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Antipodean agricultural and resource economics at 60: climate change policy and energy transition

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The Australian and New Zealand agricultural and resource economics profession has made a significant contribution in the field of climate policy and analysis of the energy sector. Much of this contribution has been based on quantitative economic modelling which had its roots in the earlier computable general equilibrium modelling on domestic policy and trade in which the profession was heavily involved from the 1970s onwards. By far the largest share of model development and analysis has been sponsored by government and conducted in the public sector, but in more recent years, there has been some shift into the private sector. However, the trend to the use of much more complex integrated assessment models in assessing the impacts of climate change and responses to new policy instruments raises the issue of whether more government support of quantitative modelling will be required in future.

Key words: climate change, climate policy, economic modelling, energy sector.

1. Introduction

Generally, a profession's contribution in a field of study is assessed by considering the published literature and this paper is no different in that respect. However, before proceeding to review the literature contributed by Australian and New Zealand (ANZ) agricultural and resource economists, I would make the observation that the profession's contribution is much broader than the published literature, whether that work be in refereed journals or the so-called grey literature. In addition to published contributions, agricultural and resource economists make their contributions both through formally training students in the wide range of disciplines who take their courses and in providing on-the-job training. Many of those students go on to work in influential roles in government and business where their training is put to good use.

It is conjecture but on the policy front, I hypothesise that the profession makes as big a contribution in preventing or moderating 'bad' policies as it does in promoting 'good' policies.[1] Unfortunately, we have no easy way of measuring the former so we run the risk of understating the profession's contribution to welfare by simply measuring the latter.

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[1] These issues are explored in detail in Pardey and Smith (2004).

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The profession's contribution in the fields of climate, climate policy and energy transition is extensive. While this review is limited to a brief consideration of the economics of climate policy and energy transition, it is important to acknowledge the broader contributions to weather-related risk analysis, the value of weather information, the impacts of drought and drought policy, and adaptation to climate change (see Quiggin and Anderson 2016 in this issue). For the most recent comprehensive review of impacts of and adaptation to climate change in Australia and New Zealand, see Reisinger and Kitching *et al.* (2014-S2).[2]

Electricity generation, and stationary energy consumption excluding electricity, is estimated to have contributed 51% of Australia's greenhouse gas inventory in 2014–2015 (Australian Government Department of Environment 2015-S2). Transport accounted for a further 17% of emissions, and agriculture (excluding land use, land-use change and forestry) accounted for 15%. Counting energy use in agriculture, this implies that over 70% of Australia's emissions arise from energy use, by far the largest share of which is derived from fossil fuels. It follows that significant reductions in greenhouse gas emissions will entail a transition in the energy sector away from fossil fuels unless economically viable carbon capture and storage becomes available. This paper therefore includes a brief review of the profession's contribution to the energy economics literature as it relates to climate policy.

The outcome of the Paris climate negotiations in December 2015 was the product of almost 25 years of effort. Garnaut (2016) characterised the process agreed at Paris as 'concerted unilateral mitigation'. In effect, this is the same as the 'pledge and review' model that was proposed as one way forward in the early negotiations on the Kyoto Protocol in the mid-1990s but rejected at the time because it was considered likely to impose commitments that were 'too weak' and not legally binding.

Early proposals in the Kyoto negotiations (advocated by the major negotiating blocs) called for the imposition of a fixed percentage reduction in emissions relative to a given base year (finally agreed as 1990) to be imposed on all developed countries, regardless of the structure of their economies. The effect of such a proposal would have been to impose widely differing costs on individual countries and because of the perceived 'unfairness' either an agreement would not have been reached or, if it had, it would have been unsustainable. In any event, the Kyoto agreement was ineffective at reaching its stated aggregate emissions reduction target because it was not ratified by the United Sates and had little impact on world emissions growth because developing countries were not bound by targets. Fisher *et al.* (1998) set out the arguments for target differentiation given the structure of the negotiations. McKibbin (1998) argued that the Kyoto agreement with its fixed targets was destined to fail. Despite the fatal flaws of the Kyoto agreement,

[2] Citations designated with an 'S2' are included in Appendix S2 in the online supporting information, along with additional references not called out here, all organised by topic.

Fisher and Matysek (2007) argued that the process itself was useful in providing crucial experience about what was politically possible in future climate negotiations. The ensuing debate both in the negotiations and publicly led to significant effort by the ANZ economics profession to understand the impact on Australia of adopting various emissions reduction targets and the trade implications of any climate agreement.

2. Economic models and climate policy

Relatively early attention was paid to the economics of the greenhouse effect in Australia (see Haynes *et al*. 1990; Beil *et al*. 1992; Hinchy and Fisher 1992; Fisher 1994, 1995 and Hanslow, Hinchy and Fisher 1994; McDougall 1993 and Marks *et al*. 1991). The very early debate on climate policy was largely driven by energy sector modellers employing so-called 'bottom-up' models such as MARKAL-MENSA, a multiperiod linear programming model of the energy sector which contained many technologies (Dalziel, Noble and Ofei-Mensah 1993-S2 and Powell 1993-S2). Such models generated relatively low estimated costs of meeting given emissions reduction targets largely because they involved assumptions that all technologies were available for use and that all were implemented at minimum cost. This led to the so-called bottom-up/top-down modelling controversy and increasing use being made of computable general equilibrium (CGE) models for policy assessments.

The dominance of CGE models in climate policy analysis occurred largely for two reason: first, because of the requirement to consider the broad trade implications of any international climate agreement and second, because of the perception that these models gave more realistic estimates of the economic impacts of policy compared with those generated by the bottom-up models. For a comparison of differences in results for various policy experiments from different classes of models, see Hourcade *et al*. (2001-S2). At the same time, some attention was paid to game-theoretic considerations of the climate change issue (see Hinchy *et al*. 1994, 1994-S2), but this avenue of research was not pursued to any great extent by ANZ economists in the ensuing climate debate largely because the policy focus was on the impacts of possible agreements rather than on how to reach an international agreement (but see Clarke 2010).

The early recognition of the likely failure of any climate negotiation based on a single percentage reduction target for all developed country participants against a given base year led to the advocacy of 'differentiated' targets by Australia, Iceland and Norway leading up to the climate negotiations in Kyoto in 1997. The concept was largely developed and modelled in Australia (see Brown *et al*. 1997; Fisher *et al*. 1998; Polidano *et al*. 1999-S2; and Jakeman *et al*. 2002-S2), and it can be fairly argued that Australian quantitative modelling played a significant role in the final outcome for Australia in the Kyoto negotiations.

From the mid-1990s, much of the analysis of the impacts of climate change policy on both the macroeconomy and on individual sectors was completed using general equilibrium models developed on the basis of earlier work on trade and domestic policy analysis using the Salter model (see Appendix S1) or macroeconomic models (see McKibbin and Wilcoxen 2013). For a comparison of the models most widely used in climate policy analysis at the time, see Pezzey and Lambie (2001).

To effectively analyse the policy complexity being debated in the international climate negotiations, significant model development was required. This led ultimately to the construction of integrated assessment models (IAMs),[3] many of which today directly couple physical models of the oceans and the atmosphere with economic models of the world economy. In addition to that complexity, the models should also account for the emissions of at least the six ‘Kyoto gases’, namely carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride. Use of such models to project global emissions trajectories is in contrast to the simpler approach outlined by Quiggin (2013).

Two main classes of CGE models were developed in Australia to analyse climate policy. Models designed to aid in the international climate negotiations such as GTEM (for documentation, see Pant 2007) and its predecessors developed in the then Australian Bureau of Agricultural and Resource Economics (ABARE), incorporated enough international country and industry sector disaggregation to allow for detailed analysis of the trade effects likely to flow from the implementation of a climate agreement. This allowed for the estimation of any ‘carbon leakage’ (the tendency for emissions to increase in countries outside a climate agreement) induced by the policies to reduce emissions; see Winchester and Rausch (2013) for an analysis of the possibilities of both positive and negative emissions leakage in CGE models, and for a more general discussion, see Winchester, Paltsev and Reilly (2011-S2); Winchester (2012-S2); and Pezzey *et al*. (2010, p. 197). For practical computational purposes, these models typically incorporated about 20 separate countries and regions and 20 to 30 industry sectors, although their underlying databases typically include many more countries and industry sectors.

At an aggregate domestic industry level, the profession has been active in its contribution to government policy reviews and emissions projections (see, for example, CIE 2013 and McKibbin Software Group 2015).

The impacts of climate change policy on the domestic economy, where significantly more sectoral disaggregation has been required than typically practical with the global models, have been conducted using models such as

[3] For a description of an early Australian IAM, see Pant *et al*. (2005) and introduction of population dynamics into such models see Fisher *et al*. (2007c). For a description of the most recent IAM version of GTEM, see Cai *et al*. (2015) and for an example of an IAM applied at the industry level, see Hanslow *et al*. (2014).

the Victoria University Regional Model – VURM (formerly known as MMRF). VURM models Australia's six states and two territories, and its current database incorporates 79 industries producing 83 commodities (Adams *et al*. 2015).[4] For an application of this model to domestic policy, see Meagher *et al*. (2014), which follows on from earlier analysis reported in Commonwealth of Australia (2008).

An alternative approach to domestic policy modelling has been to couple models at different levels of aggregation to trace the microeconomic impacts of policy change. An example is the work reported by Jiang *et al*. (2009), where the authors couple a highly aggregated global model (OZ-CUBED[5]) with a number of agricultural industry level models including some spreadsheet models in order to trace the effects of an emissions trading scheme from the international level down to the farm level.

A range of the models described above were employed in the completion of the Garnaut Reviews of climate change policy (Garnaut 2008, 2011) and the Australian government's December 2008 White Paper on the Carbon Pollution Reduction Scheme.[6]

In a contentious space such as climate change policy, it will remain the case that estimates of economic impacts derived from the climate models will be subject to criticism, and to calls in the popular press for the results to be ignored regardless of whether the results are generated from models that have been subjected to international peer review. The most important advantage of CGE models is that they take full account of indirect and feedback effects in the economy. For example, the possible contraction of output and the release of labour from one sector due to a policy change will have some offsetting effects elsewhere in the economy, resulting in structural adjustment and re-employment of at least some of that labour. Such economy-wide effects are important in considering climate policy which has the potential to have an impact on all sectors, because simple models do not properly capture these outcomes. Inputs into the policy process from these models are only one source of information for policy makers, but I predict that it will remain an important one.

3. Technology and its potential contribution to mitigation

As mentioned previously, the energy sector programming models that have been used for the analysis of climate change policy options have been technology option rich but CGE models have dominated the climate policy field in Australia. Much effort has been made to ensure that CGE models incorporate new technology options and that the models reflect real-world

[4] For a general description of the suite of Centre for Policy Studies models, see http://www.copsmodels.com/models.htm and Adams *et al*. (2013-S2).

[5] Based on G-CUBED (McKibbin and Wilcoxen 1992, 1999-S2).

[6] For a review of some of the features of the policies advocated by these reports, see Ergas (2010).

behaviour in the energy sector. For example, GTEM (Pant 2007) and its predecessor MEGABARE (Hanslow, Hinchy and Fisher 1995; Brown *et al.* 1997) incorporate a 'technology bundle' approach to both the electricity and iron and steel industries, so as to reflect the medium-term rigidity in these industries in the presence of sunk costs and resource immobility. In other words, the production structure is specified to produce a homogeneous output (electricity or steel) without the possibility that a single production technology can capture 100% of the production share, thus eliminating corner solutions.

Significant attention has been paid to the potential role of carbon sequestration due to reforestation (Polidano *et al.* 2000), land-based mitigation (Rose *et al.* 2012) abatement of methane emissions from livestock (Brown *et al.* 1999), adoption of new technology in the electricity and iron and steel sectors (Heaney *et al.* 2005-S2), and carbon capture and storage as part of the solution to reducing carbon dioxide concentrations in the atmosphere. Attention has also been paid to induced technical change in modelling climate change policy (Jakeman *et al.* 2004).

The role of innovation and new technology in assisting in mitigation, as distinct from other policy measures such as carbon taxes, has been addressed by Fisher *et al.* (2006), Matysek *et al.* (2006) and Ahammad *et al.* (2006), and the interplay between carbon pricing and technology promotion is covered by Pezzey *et al.* (2008).

4. Market-based instruments and mitigation

The recent policy controversy in Australia over the merits (or otherwise) of market-based instruments such as emissions trading or a carbon tax versus regulatory instruments (e.g. mandatory renewable energy targets in the electricity industry or the use of the federal government's Emissions Reduction Fund; www.environment.gov.au/climate-change/emissions-reduction-fund/about) is predated by an extensive literature. For example, Hinchy, Thorpe and Fisher (1993) outlined the use of side-payments to induce participation in an agreement, a concept implicitly embedded in the Kyoto agreement in the form of 'free' permits provided to some economies in transition by setting their targets well above their expected emissions levels during the first commitment period. Much of the early thinking on climate policy was collated in detail in the Department of Foreign Affairs and Trade and ABARE (1995).

In 1998, ABARE brought together a group of international climate negotiators and Australian policy experts in Sydney to discuss the wide range of issues being debated at the time arising from the introduction of an international emissions trading scheme as part of the Kyoto Protocol (ABARE 1998). This was followed by analysis of the potential benefits and impacts of emissions trading schemes by Hinchy *et al.* (1998-S2), Kennedy, Polidano *et al*. (1998-S2), Kennedy, Brown *et al*. (1998-S2), Beil *et al*. (1999), and Tulpule *et al*. (1999).

The further development of concepts for domestic Australian emissions trading led to the reports by Garnaut (2008), Garnaut 2010), the Australian government White Paper already mentioned (Commonwealth of Australia 2008), and Adams *et al*. (2014). The issues involved in emission permit auction design have been reviewed by Betz *et al*. (2010).

The profession has undertaken only limited analysis of the effects of a carbon tax, but Freebairn (2012) has considered the impacts of a change in the tax mix on the Australian economy. Economists have examined alternatives to the Kyoto Protocol (Fisher *et al*. 2004), multigas solutions (Jakeman and Fisher 2006), optimal carbon price pathways and uncertainty (Fisher *et al*. 1994; McKibbin and Wilcoxen 2002a,b), international policy coordination (Fisher *et al*. 2007a) and the detailed consideration of the trade implications of climate mitigation (Jiang *et al*. 2013). Chen *et al*. (2013) explored the regional effects of carbon pricing, Jiang *et al*. (2009) studied the farm level impacts of an Australian emissions trading scheme and Hale *et al*. (2015) and Cacho *et al*. (2003) explored the impacts on forestry and the role of reafforestation in mitigation.

5. International collaboration, international reviews and contributions of government-sponsored modelling to private firms

The collaboration of ANZ economists in the various assessment of climate change undertaken by the Intergovernmental Panel on Climate Change (IPCC) (see Fisher *et al*. 1996; Hourcade *et al*. 2001-S2, Fisher *et al*. 2007b) has led to increased and ongoing collaboration with overseas experts, particularly in the area of integrated assessment modelling and model intercomparisons (see Fisher *et al*. 2007b; Rose *et al*. 2012; McJeon *et al*. 2014).

The Stanford University Energy Modelling Forum (https://emf.stanford.edu) remains a valuable focal point for testing competing ideas and comparing model results on the wide range of policy issues of interest in climate science and emissions mitigation. The ANZ profession has regularly contributed to the forum (see for example, https://web.stanford.edu/group/emf-research/docs/emf21/EMF21FinalReport.pdf). This has provided the opportunity to ensure that economic models constructed in Australia are world class.

The empirical work undertaken in universities and government agencies has been fundamental to the establishment of economic modelling capacity that has been further developed and maintained in the private sector – another contribution of the profession that goes largely unaccounted for when counting literature citations. Examples of CGE models in this category are cited in the online Appendix S1.

6. Energy transformation and adjustment in the electricity sector

Given that the largest share of Australia's greenhouse gas emissions is generated by the consumption of fossils fuels in the production of electricity or transport services, it is clear that a significant transformation has to occur in these sectors if greenhouse gas emissions are to be abated efficiently.[7] This fact has led to a policy focus on both the energy mix in the electricity sector and energy technology and trade in energy products.

Fairhead *et al.* (2002) explored the likely impacts on energy markets in APEC countries of energy market deregulation and pointed out the likely impacts of uncoordinated deregulation across sectors within countries. For example, deregulation of the coal industry without coordinated deregulation of the gas industry is likely to lead to increases in coal use compared to gas. This would increase greenhouse gas emissions overall because, compared with natural gas, coal is typically about twice as greenhouse gas intensive per megawatt of electricity produced. Heaney *et al.* (2005-S2) set out a comprehensive description of new energy technologies and their likely impacts in the Asia–Pacific region together with emission trajectories for the major APEC economies. The technical data collected for this analysis helped form the basis for the technology pathways incorporated in subsequent ABARE analysis of climate change policy.

In his survey of the possible impacts of an emissions trading scheme on the electricity generating sector, Lambie (2010) pointed to the many design factors likely to have an important influence on behaviour. They included how emissions permits are initially allocated, the credibility of the targets, and whether participants can bank and/or borrow permits. Determining the influence of climate change policy on emissions from the electricity sector is complicated by a number of factors. First, policy uncertainty has made it difficult for the industry to make rational long-term investment decisions. The proposal for an emissions trading scheme was replaced in the initial years of implementation by a carbon tax which was in place from July 2012 to July 2014. This tax was abolished and subsequently replaced by a project-based scheme financed directly by the government from the Emissions Reduction Fund (ERF) (www.environment.gov.au/climate-change/emissions-reduction-fund).

Second, if the single goal of climate policy was to reduce emissions, then one economically efficient instrument should be sufficient. However, the government has stated that the ERF will operate alongside other policies, including the renewable energy target[8] and myriad regulations on energy

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[7] For a comprehensive description of Australia's production and use of energy, see Australian Government Department of Resources, Energy and Tourism (2011-S2). For long-term energy projections, see BREE (2014-S2), which includes a description of the energy forecasting model originally developed in ABARE. For a contribution to emissions projections, see Garnaut (2008-S2).

[8] For a description of the initial renewable energy target (RET) and its potential economic impacts, see Melanie *et al.* (1998) and Naughten and Noble (2001). For a full history of the RET in its various forms up until 2014, see Warburton *et al.* (2014).

efficiency. These policies do not necessarily lead to consistent outcomes. For example, Fisher *et al*. (2012) show that the combination of a renewable energy target and an emissions trading scheme is less efficient than an emissions trading scheme alone in reaching the same emissions abatement target. In addition, a renewable energy target was shown to force gas out of the generation mix in favour of coal, thus driving aggregate emissions higher than they otherwise would have been, contrary to stated policy. As Bennett (2012, p. 38) points out, 'Interventions that mandate change or seek to manipulate the process of change are likely to be counterproductive'.

Third, policies designed to reduce emissions in the electricity sector were imposed at the same time as the effects of a range of energy market reforms, introduced in the 1990s, were playing out.[9] In addition, contrary to earlier expectations, electricity demand fell over the past decade because of restructuring in the Australian industrial sector, including the closure of a number of smelters. The combined effects of these factors made it difficult for modellers to determine the correct counterfactual against which to compare their policy modelling.

7. Current issues and future directions

At the time of my appointment as a lecturer in agricultural economics in 1976 at the University of Sydney, Professor Keith Campbell remarked to me that if I had an interest in influencing agricultural policy, I could expect to wait 25 years between the time of having a good policy idea (on the bold assumption that I ever had a good idea) and its implementation by government. Perhaps such a lead time is an overestimate in the case of agricultural policy but it is certainly relevant in the case of the international climate negotiations – patience and detailed analysis continue to be paramount.

Much remains to be done in understanding the political economy of the international climate negotiations and what will drive effective international cooperation. Perhaps an effective deal will only be struck once there is convincing evidence that the two largest single emitters, the United States and China, are imposing damages on themselves costly enough to warrant their joint action. This implies that there is a need to better understand climate damages as well as the costs of abatement, although it is crucial to understand the costs of action because political processes tend to focus on shorter-term costs at the expense of longer-term and less certain benefits.

Over the past decade, much of the federal government's climate modelling expertise and analytical models have dissipated. It could be argued that the large investment in this field undertaken by ABARE in the 1990s and the first half of the following decade crowded out investment in this field by the private sector. However, much of the private-sector modelling that has

[9] For a description of these reforms, see Bush *et al*. (1999, pp. 9–21).

developed has built on the expertise developed by ABARE and other government-sponsored quantitative modelling work, and to some extent, it has relied on staff originally trained within government. In any event, change in the location of modelling expertise points to the future need for more interaction between the private sector and government in policy development. This will require goodwill on both sides.

Climate change and climate change policy continue to generate much political debate, much of which is far from rational and often only loosely based on facts. There continues to be an important role for model development (particularly of the global IAMs) and use of those models to analyse climate policy and possible emissions and climate trajectories. The research infrastructure required to develop and properly support an IAM is significant. This raises the question of whether governments will need to increase their support for this type of modelling in the future if Australia is to keep up with its peers in the field.

In addition to quantitative analysis, there is also an important role in distilling the facts and highlighting the incentives that drive economic agents in the energy field. For example, future changes in electricity network and distribution charges and their share of total electricity prices could accelerate the adoption of renewable energy technology by consumers, particularly those in remote locations. An important challenge here will be providing policy makers with an understanding of how such trends will influence the uptake of off-grid power solutions and the risk of stranding grid assets so that needed electricity market reforms can be debated in a timely way.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1 CGE models.

Appendix S2 Additional references.