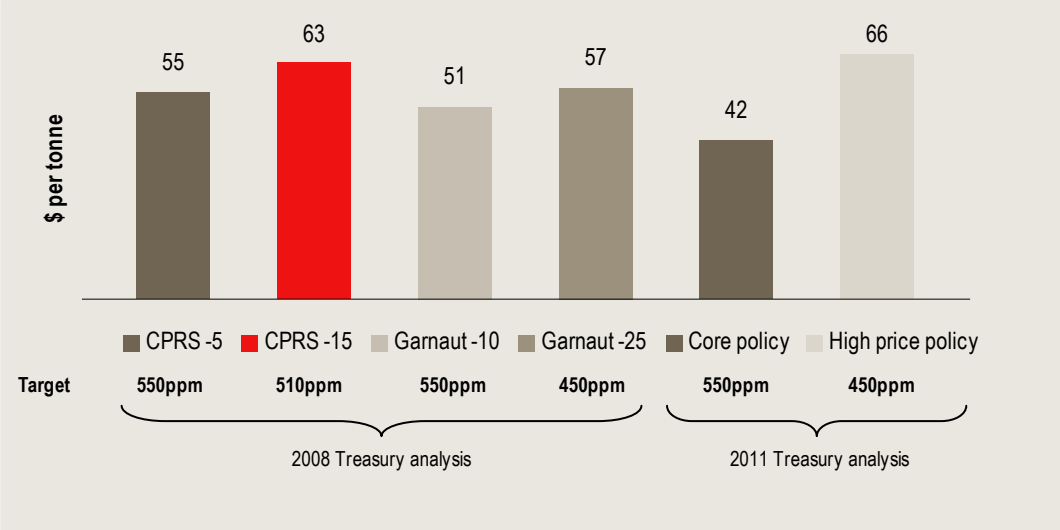
This naturally raises the question about the sensitivity of outcomes to other marginal changes in policy. Again, however, the Treasury analysis reports no overall sensitivity here.

Lower overall costs

One way of comparing different policy scenarios is to calculate a levelised cost of abatement under those scenarios. This levelised cost is defined as the present value of GNI[10] (gross national income) foregone per unit of cumulative carbon abated.

Chart 4.2 illustrates these levelised costs for the scenarios Treasury has reported in ALPF and SGLP. Despite the observation above that the marginal cost of abatement is higher under the 2011 analysis, this is not evident in the average cost comparison in chart 4.2. The reasons for this are not clear.

4.2 **Levelised cost from different policy simulations**



Data source: CIE estimates based on results in ALPF and SGLP.

CGE vs PRISMOD

Treasury use both the MMRF model (a CGE model) and PRISMOD (an input-output pricing model) to assess the impacts of the proposed carbon price.

The economic mechanisms operating in the two models are fundamentally different and tell a very different story about adjustment to a carbon price.

Within the CGE model, the core mechanisms leading to a reallocation of activity within the economy are changes in real wages and changes in the real exchange rate. Both of these must fall, although the real exchange rate results are not directly reported. This mechanism has important implications for many subsequent variables including changes in prices and output.

[10] We use GNI rather than GDP to capture the cost of purchasing international abatement.

PRISMOD is not capable of capturing these components of the story and postulates a very simple adjustment mechanism based solely around price changes flowing from the initial carbon costs. It is quite difficult to know how to interpret the PRISMOD results. On the one hand, because it does not allow quantity adjustment of any kind it is a 'morning after' model. Yet Treasury argue that it also represents 'long term' price impacts[11]. It is hard to see how these different implications can be reconciled.

The price implications with MMRF are not explored in the Treasury analysis although it is likely that they are quite different to those implied by PRISMOD. For example, the increase in output of agricultural sectors under the core policy scenario implies a reduction in prices (arising through a reduction in wages and a depreciation of the exchange rate). This means that the food price impacts may be small (or even negative), while PRISMOD implies and increase in prices. This is not a good news story, however, as the fall in real wages means a reduction in household ability to purchase products.

Implications of lower availability of international abatement

As noted above, there are a number of reasons why less international abatement may be available. Without redoing the modelling it is difficult to estimate the implications of this, however a BOTE analysis may suggest some orders of magnitude. A procedure for this is as follows:

- first, estimate the 'marginal cost of abatement' (MCA) for Australia using the published Treasury results[12];
- second, assume that less international abatement is available so that a greater proportion of domestic abatement needs to be undertaken than reported in the Treasury analysis. In particular we assume
  - (i) that Australia's entire abatement target must be met domestically and
  - (ii) that only 50 per cent of the international abatement reported by Treasury is available;
- third, use the estimated MCA for Australia to calculate the new Australian carbon price required to achieve the new implied targets for *domestic* abatement.

The results are illustrated in chart 4.3. These results are not designed to be definitive in any way, or to provide a forecast of Australian carbon prices. They illustrate,

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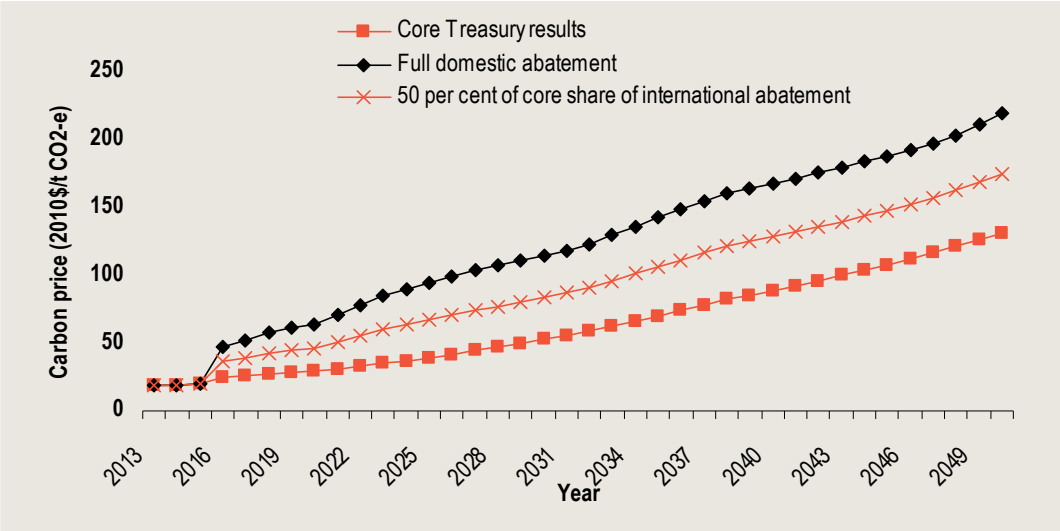
11 See SGLP p. 132

12 Technically, this is derived by applying a log linear model to the published Treasury results for Australian abatement under different prices. The model is of the form $Ln(Price) = a + b*Ln(Abatement)$ where Ln is the natural logarithm. This model provides a good fit with an R^2 of 0.96, and an estimate of b (the marginal cost of abatement) of 0.717 with a standard error of 0.02.

however, the way in which the magnitude of the Australian price could vary as assumptions about the availability international abatement vary. Clearly it would be preferable to do this sort of analysis with the full models used by Treasury.

4.3 Sensitivity analysis of carbon prices



Data source: CIE estimates

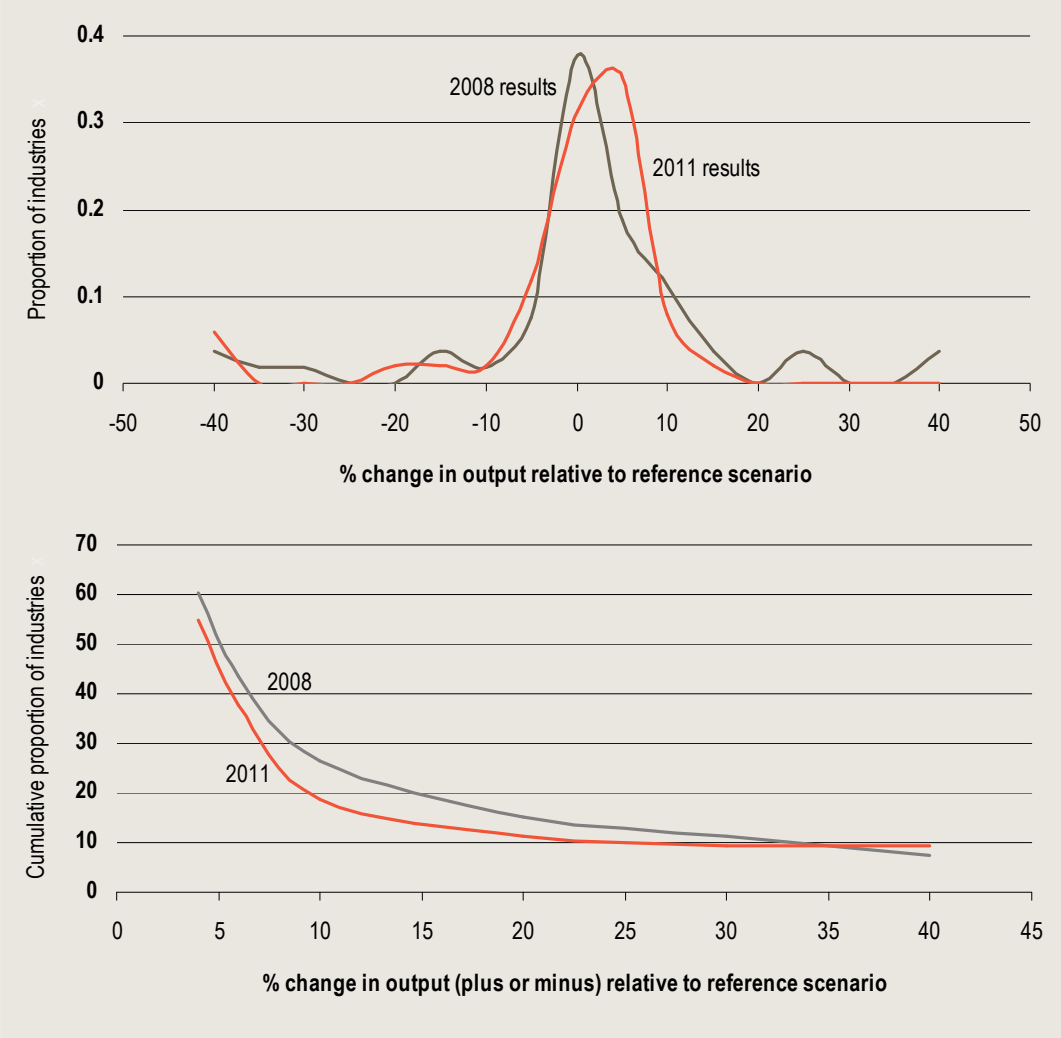
Industry impacts and CGE effects

The broad pattern of industry results is quite similar for the 2008 and 2011 analyses (chart 4.3), although in 2011 the dispersion of industry outcome is not as great (and with a mean shifted towards the positive). There are likely to be a variety of factors driving this outcome.

As noted above, the 2011 modelling uses a different baseline comparison, so that some of the industry adjustment apparent in the 2008 version of the modelling are already included in the baseline.

In addition, the pattern of industry results itself depends on assumptions in the international modelling: in particular the path of prices, but also the coverage of sectors assumed for the carbon price in competitor countries.

4.4 **Distribution of industry impacts in 2050**



Data source: CIE estimates derived from ALPF table 6.11 and SGLP table 5.7.

The trajectory of Australian abatement

In the Treasury modelling, Australia purchases international abatement even in the first three years of the policy when this is not allowed under the proposed policy package. What this implies (at least on the basis of the cost of abatement implicit in the Treasury models) is that the fixed early price is not sufficient to keep Australia on the linear abatement trajectory to 2020.

Depending on how Australia's obligations are ultimately defined, this clearly has implications for Australia's trajectory after the end of the fixed price period. The policy question is whether that trajectory is designed to preserve a particular amount of cumulative abatement or whether the trajectory to the ultimate 2020 target is entirely arbitrary.

Put another way, does the Treasury modelling imply a deficit in cumulative abatement as a consequence of the early fixed price? If so, how will policy adjust to remedy this?