Efficacy of emissions trading schemes in Australia

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Table of Acronyms, Abbreviations and Units

Acronyms, Abbreviations and Units	Description
ABS	Australian Bureau of Statistics
ACCC	Australian Competition and Consumers Commission
ACT GGAS	Australian Capital Territory Greenhouse Gas Abatement Scheme
AEMO	Australian Energy Market Operator
AFMA	Australian Financial Markets Association
AR	Autoregressive model
AUD	Australian Dollar
CDM	Clean Development Mechanism
CEFC	Clean Energy Finance Corporation
CER	Clean Energy Regulator
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent and measures the global warming potential of the six greenhouse gases equal to one unit of carbon dioxide
COP	Conference of Parties
CPRS	Carbon Pollution Reduction Scheme
CSIRO	Commonwealth Scientific and Industrial Research Organisation
ESC	Energy Savings certificate
ESS	NSW Energy Savings Scheme
ETS	Emissions trading scheme
EU	European Union
EU 27	The 27 European Union countries
EU ETS	European Emissions Trading Scheme
GEC	Gas Electricity Certificate
GHG	Greenhouse gas
GIRF	Generalised impulse response function
GVD	Generalised forecast error variance decomposition
GWh	Gigawatt hour
IEA	International Energy Agency
IPART	Independent Pricing and Regulatory Tribunal of NSW
IPCC	Intergovernmental Panel on Climate Change
JI	Joint Implementation
LGC	Large scale generation certificate
LRET	Large Scale Renewable Energy Target
LRSM	Long-run structural modelling technique
MRET	Mandatory Renewable Energy Trading Scheme
Mt	Megaton
MWh	Megawatt hour
NEMMCO	National Electricity Market Management Company Limited
NGAC	NSW Greenhouse Gas Abatement Certificates
NGAS or GGAS	New South Wales Greenhouse Gas Abatement Scheme
NSW	New South Wales
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary least squares
ORER	Office of the Renewable Energy Regulators
REC	Renewable Energy Certificate

REDD	Reducing Emissions from Deforestation and Degradation
RET	Renewable Energy Target Scheme
RPP	Renewable Power Percentage
SRES	Small-scale Renewable Energy Scheme
STC	Small-scale technology certificates
UNFCCC	United Nations Framework Convention on Climate Change
US or USA	United States of America
VAR	Vector autoregression
VECM	vector error correction model
VEET	Victorian energy efficiency certificate
VREC	Victorian Renewable Energy Certificate
VRET	Victorian Renewable Energy Target Scheme

Abstract:

The aim of the thesis is to bridge the gap between the research conducted in Europe and the USA and the situation in Australia in relation to the efficiency of market based climate change mitigation schemes. The thesis is motivated by the gap in research covering what action on mitigation is occurring in Australia and what the Australian public actually wants in relation to climate change mitigation. The analysis of responses to our survey of the Australian public revealed a wide range of responses to questions on the expected effects of climate change, appropriate policies and whether action should be taken. The dominant view was that the Australian Government should take action on climate change irrespective of international agreement. Two studies were undertaken to test the efficiency of already existing emissions trading markets in Australia with the second using a generalised forecast error variance decomposition analysis technique for the first time on this type of market. It then undertook generalised impulse response function analysis which indicated that when shocks are applied to the electricity prices by the two schemes it returns to equilibrium very quickly. Our research on the efficiency of the market-based schemes found them to be largely inefficient and this is in line with some of the existing International research. While some research has been undertaken internationally to determine why this may be the case, this thesis took current techniques for conducting research on financial markets and applied them to these schemes. The behavioural aspects of the market were analysed and we found evidence that market ambiguity is a factor in the inefficiency. This analysis of actual markets is among the first of its kind on ambiguity in markets. This thesis contributes to existing research in areas either not previously analysed in this depth and by using new research methods. It will benefit both future research and climate mitigation policy direction.

Statement of Candidate

I certify that the work in this thesis entitled "**Efficacy of emissions trading schemes in Australia"** has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree to any other university or institution other than Macquarie University.

I also certify that the thesis is an original piece of research and it has been written by me. Any help and assistance that I have received in my research work and the preparation of the thesis itself have been appropriately acknowledged.

……..

Deborah Joan Cotton

In addition, I certify that all information sources and literature used are indicated in the thesis.

The research presented in this thesis was approved by Macquarie University Ethics Review Committee, reference number:

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Approval document attached at the end of the thesis.

Academic papers in thesis

Chapter	Paper	Published	Presented
2	Emission mitigation schemes in Australia – the past, present and future – co-author Professor Stefan Trück (5%)	Low Carbon Economy, 2013, 4, 80-94	Low Carbon Earth Summit, 19-26 October 2011, Dalian, China
3	Climate Change: Level of concern and policy preferences - co-author Professor Stefan Trück (10%)		1. Third International Conference on Climate Change: Impacts and Responses, 21-22 July, 2011, Rio De Janeiro, Brazil – received Graduate Scholar Award. 2. Climate Futures Forum, November, 2011 – received $500 prize for best presentation
4	Interaction between Australian carbon prices and energy prices – co-author Professor Stefan Trück (10%)	Australasian Journal of Environmental Management, 2011, 18 (4), 208-222	Seminar, March, 2011, University of Technology, Sydney
5	Econometric analysis of Australian emissions markets and electricity prices – co-	Energy Policy, 2014, 74, 475 – 485	9th International Conference on Applied Financial Economics, 28-30 June, 2012,

	author Dr Lurion De Mello (10%)		Samos Island, Greece
6	Ambiguity in Markets: A Test in an Australian Emissions Market	ACRN Journal of Finance and Risk Perspectives, 2014, 3 (4), 99 - 119	Behavioural Finance Working Group/Mergers and Acquisitions Centre Conference, CASS Business School, 21-22 June, 2012

Chapter 1

1. Introduction

1.1 Overview

This thesis aims to contribute both locally and globally to the mitigation of climate change. Due to the highly political nature of climate change mitigation around the world, the views of the public are paramount to any method's success. The contribution of this thesis is in the form of analysis into the emissions trading schemes currently operating in Australia. This analysis provides information on the efficiency of these schemes and the possible causes of existing inefficiencies. These results can also be indicative of likely results globally. The terminology of efficacy, efficiency and effectiveness are used throughout this thesis with the understanding that all these terms can be defined as the capacity or competency to produce a desired result. This chapter describes the issue of climate change in terms of what it is and how it is evolving. It also looks at the major mitigation methods currently in use globally and the basic economics behind these methods. It then provides an overview of the remaining chapters and their contributions to the current literature and understanding of the Australian situation.

1.2. Climate Change

Climate change is an issue that is the perfect example of a tragedy of the commons. This concept was explained by Hardin (1968, p. 1244) in regards to pollution:

> it is not a question of taking something out of the commons, but of putting something in -- sewage, or chemical, radioactive, and heat wastes into water; noxious and dangerous fumes into the air; and distracting and unpleasant advertising signs into the line of sight. The calculations of utility are much the same as before. The rational man finds that his share of the cost of the wastes he discharges into the commons is less than the cost of purifying his

wastes before releasing them. Since this is true for everyone, we are locked into a system of 'fouling our own nest' so long as we behave only as independent, rational, free enterprisers.

Climate change fits this description perfectly as not only is it something that is not easily seen by people, but also there is not unanimous agreement that it is a problem. Litter and the wider problem of waste, for example, can easily be seen; the piles of rubbish we produce are easily visible, and so are the problems councils and other organisations have trying to deal with them. We are charged a fee by the council to get rid of our rubbish and we are encouraged to recycle and reduce our waste continually through Australia-wide and local campaigns. However, climate change requires more scientific knowledge, this in many ways makes it much more difficult for the general public to understand the problem, and to feel responsible not only for its occurrence but also for the changes that are required to ameliorate it.

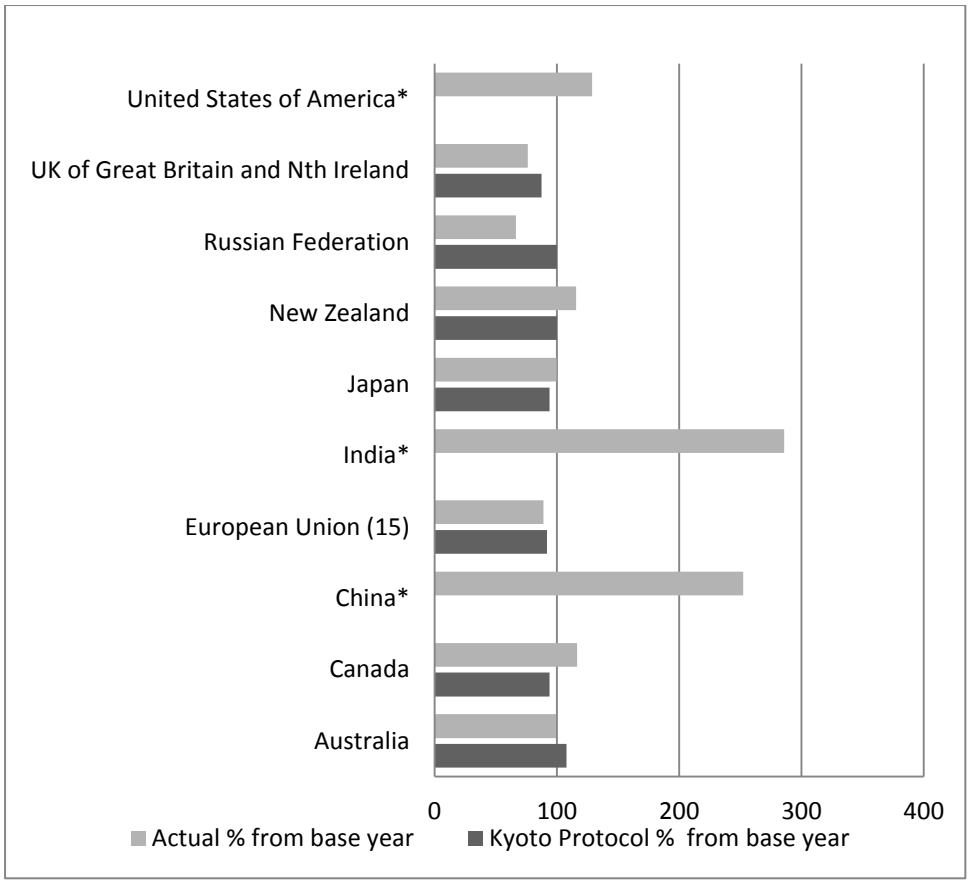
Climate change is a global issue which requires understanding from a multidisciplinary perspective. Initially, understanding it is purely a scientific matter, however once we begin to look at how we, as a global community, are going to be able to solve the problem it becomes clear that it involves a vastly diverse range of stakeholders. These stakeholders are not only the contributors to the problem but also the problem solvers.

Before looking into the different aspects of climate change it may be worthwhile explaining what the difference is between the terms 'climate' and 'weather'. Weather refers to short term and often fast changing conditions of the atmosphere in a specific location that are influenced by movements of air masses. Climate refers to average weather conditions that occur over long periods of time. While weather may be measured in days or months, climate is measured in terms of years and decades. Climate change involves systematic changes in trends over the long term, of warmer or cooler summers for example. In reference to climate change, much of the emphasis is placed on the concentrations of greenhouse gases (GHGs) in the atmosphere and what is known as the greenhouse effect.

Dieter Helms' second chapter in *The Economics and Politics of Climate Change* (2009) discusses the limited response on a global level so far to the problem of climate change. He suggests that, even though the United Nations Framework Convention on Climate Change (UNFCCC) agreed in 1992 to international scientific collaboration and achieved the setting of targets in Kyoto in 1998, little has actually been achieved. In part he suggests that the lack of any binding agreement involving the United States of America, and the absence of mitigation targets for China and India, are responsible for this. The emission limitation commitments, shown in Figure 1.1 are a likely indication of disengagement by the population due to the tragedy of the commons scenario and the lack of any real political desire in many countries. Figure 1.1 shows the quantified emission limitation or reduction commitments under the Kyoto Protocol (as percentages of base year or period levels) compared to actual CO_2e emissions as percentages of base years. Note that India, China and the United States of America have not ratified or agreed to the commitments under this Protocol. The targets set by the UNFCCC aim to stop the increase in emissions so that atmospheric concentrations of CO_2e[1] stabilise at between 450 and 550 parts per million. These levels were initially determined due to their likely link to an increase in average temperatures of around 2^0 Celsius. More recent research suggests that this should be limited to 400 to 450 parts per million to restrict increases to 2^0 Celsius. Research by the Swedish Environmental Protection Agency among others indicates that this level can be used as a threshold, as temperature increases above that level would be significantly more difficult to ameliorate. They also indicate that in order to achieve this, the stabilisation of the parts per million of CO_2e would require global emissions to peak in 10 to 15 years and decrease after that prior to the end of the century.

[1] CO_2e denotes the carbon dioxide equivalent and measures the global warming potential of the six greenhouse gases equal to one unit of carbon dioxide.

Figure 1.1: Quantified emission limitation or reduction commitment (percentage of base year or period level) compared to actual percentage of base year in CO_2e



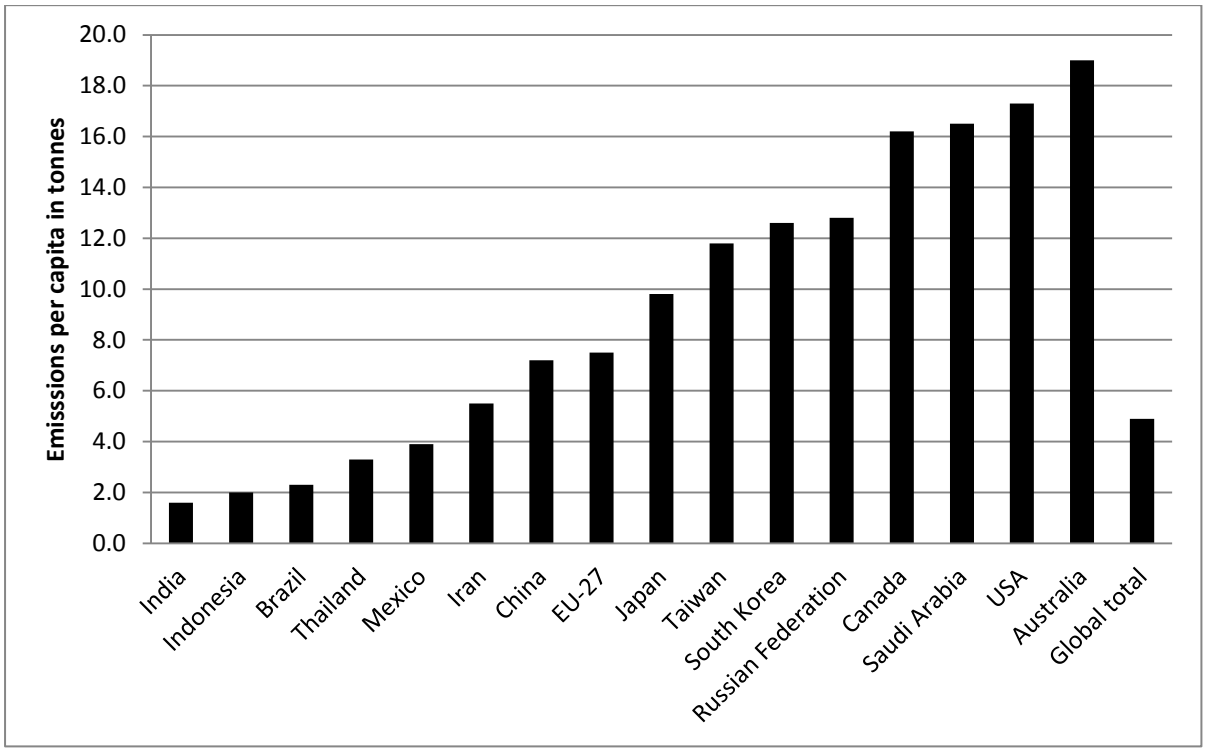
Note: the countries signified with * show the change in CO_2 emissions for 2008 compared to the base year of 1990, the data source is the World Bank. All other countries' data is from the UNFCCC.

The figure shows a wide variety of results in regards to emission changes with India and China increasing their levels significantly over the period, while many of the European countries have been able to reduce their emissions by a greater level than the one required under Kyoto. The global trends of increasing population, energy demand and transport continue to make these reductions increasingly difficult for each country to achieve. It is worth noting that some of the better than expected results have been assisted by the global recession. While the world's population tripled during the 20th century, it is expected to increase from around six to nine billion by 2050. These increases in population also naturally increase the demand for energy, food and transport. The

International Energy Agency (IEA), in their World Energy Outlook 2012, state that energy reduction targets are being set by some of the most energy intensive economies including China which is targeting a 16% reduction by 2015, the European Union which has a 20% reduction target in energy demand by 2020 and Japan which is targeting a 10% cut in electricity consumption by 2040.

Australia produces a relatively low level of total CO_2 emissions, however, when this data is presented on a per capita basis, Australia ranks as the world's largest emitter of CO_2. This fact has been a difficult one for Australia as many argue that, as a relatively small emitter overall, anything done in Australia will have a small effect on global emissions. The large per capita level though gives a strong indication of a lack of will to reduce emissions. This is discussed further in Chapters 2 and 3, when looking at what Australia is currently doing and what the population believes should be done.

Figure 1.2: Per capita CO_2 emissions in 2011



Source: PBL Netherlands Environmental Assessment Agency, Trends in Global CO_2 Emissions; 2012 Report

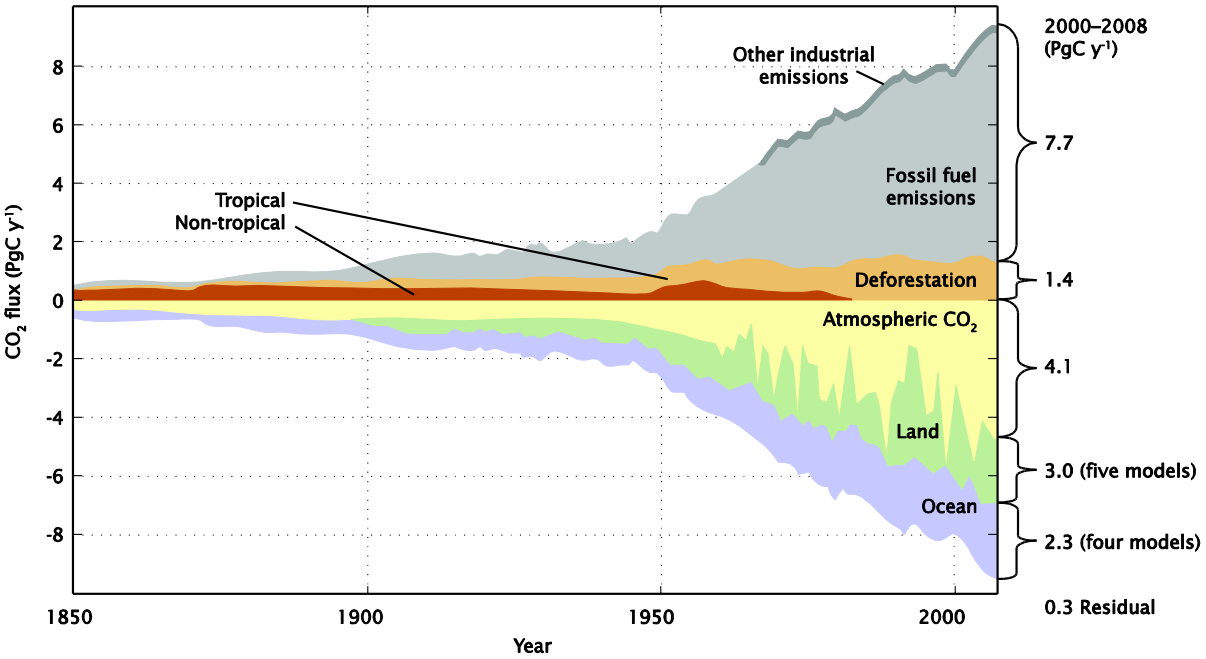
The greenhouse effect is natural and allows humans to exist on Earth. It is the increased anthropogenic impact that is the concern of most scientists. The Intergovernmental Panel on

Climate Change (IPCC) was established in 1988 by the World Meteorological Organisation and the United Nations Environmental Program to evaluate the existing climate science in order to inform government agencies. The IPCC primarily bases its findings on peer reviewed and published scientific literature in a similar manner to the Commonwealth Scientific and Industrial Research Organisation (CSIRO). Chapter 2, section 2.3.1 second paragraph in the IPCC's Fourth Assessment Report, from Working Group I: The Physical Science Basis, explains the relatively recent changes to the greenhouse gas layer:

> the first 50 ppm increase above the pre-industrial value was reached in the 1970s after more than 200 years, whereas the second 50 ppm was achieved in about 30 years. In the 10 years from 1995 to 2005 atmospheric CO_2 increased by about 19 ppm; the highest average growth rate recorded for any decade since direct atmospheric CO_2 measurements began in the 1950s.

According to Karl and Trenberth (2003) "The main source of global climate change is human-induced changes in atmospheric composition" (p. 1719). They state that greenhouse gas emissions are predominantly the result of the burning of fossil fuels and the production of methane and nitrous oxide from other human activities, and that these gases are cumulative in the atmosphere. This information is corroborated by the CSIRO (2011). The CSIRO findings are based on rigorous peer-reviewed scientific literature and the conclusions are drawn from the research conducted by the CSIRO itself as well as other Australian and international researchers. Figure 1.3 provides an indication of some of the anthropogenic sources of increased CO_2 in the atmosphere. This shows the significant impact of fossil fuels which is the subject of Chapter 3 of this thesis.

Figure 1.3: Sources and Sinks of atmospheric CO_2



Source CSIRO (2011) Note: Sources and sinks of atmospheric CO_2. Those above the zero-line represent anthropogenic additions to the atmosphere (inflows); those below are sinks for CO_2 (outflows), together with the accumulation in the atmosphere. Units are in petagrams of carbon per year (Pg = petagram; 1 petagram = 10^{15} grams = 1 billion tonnes). The small residual reflects minor discrepancies in independent measurements of different terms.[15] Printed with permission of CSIRO 19/4/2013

1.3. Mitigation Methods

There are a range of mitigation methods currently in use and proposed for the mitigation of climate change. While these schemes have differing methods of reducing these emissions the overall goals are effectively the same. Some are viable on a global basis and others are only possible on a regional or country-specific scale. The largest type in Australia has been the renewable energy trading scheme. This type of scheme aims to increase renewable energy as a source of electricity and will usually have a goal percentage e.g. the Mandatory Renewable Energy Trading Scheme in Australia has increasing goals to 20% by 2020. The cap and trade scheme is probably the better known type as this is the system used in the European Emissions Trading Scheme where an overall emissions cap is

set to achieve emission reductions. Under this mechanism participants can generate credits where they have had emission reductions relative to the baseline, this is argued by some to be preferable as it reduces the cost pass on that occurs under some other schemes. In Australian the NSW Greenhouse Gas Abatement scheme was probably the largest of this type and it set benchmarks for the level of carbon dioxide equivalent of greenhouse gas emissions allowed per capita in NSW. This and the MRET are covered in greater detail in Chapter 2. A baseline and credit scheme sets emissions intensity baselines for certain emitting activities. All these are market based instruments and allow trading to occur to benefit from reductions and purchase credits when/where needed.

There are however many other options for policy makers to consider which, as the next chapter indicates, are being implemented in Australia currently. The IPCC Technical Paper 1 on Technologies, Policies and Measures for Mitigating Climate Change (1996) and the IPCC Climate Change 2007: Synthesis Report provides an overview of the current methods in use. As climate change is a global issue there have been a number of schemes introduced that deal specifically with the international nature of the problem. Some are already being implemented while others are not operating and are less likely to occur due to the level of international agreement that would be required. An international tax would require an overriding agency to impose it, or it could be agreed that at a domestic level a comparable GHG tax be imposed. This would be extremely difficult to negotiate, in particular in the current economic climate. Countries may also negotiate specific emissions limits, not unlike those already agreed upon by the signatories to the Kyoto Protocol. They may then be able to trade their quotas internationally, thereby allowing those countries who can more easily reduce their emissions to trade with those who cannot. The European Union is already applying this concept to some extent in the European Emissions Trading Scheme (EU ETS), which in the future may be tradable with an Australian scheme.

Under the Kyoto Protocol a mechanism known as the Joint Implementation (JI) was set up. This allows one Annex 1 country to invest in an emission reduction project in another Annex 1 country.

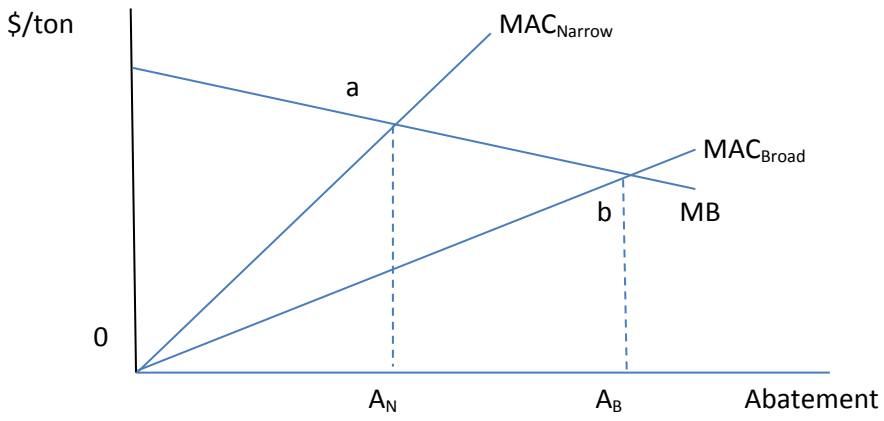
They are then able to have the emissions credits for the project to be transferred to them. An Annex 1 party is any one of the industrialised countries that is a member of the OECD or any country with an economy in transition (i.e. the Russian Federation, the Baltic States and other central and eastern European states). A project must provide emission reductions greater than the reductions that would otherwise have occurred. Another international emission reducing agreement under the Kyoto Protocol is the Clean Development Mechanism (CDM). This provides for emission reducing projects to be undertaken in developing countries to earn certified emission reduction credits which can then be traded and sold. Industrialised countries which are a party to the Kyoto Protocol can use these credits to meet their emission reduction targets. Climate Focus, an independent expert in international and national climate law, claim that these flexible mechanisms have generated 4.5 billion tonnes of greenhouse gas emissions reductions since 2003 (Climate Focus 2014).

There are a few slightly different Reducing Emissions from Deforestation and Degradation (REDD) schemes. The UN-REDD program was developed by the United Nations to assist countries to prepare and implement programs under the REDD+ strategy. The REDD is a program used to create incentives for developing countries to better protect and manage their forest resources. It does this by providing a mechanism where a developed country can pay a developing country for carbon offsets for their standing forests. Similar programs hosted by the World Bank include the Forest Carbon Partnership Facility and the Forest Investment Program. All these programs assist in raising funds for REDD activities. The UN REDD Program website states that as at June 2014 there are 53 partner countries across Africa, Asia-Pacific, Latin American and the Caribbean. These countries are the locations of 34% of the world's forests and 56% of the world's tropical forests, which indicates this program is achieving a broad coverage.

The IPCC issued a report on technologies, policies and measures for mitigating climate change in 1996 (IPCC, 1996) which encompasses the main mitigation measures still in use. These include subsidies which may involve a transfer of funds or preferential tax treatment for conducting

activities that reduce GHG emissions. Similarly, they may include the withdrawal of subsidies that previously were in place, for example those that reduce the cost of fossil fuels. Such withdrawals of subsidies increase the cost of fossil fuels and in turn reduce the economic benefits of their use.

Figure 1.4: Illustrative Economic Benefit from Broadening Tax Base



Source: Metcalf and Weisbach (2009)

Where: $/ton = dollar cost per ton of abatement

MAC_{Narrow} = Marginal Abatement Cost of a narrow base

MAC_{Broad} = Marginal Abatement Cost of a broad base

MB = Marginal Benefit of Abatement

A_N = Abatement of narrow base

A_B = Abatement of broad base

In Australia in 2012 a carbon pricing mechanism, similar to a carbon tax, was introduced. A carbon tax imposes a tax, or penalty, on polluters generally per tonne of carbon released into the atmosphere. The proposal in the Australian carbon pricing mechanism was to set a tax of $23 per tonne initially increasing it gradually over time. This type of scheme to reduce emissions has been quite popular internationally with schemes in Canada and the United States of America within specific provinces or states. Nationwide schemes have been implemented in India, South Korea, Japan, Finland (the worlds' first in 1990), The Netherlands, Sweden, Norway, Denmark, Switzerland, the United Kingdom, Ireland, Costa Rica and South Africa. These schemes range from taxes on fossil

fuels to taxes on new vehicle sales. Taxes can be implemented on a domestic or international level however international schemes require a great deal of cooperation among those countries wishing to participate. At a domestic level the tax, or more appropriately, in some cases, the fee, requires those sources producing the highest levels of greenhouse gas emissions to pay an amount per unit of emissions, generally when emissions go above a set limit. Ideally all activities that produce climate externalities should be included in a tax however the measurement of many of these would be extremely difficult if not impossible. The tax base should be broadened until "the benefit of a small expansion in the base is equal to the increase in administrative or compliance costs" (Metcalf and Weisbach 2009, p. 521). Figure 1.4 below provides an illustration of the broadening of a tax base. The triangle Oab shows the marginal benefit from broadening the tax base.

If the tax is administered on CO_2 emissions then this would include taxing those companies who are large users of energy, and this would mean that the cost of all goods would increase with only a relatively limited ability for these companies to reduce their energy use. If the tax is only placed on the carbon content of fossil fuels, then this may create a desire for companies to change to more renewable and less carbon intensive sources of energy, thereby directly reducing GHG emissions. This type of economic instrument sets a price directly on the emissions. Hepburn (2009) argues that in a market such as this, where the appropriate response varies between firms and the regulator is uncertain about individual firm costs, economic instruments such as markets are the most appropriate. A tax sets a price on carbon content and not a quantity target while an emissions trading scheme sets a quantity on allowable emissions and not a price.

The idea of tradeable quotas or permits, often known as an emissions trading scheme, has been used in Australia since 2001. This is a market-based instrument where, in general, the quotas are prescribed by government regulation and the parties who are required not to exceed these quotas may trade their emissions permits with each other in a prescribed market. There are many different forms that this type of system can take, including state- or province-based schemes. Such schemes

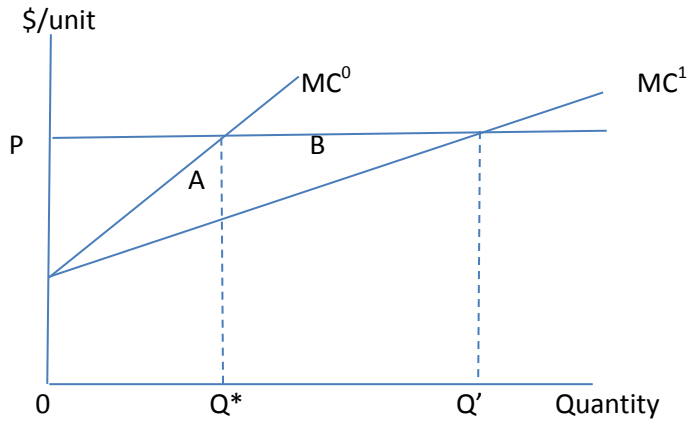
exist in China (which is moving to a nationwide scheme in 2015), the United States of America, Canada and Japan. South Korea will be starting a nationwide scheme in January 2015 and Brazil is currently looking at implementing one too. New Zealand's emissions trading scheme began by only covering the forestry sector but now includes stationary energy, transport, liquid fossil fuels and industrial processes. One of the better known schemes is the EU ETS which covers 27 European Union countries and the three non-European Union countries of Iceland, Liechtenstein and Norway. An emissions trading scheme allows the market, or companies involved in the market, to determine how best (cost efficiently) to keep within the quotas that are set. The government will usually provide or sell the tradable allowances to individuals or firms who are then able to trade them in a market created specifically for this purpose. How the permits are issued has had an important influence on the efficiency of the EU ETS. The usual methods include auctioning of permits or allocating them via a grandfather clause. In the grandfathering of permits they are allocated according to past usage, by some measure of previous output of emissions, or it may be based on political expediency. This way more control is in the hands of the politicians as to the distributional effect of the regulations. Betz, Rogge and Schleich (2006) state that from an economic perspective auctioning is preferable to grandfathering as it avoids most of the distributional problems which result in inefficiencies. These inefficiencies include excess allocations which may be due to overestimations on the part of the company or government. These have in the past been seen to provide windfall profits to some companies who can continue with their existing level of emissions while selling off the oversupply. It has been found that these companies will often pass costs on to their customers which they have not incurred (Sjim, Neuhoff & Chen 2006; Woerdman, Couwenberg & Netjes 2009). Auctioning provides greater transparency and ensures the application of the polluter pays principle. Betz et al. conclude that the grandfathering done by many of the countries party to the EU ETS has meant a greater cost to many sectors of the economy. Cramton and Kerr (2002) describe a number of different methods of auctioning including sealed-bid, ascending and descending-clock auctions. They argue the best approach is to auctioning on a regular basis where so

that revenue for the government can be applied to providing efficiency benefits. Cramton and Kerr (2002, p. 344) recommend carbon permits with a simple homogenous design and auctioning using an ascending-clock auction method described by them as follows;

> The auction begins at a low price. With each round, the bidders are asked what quantity they demand at the price posted on the auction clock. If there is excess demand, the price is increased. This process continues until the excess demand falls to zero. The bidders then receive their quantity bid at the final price. This auction generates a uniform price for carbon permits. All bidders get their demands at the market price. A secondary market will allow the sale and purchase of permits as circumstances change.

The goal of all of these policies is to encourage a reduction in emissions which is likely to occur due to changes in practice which may involve the use of new technology. Maleug (1989) shows, (see Figure 1.5), how firms may be encouraged to adopt new technology, even if it is more expensive, in order to reduce the costs associated with compliance and the ability to sell the excess permits in the market. With trading, the firm will be able to sell its excess permits (Q' – Q*) achieved by using the new technology, thereby effectively reducing its costs to area B from area A.

Figure 1.5: Costs and Incentives of New Lower Emission Technology



Where: MC^0 = firm's marginal cost of reducing emissions using current technology

MC^1 = firm's marginal cost of reducing emissions using new technology

Q* = amount by which the firm is required to reduce its emissions under emissions trading scheme

Q' = the amount by which the firm will reduce its emissions when using the new technology

A = the amount by which the firm would reduce its costs with new technology with no trading

B = the amount by which the firm would reduce its costs with new technology with trading

Hepburn (2009) suggests that while both quantity and price policies benefit from their simplicity, their introduction as sole policy measures may be inefficient. He suggests that a hybrid, a combination of price and quantity instruments, may better serve from an economic and an effectiveness viewpoint. He argues that many countries with emissions trading schemes impose penalties for non-compliance which effectively become the price component for a hybrid scheme. Likewise many countries have multiple policy instruments which may involve subsidies, taxes, emissions trading schemes and other measures running simultaneously. This is often as a result of different levels of government introducing differing policy instruments and also the political ramifications of introducing a large and unpopular policy instrument. To some extent this can be seen in the next chapter of this thesis which provides an overview of the policies in Australia.

Research and development is a key initiative for many countries, on both a nationwide and international level, which is most likely to provide the reductions in CO_2-e emissions that are proposed in, for example, the Kyoto Protocol. In Australia the CSIRO is conducting a great deal of research into ways to reduce emissions. These particularly apply to the electricity sector as it produces 35% of Australian greenhouse gas emissions. The research includes the use of solar thermal power, solar photovoltaics, hot fractured rocks and coal with CO_2 capture and storage to supplement the use of gas and wind power. In the transport sector it includes investigating the

possibility of moving to fully electrified road transport and the use of biofuels, hydrogen and natural gas as alternative fuel sources. In the agricultural sector the challenges are not only emissions reduction but also catering for the increasing demand for food due to rapid population increases. The CSIRO believes that Australia has strong potential for carbon sequestration in forests and soils, however, this may reduce the food production capabilities of the soil. They are currently undertaking a great deal of research into increasing productivity through the more efficient use of land, water, nutrients and energy resources.

1.4. Summary of the following chapters

Chapter 2 provides information on the emissions mitigation schemes currently and previously operating in Australia. This chapter, "Emissions Mitigation Schemes in Australia – the past, present and future", was published in *the Low Carbon Economy Journal*, 2013 Volume 4 pp. 80 – 94. It shows how Australia was an early adopter of emissions trading schemes with its main scheme, the Mandatory Renewable Energy Trading Scheme. The scheme commenced in April 2001, nearly four years before the EU ETS. This federal scheme is still in operation today, but is currently under review by Federal Coalition Government. The goal of this scheme is to encourage additional electricity generation from renewable sources. To this end it has an increasing requirement for renewable energy which increases each year. The final aim is to ensure 20% of Australia's electricity supply to be sourced from renewable energy by 2020. Other schemes have been introduced by the states over the years, with the first being the NSW Greenhouse Gas Abatement Scheme in 2003, it and the federal scheme are analysed in Chapters 4 and 5 of this thesis. The trading in these schemes has been fairly low, relative to the EU ETS for example, however the schemes have been long running. The NSW scheme aimed to reduce greenhouse gas emissions and used benchmarks. The scheme ceased operation in June 2012 with the introduction of the carbon pricing mechanism by the then Federal Labor Government. This chapter also describes similar schemes operating in NSW, Queensland and Victoria. It makes a valuable contribution to the academic literature by providing an

overview, including key details of the schemes. This has not previously been done. It also provides an easy access to information for Australian and international businesses who may have operations or desired links that fall within the scope of these schemes. An appendix to this chapter provides updated information on the continuation and changes to these schemes and climate change policy in Australia since the paper was written. This information was up-to-date in January, 2014.

Climate change policy has been a highly volatile issue in Australia, with political leaders winning and losing their positions due to their stances on this issue. There have been some relatively localised surveys done of the Australian public on their views of climate change and climate change policy, however, there was a gap in the research for Australia-wide opinion. Chapter 3 is a paper based on the results of an Australia-wide survey to determine views, not only on climate change as an issue, but also on what type of policy was preferred, including sectoral coverage and what subsidies should be provided. The survey effectively replicated the Australian voting age public in gender, age and state distribution. The survey provided information on what was meant, specifically for survey purposes, by 'a cap and trade scheme' and 'a carbon tax'. It also gave an overview, based on CSIRO research, of what climate change is, and what its effects have been in Australia. This was similar to a methodology used by Lee and Cameron (2008) in their US study. Lee and Cameron's methodology was based on earlier research by Cameron (2005) who found prior information was an important determinant in survey responses. Of particular interest to this thesis were the views of the Australian public on climate change as an issue and what sort of policy should be enacted by the government. It found that over 50% of respondents want Australia to proceed on climate change policy irrespective of whether there is international agreement. A further 32.9% supported Australian action in the event of an international agreement. When looking at the policy choices, a policy mix was the preference of over 30% of respondents with a cap and trade scheme at 25% and a carbon tax at around 17%. Of those who chose no policy, around 12% indicated that they were opposed to an Australian policy unless there was global action. This paper, "Climate Change: Level of concern and policy preferences in Australia", has been submitted to *Global Environmental Change*

for review. This is the first paper of its kind in Australia to survey the whole nation and conduct in-depth analysis of its beliefs and views on climate change. The survey questions used are included in an appendix to the chapter, as are some additional results and demographic details.

The analysis of the effect of the major emission trading schemes in Australia, the Mandatory Renewable Energy Trading Scheme (MRET) and the New South Wales Greenhouse Gas Abatement Scheme (NGAS), commences in Chapter 4. This paper, "Interaction between Australian carbon prices and energy prices", was published in the *Australasian Journal of Environmental Management* in 2011 volume 4 pages 208-2011. As discussed in this chapter, the aim of the MRET is to increase renewable energy as a source of electricity and the aim of the NGAS is to reduce greenhouse gas emissions. In Australia the energy sector contributes 76% of the greenhouse gas emissions with the energy industries relating to combustion of fossil fuels contributing 54% (Australian Bureau of Statistics, 2010). Therefore, it can be seen that the electricity sector is a major contributor to greenhouse gas emissions, making it an important target for the NGAS and the main aim for the MRET. This chapter analyses the relationship between the prices of the traded certificates of the MRET and the NGAS and wholesale electricity prices in Australia. A relationship is anticipated, because, if electricity producers are using more renewable energy sources, the price of electricity was expected to rise as these sources are more expensive than coal and other fossil fuels in Australia. The analysis is done over the period July 2004 to 26 August 2010. This period was then split into two, dividing at 18 April 2007, to see not only if there was a relationship but if this had changed as these two markets increased in volume and trading. Both these schemes had very light trading initially, making 2004 the first time when analysis could be effectively undertaken. Cointegration analysis was used to determine if there was a long-run or equilibrium relationship between these two schemes and electricity and gas prices. Similar studies by Bunn and Fezzi (2008) and Fezzi and Bunn (2009) were applied to the EU ETS, found that carbon prices were an important influence on electricity prices. This type of investigation had not been undertaken in Australia previously. This study found that there was no relationship during the first period, while for the

second period a significant relationship was found. This change is most likely due to increased trading, allowing the carbon price to become a factor. The findings were significant, providing an indication that these schemes were having an impact on the sector with the highest contribution to emissions and climate change.

The Chapter 5 paper, "Econometric analysis of Australian emissions market efficiency", has taken this analysis further. It is forthcoming in the journal *Energy Policy.* The long-run structural modelling techniques of generalised forecast error variance decomposition (GVD) and generalised impulse response function analysis (GIRF) were used on the data discussed above for the first time in a market of this kind. These models were developed by Pesaran and Shin (1998) and Koop et. al (1996). The research described in this paper was done in order to better provide a practical long-run approach to understanding the structural relationships between carbon prices and electricity prices. The analysis found a long-run relationship between the considered variables in each of the time periods, concurring with the analysis in 4. When short-run shocks were applied to NGAS certificate prices and the MRET certificate prices, we found they played a minimal role in explaining movements in the electricity prices. These findings are different from many studies, both international and Australian, including the earlier paper in Chapter 4. However, the findings may more clearly reflect the continued high level of use of coal as an energy source in Australia which would indicate a failure of these schemes to achieve their goals.

A conclusion that we can draw from the analysis in Chapter 5 is that the markets are not acting efficiently in achieving their goals. In order to understand why this might be the case, the discussion in this chapter on the political volatility surrounding climate change issues in Australia was worth consideration. With this in mind, and because much of the analysis on market efficiency is conducted in financial markets, it was decided to look at these markets for a possible cause of the inefficiency found. The behavioural concept of ambiguity in financial markets sees inefficiency as a response to uncertainty in a market which produces a reduction in participation in the market

(Easley and O'Hara, 2009). The sixth chapter of this thesis, "Ambiguity in markets: a test in an Australian emissions market", conducts a test to see if ambiguity exists in this market. This is the first paper to test for ambiguity in any market using this methodology. This analysis is based on identifying when information events enter the market and assessing their effect on bid-ask spreads and trading volume. The test is undertaken on MRET certificate prices from June 2007 until the end of 2010. At the end of 2010 the MRET certificates were broken into two components, making comparisons past this date tenuous. The results from the tested period clearly indicate that news events relating to climate change in Australia, and some major international information, have a positive effect on the volume while decreasing the bid-ask spread. This test and the results provide an innovation in testing this theory and lessons for improving market efficiency internationally.

Finally, the thesis is concluded in Chapter 7 where the findings of the individual papers are summarised and linked. These individual results provide a cohesive overview of the emissions trading markets in Australia. These markets are of international significance. One of the main goals of this thesis is to inform policy makers in order to improve the efficacy of this type of climate change mitigation.

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Chapter 2

Emissions mitigation schemes in Australia – the past, present and future

Abstract

Australia was one of the first countries in the world to adopt mandatory emissions trading schemes as part of its emissions mitigation program. To date there have been six state and one federal emissions mitigation schemes. Some state schemes operate in conjunction with other states or the federal scheme and some operate independently. This complex set of regulations and requirements for emitters has led to a deficiency in nationwide coverage with no firm target set for Australia. In July 2011 the Federal Labor Government released details of a carbon pricing mechanism proposal which was passed by the two houses of Parliament by the end of 2011 and was introduced in July 2012. The Government states that an emissions trading scheme will be introduced in 2015 with a possible link to the European Emissions Trading Scheme (EU ETS). This paper provides a critical overview of Australian responses to climate change, with a particular emphasis on the numerous emissions mitigation schemes.

Key words: *climate change mitigation, emissions trading, carbon tax*

2.1. Introduction

Global warming is seen by many as one of the greatest challenges the world faces today. In the 1800s Fourier (1827) discovered that the earth's atmosphere provided an insulation effect known from that time as the greenhouse effect. Later, Tyndall (1863) proved that the greenhouse effect existed by concluding that water vapour was the strongest absorber of radiant heat in the atmosphere. In 1972 the United Nations convened a conference on the Human Environment in Stockholm that was the first major international conference to be held to discuss global environment issues (United Nations Environment Program, 1972). Twenty years later the United Nations Framework Convention on Climate Change (UNFCCC) was established with the goal of stabilising atmospheric greenhouse gas concentrations. At the Kyoto Conference of Parties (COP) in 1997 it was agreed to reduce overall emissions of six greenhouse gases to around 5% below 1990 levels by 2010 (targets varied for different countries). Australia's target enabled it to increase its greenhouse gas emissions over the first 5 year commitment period to 108% of their 1990 levels. This protocol was ratified by Australia in 2007 but remains unratified by the U.S.A. The election of Barak Obama, of the Democratic Party, as President of the U.S.A. in 2008 saw what appeared to be a clear signal to move forward on the fight against climate change and possibly see them sign the Kyoto Protocol. At the 2009 UNFCCC COP in Copenhagen there were 23 decisions made, however Obama stated that better agreements needed to occur between emerging, least developed and developed countries before a legally binding global agreement on climate change could be made. A new set of targets for the Annex 1 parties, i.e. industrialised countries that were members of the Organisation for Economic Co-operation and Development (OECD) in 1992, was agreed to. Fundamentally, all countries agreed to some reduction in emissions for 2020 however there are many specified conditions. Australia agreed to a 25% cut if there was global agreement to stabilise greenhouse gas emissions to 450 ppm CO_2–equivalent (CO_2-e) or less, a 5% cut unconditionally or a 15% cut dependent upon global agreement by developing and advanced economies to make a

comparable agreement (United Nations Framework Convention on Climate Change, 2010). The dominant condition was that all developed countries commit to comparable levels and that also developing countries contribute adequately.

In 2005 the Chancellor of the Exchequer of the United Kingdom engaged Sir Nicholas Stern to lead a review into the economics of climate change. The Stern Report looked at policy responses for mitigation with eight key messages noted on carbon pricing and emissions markets. They included the need for tax and trading to be used to create an explicit price for carbon and that regulation could create an implicit price. Further it was noted "To reap the benefits of emissions trading, deep and liquid markets and well-designed rules are important. Broadening the scope of schemes will tend to lower costs and reduce volatility. Increasing the use of auctioning is likely to have benefits for efficiency, distribution and potentially the public finances" (Stern, 2006: 324).

Legislation for pollution control began in Australia in the 1960s and 1970s with different policies associated with land, water and air in most states and nationally. These policies have continued to cover a wider variety of pollution types predominantly through legislation with little contribution from common law over the years (Bates, 2005). A number of reviews have been undertaken to determine how best to proceed on action against climate change since a task force was set up by the Federal Government in 2006, including reports by Martin Parkinson in 2007 and Ross Garnaut in 2008. The seven differing emission mitigation schemes have led to a complex set of regulations and requirements for emitters and have been seen to lead to an imbalance in coverage and requirements for business. At the 6th Australia-New Zealand Climate Change and Business Conference in 2010 the resounding opinion from all the business sectors was for a clear carbon price to be determined. The general agreement at this conference was that a cut of greenhouse gas emissions by at least 15% by 2020 would be economically beneficial. The companies involved in electricity generation and sales called for certainty in order to plan for the future.

In 2010 the Australian Labor Party's website stated that "Climate change is the most dangerous long-term threat to Australia's prosperity. As one of the hottest and driest continents on Earth, Australia's environment and economy will be one of the hardest and fastest hit by climate change if we do not act." (Australian Labor, 2009).The dilemma facing governments, businesses and consumers around the world was summarised by Tietenberg, "The risks of being wrong are clearly asymmetric. If it turns out that we controlled more than we needed, current generations would bear a larger than necessary cost. On the other hand, if the problem turns out to be as serious as the worst predictions indicate, catastrophic and largely irreversible damage to the planet could be inflicted on future generations." (Tietenberg, 2007). This level of investigation and the nature of statements made by political parties would seem to indicate the importance of climate change as an issue and would suggest urgent action would be undertaken.

This paper, to our best knowledge, provides the first overview of the Australian responses to international developments addressing climate change with a particular emphasis on the numerous emissions mitigation schemes. It is set out in the following way: Section 2 initially outlines all the emissions mitigation schemes that have been and are currently operating in Australia. It does not endeavour to cover the various subsidies for solar panels and similar schemes as these are both too numerous and in many cases too short term to be included. It does include an overview of the current legislated carbon pricing mechanism to be followed by an emissions trading scheme. Section 3 discusses some of the major issues to be decided in setting up an appropriate scheme and section 4 concludes with a look at the possible future perspectives for emissions mitigation in Australia.

2.2. Australian Emissions Mitigation Schemes

2.2.1 The New South Wales Greenhouse Gas Abatement Scheme

The New South Wales Greenhouse Gas Abatement Scheme (GGAS) commenced in January 2003 and was one of the first mandatory trading systems in the world. It was introduced under the Electricity Supply Amendment (Greenhouse Gas Emission Reduction) Bill 2002 (ESA Bill 2002) which was passed in the Legislative Assembly on 15 November, 2002 and the Legislative Council on 6 December, 2002 (New South Wales Government, 2006). The Amendment Act was introduced to "amend the Electricity Supply Act 1995 in order to encourage the reduction of greenhouse gas emissions through the use of benchmarks. It was originally planned to continue at least until 2012 however it is uncertain at this time whether or not it will continue past that date. The scheme ceased operation on 30 June, 2012 with the introduction of the carbon tax to be discussed in section 2.9. The Federal and NSW governments have proposed that they work together to ensure a smooth transition for stakeholders. Certificates not surrendered after meeting compliance for the year to June 30 2012 are still able to be traded and surrendered in the voluntary market.

Section 97B of this amendment sets out the New South Wales greenhouse gas benchmarks in the form of the level of carbon dioxide equivalent of greenhouse gas emission per head of State population (NSW Greenhouse Gas Abatement Scheme Registry, 2007). These decreased from 8.65 tonnes per head for the year commencing 1 January 2003 to 7.27 tonnes from 2007 until the end of the scheme. They form the basis for calculating the benchmarks for each of the participants. These include retail suppliers, electricity generators or other suppliers of electricity to a customer, and market customers. The latter are customers who have classified any of their electricity loads as a market load and are registered with the Australian Energy Market Operator (AEMO), formerly the National Electricity Market Management Company Limited (NEMMCO), as a market customer under

the National Electricity Code, and large customers who are identified as users of 100 gigawatt hours or more of electricity at one or more sites in New South Wales (Section 97BB ESA Bill 2002). This paper will refer to these participants in a general way as “suppliers” and “large use customers”. The calculation of each participant’s benchmark is done by multiplying the State population by the benchmark allowances of greenhouse gas emissions per head and multiplying this amount by the proportion of total electricity demand in the State applicable to each participant (Section 97BC ESA Bill 2002). Compliance is therefore determined by calculating the megawatt hours of electricity supplied or purchased by the participant and deducting that from the benchmark allowance. Any ‘greenhouse shortfall’ (S97Be ESA Bill 2002) for a year, other than the year commencing 1 January 2007, may be carried forward to the next year. To the extent that this shortfall is not abated by the surrendering of abatement certificates by the participant during the following year they will be subject to a penalty. The participant is not permitted to carry forward more than 10% of their benchmark for that year. The penalties imposed were amended in Section 97CA of the ESA Bill 2006 to be $11.50 per ton of CO_2 until end 2009, then increasing by $1 p.a. until 2013 to a maximum of $15.50 in 2013. This was amended in 2012 to a level of $17.00 to be adjusted by the consumer price index thereafter.

Abatement certificates may be created if the person creating them has been accredited and they are in respect of activities or a class of activities that promote greenhouse gas emission reduction. They may also be classed as eligible activities if the activities involve:

“(a) the generation of electricity in a manner that results in reduced emissions of greenhouse gases,

(b) activities that result in reduced consumption of electricity,

(c) activities of elective participants, associated with production processes that use electricity in this State, that result in reduced emissions of greenhouse gases.” (S97DA ESA Bill 2002).

Each certificate represents one tonne of carbon dioxide equivalent of greenhouse gas emissions that the activity has abated. Further the rules may allow eligibility for accreditation of carbon

sequestration, the process of removing carbon from the atmosphere, through the planting of forests or other means only if it occurs in New South Wales or as approved by the Minister. The abatement certificates can only be received if the activity has not already received a similar certificate from another mandatory scheme. Each abatement certificate must be created immediately after and no later than six months after the end of the year in which the activity it relates to takes place. These certificates remain in force until cancelled by the Scheme Administrator. The Demand Side Abatement component, predominantly the market customers outlined above, of the GGAS ceased on 1 July 2009 becoming incorporated into the Energy Savings Scheme in Section 2.2.

Any accreditation of a person as an abatement certificate provider remains in force until suspended or cancelled by the Scheme Administrator. The Scheme Administrator is the Independent Pricing and Regulatory Tribunal of NSW (IPART). IPART is the independent economic regulator in NSW and they oversee the regulation of the electricity, gas, water and transport industries (Acuiti Legal, 2003).

There are two types of NSW Greenhouse Gas Abatement Certificates (NGAC), transferable and non-transferable, both in fact may be transferred but require the Scheme Administrator's approval and must be registered with the Scheme Administrator upon completion of transfer. The register that is kept contains information regarding the name of the person who created the certificate, the current registered owner as well as any previous owners and other relevant information regarding the type of certificate. The creation and cancellation of these certificates is also kept on register as is any transfer of them and may be made available to the public. The trade statistics from the registry, as shown in Table2.1, indicate a strong increase in the number of trades and the number of certificates traded since its' inception in 2004. The last column shows the total number of certificates required to meet abatement compliance obligations for the year. It indicates an increase in the number of NGACs traded relative to the compliance requirements. Compliance has been strong throughout the operation of the GGAS. In a report by the Independent Pricing and Regulatory Tribunal on

compliance and operation of the GGAS during 2008, produced in July 2009, it stated that there was a shortfall of 2.6% in 2003, 1.6% in 2004, 0.9% in 2005, 0.9% in 2006, 0% in 2007 and 0.01% in 2008 (Independent Pricing and Regulatory Tribunal of NSW, 2010). No shortfalls were allowed to be carried forward in 2007 to ensure that NSW met the target in line with the Kyoto Protocol. During 2008 three participants carried forward a small shortfall and two paid a small penalty for non-compliance.

This level of trading reveals some efficiency in certificate transfer provided by the scheme. However the number of certificates created relative to the required number for abatement quantifies the oversupply in the market. The number of certificates increased significantly from 2003, indicating the market was able to create more low cost abatement opportunities than was anticipated. It is most notable in 2006 – 2007 with a number of companies creating certificates by providing energy efficient light bulbs and efficient showerheads.

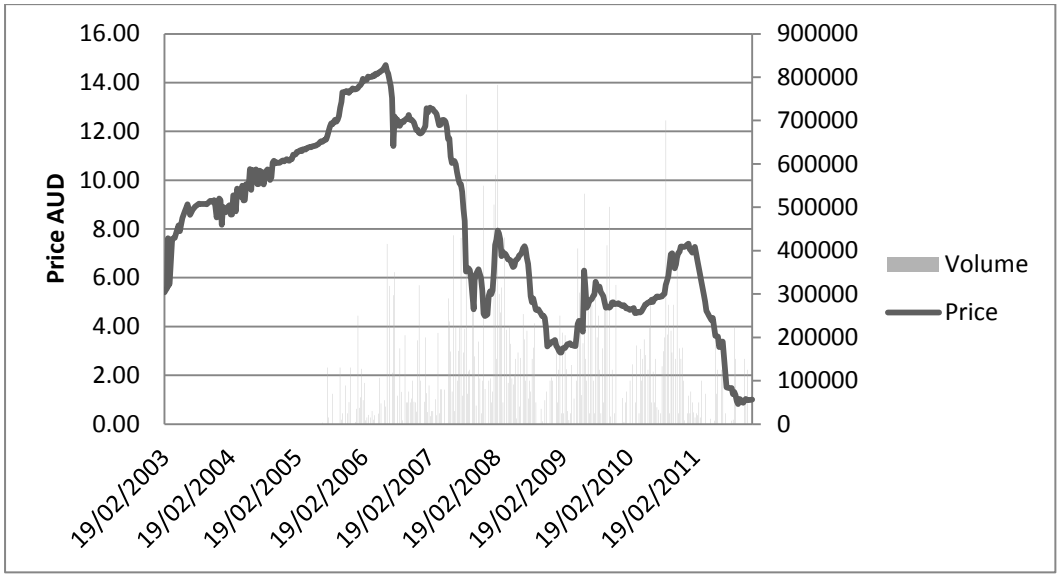
Table 2.1: NGAC Transactions

Year	Transfers	Number of NGACs	Certificates required
2003	9	725,775	1,699,941
2004	108	5,015,689	5,897,236
2005	225	6,106,876	9,150,547
2006	685	20,161,464	13,802,181
2007	1779	25,427,929	18,730,871
2008	1780	30,595,597	23,704,309
2009	1601	33,795,005	24,852,164
2010	1166	31,810,106	23,107,821
2011	530	23,139,879	19,290,286

Source: https://www.ggas-registry.nsw.gov.au/searching/tradestatistics.aspx

The fall in price as a result of this in 2007 can be seen in Figure 2.1 which shows the weekly price, provided by the Australian Financial Markets Association (AFMA), and volumes provided by Next Generation Energy Solutions, which maintain records for over 90% of the market. AFMA data consists of weekly bid and ask quotes from dealers in the carbon markets and the price is taken as the midpoint between these two values. (Volumes prior to 2003 were not available.) This fall in price is further discussed in section three of this paper. The graph shows that while prices were relatively stable since the fall in 2007 until the end of 2010 the trading volume shows great variation. As this scheme was known to cease with the introduction of the carbon pricing mechanism the price has fallen to its lowest levels since inception in a free fall since the middle of 2011.

Figure 2.1: NGAC Weekly Price and Volume



Source: Australian Financial Markets Association (Price in AUD) and Next Generation Energy Solutions (Volume) 2012

It was estimated that the GGAS delivered a reduction of 4.7 million tonnes of concentrated CO_2 that would cause the same level of radiative forcing as a given type and concentration of greenhouse gas (CO_2-e) abatement in 2010 and that it was the third largest single abatement policy measure (Daley and Edis, 2011). This would indicate a level of success on the part of the scheme with Daley and Edis stating that this scheme, along with the MRET and Qld Gas Scheme, to be discussed, contributed

more than 40% of Australia's emissions reductions since 1997. The NGAC abatements were achieved at the lowest cost of these schemes at around $15 to $40 per tonne CO_2-e. It produced reductions greater than the legislative requirement in the period 2003 to 2011. However, it should be noted that also other grants, rebates etc. would have contributed to the take up of reduction mechanisms such as more solar energy use by the general public. Only since 2007 has there been a relationship between NGACs and electricity prices with tangible evidence during this period of an increase in investment in renewable energy (Cotton and Trück, 2011).

2.2.2 The NSW Energy Savings Scheme

The NSW Energy Savings Scheme (ESS) was established through the Electricity Supply Act 1995 and is supported by the Electricity Supply (General) Regulation 2001 and two sets of rules, the Energy Savings Scheme Rule of 2009 and the Ministerial Order and Scheme Regulator Exemptions Rule No. 1 of 2009 (Independent Pricing and Regulatory Tribunal of NSW, 2010). The goal is to: "to assist households and businesses to reduce electricity consumption and electricity costs; to complement any national scheme for carbon pollution reduction by making the reduction of greenhouse gas emissions achievable at a lower cost; and to reduce the cost of, and the need for, additional energy generation, transmission and distribution infrastructure." (Overview, http://www.ess.nsw.gov.au/).

It is estimated the scheme will reduce electricity by 8.5 million megawatt-hours (MWh) in the first four years. It commenced on 1 July 2009, taking over from the Demand Side Abatement component of the GGAS, and was developed to complement the Federal Government's proposed Carbon Pollution Reduction Scheme (CPRS). As noted in section 2.1 this will now be a carbon pricing mechanism and the ESS is to continue alongside this tax. It is planned to continue operation until 2020 or until a Federal scheme is introduced with similar objectives. The Scheme is regulated by IPART.

Scheme participants include electricity retailers and generators who supply direct to a customer and market customers who buy or sell electricity in NSW. Energy Savings certificates (ESCs) are created for activities which reduce electricity consumption or increase electricity usage efficiency. The initial targets for participants were 0.4% of total electricity and will increase to 4% in 2014. The allocation for participants is in proportion to their liable electricity sales. Penalties for non-compliance are $24.50 per ton of CO_2-e initially and may increase by changes in the consumer price index. The maximum allowable shortfall is 20% except for the first year, when participants may have a shortfall of up to 50%. There had only been one year's compliance results at the time of writing. A total of 289,118 ESCs were required to meet obligations and only 148,928 were surrendered. Most achieved at least the minimum level required for the first year with their balances being carried forward to 2010. Penalties were paid equivalent to 347 ESCs. Some of the shortfall was attributable to Jackgreen International Pty Ltd, an electricity retailer, which went into voluntary administration in December, 2009 and was suspended from trading.

2.2.3 The Australian Capital Territory Greenhouse Gas Abatement Scheme

The Australian Capital Territory Greenhouse Gas Abatement Scheme (ACT GGAS) commenced operation on 1 January 2005 and is legislated under the Electricity (Greenhouse Gas Emissions) Act 2004. It began with the same design as the NSW GGAS scheme and effectively mirrored it until 20 June 2009. In November 2007 the scheme was extended from finishing in 2012 to run until 2020. In line with the NSW GGAS it establishes targets for greenhouse gas emission reductions for the benchmark participants, at this stage it only applies to retail suppliers of electricity but may include large electricity users in the future. The targets are the same as the NSW scheme as discussed in Section 2.1 of this paper. Like the NSW Scheme, the NSW IPART is the scheme administrator. Also like the NSW scheme it ceased operation on 30 June 2012 with the introduction of the carbon pricing mechanism.

The Independent Competition and Regulatory Commission states in its overview of the ACT GGAS that abatement certificates may be created by (Independent Competition and Regulatory Commission, 2009):

- "reducing the greenhouse gas intensity of electricity generation;
- Generating low emission intensity electricity;
- Demand-side abatement activities which involve reducing consumption, or increasing the efficiency of the consumption of electricity; or
- Carbon sequestration activities."

The compliance rules also closely mirror the NSW scheme with penalties assigned to those who fail to meet their benchmarks. Both NGACs (from NSW and ACT) and RECs (see section 2.5) can be submitted to meet obligations however they must be in respect to electricity generation and demand in the ACT. For the 2010 year all liable entities submitted their required abatement certificates with none electing to carry forward until 2011. The number of abatement certificates has increased since inception from 312,377 in 2005, 202,724 in 2006, 398,276 in 2007, 675,534 in 2008, 743,151 in 2009, with a reduction in 2010 to 543,006 due to a reduced demand for electricity.

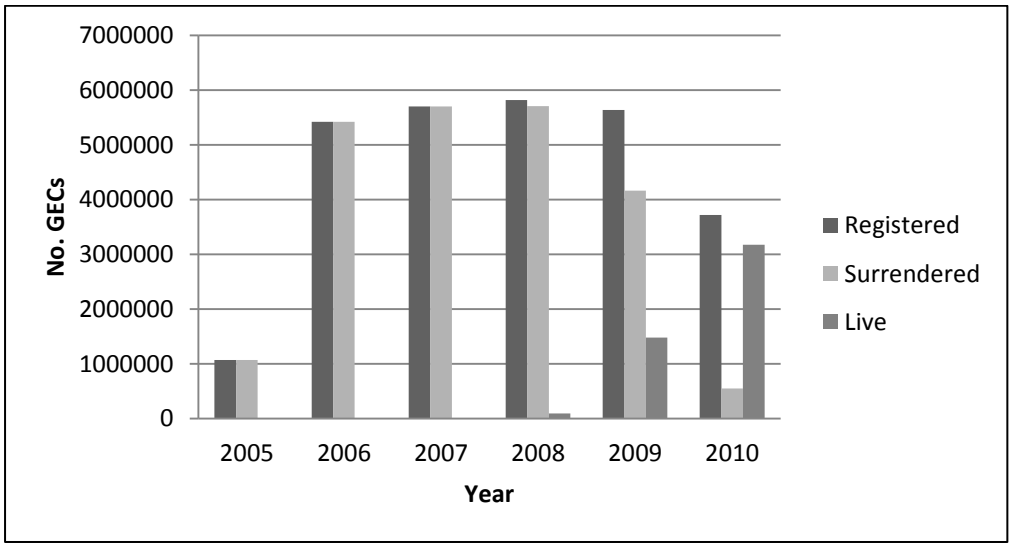
2.2.4 Queensland 13% Gas Scheme

The Queensland Gas Scheme commenced in 2005 with a goal to expand the Queensland gas industry and reduce greenhouse gases. In order to achieve this, the scheme had initially targeted 13% of electricity to be sourced from gas from 2006 onwards. This has increased to 15% and may reach a target of 18% by 2020. It operates under the Electricity Act 1994 and the administrator is the Chief Executive of the Department of Mines and Energy. The Scheme's certificate creators include accredited generators who generate electricity from natural gas, coal seam gas, liquefied petroleum gas and waste gasses. Liable parties are electricity retailers and end use customers who purchase electricity for consumption in Queensland. One Gas Electricity Certificate (GEC) is equal to one megawatt hour (MWh) of eligible electricity generated. If insufficient GECs are surrendered there is a

penalty which commenced at $11.50 per tonne CO_2 increasing by the CPI, in 2010 it was $13.13 (Queensland Government, 2009).

In 2010, 32 of 37 liable parties surrendered sufficient GECs to meet their requirements. Of the five who did not meet their requirements four paid the fines and one failed to submit a report, a default assessment and civil penalty was given to this participant. The Annual Report in 2010 stated that gas-fired generation has increased by an additional 672 MWh in 2009. As at 1 September, 2010, a surplus of 4,741,326 live certificates was available to meet future liabilities. Figure 2.2 below shows the increase in registered, surrendered and live certificates up until the end of 2010. The scheme would have transitioned into the CPRS however due to the postponement of the CPRS and legislated carbon pricing mechanism it is not yet clear what transition will occur. It will continue to operate with the 15% target until a federal scheme commences, possibly in 2015. This scheme has reduced abatement by 2.2 million tonnes in 2010 with an anticipated level of 4.3 million tonnes in 2020 if it were still in operation (Cotton and Trück , 2011).

Figure 2.2 GEC Summary



Source: Queensland Gas Scheme Annual Report, 2011

2.2.5 Mandatory Renewable Energy Target Scheme

The Mandatory Renewable Energy Target Scheme (MRET) is the only Australia-wide scheme operating at this time, with discussion currently underway for a new Federal scheme which will be outlined later in this section. It commenced on 1 April 2001, prior to Phase I of the European Emissions Trading Scheme which commenced operation in January 2005. The MRET was introduced under the Renewable Energy (Electricity) Act 2000 and applies from January 2001 to January 2021. The goal was to encourage additional generation of electricity from renewable energy resources and thereby reduce greenhouse gas emissions, and to ensure that renewable energy sources are ecologically sustainable with the aim to generate 9,500 GWh of extra renewable energy by 2010 (Office of the Renewable Energy Regulator, 2009). It is seen as an important complement to the newly introduced carbon pricing mechanism.

Trading in Renewable Energy Certificates (REC) is over the counter and one REC is equal to one MWh of electricity. Renewable sources of electricity include hydro, wave, tide, ocean, wind, solar and various types of waste. Certificates may be created for each whole MWh of electricity generated by the power station from these renewable sources that is above the baseline amount required. The installation of solar water heaters creates certificates for the owner of the heater at the time of the installation. All created certificates must be registered by the Renewable Energy Regulator before being able to be traded under the MRET. The liable entities include suppliers and wholesale buyers of more than 100 MWh of electricity (Office of the Renewable Energy Regulator, 2010). The scheme administrator is the Office of Renewable Energy Regulator (ORER). The number of certificates required to be surrendered under the scheme is determined by calculating the Renewable Power Percentage (RPP) for the year and multiplying it by the total electricity acquired under relevant acquisitions during the year. The RPP is calculated by the following formula:

$$RPP_t = RPP_{t-1} \times \frac{\text{Required GWh of renewable source electricity for year t}}{\text{Required GWh of renewable source electricity for year t} - 1}$$

The initial RPP was 0.24% for 2001 and the required amounts change from year to year. The required gigawatt-hours (GWh) of renewable source electricity increased from 300 in 2001 to 9,500 in 2010. Legislation to implement an expanded national Renewable Energy Target Scheme (RET) was passed on 20 August 2009. The original Act, under which the MRET was implemented, the Renewable Energy (Electricity) Act, was enhanced by the *Renewable Energy (Electricity) Amendment Act 2009* (Commonwealth Amendment Act). The goal of the new Federal Government-implemented RET is to deliver on the Government's commitment to ensure that 20 per cent of Australia's electricity supply will come from renewable sources by 2020. This goal is a targeted growth of over four times the current goal to 45,000 GWh in 2020. The commodity name and equivalence in MWh of electricity generation remains the same at one REC equal to 1MWh. The Office of Renewable Energy Regulator remains the regulator of the Scheme.

Table 2.2: REC Transactions from 2001 to 2010

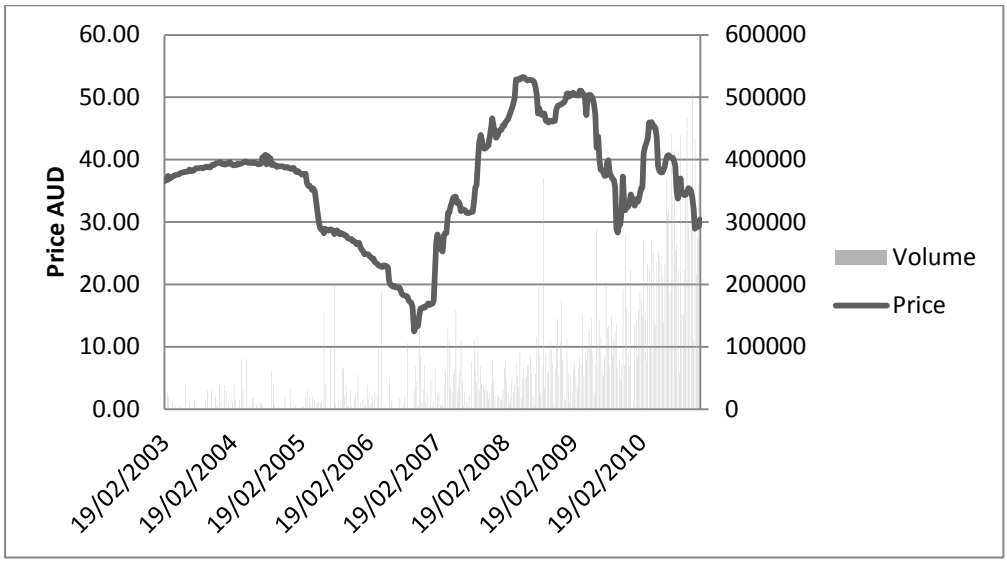
Year	Transfers	Number of RECs	Target MWh
2001 and 2002	417	1,446,378	1,400,000
2003	548	2,688,418	1,800,000
2004	791	5,218,713	2,600,000
2005	1,010	6,935,314	3,400,000
2006	1,338	11,165,781	4,500,000
2007	1,493	11,993,060	5,600,000
2008	2,793	17,243,633	6,800,000
2009	4,157	29,024,622	8,100,000
2010	10,710	63,834,001	12,500,000

Source: Mandatory Renewable Energy Trading Scheme Annual Report, 2010

Renewable energy shortfalls incur a charge if the amount is 10% or more for the year, otherwise they may be carried forward to the next year. In addition to the charge of $40 per MWh shortfall,

the whole amount must be made up over the next three years. Registered RECs can be voluntarily surrendered – this effectively removes the RECs from the market thereby further reducing the level of greenhouse gas emissions.

Figure 2.3: REC Weekly Price and Volume



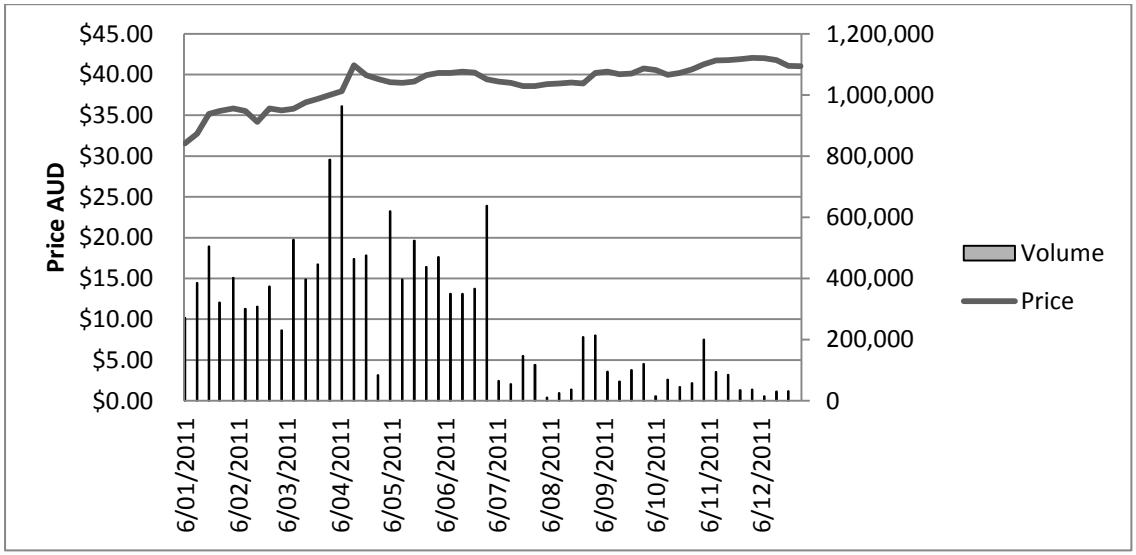
Source: Australian Financial Markets Association (Price in AUD) and Next Generation Energy Solutions (Volume) 2012

Compliance has been high throughout the scheme's operations and in the most recent annual report suggests that compliance has ranged from 92.3% in 2001 to 99% and above for all subsequent years. The scheme achieved greater reductions in greenhouse gas emissions than its legislative requirement for 2001 to 2010 (Cotton and Trück, 2011). Also worth noting is that not all shortfalls resulted in the payment of the penalty of $40/MWh, as shortfalls within 10% of the total requirement are carried forward and added to next year's target (Australian Greenhouse Office, 2003). Table 2.2, using data from the annual reports, shows the number of transfers and the number of RECs traded from 2001 through to 2010. The last column indicates the number of certificates required to meet the Renewable Energy Target in MWh each year. It shows an increase in the

number of RECs traded relative to the target levels for compliance from around 1:1 to approximately 5:1.

Figure 2.3 displays the weekly price and volume for the RECs from the beginning of 2003 through the end of 2010 after which time the splitting of the RECs into the large and small scale certificates occurred as discussed below. There has been relatively steady volume with some areas of volatility which mostly appear to be related to changes in legislation and the uncertainty that this reflects. Similar to the NGACs, there is no statistically significant relationship between volume and the price of RECs. Figure 2.5 also shows the fall in prices in 2007 similar to the NGACs due to the oversupply of certificates.

Figure 2.4: LREC Weekly Price and Volume

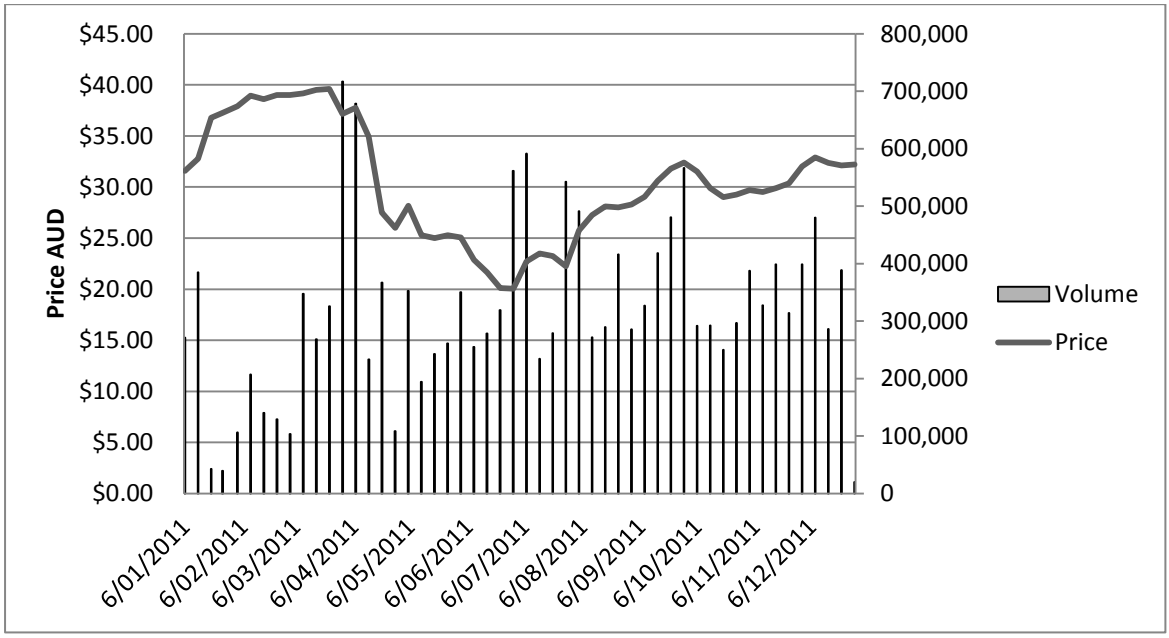


Source: Australian Financial Markets Association (Price in AUD) and Next Generation Energy Solutions (Volume) 2012

On 26 February, 2010 the Government announced further changes to the scheme. The revisions, as explained in the Department of Climate Change website, were "to provide greater certainty for households, large-scale renewable energy projects and installers of small-scale renewable energy systems like solar panels and solar water heaters". They entail separating the targets for large scale

renewable energy projects from small-scale ones. This change should ensure that the 45,000 GWh target is met even if the uptake on small scale projects is less than expected. The Large Scale Renewable Energy Target (LRET) allows the liable entities to meet their obligations with projects covering large-scale renewable energy projects like wind farms, commercial solar and geothermal energy. It will operate in a similar way to the MRET. The Small-scale Renewable Energy Scheme (SRES) allows small-scale technology certificates (STCs) to be created by small-scale technologies like solar panels and solar water heaters. The STCs will commence at a value of $40 and the price will be monitored over time to ensure it remains appropriate. The SRES is a voluntary arrangement and has no cap on the amount of STCs created.

Figure 2.5: STC Weekly Price and Volume



Source: Australian Financial Markets Association (Price in AUD) and Next Generation Energy Solutions (Volume) 2012

Figures 2.4 and 2.5 show the weekly prices and volumes for both schemes in 2011. The Large scale renewable energy certificates (LREC) price has remained high with volumes reducing over the year, indicating the higher cost of reductions in emissions. STCs show a more volatile price and much higher levels of volume, an indication of the greater ease of certificate creation as discussed with the NGACs.

The targets for these large scale projects are shown in Table 2.3, including the original and amended levels. The amended levels include the anticipated 4,000 GWh p.a. from the SRES and the increasing levels from the LRET.

Table 2.3: Required GWh of renewable source electricity

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020 to 2030
Original Target (GWh '000)	10.4	12.3	14.2	16.1	18	22.6	27.2	31.8	36.4	41
New Target (GWh '000)	14.4	16.3	18.2	20.1	22.0	26.6	31.2	35.8	40.4	45.0

Source: Australian Government, Clean Energy Regulator, Renewable Energy Target, 2011 http://ret.cleanenergyregulator.gov.au/About-the-Schemes/Large-scale-Renewable-Energy-Target--LRET-/about-lret

Daley and Edis found that this scheme produced annual reductions in 2010 of 8.8 million tonnes of abatement with an estimated level of 29.9 million tonnes in 2020. This is achieved at the relatively low cost of $30 to $70 per tonne CO_2 – e (Cotton and Trück, 2011).

2.2.6 Victorian Renewable Energy Target Scheme

The Victorian Renewable Energy Target Scheme (VRET) was enacted under the Victorian Renewable Energy Act 2006 which was passed on 19 September, 2006 and commenced operating on 1 January, 2007. The goal was to increase electricity generated from renewable energy sources to 10% by 2016. Coverage included all electricity retailers and large wholesale purchasers of electricity in Victoria.

Interim annual targets were set to ensure consistent progress towards achieving the 3,274 GWh target by 2016 to ensure that all of the investment does not occur in the final years of the scheme. The Essential Services Commission of Victoria was responsible for registering persons, accrediting renewable energy power stations, maintaining registers, overseeing the creation, registration, transfer and surrender of the Victorian Renewable Energy Certificate (VREC), imposing penalties, conducting audits and monitoring compliance (Allens Arthur Robinson, 2004).

Each VREC represents one MWh of eligible renewable electricity. VRECs can be created:

- for small generation units – after the unit is installed, or
- for accredited power stations – for renewable energy electricity generation utilising scheme capacity.

In the first year of operation (2007) there were no liability targets applied, however relevant entities were required to submit an audited statement. All twenty-one entities submitted their reports. In 2008 there was a shortfall of Renewable Energy Certificates surrendered of 67,200. This shortfall was incurred by ten entities with a total penalty paid of $2,950,080 as detailed in the Victorian Renewable Energy Target Scheme Annual Report 2008. In December 2008 the Victorian Government agreed to transition the VRET into the new RET, discussed above in Section 2.5. Therefore 2009 was the final year of VRET obligations by the participants in the scheme. Three entities encountered a shortfall obliging them to pay a penalty of $74,273.85. An amount of $11,083.59 of this was

associated with Jackgreen (International) Pty Ltd which went into voluntary liquidation (Essential Services Commission, 2009).

2.2.7 The Victorian Energy Efficiency Target Scheme

The Victorian Energy Efficiency Target Scheme (VEET) was established through the Victorian Energy Efficiency Target Act 2007 and is supported by the Victorian Energy Efficiency Target Regulations 2008. The goal is to: "to promote the reduction of greenhouse gas emissions by establishing the VEET scheme which – a) provides for the creation and acquisition of energy efficiency certificates and b) requires the surrender of energy efficiency certificates." (The Victorian Energy Efficiency Target Act 2007, Part 1, Section 1) (The Victorian Energy Efficiency Target Act 2007, 2012).

It commenced on 1 January 2009 with a target of reducing greenhouse gas emissions by 2.7 million tons per annum during its first three year phase increasing to 5.4 million in the second three year phase. The three year phases are planned to continue until 2029. The scheme aims to achieve this by placing a requirement on large Victorian electricity retailers, known as relevant entities, to surrender a specified number of energy efficiency certificates (VEECs) each year. These certificates may be created or purchased in the market with each certificate representing one tonne of greenhouse gas abated.

The Scheme is maintained by the Department of Primary Industries with administration through the Essential Services Commission (Victorian Energy Efficiency Target, 2012). There were 14 relevant entities for the 2011 years who all surrendered a sufficient number of VEECs to acquit their liabilities for the period. For the first three year period 8,058,781 VEECs were surrendered meeting the legislated requirements for the schemes target.

2.2.8 Carbon Pollution Reduction Scheme

The Carbon Pollution Reduction Scheme (CPRS) was passed by the House of Representatives on 4 June 2009. The Bill's aim was to give effect to Australia's obligations under the Climate Change Convention and the Kyoto Protocol and, in general, support an effective global response to climate change. It was a cap and trade scheme which was set to commence at a price of $10 per tonne CO_2-e greenhouse gas emissions. The number of emission permits issued would have been capped by the Australian Government in order to ensure greenhouse gas emissions would reduce over time to achieve the target levels. Some of the permits would have been auctioned and others directly allocated to businesses (Australian Government, 2008).

According to the scheme, Australia would unconditionally reduce its emissions by 5 per cent compared with 2000 levels by 2020 and would reduce its emissions by 15 per cent by 2020 if there was an international agreement where major developing economies commit to substantially restrain emissions and advanced economies take on commitments comparable to Australia's. The coverage would broadly include persons who are responsible for greenhouse gas emitted from the operation of a facility, who import, manufacture or supply synthetic greenhouse gas and who import, produce or supply eligible upstream fuel. They must surrender equivalent eligible emissions units. There would be a cap which limits the total number of auctioned emissions units, which would generally be transferrable, most of which would be issued through an auction.

The Bill was then put to the Australian Senate twice in 2009 and was rejected on both occasions. The 2010 version of the Bill with amendments went to the Senate on 24 February 2010 but was adjourned until the next sitting. The government continued to indicate that it would go to the next sitting and remained committed to commencing the scheme in 2012. However this did not eventuate with the Government stating in April 2010 that it had been dropped from the most recent

four year estimates in the next budget. Resources Minister Martin Ferguson told Radio National on 27 April 2010 that it was clear that there was not enough support to pass the legislation (Kirk, 2010). Further he indicated that the lack of any significant progress at the UNFCCC in Copenhagen meant that it would be preferable to reassess the CPRS after the end of the Kyoto Protocol's first commitment period at the end of 2012.

2.2.9 Carbon Pricing Mechanism

In September 2010 the Federal Government established the Multi-Party Climate Change Committee to explore options for implementing a carbon price to mitigate climate change. This committee was made up of members of the current Federal Labor Government, independents and the Australian Greens Party. No members of the Liberal Opposition were included in the committee. On 10 July 2011 the Government released details of the plan proposed by the committee in a document called the Clean Energy Agreement (The Parliament of Australia, 2011). The Clean Energy Bill 2011 was passed in the House of Representatives on 12 October and the Senate on 8 November, 2011. The proposal was for a carbon pricing mechanism which was implemented on 1 July, 2012.

It was initially suggested that the carbon price would be set through a tax being levied on approximately 500 of the largest carbon polluting companies in Australia. However, the list of liable entities that was released in June 2012 included only a total of 294 liable entities. The list contains companies that produce 25,000 tons of CO_2-e emissions each year such that most major power stations, mines and heavy industry will have to pay the tax. Also a number of local government areas, in total 34 councils, will require emissions permits, in particular those with a population greater than 20,000 and those that own landfills.

The tax has been set at $23 per tonne and will rise by 2.5% p.a. in real terms to $24.15 for the 2013-14 financial year and $25.40 for the 2014-15 financial year, until 30 June 2015, when the price will be

set by the market in an emissions trading scheme. The scheme is administered by a new authority, the Clean Energy Regulator (CER), which issues units known as carbon units. In the first three years in which the market is setting the price there will be a floor price of $15. This will increase by 4% p.a. in real terms and a ceiling price of $20 above the likely international price will increase at 5% p.a. in real terms.

As part of the scheme, assistance has been provided to households who may be affected by increased costs through e.g. pension increases, allowances and family payments and income tax cuts. There will also be a Jobs and Competitiveness Program supporting local jobs and production and a Clean Technology Program to assist the manufacturing sector. Further a Clean Energy Finance Corporation (CEFC) will be established to drive innovations in clean energy and the Australian Renewable Energy Agency will coordinate and support research and development in new renewable energy technologies. The target of the scheme is to ensure that 20% of Australia's electricity comes from renewable energy by 2020.

The current plan under the Governments' Clean Energy Future is for the carbon pricing mechanism to transition into an emissions trading scheme on 1 July 2015. This is likely to be based on the CPRS however these details are as yet undecided. It is also proposed that this emissions trading scheme to be linked to an international carbon market or markets at this time. Early discussion has indicated this is likely to be the EU ETS however again this is as yet undecided.

2.3 Key issues in emissions mitigation schemes

One of the most important issues in any emissions mitigation scheme is the method of permit allocation, which in general may be referred to as auction versus grandfathering. Grandfathering, where emitters are allocated free permits in relation to their historical requirements, is to ensure that no company is overly burdened with the expense of reducing their emissions and to ensure that

they are able to continue in business while reducing the emissions. This allocation method is dominant in US sulphur trading, the longest running scheme of this type. It is simple and popular with emitters, partly as it enables them to participate in the allocation process but also it may give some current emitters windfall profits. Another advantage for them is that new entrants may be disadvantaged as it is based on past emissions therefore new entrants in, e.g. electricity production, will have difficulty producing evidence of a requirement for permits. This requirement significantly reduces their competitiveness. It may also create perverse incentives to overestimate requirements; the base year chosen will affect this possible incentive.

Auctioning where emitters buy permits means there is no compensation for emitters. It is seen to be transparent and efficient. A further benefit of auctioning is that it is possible for auction revenues to enter general government revenue and ideally to reduce the costs of greenhouse gas emissions on the community. It has also been suggested that over-allocation under grandfathering was the major cause of the fall in EU-ETS prices in April 2006 and the fall in the NGACs in 2007. Betz and Sato (Betz and Sato, 2006) in their analysis of lessons learnt from the EU-ETS, suggest that, higher levels of auctioning or the tightening of rules for new entrants and closure will ensure an efficient marketplace. In Phase III of the European Union Emissions Trading Scheme (EU-ETS) the level of auctioning will increase from around 3% to at least 50% (Department of Energy and Climate Change).

Another issue to consider is whether the scheme would follow a cap and trade approach where a fixed amount of emissions allowances are allocated. In this case penalties are set for noncompliance. The cap provides not only an incentive to comply but also caps the cost of compliance and therefore adds to the certainty provided by the scheme. It enables a maximum cost to be incorporated into the investors' compliance calculations. A 'make-good' provision may be required, where if permit holders exceed their permit holdings at the end of the compliance period they have not only to pay the penalty but also to surrender the appropriate number of permits from their next years'

allocation or purchases. The EU–ETS uses large fines and industries have to make up the missed emission reductions in the next year of the scheme. Early in the scheme they were allowed additional allowances if they had unusually high emissions if these were due to a 'force majeure' or act of God. Other schemes, such as in the U.S., use make up provisions but not necessarily on a one to one basis. For example the over the counter regional sulphur trading program is on a three to one basis (National Emissions Trading Taskforce, 2006).

Banking allows participants to bank excess permits from current allowances for use in future years when it is anticipated abatement costs will be higher. The decision whether to allow this or not from an environmental perspective is not a problem as climate change is caused by an accumulation of greenhouse gases, not so much from the timing of their dispersion into the atmosphere. However this feature is an important consideration when it has an impact on prices and liquidity. The EU–ETS allowed banking in the first phase but banking between phases was at the discretion of the member states (Pew Center on Global Climate Change, 2005). The complementary side to banking is the ability to borrow permits from the future - which is a far more contentious issue due to the risk that they may never be repaid. Some borrowing has been allowed in EU–ETS and in the USA. The NSW GGAS allows a limited shortfall providing it is made up the following year.

2.4 Environmental Indicators

The Australian Bureau of Statistics (2015) publishes Environmental-Economic Accounts which provide information on socioeconomic and environmental indicators. Within this report they detail the changes in energy consumption and greenhouse gas emissions for Australia overall. These are also divided into selected industries providing a broad understanding of where the greatest use of energy occurs and greenhouse gas emissions occur. Of interest to this paper and possibly as a measure of the effectiveness of the emission reduction schemes operating in Australia is the change

in greenhouse gas emissions. Over the period 1996-97 to 2012-13 GHG emissions has increased by 21%. To put this into perspective we note that the population has increased by 25% and economic production, which is measured by gross value added, has increased by 69% over the same period. While not a reduction as is the aim of the various schemes it can be seen that the ABS measures what they call 'intensity measures' which measure the environmental pressure per unit of gross value added. In this greenhouse gas emissions declined by 26% over the period. Greenhouse gas emissions measured in this way by sector were found to decrease in both agriculture and manufacturing. Black coal remains the largest contributor to energy by far and the largest of the net energy exports by Australia in 2013.

2.5 Future Perspectives

There remain climate change sceptics, however, the overriding evidence continues to indicate climate change is a real issue. The UNFCCC website states that human activity has increased the thickness of the blanket of greenhouse gases around the earth resulting in an increase in the global temperatures. This increase has and will continue to alter the complex systems that allow life to continue on earth. Specifically, levels of cloud cover, rainfall, wind and ocean currents are affected which contribute to changes in the distribution and survival of plant and animal species. While predictions of the level of changes in the climate system vary considerably, they all seem to forecast extreme weather conditions including frequent flooding and disruptions to food and water supplies.

Australia can be seen to have been attempting to address the issues associated with climate change for over ten years and was one of the earliest instigators of an emissions trading scheme. Appendix 1 outlines the emissions mitigation schemes in operation to date. The Australian approach has differed between states without an overall nationwide perspective. The Australian National Greenhouse Accounts for the September quarter of 2011 show an annual decrease of 1% (Department of Climate

Change and Energy Efficiency, 2011). Much of this was due to a reduction in electricity generation emissions by 3.8%, in part due to a reduced demand caused by a mild winter. There was also a decrease in fugitive emissions due to flooding in Queensland which reduced coal mining activity. Transport and stationary energy emissions increased during this year, reducing the benefits of the abovementioned reductions. Some of the states have made serious inroads into managing carbon emissions however they appear to be floundering under the uncertainty of what is to come from any proposed CPRS. Likewise, continued global uncertainty stems from a lack of real commitments being made at any of the COPs.

Economically, emissions trading schemes have the ability to provide a fair and transparent way to reduce emissions. The level and cost of abatement by some of the schemes has been discussed in Section 2 while Section 3 outlines many of the issues pertaining to the appropriate type of scheme to introduce. The nature of these issues, and debate about how widespread the schemes' coverage should be, complicate and consequently contribute to the delay of a global response. Passey et al. (Passey et al., 2008:3016) state that "Poorly designed emissions trading schemes could delay meaningful action." The continued response by high emitting nations that they are unwilling to reduce emissions unless there is a fair reduction made by others also may result in a continuation of global inaction.

The highly political nature of climate change action has slowed progress towards an optimal solution in Australia. The former leader of the main federal opposition party was changed due in part to his stance on climate change as was the previous leader of the incumbent party. The current Federal Government is dependent upon Independents and Australian Greens Party representatives in order to remain in power. This has not only limited their policy options but has potentially over-complicated its road to an appropriate policy. Australia has achieved the target emissions set by the Kyoto Protocol to date with an increasing surplus over the past four years. The relative success of

the existing emissions trading schemes in Australia has not given rise to the introduction of a Federal Scheme. However it is likely that the introduction of a Federal scheme in the form of a carbon pricing mechanism will pave the way for the development of more complete and effective policy implementations via the CPRS in the future.

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Appendix 1: Summary Table of Australian Emissions Mitigation Schemes

Name	The New South Wales Greenhouse Gas Abatement Scheme
Start Date	January 2003
Administrator	Independent Pricing and Regulatory Tribunal of NSW
State/s	New South Wales
Sectors/participants	Retail suppliers, electricity generators or other suppliers of electricity to a customer, market customers and large customers.
Goal	"..to establish greenhouse gas benchmarks for the electricity industry and to encourage activities relating to the reduction of greenhouse gas emissions;…"
Requirements	Set benchmarks for level of carbon dioxide equivalent of greenhouse gas emissions per head of State population reducing from 8.65 tonnes per head in 2003 to 7.27 tonnes from 2007 until the end of the scheme.
Permit	1 NGAC = one tonne of carbon dioxide equivalent of greenhouse gas emissions
Deliverable certificates	NGACs
Fines	Able to carry forward a shortfall of up to 10% of their benchmark for that year until following year. If not abated during that year a penalty applies of $11.50 per permit/certificate until 2009 then increasing by $1 p.a. until 2013 when it will remain at $15.50.
End Date	On 5 April 2012, the Minister for Resources & Energy announced the closure of GGAS effective 1 July 2012. The scheme was closed due to the commencement of the federal Commonwealth carbon pricing mechanism.
Gov't Act	Electricity Supply Amendment (Greenhouse Gas Reduction) Bill 2002

Name	The New South Wales Energy Savings Scheme
Start Date	July 2009
Administrator	Independent Pricing and Regulatory Tribunal of NSW
State/s	New South Wales
Sectors/participants	Electricity retailers and generators who supply direct to a customer or market customers who buy or sell electricity in NSW
Goal	The objectives of the Energy Savings Scheme are: to assist households and businesses to reduce electricity consumption and electricity costs; to complement any national scheme for carbon pollution reduction by making the reduction of greenhouse gas emissions achievable at a lower cost; and to reduce the cost of, and the need for, additional energy generation, transmission and distribution infrastructure.
Requirements	Certificates created for reduction in electricity consumption or increase in usage efficiency with targets set at 0.4% of total electricity sales in NSW increasing to 4% by 2014.
Permit	1 ESC = one tonne of carbon dioxide equivalent of greenhouse gas emissions
Deliverable certificates	Energy Saving Certificates
Fines	$24.50 initially increasing by CPI, ($25.52 in 2011) maximum allowable shortfall is 20%.
End Date	Until 2020 or a federal scheme with similar objectives is introduced, may continue alongside the carbon pricing mechanism.
Govt Act	Electricity Supply Act 1995 No 94 (Current version for 7 January 2011)

Name	The Australian Capital Territory Greenhouse Gas Abatement Scheme
Start Date	January 2005
Administrator	Independent Pricing and Regulatory Tribunal of NSW
State/s	Australian Capital Territory
Sectors/participants	Retail suppliers of electricity
Goal	To reduce greenhouse gas emissions associated with the production and use of electricity; and develop and encourage activities to offset the production of greenhouse gas emissions.
Requirements	Set benchmarks for level of carbon dioxide equivalent of greenhouse gas emissions per head of State population reducing from 7.96 tonnes per head in 2005 to 7.27 tonnes from 2007 until the end of the scheme.
Permit	1 NGAC = One tonne of carbon dioxide equivalent of greenhouse gas emissions
Deliverable certificates	Renewable Energy Certificates (RECs) under the Australian Government Mandatory Renewable Energy Target (MRET) and NGACs from NSW and ACT scheme. Only RECs and NGACs surrendered to the Office of the Renewable Energy Regulator in respect to electricity generation and demand in the ACT may be counted.
Fines	Benchmark participants can carry forward a shortfall of up to 10% of their greenhouse gas benchmark in all years of the Scheme except 2007. Penalties started at $10.50 per tonne CO_2 equivalent greenhouse gas emissions increasing by the CPI annually, at a level of $13.00 in 2010.
End Date	2020 - The date may depend on introduction of carbon pricing mechanism as it may cease to operate if a federal scheme is introduced.
Govt Act	Electricity (Greenhouse Gas Emissions) Act 2004

Name	Queensland 13% Gas Scheme
Start Date	2005
Administrator	Chief Executive of the Department of Mines and Energy
State/s	Queensland
Sectors/participants	Electricity retailers and end use customers who purchase electricity for consumption in Queensland.
Goal	Increase the Queensland gas industry and reduce greenhouse gases.
Requirements	To source 13% of electricity from gas from 2006 onwards. This will increase to 15% from 2010 with a possible target of 18% by 2020.
Permit	1 GEC = one megawatt hour of eligible electricity generated
Deliverable certificates	GECs
Fines	Penalty of $11.50 per tonne CO_2 equivalent greenhouse gas emissions increasing to $15.50 in 2013
End Date	2020 however may transition into the carbon pricing mechanism scheme if introduced.
Govt Act	Electricity Act 1994

Name	(i) Mandatory Renewable Energy Target Scheme (ii) Expanded in 2010 to Renewable Energy Target Scheme with two parts; Large-scale Renewable Energy Target and the Small-scale Renewable Energy Scheme
Date Start	(i) April 2001 (ii) July 2010
Administrator	Office of Renewable Energy Regulator
State/s	All states of Australia

Sectors/participants	Suppliers and wholesale buyers of more than 100 MWh of electricity
Goal	(i) Encourage additional generation of electricity from renewable energy resources and reduce greenhouse gas emissions (ii) Encourage additional generation of electricity from renewable energy and reduce greenhouse gas emissions from the electricity sector
Requirements	(i) Generate 9,500 GWh of extra renewable energy by 2010. Amended in 2009 to ensure 20% of Australia's electricity supply will come from renewable resources by 2020. (ii) The Large-scale Renewable Energy Target (LRET) has a target of 41 000 GWh by 2020 and only large-scale renewable energy projects are eligible. The Small-scale Renewable Energy Scheme (SRES) targets a theoretical 4000 GWh annually and is eligible only to small-scale or household installations.
Permit	1 REC = one megawatt hour of electricity
Deliverable certificates	RECs Converted State certificates from 2010.
Fines	Able to carry forward a shortfall of up to 10% of their benchmark for that year until following year. If not abated during that year a penalty applies of $40 per MWh shortfall and whole amount must be made up over the next three years.
End Date	(i) Planned until 1 January 2021 (ii) Planned until 1 January 2031
Govt Act	(i)Renewable Energy (Electricity) Act 2000 (ii) Renewable Energy (Electricity) Amendment Act 2009

Name	Victorian Renewable Energy Target Scheme
Start Date	January 2007
Administrator	Essential Services Commission of Victoria
State/s	Victoria
Sectors/participants	All electricity retailers and large wholesale electricity purchasers in Victoria
Goal	To encourage additional generation of electricity from renewable energy sources, investment in the generation of renewable energy and the development of renewable energy technologies, regional investment and employment, contribute to the diversity of Victorias energy supplies and reduce emissions of greenhouse gases.
Requirements	Target of 10% renewable electricity by 2016.
Permit	1 VREC = one megawatt hour of eligible electricity generated
Deliverable certificates	VREC
Fines	$43 per MWh in 2007 and adjusted annually to $45.99 in 2009
End Date	Concluded December, 2010
Govt Act	Victorian Renewable Energy Act 2006

Name	The Victorian Energy Savings Scheme
Start Date	January 2009
Administrator	Essential Services Commission
State/s	Victoria
Sectors/participants	Large Victorian Electricity Retailers
Goal	The objectives of the Energy Savings Scheme are: to encourage greater efficiency in the use of gas and electricity and encourage investment, employment and the development of technology pertaining to the reduction of the use of gas and electricity by energy consumers.
Requirements	Certificates created by helping consumers make energy efficiency improvements in their homes and businesses with target of reducing greenhouse gas emissions by 2.7 million tonnes p.a. in first 3 year phase and 5.4 million tonnes in the second 3 year phase.
Permit	1 VEEC = one tonne of greenhouse gas emissions
Deliverable certificates	Victorian Energy Efficiency Certificates
Fines	$40 for 2010 year increasing by CPI, ($42.73 in 2012)
End Date	In three year phases until 2030.
Govt Act	Victorian Energy Efficiency Target Act 2007

Addendum 1: This document does not form part of the original publication but is an update of information for the purposes of the thesis only.

Updated Information on Emissions Mitigation Schemes in Australia – January 2014

1. The NSW Greenhouse Gas Abatement Scheme

This scheme ceased operation on 30 June, 2012. The Labor Party undertook to compensate the holders of around 16 million unused certificates held by retailers and certificate creators. The compensation was likely to amount to approximately $80 million (Hartcher, 2012). The goal for most participants in this scheme was for them to transition into the carbon pricing mechanism introduced by the then Federal Labor Government on 1 July 2012. This carbon pricing mechanism is often referred to as the carbon pricing mechanism and is discussed in Section 2.9 of the paper.

2. NSW Energy Savings Scheme

This scheme has continued to operate alongside the carbon pricing mechanism. A review of the scheme was undertaken by the NSW Government in August 2013 with proposed changes, after consultation, to commence in early 2014. Some of the likely changes include more household energy efficiency activities, more opportunities for business to access the scheme and a streamlining of the certificate creation process (NSW Trades and Investment n.d.).

3. The ACT Greenhouse Gas Abatement Scheme

This scheme ceased operation on 30 June, 2012 with similar transition arrangements to the NSW Greenhouse Gas Abatement Scheme.

4. Queensland 13% Gas Scheme

The *Energy and Water Amendment Act 2013 (Qld.)* introduced in September 2013 arranged for the closure of the Queensland 13% Gas Scheme. The scheme ceased operation on 31 December, 2013 with all GECs expiring at midnight on 30 June, 2014. The Queensland Government found that the

introduction of the carbon pricing mechanism meant this scheme was simply a duplication. They also felt that as nearly 20% of electricity production in Queensland was now sourced from gas, that it had already served its purpose.

5. Renewable Energy Target Scheme

This scheme is continuing alongside the carbon pricing mechanism. The federal government has announced that there would be a review of the scheme in 2014. The results of this review had not been announced at the time of this thesis submission.

6. Victorian Renewable Energy Target Scheme

This scheme is similar to the RET and has been continuing alongside the carbon pricing mechanism but is likely to be reviewed in 2014. This was indicated by Greg Hunt when he was still in opposition in March 2013.

7. Victorian Energy Saving Scheme

This scheme is currently still in operation and is also undergoing a review.

New information in light of the change of federal government:

The Federal Coalition under Tony Abbott was voted in to power in the federal election in September 2013. The Liberal Party formed a coalition government with the Liberal National Party, the Nationals and the Country Liberals. The coalition holds 90 of the 150 seats in the House of Representatives. On 13 November 2013 the Coalition introduced to the House of Representatives a number of bills including the *Clean Energy Legislation (Carbon Tax Repeal) Bill 2013* to remove the carbon tax pricing mechanism. It was passed by the House of Representatives on the third reading on 21 November, 2013 and was introduced and read a first time in the Senate of 2 December, 2013.

The Coalition has a green paper, the “Emissions Reduction Fund Green Paper”, with a consultation period from 20 December, 2013 until 21 February, 2014. The government has asked for input from the public and organisations which will contribute to the White Paper to be released in early 2014. The Green Paper outlines the government’s Direct Action Plan which involves a policy mix approach to climate change mitigation. It includes a commitment to reducing Australian emissions levels to 5% below 2000 levels by 2020 – this target will be reviewed in 2015. The view of the Coalition is that climate change mitigation can only be effective if all major economies in the world take coordinated action. The proposed Emissions Reduction Fund would commence on 1 July 2014 to align with the removal of the carbon tax. It would be administered by the Clean Energy Regulator (Emissions Reduction Fund Green Paper, 2013). Its goals are to generate emissions reductions at low cost – businesses will determine what actions are brought forward and the government will assess these and aim to fund them quickly. An example of the type of action would be switching energy sources for electricity to natural gas as proposed by the Australian Pipeline Industry Association. Further direct action is indicated to include local actions such as funding the One Million Solar Roofs and 20 Million Trees programs. Internationally an example would be participation in the United Nations Clean Development Mechanism.

Australia sent only non-ministerial delegates to the UNFCCC in Warsaw in November 2013. The Durban Agreement which has a goal for an international agreement by 2015 to be in force in 2020 was debated further at the conference. The discussions were predominantly around the character of the various nations’ commitments for greenhouse gas reductions, mechanisms for differentiating between rich and poor countries, and a process for reassessing commitments in the future. While the US, UK, Norway and Germany made pledges on finance for the Reducing Emissions from Deforestation and Degradation (REDD) Program some countries, including Australia and Canada indicated that the financing should come from the private sector and that many emerging economies should make their own pledges.

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Chapter 3

Climate change: level of concern and policy preferences in Australia

Abstract

The aim of this paper is to determine the level of importance and concern the Australian public feels about the issue of climate change. An online survey was undertaken with 1000 participants with demographics that aligned with the overall Australian population. This survey initially gauged the importance respondents place on global and local policy issues. It revealed that over 70% found climate change to be important or very important. Over 50% of participants believed climate action should be undertaken in Australia irrespective of whether other countries take action or not. A further 33% supported action if there is international agreement. The study also determined details about policy preferences. A policy mix was preferred by most, and those opposed to action gave their main reason as a need for global action. The study also found that a broad coverage in terms of sectors and worldwide reach was preferred and that government funds should be targeted towards a combination of areas. In particular, respondents favoured investing in renewable energy and subsidising those in lower income groups. While some similarities were found with previous studies in Europe and the US, the views of a country in the Asian region are felt to contribute to the overall understanding of climate change as a global issue.

Keywords: climate change**,** climate policy**,** public concerns

3.1. Introduction

Australia's close proximity to and trade dependence on China may give it a different view of climate change mitigation compared to Europe and the US. Australia emitted only 430 million tonnes of CO_2 in 2011 according to the Trends in Global CO_2 Emissions 2012 Report[2], far below the 5,420 of the US, the 3,790 of the EU 27[3] and the 9,700 of China. However, when measured on a per capita basis, Australia's emissions are 19.0 tonnes CO_2 per person, well ahead of the US at 17.3, the EU 27 at 7.5, and China at 5 tonnes. Also, by 2011, Australia had seen an increase of emissions by 57% since 1990, second only behind the Ukraine (58%) among Annex 1 Countries under the United Nations Framework Convention on Climate Change (UNFCCC). This growth rate casts doubts on the success of the emissions trading schemes that Australia has had since 2001, and Australia's role as a signatory to the Kyoto Protocol. As Australia can be considered to be one of the leading democratic and developed economies in the Asian region, this paper aims to determine if Australians have the same views as those in other similarly developed countries. Previous research on public opinion about climate change and climate change mitigation has predominantly been conducted in the US and Europe. In this study we conducted a survey to determine whether the emissions growth in Australia is caused by a lack of desire to act on climate change mitigation. The survey we used also questioned participants on their policy choices and other details regarding coverage and subsidies.

We find that climate change mitigation action is desired by over 80% of respondents and that whether or not there is a concerted international response influences people's views on this desire for action. Belief in information about the existence and causes of climate change and the importance placed on climate change as a policy issue are found to be significant factors in the respondents' desire for action. We also find that a mix of policies, which may include a cap and trade scheme and a tax, is the preferred method of taking this mitigation action. The survey also

[2] Trends in Global CO_2 Emissions 2012 Report by PBL Netherlands Environmental Assessment Agency, European Commission Joint Research Centre.
[3] EU27 is the 27 European Union countries.

determined that over 50% of the Australian public felt that all sectors should be covered by any scheme enacted, with a combination of ways to spend the revenue. This included investing in renewable energy and subsidies to those in lower income groups for likely increased power costs.

The remainder of the paper is organised as follows: Section Two outlines the current situation with regards to climate change mitigation in Australia and provides a review of the literature on public perceptions of climate change and preferences for mitigation action. In particular, we review the climate change literature that has focussed on surveys regarding public perceptions of climate change, the importance of international agreement on climate action, policy preferences and possible correlations between demographic characteristics and respondents' views Section Three outlines our survey design and methodology while Section Four presents the results from the survey. The discussion concludes with an overview of the implications of the survey results in Section Five.

3.2. Background and Literature

3.2.1 Australian Action

Legislation for pollution control began in Australia in the 1960s and 1970s with different policies associated with land, water and air in most states and nationally. Australia was one of the first countries in the world to have a mandatory trading scheme to reduce greenhouse gas emissions in 2001. Since then, there have been many changes in proposed policies with the leaders of both the current federal government and the opposition party being ousted in part due to their stances on climate change policy. In 2008–9, legislation for a carbon pollution reduction scheme (CPRS) was introduced twice in parliament by the then Labor Government. Both times, it was rejected by both the conservative Liberal Party and the environmental Greens party. This indicates what an extremely divisive and uncertain issue climate change policy appears to be in Australia.

At the time of writing, and post survey, the Australian Government implemented a carbon tax commencing in July 2012. The details of the carbon tax are set out in the Exposure Draft (28/7/11) of

the *Clean Energy Bill 2011.* The tax applies to around 500 of the top emitting companies with the goal to cut pollution by 5% compared to 2000 levels by 2020, and by 80% by 2050. From 2015 onwards, the Labor Government planned to introduce a CPRS, with the price being set by the market. Plans were in place to link this CPRS with the European Emissions Trading Scheme (EU ETS) by July 2018. These plans were dependent upon the Labor Party continuing in power after the federal election on 7 September, 2013. With the win by the Liberal Coalition in the September 2013 election, the new policy structure remains uncertain. Legislation was put forward almost immediately to cancel the carbon tax. While little research has appeared on carbon taxes, a number of other countries, including Norway in 1990, Sweden in 1991 and Denmark in 1992, have introduced carbon taxes. Sumner, Bird and Smith (2009) show that there have been mixed results, with Norway increasing its emissions by 15% between 2008 and the introduction of its scheme, Sweden cutting its carbon pollution by 9% up to 2006 and Denmark reducing its per capita emissions to 15% below their 1990 levels by 2005.

3.2.2 Level of Public Interest and Concern

Studies on public understanding of climate change were found to have differing effects of the likelihood of public action. Fortner et al. (2000) studied how knowledgeable and certain the participants in Columbus, Ohio were about global warming just prior to the Kyoto Conference of Parties (COP). Their survey found the respondents trusted the information media sources provided about climate change more than 50% of the time, and were fairly knowledgeable and certain about global warming information. This belief was significantly related to their trust in the media and their willingness to act responsibly. Poortinga and Pidgeon (2003) took this further by looking at the type of organisation providing the information and the consequent level of trust. They found that scientists and environmental organisations were the most trusted sources, and were believed by over 75% of respondents, while information provided by government ranked very low in trust. Bulkeley (2000), found a level of confusion amid the scientific uncertainty and the claims and

counter claims made in the media in Australia. From this uncertainty some level of scepticism was evident among participants. However, they continued to place their trust in science and education as reliable sources of climate change information. An Australian study by Kaczan et al. (2010) found 83% of respondents were completely confident in global warming science.

Cameron (2005) found that the willingness to pay to mitigate climate change of undergraduate economics students in the US depended almost entirely on two main perceptions of uncertainty surrounding climate change. The first was uncertainty about the extent of the damage that would occur as a result of climate change if there was no mitigation. The second was uncertainty surrounding climate change science. A wider survey of US households by Lee and Cameron (2008) found more concern about harm to agriculture and water resources than health. The impacts on ecosystems were not seen to be important unless extreme damage was likely. The authors suggest that this may be due to a lack of understanding of the importance of these systems. According to a survey conducted by Berk and Fovell (1999), residents of Los Angeles were mainly concerned about warmer temperatures and less precipitation. In South Africa, belief that climate change was human induced was directly correlated with the likelihood that participants would support taking steps to ameliorate it (Oliver et al., 2011). Akter and Bennett (2011) conducted a survey in the state of New South Wales in Australia. They found that 90% of respondents who believed the temperature would increase by more than 5^0C by 2100 also believed that climate change was human induced. Responses also suggest that willingness to pay for climate change mitigation is related to the level of future temperature rise anticipated.

3.2.3 International Agreement

Participants' beliefs about whether the rest of the world would also take steps to stop climate change was found to be a critical factor in their desire to undertake mitigation action, as suggested by Akter and Bennett (2011) for Australia, as well as Lee and Cameron (2008), and Li et al. (2004) for the US. De Chaisemartin and Mahe (2009) found altruism and self-interest to be significant

motivators for action in France, with altruism being stronger from a statistical point of view. In Akter and Bennett's (2011) study, 80% of the New South Wales respondents felt there was less than a 50% chance of a global agreement on climate change mitigation. New South Wales comprises approximately 32% of the Australian population. Cai et al. (2010, p.455) state that "there is unlikely to be any single policy that will be supported by everyone". They conclude that the vastly different impacts and costs to different parts of the global community will most likely always be a source of conflict. When adopting any scheme, whether it is a carbon tax or an emissions trading scheme, the distributional consequences of the scheme need to be investigated. This has been looked at in some depth by Cai et al. (2010) in their survey of US and Canadian students. They found the participants were willing to pay more when the largest proportions of the costs would be borne by those who were deemed responsible for the emissions. The willingness to pay for climate change mitigation also increased when respondents indicated they cared about the impacts on the world's poor.

3.2.4 Policy Preferences

Akter and Bennett (2011), examined preferences for mitigation action among respondents in New South Wales, and found that 67% rejected any increase in household expenses to support the Australian Carbon Pollution Reduction Scheme. This reaction may in part be due to less than 50% believing the CPRS would be successful. O'Connor et al. (1999) suggests that it is incorrect to assume that most opponents to one proposal on climate change mitigation will oppose all proposals. Therefore, they argue, studies concentrating only on one proposal may not necessarily come to the correct conclusions about respondents' overall desire for action against climate change. Both Akter and Bennett (2011) and Lee and Cameron (2008) found that if proposals involved spreading the costs over a range of areas, rather than selecting one method, this led to a reduction in willingness to pay. Leiserowitz (2006) conversely found strong bipartisan support in the US for action at both the national and international levels. However direct actions, such as higher fossil fuel-based energy prices, they were strongly opposed.

3.2.5 Demographic Influences

The literature reports ambiguous results when looking at the connections between gender, willingness to pay and action on climate change. Bord and O'Connor (1997) studied gender differences in the US and found that women were more likely to see more risk in global warming, and were also more likely to perceive negative outcomes as a result of climate change. However, when health issues related to climatic change were considered the gender gap disappeared. O'Connor et. al. (1999) found males were more likely to take climate change-related issues into account in their voting behaviour, while Akter and Bennett (2011) found females to be far more likely to want to take action, even voluntary action, on environmental issues.

Akter and Bennett (2011) also report that income level had a positive relationship with respondents' willingness to reduce their personal carbon footprints. However, increasing education levels led to a decrease in this likelihood. A survey conducted in South Africa by Oliver et al. (2011) found a significant positive link between income level and willingness to pay for green electricity. However, the authors do not report a linear relationship between these two variables. Kaczan et.al. (2008) report that average incomes grow over time and this increased their respondents' willingness to pay. Their research also found that socioeconomic or demographic factors did not significantly influence respondents' views. The majority of their respondents were willing to 'shoulder the burden' of increases in electricity costs to avoid climate change. On the other hand, Adaman et al. (2011), conducting a contingent valuation survey in Turkey, found that education had a positive relationship with willingness to pay.

The research described in this section indicates some highly ambiguous results, including findings about the effects of certain demographics such as income and gender, on the importance placed on the issue of climate change. However a consistent finding was that increased trust in information is associated with an increased desire for climate change mitigation. In some instances this may be explained by the particular country of study and also by the very specific cohort of people surveyed.

While some of the Australian results are similar to those the findings of our survey, we are able to generalise about the Australian population to a greater extent due to the distribution of respondents.

3.3. Survey Design

3.3.1 Distribution Method and Respondent Profile

An online survey was sent out on 12 April, 2011 achieving the goal of 1,000 participants. This was prior to the carbon tax passing through both houses of parliament and the campaigning for the Clean Energy Future policy by the Labor Party and at that time there was a level of certainty about whether the legislation would be passed. The survey for this study was conducted by Pure Profile Pty Limited and the results were received on 19 April, 2011. In order to ensure a good representation of the Australian voting public there were three control questions asked. The respondents needed to be at least 18 years of age and questions on gender and the state in which they lived were asked. The demographics achieved were within 5% of the ABS Census[4] for age and 1% for gender and state. Post survey, the voting intentions of respondents were examined and we found 29.7% intended voting Liberal, 28.7% Australian Labor Party, 10.6% Australian Greens Party, 8.9% other with 22.1% unsure. These results were similar to first preference by party in the House of Representatives and first preferences by group in the Senate in the 2010.[5] It is important to note that any research that uses a survey which will only be participated in by a relatively small percentage of the whole population must be cautious with any claims made regarding the whole population.

An online survey was chosen to ensure an Australia-wide reach, speed and timeliness, low cost and ease of obtaining a large sample (Evans and Mather, 2005). The Australian Bureau of Statistics (ABS)

[4] ABS File 3235.0 Population by Age, Sex and Regions of Australia 2010.
[5] This information can be found on the Australian Electoral Commission website for the House of Representatives and the Senate in the results of the Federal election in 2010.

states in their 2008 Census that, in 2008–9, 72% of Australian households had internet access. It is assumed that in 2011 the percentage would have been greater or equal to this level which indicates that the online survey would have covered the majority of the population. Additional questions were asked of the respondents in order to better analyse the results including voting intentions, and education and income levels. For most questions, a five-point Likert scale was used, providing two degrees of low or negative response, a neutral response and two degrees of a high or positive response. This balanced scaling was found by Brace (2008) to provide respondents with the best available way of indicating their true opinions. A draft version of the survey questionnaire was tested on groups of 20, randomly selected by email, to determine if the questions were in any way leading or unclear. Any comments made to that effect were used to assist in the rewording of the survey. The amended survey was subsequently tested twice on new groups of respondents until no such comments were made.

3.3.2 Information and Question Organisation

Information from the CSIRO was provided regarding changes that have already occurred in Australia due to climate change. Cameron (2005) discusses how different amounts of prior information known by the respondents will influence their responses. Lee and Cameron (2008) use a similar methodology of providing information and then asking questions so that respondents can, if they want to, use this information to assist in their understanding of the subject matter. Participants were asked a series of questions to determine their concern and expectations of what they believed would be future effects of climate change. They were then asked how likely they believed certain problems were to occur in the next 50 years due to climate change. These questions initially focused on worldwide issues of standard of living, water shortages and serious disease. The next questions refocused on similar issues and the likelihood they would affect them personally. The survey also asked how much they believed the information provided by national organisations such as the CSIRO.

The next step was to determine what type of policy, if any, they would prefer the Australian Government implement to respond to climate change. The survey provided a brief description of both a carbon tax and an emissions trading scheme. The aim of the descriptions was to enable respondents to be certain about what they were actually responding to. Berk and Schulman (1995) found that in some cases the public is capable of considering environmental issues of the same level of complexity as informed policy makers. However, as Kahneman and Tversky (1979) found, people were seen to be generally risk averse and that any uncertainty they felt could cause them to give more negative responses then they may otherwise give. Participants were asked to nominate which policy they would prefer and were given the opportunity to reject any of them. The survey sought details of participants' preferred policies including types of compensation and sectoral coverage.

3.3.3 Statistical Analysis of Results

The results are analysed in different ways and a variety of tests were carried out, dependent on the level of measurement of the considered variables. In particular we were interested in whether the responses of participants in the survey were independent of characteristics such as gender, age, income. To test for independence between a characteristic and the outcome of the set of responses, we conducted simple Chi-Square tests. Thus, we tested the null hypothesis, H_0*: response with respect to concern level about climatic change is independent of the characteristic of the respondent,* against the alternative hypothesis of dependence between responses and gender, age or income level. Each observation was allocated to one cell of a two-dimensional contingency table according to the values of the two outcomes. Given *p* possible outcomes of the first variable and q possible outcomes of the second, i.e. *p* rows and *q* columns in the contingency table, the test statistic of the conducted test for independence is defined as

$$\chi^2 = \sum_{i=1}^{p} \sum_{j=1}^{q} \frac{(O_{i,j} - E_{i,j})^2}{E_{i,j}} \qquad (1)$$

where $O_{i,j}$ denotes the actual observed number of outcomes allocated to cell *(i,j)* in the contingency table, $E_{i,j}$ is the expected number of outcomes in cell *(i,j)* under the null hypothesis of independence between the variables, while $p \cdot q = N$ is the total number of observations. The test statistic χ^2 is then approximately the Chi-square distributed with *(p-1)(q-1)* degrees of freedom.

We were also interested in examining whether there were significant differences in the importance the respondents placed on certain global and local issues such as education, preventing climate change, improving health, reducing violent crime, and protecting the natural environment. Further, we investigated whether there were significant differences between groups of respondents with respect to their level of concern about climate change, policy preferences and required actions. To test whether two populations or groups differ significantly in a single categorical characteristic, i.e. tests on the difference between proportions, can be conducted by testing the null hypothesis , H_0: $p_i=p_j$ *(equal proportion)* against the alternative hypothesis for significant differences between the proportions. That is:

$$H_0 : p_1 = p_2 \quad vs \quad H_1 : p_1 \neq p_2$$

Alternatively, one can test whether one group has a significantly higher proportion than the other group. That is:

$$H_0 : p_1 \geq p_2 \quad vs \quad H_1 : p_1 < p_2$$

Tests for proportions are based on a binomial distribution *B(n,p)* modelling the number of successes in a sequence of *n* independent yes/no experiments, each of them with success probability *p*. For

independent observations, when the conditions $n_1p_1>5$, $n_1(1-p_1)>5$, $n_2p_2>5$, $n_2(1-p_2)>5$ are satisfied, the binomial distribution can be approximated by a normal distribution and the test can be carried out using a one- or two-sided t-test for differences between the proportion means.

Finally, in order to rigorously examine the effects of certain demographics and beliefs on major issues, we applied a multiple logistic regression model to the data. We investigated participants' desires to proceed on climate change policy by dividing the responses into those who favoured proceeding irrespective of what other countries do, proceeding only if there is international agreement, and, not proceeding. The paper also examines these demographics and beliefs in regard to policy preferences. The regression equation is set out below. Logit analysis was used in this study as it has been found to be more robust than discriminant analysis by Lo (1986) and McFadden (1976). This methodology is also used in similar studies by McCright and Dunlap (2011) and Hamilton (2011).

$$logit[\pi(X)] = ln\frac{\pi(X)}{1-\pi(X)} = \beta_0 + \beta_1X_1 + \beta_2X_2 + \cdots + \beta_pX_p \quad (4)$$

Where; $\pi(X) = \frac{e^{\beta_0+\beta_1X_1+\beta_2X_2+\cdots+\beta_pX_p}}{1+\beta_0+\beta_1X_1+\beta_2X_2+\cdots+\beta_pX_p}$

p_i = the probability of event X

p = number of independent variables used

β_i = the coefficient i

X_i = the variable i

3.4 Empirical Results

3.4.1 Importance of Climate Change – Global and Local Issues

The level of importance respondents placed on certain global and local issues was gauged using questions asked at the beginning of the survey. The global issues chosen were improving education,

preventing climate change, improving health, reducing violent crime, protecting the natural environment, reducing poverty and hunger and preventing wars. These issues and the local issues were based on previous surveys, see for example Lee and Cameron (2008), and adapted to suit an Australian context. As indicated by Table 3.1, all these issues were considered important or very important by over 70% of respondents.

Table 3.1*: Responses of participants to the question 'How important do you believe the following global issues are?' (upper panel) and 'How important do you believe the following Australian issues are?' (lower panel). For both questions, results are reported based on summarising the responses into two categories: 'Very Important / Important' versus 'Neutral / Unimportant / Very Unimportant'.*

	Global Issues	
Issue	**Important / Very Important**	**Neutral / Unimportant / Very unimportant**
Preventing wars	0.916	0.084
Reducing poverty and hunger	0.921	0.079
Protecting the natural environment	0.884	0.116
Reducing violent crime	0.922	0.078
Improving health	0.921	0.079
Preventing climate change	0.721	0.279
Improving education	0.906	0.094
Australian Issues		
Issue	**Important / Very Important**	**Neutral / Unimportant / Very unimportant**
Improving education	0.920	0.080
Improving health	0.931	0.069
Reducing violent crime	0.897	0.103
Protecting the natural environment	0.872	0.128
Preventing climate change	0.731	0.269
Reducing illegal drug use	0.785	0.215
Reducing unemployment	0.814	0.186

The issue of climate change was the lowest at 72.1% which was statistically significantly less when tested against the population average for those who consider it important or very important than all the other issues (t = -11.5053). When considering local issues we found very similar results. We looked at the issues of reducing unemployment, reducing illegal drug use, preventing climate

change, protecting the natural environment, reducing violent crime, improving health and improving education. Preventing climate change still received the lowest ranking, and statistically significantly so, with the combined 'very important' and 'important percentage' at 73.1% (t = -3.784). These are similar results to studies in both Europe and the US. For example Lorenzoni and Pidgeon (2006) found that those who worried a great deal or a fair amount about climate change ranged from 50% to 72% of respondents. They also found respondents felt climate change to be of secondary importance compared to other environmental, personal and social issues.

3.4.2 Global and Local Expectations about Climate Change Impacts

In a next step we investigated perceptions on the global and local effects of climate change. Over 65% of the Australian public were found to be worried or very worried about how climate change is affecting agriculture and water resources, ecosystems such as forests, wetlands, wildlife, etc. and severe weather conditions and sea levels. We found 55% of respondents were worried or very worried about the effects on human health including disease.

Interestingly, we found clear differences with respect to perceptions about how climate change will impact globally in comparison to Australia. Leiserowitz (2006) reports that US participants were far more likely to believe greater effects would occur in other countries and to other people. Our survey found a similar bias. The greatest difference was associated with standard of living decline: 56.9% believed living standards would decline worldwide and only 42.5% believed they would decline locally (t = -9.2116). Similarly, 63.3% felt water shortages would be a problem globally and only 55.1% indicated they had this concern on a local level (t = -5.2133). An increase in the likelihood of serious disease was considered to be the least likely outcome with 50.7% believing this would occur worldwide and only 37.8% believing it on a local level (t = -8.413). Lee and Cameron (2008) found this belief that there would be few health effects was also dominant in the US.

The participants' beliefs are in contrast to the CSIRO Report on Climate Change: Science and Solutions for Australia (2011). The report predicts substantial climate change impacts in Australia. It

predicts there will be less rainfall in the southern areas, and that summer tropical rainfall in northern areas will be highly uncertain with intense rainfall events becoming more extreme. Horton and McMichael (2008) include in their analysis of climate change risks to health in Australia effects such as increased vector-borne infectious diseases (e.g. dengue fever), food-borne infectious diseases (e.g. salmonella) and diminished food production and nutritional consequences.

Participants' levels of belief in information about climate change from government agencies was found to increase the level of worry about effects of climate change (t = 6.5784) and the perceived likelihood of certain effects occurring in the next fifty years (t = 4.5204). This was determined using a t test for differences in cells within a Chi square analysis.

3.4.3 Climate Change Mitigation Action

We were particularly interested in the desire of respondents to proceed on climate change policy irrespective of whether other countries do so (proposition 1); to proceed only if there is international agreement (proposition 2); and not to proceed at all (proposition 3). We found that over 50% of respondents wanted Australia to act irrespective of whether other countries proceed or not, with a further 32.9% wanting Australia to act if there is international agreement. In total only 16.1% of participants supported proposition 3, and preferred not to proceed at all with climate change policy action.

Table 3.2 provides the results of a multiple logistic regression in which the dependent variable was based on the question "Do you believe Australia should proceed on climate change policy?" We investigated the impact of gender, age, income level, education level, voting intention, attitude towards the importance of climate change as a policy issue in Australia, and belief in information about climate change from government agencies.

Gender was not found to be significant influence on attitudes towards climate change mitigation action, however age was found to be inversely related to a desire for action irrespective of

international agreement. Thus, younger participants were more likely to respond that Australia should proceed on climate change policy irrespective of what other countries do. On the other hand, older participants were significantly more likely to suggest that Australia should proceed only if there is international agreement on climate change action. Age was not found to be significant for responses to proposition 3 (i.e. not to proceed at all).

The importance placed on climate change as an issue that will affect Australian, and belief about information on climate change provided by government agencies, significantly affected the likelihood of agreeing to proposition 1. We also found that the greater the importance placed by a participant on climate change, and the greater his or her belief about information provided, the less likely he or she was to agree with proposition 3 (i.e. not to proceed at all). Interestingly, these variables were not found to be significant with respect to participants agreeing or disagreeing to proposition 2 (i.e. proceed on climate change only if there is international agreement). Overall, our results clearly indicate that the higher participants rate the importance of climate change and the more they believe in information provided by government agencies, the more likely they are to suggest that Australia should proceed on climate change policy irrespective of what other countries do.

The higher the education levels of respondents, the more likely they were to want to act irrespective of international agreement. However, respondents with higher education levels were less likely to suggest that Australia should proceed on climate change action only if there was international agreement. This second part may be a result of the desire to act irrespective of international action rather than indicating a lack of desire to act if there is international agreement. Education was not found to be significant with respect to proposition 3, however the variable still yields a negative sign, indicating that participants with higher education levels might be less likely to advocate not proceeding with climate change policy under any circumstances.

***Table 3.2**: Results for multiple logistic regression, examining the impact of explanatory variables, demographics, importance placed on climate change as a policy issue, belief of information about climate change and voting intentions, on responses to propositions on climate change policy.*

Independent Variables	**Proposition 1 – Proceed irrespective of other countries**	**Proposition 2 – Proceed if there is international agreement**	**Proposition 3 – Do not proceed at all**
Gender (0 = male, 1 = female)	0.1929 (0.1609)	-0.1407 (0.1471)	0.0117 (0.2330)
Age	**-0.0262***** **(0.0048)**	**0.0152***** **(0.0041)**	0.0045 (0.0066)
Importance of climate change as a policy issue in Australia (1=very important to 5 = very unimportant)	**-0.5905***** **(0.0935)**	0.0461 (0.0779)	**0.6026***** **(0.1068)**
Belief of information about climate change from Government agencies (1= to a great extent to 5 = not at all)	**-0.6163***** **(0.0887)**	-0.0815 (0.0760)	**0.9841***** **(0.1098)**
Education level (1= School, 2= diploma level, 3 = bachelor degree or above)	**0.2037*** **(0.0927)**	**-0.1969*** **(0.0843)**	-0.0642 (0.1310)
Income level (1=<20,000, 2= 20,000 to 50,000, 3 = 50,000 to 80,000, 4 = 80,000 to 110,000, 5 = >110,000)	0.1208 (0.0733)	-0.0738 (0.0664)	0.0232 (0.0978)
Intend to vote Liberal	**-0.8976***** **(0.1990)**	**0.3775*** **(0.1760)**	**0.4979*** **(0.2536)**
Intend to vote Labor	0.3033 (0.1929)	-0.2638 (0.1830)	-0.5370 (0.3234)
Intend to vote Greens	**0.9138**** **(0.3111)**	**-0.9892**** **(0.3100)**	-1.4235 (0.7936)
Constant	**2.8038***** **(0.5062)**	-0.4320 (0.4388)	**-6.0896***** **(0.7252)**
McFadden R^2	0.2612	0.0485	0.3614
Number of observations[6]	509	329	161
Standard errors are in parentheses.			
***p<0.05 **p<0.01 ***p<0.001**			

[6] Only 999 responses because one respondent did not complete all questions included in this regression.

Interestingly, we did not find a significant relationship between income level and attitude towards climate change policy action. We attribute this to the non-monotonic relationship between income and responses with regards to climate change policy action and provide more details about this relationship below.

Finally, we investigated the impact of the participants' voting intentions on their agreement with propositions 1, 2 and 3. We introduced dummy variables for measuring the impact of respondents' intentions to vote for the Liberal Party, the Australian Labor Party and the Australian Greens in comparison to those who intended voting for another party or were still unsure about which party to vote for in the next election.

Overall, the results with respect to voting intentions are not surprising. We found that participants intending to vote for the Liberal party were significantly less likely to agree to proceeding with climate change action irrespective of whether other countries did, and they were significantly more likely to agree to propositions 2 or 3 (i.e. either to only proceed if there is international agreement, or, not to proceed at all). On the other hand, results for participants intending to vote for the Greens indicated that they were significantly more likely to agree with proposition 1. They were also significantly less likely to suggest that Australia should only proceed if there was international agreement, while they were less likely to agree with proposition 3. Note that for the latter the p-value of the estimated coefficient is approximately 0.07 such that the variable is only significant at the 10% level, but not at the 5% level. Interestingly, the estimated coefficients for intention to vote Labor are not significant in the logistic regression models such that results are not so clear-cut for this group. However, the signs of the coefficients still indicate that these participants are more likely to agree with proposition 1 (p-value approximately 0.12) and less likely to agree with proposition 2 (p-value approximately 0.15) or proposition 3 (p-value approximately 0.10).

Of interest to politicians in Australia would be the views of the unsure voters who may represent the swinging voters. In the 2010 federal election the Australian Labor Party held 72 seats while the

Liberal/National Coalition held 73 in the House of Representatives with the balance of power being held by the Greens and independents who aligned with the Labor Party to give them power. These close results indicate the swinging voters are likely to be the ones who determine which party is in power and what policy action is, or is not, undertaken They were found to be statistically significantly the least likely to oppose climate mitigation action under any circumstances (t = -4.6946). They were also significantly less likely to want a carbon tax (t = -3.9888) and more likely to want a mix of policies (t = 4.5491).

The model with the highest explanatory power was the response for proposition 3 where the Mc-Fadden pseudo R^2 was approximately 0.36, while explanatory power of the model for proposition 1 was $R^2 = 0.26$. Clearly, the lowest explanatory power is given by the model for proposition 2, where we obtained a value of approximately $R^2 = 0.05$. Note, however, that the interpretation of McFadden pseudo R^2 is not as straightforward as for the coefficient of determination in a linear regression model. As a general rule of thumb it has been suggested that a McFadden pseudo R-squared ranging from 0.2 to 0.4 indicates a very good fit of the model, (see e.g. McFadden 1978). Thus, the considered variables provide a high contribution to explaining participants' responses regarding whether to proceed with climate change policy action irrespective of other countries, or, not to proceed at all.

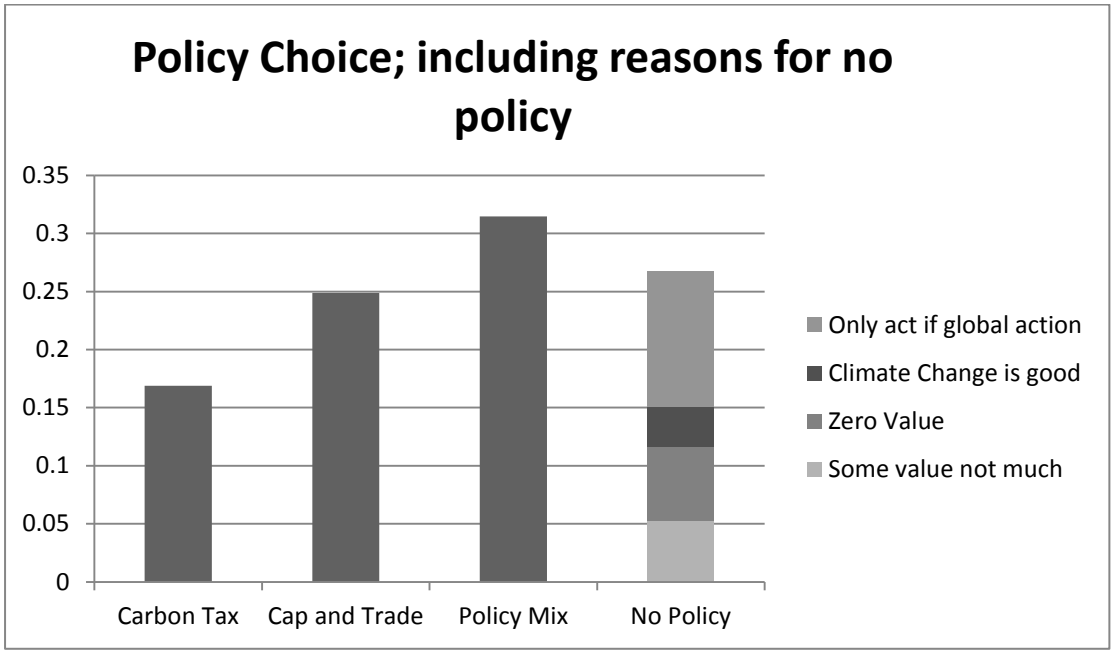
Overall, we find strong evidence that participants' views on whether Australia should proceed with climate change policies were influenced by their views on the importance of climate change and their level of trust in information about climate change from government agencies. Also, education levels and age were significant influences. Voting intention was found to be a highly significant variable, with the less conservative voters indicating a desire for proposition 1, and the 'no action' option being strongly aligned with conservative voters.

3.4.4 Climate Change Policy

In the next step we analysed participant responses to the question "*What policy response do you believe would be the preferable one for Australia to follow?"* Participants were given four options: (i) a carbon tax, (ii) a cap and trade scheme, (iii) a policy mix or other policy, and, (iv) no policy. Figure 3.1 displays the preferred policy choices of respondents as well as the reasons provided when their preferred option was (iv) no policy. This graph shows that respondents preferred a policy mix to any of the other choices. The general term of a 'policy mix' was used for those respondents who felt a range of policy was their preference. It was important not to imply a specific set of policies but rather to garner some knowledge as to whether respondents had a specific tool they thought should be used or not or, in fact, no policy at all. A policy mix was the most desired by 31.5% of respondents with a cap and trade the next preferred policy at 24.9%. A carbon tax was only the preferred choice for 16.8% of the participants, while 26.7% preferred no policy at all. The different sections in the 'no policy' column indicate the reasons for this choice. We find that among the respondents who prefer no policy, 43% said their reason was because they believe Australia should only act on climate change if there is global action undertaken. This is consistent with the results we found above with respect to a high proportion of participants saying Australia should act only if there is international agreement. Nearly 20% indicated they placed some value on prevention, but not much, 24% placed zero value on prevention and a further 13% felt climate change could actually be a good thing. Note that our findings also confirm results from earlier studies, such as Leiserowitz (2006), who found strong opposition to a carbon tax of any kind. Overall, in our survey more than 80% of participants preferred no policy or an alternative climate change policy action over a carbon tax.

Results for the multiple logistic regressions are presented in Table 3.3. We examine the responses of the participants using the same explanatory variables as for the analysis of the participants' attitude towards proceeding with climate change mitigation action. However, note that we also add the participants' responses to the question of whether to proceed with climate change mitigation action or not as an additional explanatory variable.

***Figure 3.1**: Responses of participants to the question "What policy response do you believe would be the preferable one for Australia to follow?" Participants were given four options: (i) a carbon tax, (ii) a cap and trade scheme, (iii) a policy mix or other policy, and, (iv) no policy. For the 'no policy' option, we also indicate the reasons provided reasons by participants for choosing this option.*



Again gender is not a significant variable with respect to the preferred policy response of participants in our survey. Interestingly, for the preferred policy response, we also do not find a significant impact from age on the preference for any of the considered policy options.

The importance placed on climate change as an Australian issue is found to be significant at the 0.1% level for the 'no policy' option and at the 1% level for respondents who preferred a policy mix or other policy. For the model investigating the no policy option, the coefficient is positive, indicating that those who are most concerned, are less likely to choose the 'no policy' option. While this is clearly an anticipated result, of interest is the significantly negative coefficient for the policy mix model. Our results suggest that those who consider climate change to be an important issue for Australia are more likely prefer a policy mix or another policy choice to mitigate climate change. Belief in information about climate change is a significant factor in all models except for the policy mix or other policy option. The estimated coefficient was found to be negative for respondents who prefer the carbon tax ($p<0.01$) and the cap and trade ($p<0.001$) policy options, while it was

Table 3.3: *Participants response to the question "What policy response do you believe would be the preferable one for Australia to follow?"*

Independent variables	**Carbon Tax**	**Cap and Trade**	**Policy Mix or Other Policy**	**No Policy**
Gender (0=male, 1=female)	0.1653 (0.1935)	-0.0520 (0.1610)	0.0967 (0.1483)	-0.2156 (0.1969)
Age	0.0087 (0.0056)	-0.0024 (0.0047)	0.0006 (0.0043)	-0.0094 (0.0057)
Importance of climate change as a policy issue in Australia (1=very important to 5= very unimportant)	-0.0315 (0.1260)	-0.1806 (0.0982)	**-0.2309**** **(0.0867)**	**0.4678***** **(0.1006)**
Belief of information about climate change from Government agencies (1=to a great extent to 5 = not at all)	**-0.3375**** **(0.1227)**	**-0.4640***** **(0.0979)**	0.0249 (0.0822)	**0.6501***** **(0.1013)**
Education level (1 = School, 2 = diploma level, 3 = bachelor degree or above)	0.0189 (0.1117)	0.1471 (0.0921)	-0.0133 (0.0848)	**-0.3231**** **(0.1122)**
Income level (1 =<20,000, 2= 20,000 to 50,000, 3=50,000 to 80,000, 4= 80,000 to 110,000, 5 = >110,000)	-0.0813 (0.0903)	-0.0108 (0.0736)	0.0357 (0.0670)	0.0075 (0.0878)
Proceed on climate change policy (1= proceed irrespective of other countries, 2 = proceed if there is international agreement, 3 = do not proceed at all)	**-1.2955***** **(0.2177)**	-0.1027 (0.1387)	**-0.4411***** **(0.1268)**	**1.3344***** **(0.1502)**
Intend vote Liberal	0.2241 (0.2845)	0.2487 (0.2080)	-0.0832 (0.1835)	-0.3166 (0.2373)
Intend vote Labor	**0.7996***** **(0.2339)**	-0.0114 (0.2005)	**-0.5913**** **(0.1852)**	0.0210 (0.2455)
Intend vote Green	0.4419 (0.2978)	0.1537 (0.2590)	-0.4298 (0.2459)	-0.5006 (0.4382)
Constant	0.1599 (0.6271)	0.2449 (0.5046)	0.3196 (0.4559)	**-4.7099***** **(0.6220)**
McFadden R^2	0.1455	0.0616	0.0360	0.3642
Number of observations[7]	169	248	314	268
Standard errors are in parentheses.				
***p<0.05 **p<0.01 ***p<0.001**				

[7] Only 999 responses due to one respondent did not complete all questions included in this regression.

significantly positive ($p<0.001$) for the no policy choice. Our results indicate that those who place more trust in the information provided by government agencies are significantly less likely to reject the carbon tax and cap and trade options. On the other hand, the less participants believed in information provided by government agencies, the more likely they were to believe that Australia should not have any policy response at all (the 'no action' option).

Education level was only significant for the no policy model. The results indicate that the higher the education level, the more likely respondents were to reject the 'no policy' option. For the other policy options, no straightforward interpretation of the results can be made, given the insignificance of the variable. Income was not found to be a significant influence in any of the models, however, we will examine the relationship between income and the suggested policy responses of participants in more detail in section 4.5.

As mentioned above, we also include the desire of respondents to proceed on climate change policy or not as an additional explanatory variable. We found it to be a significant factor in three of the models. Participants who believed Australia should not adopt any climate mitigation actions at all were also less likely to choose the carbon tax as the preferred policy option ($p<0.001$). Further, the more participants were opposed to climate change mitigation action, the more likely they were to suggest no policy ($p<0.001$) as the preferred option. Those who opposed action were also more likely to reject a policy mix or another policy ($p<0.001$).

The results from the applied multiple logistic regression do not indicate a significant relationship between those who tend to vote Liberal or those who tend to vote Green with any of the policy options. Note, however, that responses to the question about whether to proceed on climate change mitigation were strongly related to voting intentions. We did find a significantly positive relationship between the intention to vote Labor and support for the carbon tax as the preferred policy choice, and participants with the intention to vote Labor were less likely to prefer a policy mix or another policy.

Note that we also investigated the relationship between climate change mitigation action, preferred policy choice and voting intentions directly, applying tests for differences between the proportions. Our findings suggest that attitudes towards a policy mix and cap and trade program were similar for Liberal and Labor voters. Labor voters appeared fairly evenly divided between the policy options with only 20.2% of them indicating no policy (t = -5.1196). Of those Labor voters indicating no policy, 41% wanted global action to be undertaken prior to Australia committing to any climate change mitigation policy. For undecided voters, of the 24% indicating no policy required, 50% gave their reason as wanting global action to be undertaken before Australia committed. The other main area for distinction among the voting groups was with regards to the carbon tax. Liberal voters (t = -8.127) and unsure voters (t = -3.9888) were less likely to select the carbon tax as their preferred option and Labor voters (t = 7.0683) were significantly more likely to prefer a carbon tax. Note that bipartisan support for overall climate change action was also found by Leiserowitz (2006) in his US survey, with no specific policy analysis undertaken.

The model with the highest explanatory power as indicated by the McFadden pseudo R^2 was the 'no policy' choice. For this model, a McFadden R^2 of 0.364 indicates a high explanatory power of the exogenous variables for the observed responses. Note that this model also has the highest number of significant explanatory variables. The model for the carbon tax policy choice yields a R^2 of 0.146 which also indicates a reasonable explanatory power. It seems that the applied variables can best explain the participants' responses for these two options. In particular, participants' attitudes towards the importance of climate change as a policy issue, their attitude towards information provided about climate change by government agencies, their desire to proceed on climate change policy or not and education level, are significantly related to the preferred policy option.

3.4.5 The Effects of Income

Let us now consider the impact of income on the desire of respondents to proceed on climate change policy and on their preferred policy choice. The effect of income on the responses with

regards to climate change mitigation action and preferred policy response was found to be insignificant in the estimated logistic regression models. This is similar to the findings of a study by Arkesteijn and Oerlemans (2005), who suggest that willingness to pay is independent of income. Derksen and Gartrel (1993) also found that level of income could not be used as a predictor for the degree to which respondents were environmentally conscious. This is in contrast to a New South Wales study by Akter and Bennett (2011) and a study by Oliver et al. (2011) in South Africa, which found positive relationships between income and the desire for climate change mitigation action.

The upper panel of Table 3.4 shows relative frequencies of the responses to climate change mitigation action conditional on income. We find that there is no monotonic relationship between income and preferred climate change mitigation action that applies to all income levels. There does seem to be, however, a fairly steady preference for action irrespective of whether other countries take action up to an income level of $80,000 p.a. For the income level group $80,000 - $110,000 p.a., this is the preferred climate mitigation action for even 58%. For the highest income level (>$110,000), however, action irrespective of other countries is only supported by approximately 43% of respondents. Note, however, that to proceed with climate change action irrespective of what other countries do, still remain the most preferable option also in the highest income group.

Our results also indicate that with increasing income, a higher fraction of participants tend to prefer the 'not at all' option. While for the lowest income group only 14.57% indicate this option as the preferred choice, for the group with the highest income level, 23.33% chose the 'not at all' option. Interestingly, this group were also least likely to believe that any occurrences due to climate change will affect them in the next fifty years. However, a test for independence yielded a test statistic of χ^2 =7.255 that is below the critical value, $\chi^2_{(8),0.9}$ =13.36, of the Chi-Square distribution with (3-1)(5-1)=8 degrees of freedom, even at the 10% significance level. Therefore, overall results indicate that there is no significant relationship between income and preferred climate change mitigation action.

Table 3.4: *Relative frequency of responses (categorised according to income level in $) to the question "Do you believe Australia should proceed on climate change policy?" (upper panel), and, "What policy response do you believe would be the preferable on for Australia to follow?"(lower panel)*

Climate Change Mitigation Action					
Income Level (Respondents in Group)	**Less than $20,000 p.a. (254)**	**$20,000 to $50,000 p.a. (331)**	**$50,000 to $80,000 p.a. (242)**	**$80,000 to $110,000 p.a. (114)**	**More than $110,000 p.a. (60)**
Proceed Irrespective of other countries	51.57%	49.85%	50.83%	57.89%	43.33%
Proceed if there is international agreement	33.86%	34.74%	33.06%	24.56%	33.33%
Do not proceed at all	14.57%	15.41%	16.12%	17.54%	23.33%
	100%	100%	100%	100%	100%
Preferred Policy Choice					
Income Level (Respondents in Group)	**Less than $20,00 p.a. (254)**	**$20,000 to $50,000 p.a. (331)**	**$50,000 to $80,000 p.a. (242)**	**$80,000 to $110,000 p.a. (114)**	**More than $110,000 p.a. (60)**
Carbon tax	14.57%	21.75%	13.22%	21.24%	6.67%
Cap and trade	24.41%	23.26%	28.10%	28.32%	16.67%
A policy mix or other policy	32.68%	30.82%	31.82%	26.55%	38.33%
No policy required	28.35%	24.17%	26.86%	23.89%	38.33%
	100%	100%	100%	100%	100%

In the lower section of Table 3.4, we report relative frequencies of participants' responses to preferred policy choice according to income level. As mentioned earlier, the overall preferred option among all income groups was a policy mix or a policy different to a carbon tax or cap and trade scheme. Again, we conducted a test for independence, yielding a test statistic of χ^2 =22.040, while the corresponding critical value of the Chi-Square distribution with (4-1)(5-1)=12 degrees of freedom is $\chi^2_{(12),0.95}$=21.026. Therefore, with 22.040>21.026, the test suggests that income levels and preferred policy choice are dependent, since the null hypothesis of independence is rejected at the

5% level of significance. However, similar to the question of whether or not to proceed with climate change mitigation action, there is no monotonic relationship between income levels and preferred climate change policy. Again, the aberration is in the highest income level, in which respondents had equal preferences for no policy and a policy mix (38.33%), while only 6.67% in this group said a carbon tax was their preferred option and 16.67% favoured a cap and trade scheme. The income level $80,000 p.a. to $110,000 is the only one to prefer a cap and trade scheme. For all other income level groups, the highest fraction of participants supported a policy mix or another policy, followed by either the no policy option or cap and trade, with a carbon tax being the least favoured option. Overall, responses in the four income groups <$20,000, $20,000–$50,000, $50,00–$80,000 and $80,000–$110,000 are at least somehow similar, while responses in the highest income group >$110,000 significantly deviate from the overall pattern.

Overall, we find that there is no significant relationship between income and climate change mitigation action, while the identified relationship between income and preferred policy option is significant, but non-monotonic. These results may also explain why income was not a significant variable in the conducted logistic regression analysis in Sections 4.3 and 4.4.

3.4.6 Other Aspects

We also examined participants' responses on who should take the main responsibility for prevention of climate change, what sectors should be covered, and how government should spend revenue raised from climate change policy action.

The survey found 49.7% of respondents indicated the main responsibility within Australia for climate change mitigation was spread among major emitters, government and taxpayers, and consumers. The data showed that 27.6% of respondents believed the main responsibility lay with the major emitters. When asked about international responsibility for climate change mitigation, 64% of the respondents in our study said they believed all countries were responsible, with 19.5% indicating

mitigation should be undertaken by countries in proportion to their current contribution to the claimed problem.

Two other important components of any climate change policy were also surveyed. Firstly, we asked what sectors should be covered by any policy. We informed respondents that 53.9% of GHG emissions come from the stationary energy sector, 15.9% from agriculture and 14.6% from transport. This data came from the Department of Climate Change and Energy Efficiency's National Greenhouse Gas Inventory for 2008.[8] Over 50% of respondents wanted all sectors to be included. The agricultural sector had the lowest individual preference to be covered by any mitigation policy of any of the sector choices.

The second important component was the question, how the revenue, earned by the government from the implementation of either a carbon tax, cap and trade emissions trading scheme or a combination of various policies, should be spent. The survey found 32% of respondents preferred a combination of ways to spend the revenue. While 28.8% indicated a preference for investing in renewable energy, 20.5% chose subsidising those in lower income groups for the anticipated increased costs of electricity. Only 1% supported assisting poorer countries to deal with claimed climate induced changes, however, these respondents may have selected a combination of items which would have included assisting these countries. O'Connor et al. (1999) found similar resistance to helping poor countries in their US study. The choice of how to spend the revenue earned was also dependent on age (χ^2 =57.5657) and income level (χ^2 =34.2103). Overall 20.5% indicated a desire to subsidise lower income groups, and 34% of those aged 65 years and over favoured this form of spending. Only 7% of the highest income level favoured supporting low income earners. Gender was not a factor for either subsidies or sectors and we found little difference in preferences between capital city and non-capital city dwellers with 53% and 52%, respectively, preferring all sectors to be covered.

[8] National Greenhouse Gas Inventory 2008 undertaken by the Department of Climate Change and Energy Efficiency was released on 27 May, 2010 by the Australian Government, http://www.climatechange.gov.au

3.5 Conclusions

This paper provides survey results from a representative sample of Australian residents of voting age. As with any survey this paper suggests there are likely limitations to projecting all the results necessarily on the whole population. It aims to increase the understanding of the issues and add to the public debate on policy direction for Australia. Our findings indicate that action for climate change mitigation is desired by most Australians and that 64% felt all countries were responsible for mitigation action. The largest cohort (31.5%) believed that the government should adopt a policy mix which was in line with the previous federal Labor government's policy i.e. possibly a mixture of renewable energy scheme, carbon tax and/or subsidies. This indicates no particular policy bias by participants. We also find that a cap and trade scheme is preferred over the carbon tax which was introduced in July 2012 and has since been repealed by the current Coalition government. The then Labor government intended replacing the carbon tax with a cap and trade scheme in 2015. The current federal coalition government has as yet not clearly defined its policy for climate change mitigation. It proposes a fund to support large companies to reduce their CO_2 emissions. However, which and how many companies and sectors are to be included is as yet uncertain. It appears to have no plans to introduce a cap and trade scheme.

Our findings also suggest that factors such as age, the attitude towards climate change as a policy issue for Australia, belief of information about climate change from Government agencies, education level, and voting intentions have a significant impact on participants' preference whether to proceed with climate change mitigation action or not. The same variables were also found significant for participants' responses with regards to the preferred policy response, i.e. whether to implement a carbon tax, a cap and trade scheme, a policy mix or no policy at all.

Many of the findings of this study are in line with those of the US and Europe with an increase in concern about climate change linked with an increase in the desire to act. However, unlike the US and Europe, gender and income were not clear factors in our analysis. The breakdown of policy

preferences into political parties, while indicating some significant differences, found that a majority of the supporters of each party desired action.

While many studies have been undertaken in Europe and the US, few have investigated the views of countries in the Asian region. This study addresses that imbalance with this Australia-wide study. The UNFCCC was set up to create a concerted worldwide response to climate change, and an understanding of global views is an important ingredient for this to commence. This survey increases that level by providing an improved understanding of the levels of commitment of the Australian public.

The final words are left to three divergent views provided by respondents in the survey:

"Climate change has not been proven. Certainly responsibility for climate change, if it exists has not been proven."

"It's a global issue that needs to be addressed by all with no exceptions."

"It can be something we can all do to help, but Australia should be a leader in policy changes and not a follower."

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Addendum 2: This document does not form part of the paper submitted to Global Environmental Change, but provides the survey used.

Climate Change Survey

Page 1:

Target group questions:

a) In what year were you born?

This will be a drop down box commencing in 1900 until 1991

b) What is your gender?

Again drop down box

Male

Female

c) In which Australian state or territory do you normally live?

Again drop down box

New South Wales

Victoria

Queensland

South Australia

Western Australia

Tasmania

Northern Territory

Australian Capital Territory

Q1. How important do you believe the following global policy issues are?

(Check one box per row.)

Scale of 1= very important, 2 = Important, 3 = Neutral, 4 = Unimportant, 5 = Very unimportant

Use buttons so that they can see all choices all the time, put them on the row next to each part of the question, one answer only allowed per row

a) Preventing wars

b) Reducing poverty and hunger

c) Protecting the natural environment

d) Reducing violent crime

e) Improving health

f) Preventing climate change

g) Improving education

Q2. How important do you believe the following Australian policy issues are?

(Check one box per row.)

Exactly as in question 1.

a) Improving education

b) Improving health

c) Reducing violent crime

d) Protecting the natural environment

e) Preventing climate change

f) Reducing illegal drug use

g) Reducing unemployment

Page 2:

Climate Change

The core topic of this survey is climate change. The following claims have been made on the CSIRO website regarding changes that have already occurred due to climate change;

- glaciers and sea-ice have receded,
- there has been a decline of 10-15% of the Arctic sea ice extent and a 40% decrease in its average thickness,
- snow depth at the start of October each year has declined by 40% in the last 40 years in the Australian Alps
- an average sea level rise of 20 mm per decade has occurred over the last 50 years,
- changes in mating and migration times of birds have been noted,
- plants and animals have shifted both towards the North and South Poles and towards higher altitudes, and
- there has been an increase in coral bleaching due to increased water temperature.[9]

Q3. Do you believe the information about climate change from Government Agencies? (Check one box below.)

Scale of 1= To a great extent, 2 = Somewhat, 3 = Unsure, 4 = Very little, 5 = Not at all

Use buttons so that they can see all choices all the time, one answer only allowed

[9] More information can be found at www.csiro.au

Q4. How worried are you about how climate change is affecting the following; (Check one box per row).

Scale of 1= Very worried, 2 = Worried, 3 = Unsure, 4 = Very little, 5 = Not at all worried

Use buttons so that they can see all choices all the time, one answer only allowed

a) Agriculture and water resources

b) Ecosystems such as forests, wetlands, wildlife etc.

c) Human health including disease

d) Severe weather conditions and sea levels

Q5. How likely do you think it is that each of the following will occur during the next 50 years due to the possible effects of climate change? (Check one box per row)

Scale of 1= Very likely, 2 = Likely, 3 = Neutral, 4 = Unlikely 5 = Very unlikely

Use buttons so that they can see all choices all the time, one answer only allowed

a) Many people's stand of living will decrease worldwide

b) Worldwide water shortages will increase

c) Increased rates of serious disease worldwide

d) Your own standard of living will decrease

e) Water shortages will increase where you live

f) Your chance of getting a serious disease will increase

Page 3

Policy Responses to Climate Change:

There are a few policy responses that have been looked at by governments around the world to combat the externality of climate change. The externality is where those who are claimed to produce the most greenhouse gas emissions do not face the full consequences of the cost of their actions. Following are two possible policy responses to climate change that are being considered both in Australia and globally. The goal of these policies is to provide incentives to companies to develop and use carbon reducing measures. Please read these summaries of the policies and answer the questions which follow regarding government policy.

Carbon Tax:

A carbon tax is a tax on the emissions claimed to be causing climate change. A tax would provide cost certainty to businesses that need to comply with emission reductions. As it is difficult to determine an exact tax level that would provide the necessary incentives the level of emission reductions this would achieve is uncertain.

Cap and Trade:

Emissions trading (or cap and trade) is where a cap or limit is placed on the total amount of emissions allowed. The cap is allocated or sold to firms in the form of emissions "permits" which represent the right to emit or discharge a specific volume of the carbon dioxide (CO_2). Firms are required to submit the number of permits equivalent to their emissions at the end of each year. The total amount of permits cannot exceed the cap, limiting total emissions to that level. Trading may occur in these permits where firms that need additional permits to equal their emissions can buy these from those firms that have either reduced their emissions below the number of permits they hold or have been able to create permits from emission reducing activities. Cost to business is less certain under this policy however the level of emission reductions achieved is certain.

Q6. What policy response do you believe would be the preferable one for Australia to follow? (Choose one only)

In this I want it to be just one answer only allowed. Also if yes to a), b), or d) they should go straight to question 8, if yes to c) they should go to question 7.

a) Cabon tax
b) Cap and trade
c) No policy required
d) A policy mix or other policy

Q7. You answered 'No policy required' in the previous question, is this because; (Choose one only)

In this I want it to be just one answer only allowed.

a) You place some value on prevention, just not much
b) You place zero value on prevention
c) From your point of view, climate change could actually be a good thing
d) You only believe Australia should act on climate change if there is global action undertaken

Q8**.** Assuming one of the policy suggestions is taken up by the Australian government they will most likely achieve revenue for the government. Which of the following ways do you think the government should spend this revenue? (Choose one only)

In this I want it to be just one answer only allowed.

a) Subsidise those in lower income groups for the likely increased power costs
b) Invest in renewable energy
c) Provide tax or other incentives for activities that reduce the emissions

d) Assist poorer countries deal with claimed climate induced changes

e) Combination of two or more of the above

f) No specific expenditure item

Q9. One of the issues to be determined if a policy is undertaken is how many sectors of the economy should be required to comply with the emission requirements. The Department of Climate Change and Energy Efficiency[10] conducted the National Greenhouse Gas Inventory for 2008 and found the largest source of greenhouse gas emissions was from the stationary sector* (53.9%), then agriculture (15.9%) and transport (14.6%). Which sectors do you believe should be included in a policy response?

*The stationary sector includes electricity production, petroleum refining, manufacture of solid fuels and other energy industries and the combustion of fuels used by manufacturing industries and construction. (Choose one only)

In this I want it to be just one answer only allowed.

a) No Sector

b) Stationary sector

c) Agriculture sector

d) Transport sector

e) Stationary and agriculture sectors

f) Stationary and transport sectors

g) Agriculture and transport sectors

h) All sectors

[10] National Greenhouse Gas Inventory 2008 undertaken by the Department of Climate Change and Energy Efficiency was released on 27 May, 2010 by the Australian Government, http://www.climatechange.gov.au

Page 4:

Q10. In Australia do you believe the main responsibility for prevention of climate change should belong to: (Choose one only)

In this I want it to be just one answer only allowed.

a) Major emitters

b) Government and taxpayers

c) Consumers

d) Combination of two or more of the above

e) No one should

Q11. Indicate how strongly you agree with one of each of the pairs of statements below: (Check one box per row)

This should be on a scale of 1= Strongly agree, 2 = Agree, 3 = Neutral, 4 = Disagree, 5 = Strongly disagree

Use buttons so that they can see all choices all the time, one answer only allowed

a) Government is almost always wasteful and inefficient

b) Government regulation of business is necessary to protect the public interest

c) Most elected officials care what people like me think

Q12. Internationally, do you believe the responsibility for prevention of climate change should belong to: (Choose one only)

In this I want it to be just one answer only allowed.

a) Densely populated developing countries like India and China

b) The U.S.A. and other industrialised countries

c) Countries in proportion to their current contribution to the claimed problem

d) All countries

e) No countries

Q13. Do you believe Australia should proceed on climate change policy;

(Choose one only)

In this I want it to be just one answer only allowed

a) Irrespective of whether other countries do or not

b) Only if there is international policy agreement

c) Not at all

Q14. At the United Nations Climate Change Conference in Cancun, Mexico in November and December 2011 the participants agreed to try to keep global warming to below 2° Celsius above pre-industrialised levels. What amount per annum would you be willing to pay to ensure a climate change policy which help would achieve this aim?

(Choose one only)

In this I want it to be just one answer only allowed

a) No extra

b) $1 to $100

c) $101 to $200

d) $201 to $500

e) $501 to $1,000

f) $1001 or more

Q15. Please make any comments you wish about the issue of climate change.

I would like a space here to enable any comments they wish to make

Page 5:

In order to better analyse these results we would like to find out a little bit about you. Please remember that any information or personal details gathered in the course of this study are confidential and in no way can any individual be identified.

Q16. In order to better analyse these results we would like to find out a little bit about you. Please remember that any information or personal details gathered in the course of this study are confidential and in no way can any individual be identified.

(Choose one only per question)

Use buttons so that they can see all choices all the time, one answer only allowed

a) What is the highest level of education you completed?

Again drop down box

Secondary School

Advanced Diploma, Diploma or Certificate

Bachelor Degree or above

Other

b) Which category best describes your current status?

Again drop down box

Work full time

Work part time

Student

Retired

Unemployed

Other

c) Do you consider yourself well informed about environmental issues:

Again drop down box

Yes

No

d) Politically do you tend to vote:

Again drop down box

Liberal Party

Labor Party

The Greens

Other

Unsure

e) Do you consider yourself:

Again drop down box

Risk taker

Risk neutral

Risk averse

f) Your personal annual income bracket is:

Again drop down box

Less than $19,999

$20,000 to $49,999

$50,000 to $79,999

$80,000 to $109,999

$110,000 and above

g) About how many lottery/powerball etc. tickets do you buy in a year?

Again drop down box

None

1 to 12

More than 12

h) How many environmental groups or organisations do you belong to?

Again drop down box

None

One

More than one

i) Do you have any children (and/or grandchildren)?

Again drop down box

Yes

No

j) Do you normally live in one of the Australian capital cities?

Again drop down box

Yes

No

Thank you for taking the time to complete this survey, the results of this research will be sent for publication in an academic journal upon its completion.

The ethical aspects of this study have been approved by the Macquarie University Human Research Ethics Committee. If you have any complaints or reservations about any ethical aspect of your participation in this research, you may contact the Committee through the Director, Research Ethics (telephone [02] 9850 7854, fax [02] 9850 8799, email: ethics@mq.edu.au). Any complaint you make will be treated in confidence and investigated, and you will be informed of the outcome.

Addendum 3: This document does not form part of the paper submitted to Global Environmental Change but provides additional information on the respondents profile obtained from the survey.

Demographic	Survey	ABS	t statistic
Gender			
Male	0.497	0.4944	0.1963
Female	0.503	0.5055	-0.1900
Age			
18 to 30	0.273	0.2590	0.9943
31 to 49	0.364	0.3425	1.4138
50 to 64	0.204	0.2241	-1.4969
65 years +	0.159	0.1744	-1.4226
State			
New South Wales	0.335	0.3230	0.8460
Victoria	0.250	0.2479	0.1339
Queensland	0.199	0.2004	-0.1281
South Australia	0.071	0.0734	-0.3026
Western Australia	0.101	0.1054	-0.4694
Tasmania	0.020	0.0229	-0.6600
Northern Territory	0.012	0.0104	0.4726
Australian Capital Territory	0.012	0.0165	-1.3040
Education			
Secondary School	0.343	N/A	
Advanced Diploma, Diploma or Certificate	0.293	0.3460	-3.7057
Bachelor Degree or above	0.343	0.2790	4.2437
Other	0.021	N/A	
Employment Status			
Work Full Time	0.447	0.4707	-1.5375
Work Part Time	0.155	0.1976	-3.7412
Student	0.108	0.0483	6.0773
Retired	0.176	N/A	
Unemployed	0.057	0.0369	2.7373
Other	0.057	N/A	
Income			
Less than $19,999	0.253		
$20,000 to $49,999	0.331		
$50,000 to $79,999	0.242		
$80,000 to $109,999	0.114		
$110,000 and above	0.060		
Income: Mean Annual in Quintile[1]			
Quintile 1: bottom 20% income level		$23,868	
Quintile 2: next 20% income level		$51,480	
Quintile 3: next 20% income level		$76,284	
Quintile 4: next 20% income level		$107,276	
Quintile 5: top 20% income level		$187,980	
Voting Intentions[2]		**House of Representatives**	**Senate**
Liberal Party	0.298	0.3958	0.3001
Labor Party	0.287	0.3799	0.3516
The Greens	0.106	0.1176	0.1311
Other	0.089	0.0512	0.1797
Unsure	0.220	0.0555	0.0375

All data is taken from the Australian Bureau of Statistics (ABS) 2011 Census other than the income and voting information.

The t statistic values are the result of a hypothesis test:

H_0: survey proportion = ABS proportion

H_1: survey proportion ≠ ABS proportion

Gender, age and state were not rejected, indicating they all statistically significantly equal. Full time workers also did not reject the H_0 while all other employment designations were all rejected.

Not available (N/A) indicates the information was not provided by the ABS in a manner which enabled a meaningful comparison with the survey statistics.

1. The ABS data is provided by mean income for the bottom 20%, the next 20% and so on. It does not precisely correlate with the manner in which the survey requested income level information. The income levels are from 2010 data at http://www.abs.gov.au

2. The data used for voting intentions are taken from the first preferences by party in the House of Representatives and first preferences by group in the Senate from the Australian Electoral Commission website for the 2010 Federal Election. The unsure numbers are taken as the informal votes in the election (see http://results.aec.gov.au/15508/Website/Default.htm).

While voting intentions and the actual results of the 2010 election are statistically significantly different this appears to be predominantly as a result of the number of unsure voters found in the survey, who, due to compulsory voting in Australia, would have made their decision when they voted. This 22% appear approximately evenly distributed among the Liberal Party, Labor Party and the Greens.

Results of each survey question and some indication of significance levels.

Question					
4. How important do you believe the following global issues are?	**Very Important**	**Important**	**Neutral**	**Unimportant**	**Very unimportant**
Preventing wars	0.6034	0.3127	0.0689	0.0070	0.0080
Reducing poverty and hunger	0.6034	0.3177	0.0579	0.0110	0.0100
Protecting the natural environment	0.5235	0.3606	0.0879	0.00170	0.0110
Reducing violent crime	0.5654	0.3566	0.0599	0.0110	0.0070
Improving health	0.5684	0.3526	0.0609	0.0070	0.0110
Preventing climate change	0.3906	0.3307	0.1978	0.0400	0.0410
Improving education	0.4935	0.4126	0.0819	0.0050	0.0070
95% confidence interval for preventing climate change	0.3604 to 0.4208	0.3015 to 0.3598	0.1731 to 0.2225	0.0278 to 0.0521	0.0287 to 0.0532

Preventing climate change is statistically significantly (using 95% confidence intervals shown above) below all other issues for very important and for protecting the natural environment and improving education for important. The high very important results for preventing wars and reducing poverty and hunger may have reduced the important results for them. It also rates statistically significantly higher for all other response categories, again using 95% confidence intervals.

5. How important do you believe the following Australian issues are?	**Very Important**	**Important**	**Neutral**	**Unimportant**	**Very unimportant**
Improving education	0.4985	0.4216	0.0649	0.0100	0.0050
Improving health	0.5694	0.3616	0.0549	0.0080	0.0060
Reducing violent crime	0.5415	0.3556	0.0879	0.0080	0.0070
Protecting the natural environment	0.4625	0.4096	0.0999	0.0190	0.0090
Preventing climate change	0.3856	0.3457	0.1758	0.0519	0.0410
Reducing illegal drug use	0.3866	0.3986	0.1469	0.0490	0.0190
Reducing unemployment	0.3556	0.4585	0.1479	0.0280	0.0100
95% confidence interval for preventing climate change	0.3554 to 0.4158	0.3162 to 0.3751	0.1522 to 0.1994	0.0382 to 0.0657	0.0287 to 0.0532

The proportion of participants who rated action on climate change mitigation as a very important issue was significantly smaller (using the 95% confidence intervals shown above) than the proportions that rated the following issues as very important: improving education, improving health, reducing violent crime and protecting the natural environment. It is also statistically significantly below improving education, protecting the natural environment, reducing illegal drug use and reducing unemployment in the important response. The proportion who were neutral about climate action was significantly greater than the 'neutral' proportions for all other issues except reducing illegal drug use. The proportion who rated climate action as unimportant was greater than the 'unimportant' proportions for all other categories.

6. Do you believe the information about climate change from Government Agencies?	**To a great extent**	**Somewhat**	**Unsure**	**Very little**	**Not at all**
	0.1868	0.4496	0.4828	0.1199	0.0609
While over 50% believed the information at least “somewhat”, the “somewhat” level s the highest, which may be reflected in some of the results found in Questions 4 and 5.					
7. How worried are you about how climate change is affecting the following:	**Very worried**	**Worried**	**Unsure**	**Very little**	**Not at all worried**
Agriculture and water resources	0.2368	0.4276	0.1978	0.0849	0.0529
Ecosystems such as forests, wetlands, wildlife etc.	0.2937	0.3576	0.1958	0.0939	0.0589
Human health including disease	0.2168	0.3477	0.2468	0.1159	0.0729
Severe weather conditions and sea levels	0.3197	0.3357	0.1728	0.1029	0.0689
When we combine the Very Worried and Worried responses to these issues we find agriculture and water resources at 0.6643, ecosystems at 0.6513 and severe weather conditions at 0.6553. The only issue for which the response rate was significantly different was human health at 0.5644 where the 95% confidence interval of this result is 0.5337 to 0.5952. This corroborates some of the discussion in the paper on the lower level of concern for human health than other climate change issues.					

8. How likely do you think it is that each of the following will occur during the next 50 years due to the possible effects of climate change?	**Very likely**	**Likely**	**Neutral**	**Unlikely**	**Very unlikely**
Many people's standard of living will decrease worldwide	0.2198	0.3487	0.2298	0.1528	0.0490
Worldwide water shortages will increase	0.2667	0.3656	0.2018	0.1169	0.0490
Increased rates of serious disease worldwide	0.1928	0.3137	0.3067	0.1319	0.0549
Your own standard of living will decrease	0.1508	0.2737	0.2897	0.2078	0.0779
Water shortages will increase where you live	0.1998	0.3506	0.2288	0.1558	0.0649
Your chance of getting a serious disease will increase	0.1169	0.2607	0.3427	0.1928	0.0869

10. Assuming one of the policy suggestions is taken up by the Australian Government they will most likely earn revenue for the government. Which of the following ways do you think the government should spend this revenue?	
Subsidise those in lower income groups for the likely increased power costs	0.2058
Invest in renewable energy	0.2877
Provide tax or other incentives for activities that reduce the emissions	0.0989
Assist poorer countries deal with claimed climate induced changes	0.0100
Combination of two or more of the above	0.3197
No specific expenditure item	0.0779

11. One of the issues to be determined if a policy is undertaken is how many sectors of the economy should be required to comply with the emission requirements. The Department of Climate Change and Energy Efficiency conducted the National Greenhouse Gas Inventory for 2008 and found the largest source of greenhouse gas emissions was from the stationary sector* (53.9%), then agricultural (15.9%) and transport (14.6%). Which sectors do you believe should be included in a policy response? * The stationary sector includes electricity production, petroleum refining, manufacture of solid fuels and other energy industries and the combustion of fuels used by manufacturing industries and construction.	
No sector	0.1359
Stationary sector	0.1269
Agricultural sector	0.0270
Transport sector	0.0410
Stationary and agriculture sector	0.0400
Stationary and transport sector	0.0869
Agriculture and transport sector	0.0160
All sectors	0.5265

12. In Australia do you believe the main responsibility for prevention of climate change should belong to:	
Major emitters	0.2757
Government and taxpayers	0.0779
Consumers	0.0370
Combination of two or more of the above	0.4965
No one should	0.1129

95% confidence intervals were determined as follows;

Major emitters: 0.2483 to 0.3037; Government and taxpayers: 0.0614 to 0.0946; Consumers: 0.0253 to 0.0487; Combination of two or more of the above: 0.4660 to 0.5280; No one should: 0.0934 to 0.1326. These indicate the combination to be statistically significantly greater than all the others, with Major emitters a clear second and Consumers to be statistically significantly lower.

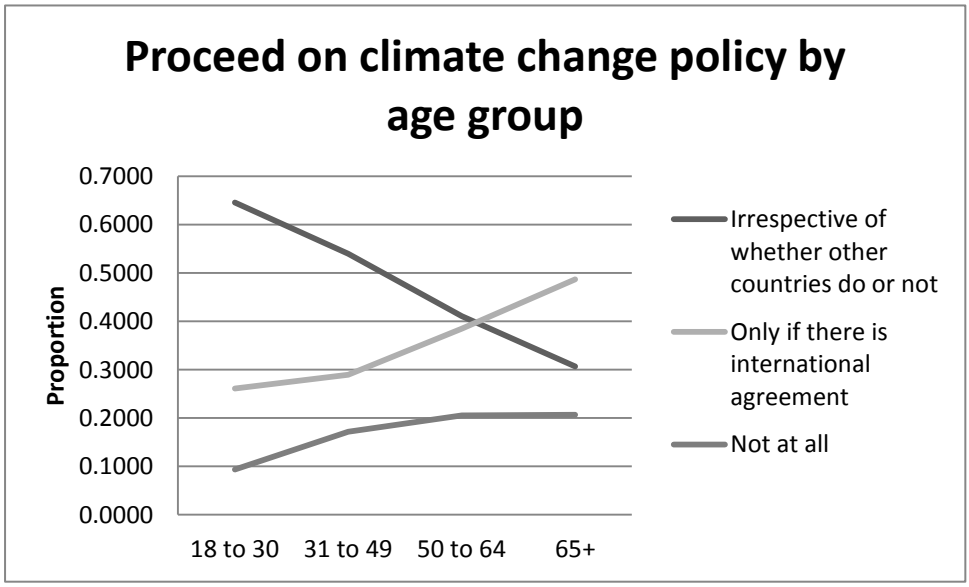
13. Indicate how strongly you agree with each of the statements below:	**Strongly agree**	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
Government is almost always wasteful and inefficient	0.3087	0.3816	0.2158	0.0829	0.0110
Government regulation of business is necessary to protect the public interest	0.1948	0.4695	0.2468	0.0649	0.0240
Most elected officials care what people like me think	0.0310	0.1688	0.2987	0.3047	0.1968

14. Internationally, do you believe the responsibility for prevention of climate change should belong to:	
Densely populated developing countries like India and China	0.0549
The US.A and other industrialised countries	0.0480
Countries in proportion to their current contribution to the claimed problem	0.1948
All countries	0.6394
No countries	0.0629
95% confidence intervals were determined as follows; Densely populated developing countries: 0.0408 to 0.0691; The USA and other industrialised countries: 0.0347 to 0.0612; Countries in proportion to their current contribution: 0.1703 to 0.2194; All countries: 0.6096 to 0.6691; No countries: 0.0479 to 0.0780. These results indicate that the proportion of 'all countries' responses was statistically significantly greater than all the others, with 'in proportion to their current contribution' a clear second while the rest were not statistically significantly different from each other.	

The table below is shown as it was not included in the Logit analysis but is of statistical significance when looked at on its own. The next two are shown as they are discussed in the paper without statistics being given.

15 x 1: Do you believe Australia should proceed on climate change policy x age	**18 to 30**	**31 to 49**	**50 to 64**	**65 years +**
Irrespective of whether other countries do or not	0.6455	0.5393	0.4103	0.3067
Only if there is international agreement	0.2609	0.2893	0.3846	0.4867
Not at all	0.0936	0.1713	0.2051	0.2067

The Chi Square statistic of 59.39772 indicates that the desire to proceed is not independent of age. The graph below provides a clear representation of the results.



15 x 23. Do you believe Australia should proceed on climate change policy x income p.a.	**Less than $20,000**	**$20,000 to $49,999**	**$50,000 to $79,999**	**$80,000 to $109,000**	**$110,000 and above**
Irrespective of whether other countries do or not	0.2569	0.3235	0.2412	0.1294	0.0490
Only if there is international agreement	0.2614	0.3495	0.2432	0.0851	0.0608
Not at all	0.2298	0.3168	0.2422	0.1242	0.0870
The Chi Square statistic of 7.6189 indicates that the desire to proceed is independent of income.					

9 x 23. What policy response to you believe would be the preferable one for Australia to follow x income	**Less than $20,000**	**$20,000 to $49,999**	**$50,000 to $79,999**	**$80,000 to $109,000**	**$110,000 and above**
Carbon tax	0.146	0.218	0.132	0.212	0.067
Cap and trade	0.244	0.233	0.281	0.283	0.167
No policy required	0.283	0.242	0.269	0.239	0.383
A policy mix or other policy	0.327	0.308	0.318	0.265	0.383
The Chi Square statistic of 22.248 indicates that the policy choice is independent of income.					

Chapter 4

Interaction between Australian carbon prices and energy prices

Abstract

The aim of carbon trading is to encourage reduction in greenhouse gas emissions by rewarding the production of power through green sources and penalising power produced by the higher-emitting sources. This article investigates the long-term interaction between carbon permit prices of the two most heavily traded Australian carbon trading schemes with electricity prices using a structural cointegrated vector autoregression model. This is analysed over two consecutive periods to determine if the scheme effectiveness changes over time. The analysis indicates that only in the second, or most recent, period do carbon prices relate to electricity prices. Our results indicate that some problems with the design of the current schemes, however, do provide some promise of an improvement more recently.

4.1. Introduction

Australia has had a number of emission control schemes operating over the last five years. This article considers the two most heavily traded schemes operating in Australia, the NSW Greenhouse Gas Abatement Scheme (GGAS) and the Mandatory Renewable Energy Target Scheme (MRET). Australia was one of the inaugural parties to the Kyoto Protocol, but it was not until the Australian Labor Party formed Government that it was ratified on 3 December 2007. While most of the states have set up separate emissions trading schemes under their own state legislation, it has always been clear that a federal scheme would provide a much more effective method to reduce emissions. An analysis of existing emission control schemes in Australia and their interaction with the main sources of electricity prices provides insights for the optimal design of this scheme. The paper brings forward

the hypothesis that an increase in the price of the certificates in these schemes would increase the wholesale price of electricity and vice versa. It may also be suggested that factors such as a reduced level of emissions from existing power stations and large energy consuming industries, an increase in renewable energy sources for electricity, improved energy efficiency and carbon sequestration - all of which are emission reducing factors - would reduce the demand for certificates and electricity. These would cause a fall in the prices of each which is another possible reason for a positive correlation between these two variables.

The GGAS is described in section 4.2.1 and explains the obligations of the benchmark participants and the manner in which certificates for compliance may be created. It can be seen that activities undertaken by electricity generators play a role in the GGAS which therefore has an impact on wholesale electricity prices which are being used in the analysis in this paper. Such activities may include investment into emission reductions from existing generation facilities as well as setting up new low emission renewable technologies, which come at a significant cost to the generators. Further, one could expect that the price of the NGACs will influence levels of investment into renewable energy and low emission technologies in the generation of wholesale electricity. However, such investments can also be expected to affect the wholesale prices of electricity.

Overall, we believe that it is not unlikely therefore to find a relationship between the price of NGACs, RECs and wholesale electricity prices. A higher price for these certificates might actually encourage generators to undertake more investments into renewable and reduced emission electricity generation. This may in return also increase wholesale electricity prices, since investment costs of the generator may be passed through to the wholesale market.

Before actual prices from carbon allowance markets were available, theoretical and simulation analyses were conducted to examine the potential effects of such schemes on energy prices. Most examinations of the relationship between carbon permit and energy prices have applied large energy-economy-environment models. A review of these types of models can be found in Huntington and Weyant (2004). Specific applications of such models and alternative simulation

studies were applied by Hauch (2003), Barreto and Kypreos (2004), Linares et al. (2006), and Simshauser and Doan (2009). While these studies provide important long-term policy insights, they usually do not consider actual observed prices in carbon emission and energy markets.

A number of papers have examined the behaviour of allowance prices in the European Union Emission Trading Scheme (EU ETS) focusing on financial and econometric issues as well as interactions with other commodity prices. Paolella and Taschini (2008) as well as Benz and Trück (2009) find that models with conditional volatility, such as generalised autoregressive conditional heteroskedasticity (GARCH), provide an appropriate description of spot price dynamics in the EU ETS. The GARCH model is able to capture the volatility clustering often found in time-series data, in particular in financial assets, where wide swings occur for a period followed by comparative stability. Also, Seifert et al. (2008) suggest that an adequate price process for CO_2 allowance contracts does not necessarily have to follow any seasonal patterns but should include a time-and price-dependent volatility structure.

The results of the influence of carbon prices on other commodity prices are varied: there is little agreement that energy prices are significantly influenced by the price of carbon emission allowances. Dealing with the interaction of European carbon trading and energy prices, Bunn & Fezzi (2008) and Fezzi & Bunn (2009) investigate the economic impact of the EU ETS prices for carbon on wholesale electricity and gas prices in the UK. Based on a structural, cointegrated vector error correction model (VECM), their results indicate that the carbon price is important in influencing the equilibrium price of electricity. They further suggest that the transmission of shocks between gas and carbon prices is quick and significant, while it is rather slow from carbon to electricity prices. Also, using EU ETS data, Nazifi & Milunovich (2010) find contrary evidence when testing for existence of a causal relationship and long-run links between the price –of carbon and the prices of energy fuels and electricity. Their results suggest that the dynamics of electricity prices are rather independent of the price of carbon emissions permits for the considered period.

However, Mansanet-Bataller et al. (2007) find positive effects of oil and gas prices as well as

weather variables on European carbon allowances, while there seems to be no significant influence of coal prices. Reinaud (2007) investigates the interaction between CO_2 allowance and electricity prices, and finds that at least some evidence for the CO_2 cost pass-through into electricity prices was provided during the abrupt fall of the CO_2 price in May 2006. Sijm et al. (2006) further investigate this cost pass-through, which in effect gives windfall profits to the power sector because of the free allocation of emission allowances in the EU ETS in the first phase. This can be explained by these emission allowances representing opportunity costs and should therefore be incorporated into the cost of the product.

Nelson et al. (2010) describe, for Australia, a number of modelling studies on the potential impacts of carbon prices on electricity prices (carbon pass-through) and broader economic impacts related to the introduction of an emission trading scheme. These studies were undertaken mainly by leading Australian economic modelling firms using techniques such as linear programming, general equilibrium modelling, or dynamic partial equilibrium analysis, and come to significantly different results. With respect to carbon pass-through, the proportion of carbon prices passed through into energy prices ranges from 17 per cent (McLennan Magasanik Associates 2006), 100 per cent (ROAM Consulting 2008), to more than 300 per cent (Simshauser & Doan 2009), reflecting a potential strategic and disruptive generator exit scenario. However, despite the controversial results, none of these studies has concentrated on observed prices from the already-existing MRET and GGAS schemes in Australia.

Overall, the literature indicates contrary evidence both for the EU ETS and with respect to the potential impacts of a national emissions trading scheme in Australia. Therefore, this article investigates the relationship between the price of electricity with gas and the greenhouse gas abatement certificates of the MRET and GGAS. The goal of this article is to determine if the existing carbon trading schemes in Australia have a significant impact on the prices of electricity and, if there is an impact, whether this can be considered to encourage the use and development of new and less carbon-polluting energy sources. We provide a summary of the proposed economic argument of

how an emissions trading scheme will promote carbon emission reductions as well as a quantitative analysis of the relationship between the price of carbon as determined within these schemes and the prices of electricity. While the existing literature on the modelling of emissions trading in the energy sector is abundant, only a limited number of publications focus on an econometric analysis of actual price data.

4.2. Australian emissions trading schemes

4.2.1 NSW Greenhouse Gas Abatement Scheme

The GGAS was first introduced into Legislation in 2002 with the scheme commencing in January 2003. The Electricity Supply Amendment (Greenhouse Gas Emission Reduction) Bill 2002[11] (ESA Bill 2002) was passed in the Legislative Assembly on 15 November 2002 and the Legislative Council on 6 December 2002. The aim of the Act was to encourage activities to reduce greenhouse gas emissions which may influence investment into renewable energy which would in turn be reflected in the wholesale electricity prices. This will occur as the liable parties, 'benchmark participants', are required to reduce a portion of the greenhouse emissions attributable to their sales and consumption of electricity in NSW. Section 97B of this amendment sets out the New South Wales greenhouse gas benchmarks in the form of the level of carbon dioxide equivalent of greenhouse gas emission per head of state population (Table 4.1).

Table 4.1: Carbon dioxide equivalent of greenhouse gas emission per head of state population

Year	**2003**	**2004**	**2005**	**2006**	**2007 and later years**[a]
Tonnes CO_2	8.65	8.31	7.96	7.62	7.27

Notes: [a]This last part has been amended in the Electricity Supply Amendment (Greenhouse Gas Abatement Scheme) Bill 2006 (ESA Bill 2006) to include subsequent years from 2012. Source:

[11]Electricity Supply Amendment (Greenhouse Gas Emission Reduction) Bill 2002, http:// wwwaustlii.edu.au/au/legis/nsw/bill/esagerb2002658/

Electricity Supply Amendment (Greenhouse Gas Emission Reduction) Bill 2002

For abatement certificates to be created, the person creating them has to be accredited in respect of activities or a class of activities that promote greenhouse gas emission reduction. Each certificate represents one tonne of carbon dioxide equivalent of greenhouse gas emissions that the activity has abated. The rules may allow eligibility for accreditation of carbon sequestration[12] through the planting of forests, or other means, only if it occurs in New South Wales or as approved by the Minister. Other means of certificate creation include improved energy efficiency and reduction of emissions from existing generators and the use of low emission technologies. Reductions in emissions from industrial processes in large energy consuming are also able to be used for certificate creation. The first two are activities undertaken by electricity generators which impacts directly on wholesale electricity prices. The abatement certificates can be received only if the activity has not already received a similar certificate from another mandatory scheme. The liable parties include New South Wales electricity suppliers and large customers who are collectively referred to as the benchmark participants. These large customers are large electricity users who elect to manager their own benchmarks which requires them to reduce their greenhouse gas emissions. They can meet these benchmarks by reducing their overall consumption or purchasing and acquitting their NGACs which were created by accredited Abatement Certificate Providers. This scheme will cease to operate if a federal scheme is introduced. The benchmark participant must submit an annual greenhouse gas benchmark statement to the Independent Pricing and Regulatory Tribunal (IPART), who are the scheme administrators and compliance regulators. This details their electricity sales or use, their greenhouse gas benchmark and the abatement certificates surrendered. These surrendered certificates may be created as described or purchased in the market. Any shortfall will be required to be submitted in the following year or a penalty will apply. The trade statistics from the registry are made available on the website and contain information

[12] Carbon sequestration refers to the processes that remove carbon from the atmosphere.

regarding the number of trades and the total number of certificates traded in each month since December 2003.[13]

4.2.2 Mandatory Renewable Energy Target Scheme

The MRET is the only Australia-wide scheme operating at this time with discussion currently under way for a new federal scheme to be introduced in 2013. It commenced on 1 April 2001, prior to the Phase I of the European Union Emissions Trading Scheme, which commenced operation in January 2005. The aim of the scheme is to reduce emissions of greenhouse gases, encourage additional electricity generation from renewable sources and ensure ecological sustainability of energy sources. It was introduced under the Renewable Energy (Electricity) Act 2000 and applies from January 2001 to January 2021. Information provided by the National Electricity Market Report 2013 on the Australian wholesale electricity market also confirms that many companies are both electricity generators and liable entities under the MRET. Thus, there is also a substantial overlap between the generation and retail business in the Australian electricity market. It is anticipated that any new emissions trading scheme would run alongside the existing MRET.

The Renewable Power Percentage (RPP) calculation determines the rate of liability and therefore the amount of Renewable Energy Certificates (REC) required to be surrendered to achieve the renewable energy annual targets (Table 4.2). The RPP is calculated by the following formula:

$$\mathrm{RPP}_t = \mathrm{RPP}_{t-1} \times \frac{\text{Required GWh of renewable source electricity for year t}}{\text{Required GWh of renewable source electricity for year t} - 1}$$

Table 4.2: Renewable power percentages (2001-2011)

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
RPP	0.24	0.62	0.88	1.25	1.64	2.17	2.70	3.14	3.64	5.98	5.62

Source: Renewable Energy (Electricity) Act 2000, Div 2 S40

[13] The registry information can be found at https://www.ggas-registry.nsw.gov.au/searching/tradestatistics.aspx

Power generators and wholesale purchasers of electricity make up the liable parties and are required to support additional generation of renewable energy. Certificates may be created for each whole megawatt hour of electricity generated by the power station from renewable sources that is above the required baseline amount. The baseline is calculated on the amount of energy generated in 1997. All created certificates must be registered by the Renewable Energy Regulator before being able to be traded under the MRET.

From 2011, the MRET has been split into two parts, consisting of the Large-scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Scheme (SRES). The LRET will continue to use the RPP mechanism for determining the required number of large-scale generation certificates (LGCs) to be surrendered. These may be created as outlined above or purchased in the market to make up the annual amount required. The liable entities under the SRES can create small-scale technology certificates (STCs) based on the amount of renewable energy the system produces or displaces. There is no target or cap; however, the Office of the Renewable Energy Regulator will estimate the number of STCs likely to be created in a given year, which will provide information for setting the Small-scale Technology Percentage.

4.3. Economics of emissions trading

Initially, economists argued strongly for the Pigou[14] tax to be used to reduce the effects of an externality such as pollution. The idea would be to set the tax equal to the cost of the marginal external damage caused by the activity causing the pollution. Firms would endeavour to reduce their costs, and therefore, as another externality, they would reduce their amount of pollution securing an optimal result for the firm and society. Coase (1960) argued that to make the property right to pollute explicit and transferable would ensure that they were used by the most productive

[14] Pigouvian taxes are said to shadow the price of the externality.

members. The theory suggests that the markets will price a product at a cost such that only the most efficient operators can afford.

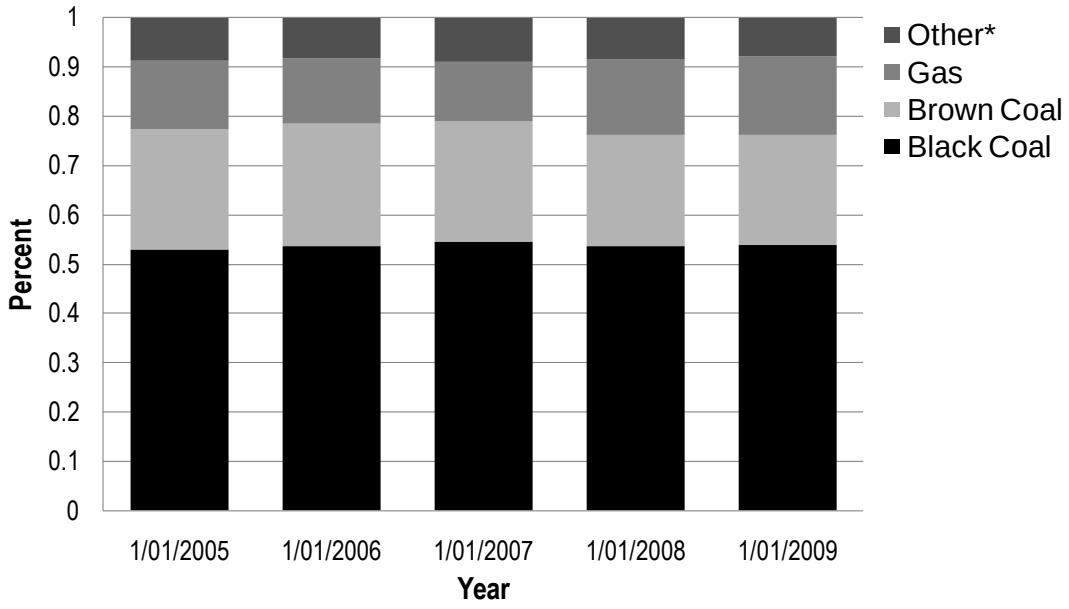
It would be naïve to suggest that there is not a political element to the implementation of any scheme to reduce emissions that requires support from business as well as the public at large. Malueg (1989) suggests that an effective emission-trading scheme can benefit a firm with cost savings and reduce emissions. Haigh (2008) believes affected organisations have been politically active and have influenced climate change policy. Brennan (2009: 316) asserts that 'if the intention is to provide firms with some advantage in the implementation of the scheme, and some incentive to lend political support for the scheme, it will be better to do this via a permit scheme than via a tax regime'. Baumol and Oates (1971) discuss the difficulty in finding the optimal structure of taxes and subsidies in order to equate these to the marginal net damage or benefit that is subsequently produced by that activity; this would have to be done in an iterative way. That is, if set too high, it would put the firms out of business; if too low, the firms would simply pay the tax and not reduce their emissions. They state that (p. 47)

There does presumably exist some optimal level of pollution (i.e. quality of the air or waterway), but in the absence of a pricing mechanism to indicate the value of the damages generated by polluting activities, one knows no way to determine accurately the set of taxes necessary to induce the optimal activity levels.

The Stern Review (2006), and others on the economics of climate change, attempted to quantify the value of the damages; however, the uncertainty is large. They suggest that a selection must be made as to what equates to an appropriate environment. Newton (2009:136) observes that the 'sensitivities, thresholds and ''tipping points'' of human and natural systems also need to be determined'.

In Australia, power, and therefore its cost, is highly dependent on coal. Since 2004, there has been very little change in percentage of coal used to generate electricity with a slight decrease in gas (Figure 4.1).

Figure 4.1: Percentage of electricity production by fuel source in Australia (2005-2009)



*Other includes oil, hydro, wind, biomass, and biogas.

Source: Australian Bureau of Agricultural and Resource Economics (2010).

Table 4.3: Estimated life-cycle greenhouse emission intensity of different technologies

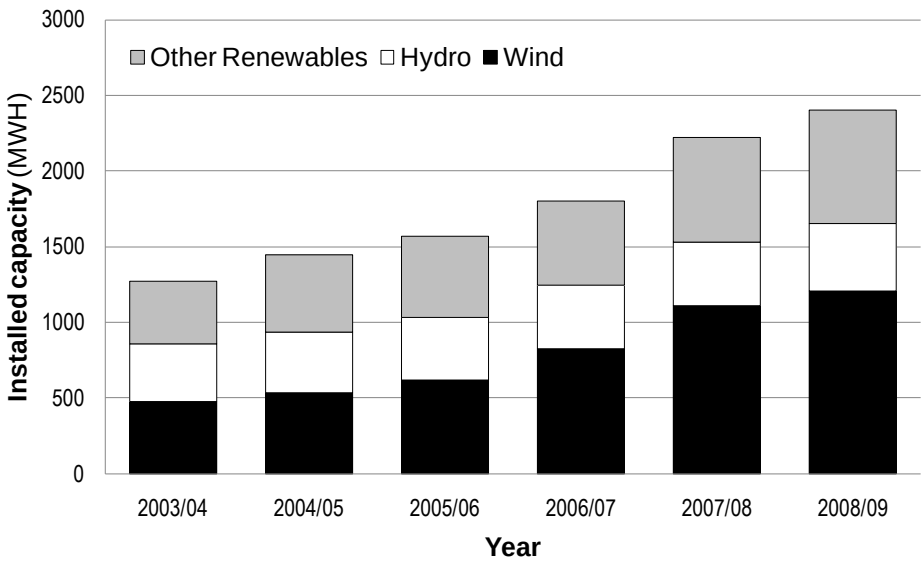
Technology	**Emissions intensity (kg CO_2/ MWh**	
	Best Estimate Years	**Range Years**
Brown Coal (subcritical)	1175	1011 – 1500
Black Coal (subcritical)	941	848 – 1171
Black Coal (supercritical)	808	774 - -1040
Natural Gas (open cycle)	751	627 – 801
Natural Gas (combined cycle)	577	491 – 655
Solar photovoltaics	100	53 – 217
Nuclear (light water reactor)	60	10 – 180
Wind turbines	21	18 – 40
Hydro (run-of river)	15	0.5 - 44

Source: Australian Competition and Consumers Commission (ACCC), 2012

The Australian Competition and Consumer Commission's State of The Energy Market Report (Australian Competition and Consumer Commission 2009) provided information on the greenhouse gas emissions for a range of different electricity generation technologies. These are based on current best practice in Australia in 2009 (Table 4.3). As CO_2 and SO_2 are emitted during the coal-burning process as soon as a price is put on these emissions, they should also impact on the cost of power. Providing the correct targets are chosen and the appropriate allocation method used for permits, the energy sector should be encouraged by the increased costs of permits to move to energy sources that have lower emissions levels.

The historical installed capacity of semi-scheduled, non-schedule and exempted renewable-energy generators in megawatts since 2003/04 shows an overall increase most significantly from wind, with little change in hydro power (Figure 4.2). Because of the higher cost of these fuel sources, the capacity is greater than the actual use.

Figure 4.2: Installed capacity (in MWH) of renewable energy generators from 2003/2004 to 2008/2009 for the total region (Australia)



Source: KPMG Report for NEMMCO Limited (2009).

The Tambling Report[15], a review of the MRET in 2003, found that most of the growth in renewable energy generation was coming from the hydro and solar hot water sectors. The wind sector had strong growth but, as it was coming from a very small base, was still relatively small. A low level of growth exists for generation of biomass and solar photovoltaics, and no RECs had been created from wood waste.

Wholesale electricity prices are likely to be influenced by many factors including exchange rates reflected in coal prices, extreme weather events and demand. This paper, while not suggesting they are the only effect, aims to determine if the trading, and hence prices in the NGAC and MRET, do affect electricity prices. If an emissions trading scheme were to change behaviour in the electricity market, we would anticipate an initial increase in electricity prices. This increase may remain, but it would stabilise as the sources of cleaner technologies became more cost competitive. These findings are extended by the International Energy Agency (2007) who discuss how climate change policy uncertainty affects the investment behaviour of power companies. It is suggested that this uncertainty, and therefore risk, encourages the energy companies to delay investment. Kent & Mercer (2006) suggest that investment is deterred as the pay-back is normally around 15 years.

4.4. Data

The analysis is conducted over the period 2004 to 2010 which is an ample time period to determine if there is a relationship between the prices of the NGACs, RECs and wholesale electricity prices. The GGAS and the MRET have been chosen for this study as they have the largest number of trades in a year of any existing schemes. The volume has been steadily increasing for both of these schemes. The GGAS had a volume of 501,689 certificates in 108 trades in 2004, increasing to 22,925,660 certificates in 886 trades in the first six months of 2009. The MRET had a volume of 5,218,713 certificates in 791 trades in 2004, increasing to 86,718,169 certificates in 12,676 trades in 2009.

[15] The Hon. Grant Tambling was the Chair of the review panel which conducted the Renewable Opportunities, A Review of the Operation of the Renewable Energy (Electricity) Act 2000 in 2003.

Because of the relatively small number of trades, there is a problem of obtaining data with regular trading. The major provider of trade data has approximately 80 per cent of the market share of GGAS certificates (NGACs). However, while many days have multiple trades, there are some trading gaps that are weeks long. For this reason, the data to be used for this analysis are not trades as such, but data collected by the Australian Financial Markets Association (AFMA). AFMA collects market participants' weekly view of the prevailing bid and offer prices. We have used as the price a mid-point between the bid and ask prices provided. Gas and electricity prices are from the Australian Energy Market Operator[16] using wholesale aggregate prices for electricity and wholesale average Victorian gas prices. The log of the prices has been used to reduce variability and change the scale so that the elasticity values can be obtained directly from the parameter estimates.

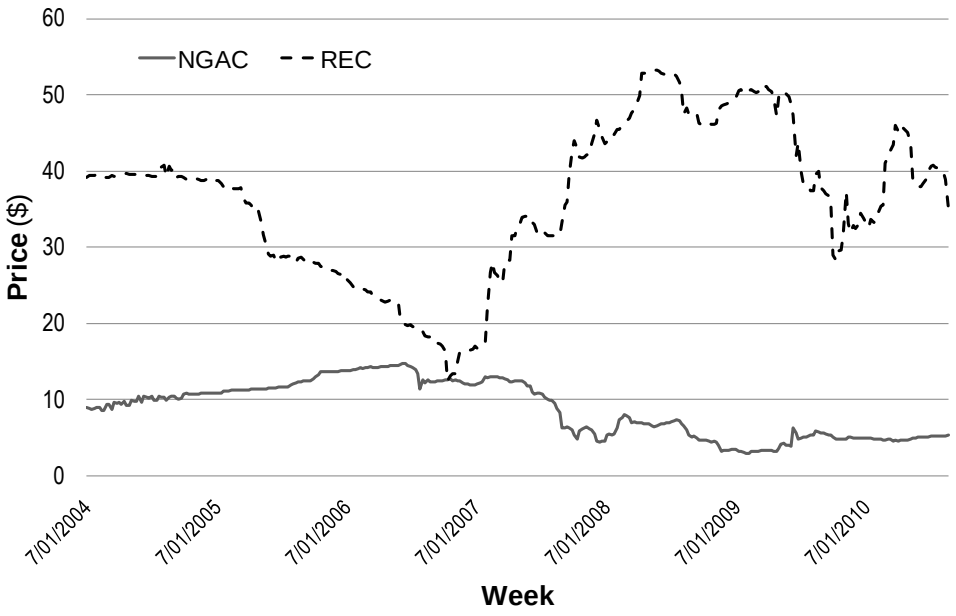
The data were split into two periods: the first covering weekly observations from 1 July 2004 to 18 April 2007 and the second covering the period from 24 April 2007 to 26 August 2010. The reason for this division was to determine if, as the market increased in volume and trading, it became more efficient in achieving its goals. To avoid bias, we have simply divided the total time into two even time periods (figures 4.3 and 4.4). The REC prices have been affected by a number of different policy decisions, Wallace (2007) outlines major drivers in the prices. During 2003 and early 2004, a review proposed an increase in the target for the MRET Scheme that pushed the prices up. Since this time, a series of reviews written looking at alternative emissions trading schemes. The Green Paper was issued in July 2008, the Garnaut Review in October 2008, and the White Paper in December 2008, which all consider possible federal emissions trading schemes as has been viewed by the federal government at the time. In April 2009 and again in May 2010, the federal Labor government announced delays for the proposed Carbon Pollution Reduction Scheme. The Clean Energy Bill 2011 will go to both houses of parliament later in 2011 with the aim of implementation of a new carbon

[16] Formerly National Electricity Market (NEMMCO) for electricity prices and Vencorp for gas prices, http://www.aemo.com.au/

tax on 1 July 2012.

The pricing in the NGAC market is less affected by these policy decisions, as it is less likely to continue with the introduction of a National Scheme. The price fall in July 2006 was due to the oversupply of certificates in the market. An oversupply in Phase 1 of the European Emissions Trading Scheme saw a similar price decline to only €0.10 in September 2007. The NGAC market steadied on the assumption that the oversupply was likely to be rectified in the next issue of certificates; however, a price fall again occurred from July 2007, when the supply information reached the market.

Figure 4.3: NGAC and REC weekly prices from 1 January 2004 to 26 August 2010.



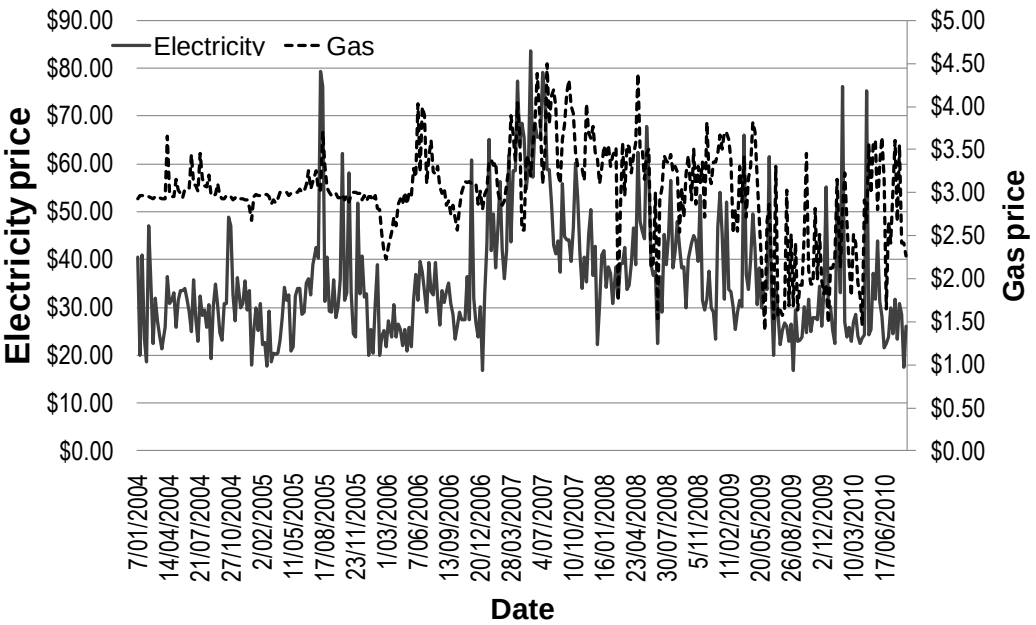
Note that the graph contains both of the considered time periods: Period 1 from 1 July 2004 to 18 April 2007 and Period 2 from 25 April 2007 to 26 August 2010.

Source: Australian Financial Markets Association (2010)

Wholesale trading in electricity in Australia occurs as a spot market where supply and demand

are matched in real time in the most cost efficient way by the Australian Energy Market Operator (AEMO). Electricity prices exhibit a large number of spikes and also appear to revert to the average over time. This can be considered a typical feature of electricity spot prices since the deregulation of the markets (see Pilipovic 1997; Weron 2006). As electricity is non-storable (other than hydro), it is particularly susceptible to demand-and-supply effects, in particular as demand in the short-term market is inelastic. Sizeable shocks in either the demand or supply can cause large price jumps. These are subject to times of demand because of extreme weather conditions, disruption in transmission, generation outages on the supply side, or a combination of these. Since the price spikes usually last only for a very short period and are not attributable to prices in an emissions trading scheme, we used a recursive filter algorithm to replace the spikes in the price series (see Clewlow & Strickland 2000). Following this approach, for the electricity and gas, we replaced all prices beyond the mean plus three standard deviations with the median of the 16 observations around the outlier. The algorithm stops when there are no more new extreme observations. The electricity and gas figures, while showing some volatility in particular since 2007, maintain an average of around S36.50 and S3.00 respectively (Figure 4.4).

Figure 4.4: Gas and electricity weekly prices from 1 January 2004 to 26 August 2010



Source: Australian Energy Market Operator (2010).

4.5. Empirical results

Results are based on a cointegration analysis of the relationship between NGAC and REC prices and Australian electricity and gas markets. Cointegration analysis allows the determination of a long-run, or equilibrium, relationship between variables, which is what we are interested in analysing. We would expect that an effective carbon trading scheme should reward the production of power through green sources, such as hydro and wind energy, and penalise the continuation of power produced by the higher-emitting sources such as coal. As these green sources are currently overall more expensive sources of fuel, we would expect to find a significant long-run effect of carbon allowance prices on observed electricity by way of a price increase. The exception to this is wind power which is able to not only displace the other renewable energy sources but also to some extent brown coal (Forrest and MacGill, 2013). The authors, however, also suggest that due to the unreliability of wind and the additional fixed costs stemming from this unreliability, any drop in prices would not persist in the long term.

Summary statistics for the original and log price series for NGAC and REC carbon prices as well as for the adjusted Australian electricity prices and gas prices indicate that most of the price series exhibit some skewness or asymmetry; however, none of them shows an extremely high kurtosis, which may affect the reliability of the probability, that would indicate heavy tails (Table 4.4). Following the majority of the literature that investigates cointegration in commodity markets, we used the natural logarithm of the variables in our analysis. Tests for cointegration are necessary, since economic and financial time series data are usually non-stationary and have unit roots. Tests for unit roots enable the determination of whether the data are stationary (where the mean, variance, and covariance of the process do not change over time). As discussed by Granger and

Newbold (1974), running regressions using non-stationary time-series data may produce the spurious regression problem. To avoid these problems, it is necessary to test for unit roots and a cointegrating relationship.

Table 4.4: Summary statistics for the weekly original and log price series for NGAC and REC carbon prices and adjusted electricity and gas prices in Australian dollars

Series	Mean	Median	SD	Skewness	Kurtosis
NGAC	8.77	9.53	3.61	-0.03	-1.47
Ln NGAC	2.07	2.25	0.47	-0.43	-1.17
REC	36.17	38.28	10.14	-0.31	-0.69
Ln REC	3.54	3.64	0.32	-0.94	0.34
Electricity	35.65	32.42	12.77	1.35	1.76
Ln electricity	3.52	3.48	0.32	0.50	-0.04
Gas	3.01	3.00	0.54	-0.55	1.09
Ln gas	1.08	1.10	0.20	-1.36	2.51

Source: Australian Financial Markets Association, 2012

Notes: The number of observations for all series is 347, where Ln indicates the log of each variable; NGAC denotes the NSW greenhouse gas abatement certificates; REC denotes the mandatory renewable energy target scheme renewable energy certificates; Electricity denotes Australia-wide adjusted electricity price; and Gas denotes adjusted gas price.

Initially, we examine the relationships during the first period. Overall, we are interested in estimating the following long-run relationships:

$$LELEC_t = \beta_1 + \beta_2 LGAS_t + \beta_3 LREC_t + u_t \qquad (1a)$$

$$LELEC_t = \beta_1 + \beta_2 LGAS_t + \beta_3 LNGAC_t + u_t \qquad (1b)$$

where LELEC denotes the log of adjusted Australia-wide electricity price, LGAS the log of adjusted gas prices, LREC the log of REC prices, LNGAC the log of NGAC prices, and u the error term.

Unit root tests were conducted using the augmented Dickey Fuller (1981) test statistics. For each of the series, we could not reject the null hypothesis of a unit root at levels, while differences appeared to be stationary, indicating that all three considered time series are I(1). Using the critical values provided by Davidson and MacKinnon (1999) unit root could be rejected for u_t, indicating that the residuals are stationary (i.e. I(0)). To determine the number of cointegrating vectors, we use the trace test introduced in Johansen (1991). Two lag VAR models provided the best results with respect to log-likelihood (allows unknown parameters to be obtained) and parsimony (models should be kept as simple as possible) model criteria for each of the considered relationships.[17]

Overall, our results suggest that there is one cointegrating vector for each of the examined models, and we find the following estimated long-run relationship between the variables:

$$LELEC_t = 1.404 + 2.062\ LGAS_t - 0.070\ LREC_t + u_t \qquad (2a)$$

$$(1.742) \quad (3.339) \qquad (-0.613)$$

$$LELEC_t = -1.120 + 3.235\ LGAS_t + 0.371\ LNGAC_t + u_t \qquad (2b)$$

$$(-1.049) \quad (5.711) \qquad (1.904)$$

where t-statistics for the estimated coefficients are provided in parentheses. Since we are considering log prices in our model, the coefficients can be interpreted as price elasticities (i.e. showing the responsiveness to changes in price). The carbon prices are less than 1, indicating inelastic relationships, while gas prices can be said to be elastic. However, the t statistics in parentheses in Equation (2a), indicate that only log gas prices have a long-run relationship with log

[17] Detailed estimation results are not provided here but are available upon request from the authors.

electricity at the 5 per cent level of significance.

We conclude that the emission-trading schemes did not significantly affect the price of electricity during this first time period and as such may be considered ineffective in reducing emissions.

For the second period, all the variables are analysed in the same manner using equations 1a and 1b as for the first period. Unit root tests are undertaken to determine if the time-series data are stationary or not using the augmented Dickey Fuller test statistics. Again for the considered data, a unit root could not be rejected, while differences appeared to be stationary, indicating that they are all I(1). The residuals u_t rejected unit root tests at levels and differences indicating they are stationary (i.e. I(0)). Once these results were determined, we were able to test if there were any cointegrating relationships. For this period, eight lag VAR models were used with the results from the Johansen LR test, suggesting only one cointegrating vector for each relationship.[18] Overall, the estimated long-run relationship between carbon, gas and electricity prices becomes

$$LELEC_t = -5.652 - 1.022\ LGAS_t + 2.688\ LREC_t + u_t \qquad (3a)$$

$$(-2.277)\quad (-1.894)\qquad (3.827)$$

$$LELEC_t = 2.581 + 0.246\ LGAS_t + 0.393 LNGAC_t + u_t \qquad (3b)$$

$$(11.327)\quad (1.451)\qquad (3.222)$$

The t statistics in parentheses in equations (3a) and (3b) indicate that for the second period, the RECs and NGACs both have a statistically significant relationship with log electricity at the 5 per cent level. This time, we find the REC is indicating an elastic relationship, while NGAC remains relatively inelastic. This can be interpreted that in the long run REC and NGAC allowance prices, and therefore both the MRET and GGAS emission trading schemes, have a significant positive relationship with the price of electricity. This positive relationship indicates that if the price of the REC and/or NGAC

[18] Detailed estimation results are not provided here but are available upon request from the authors.

increases, then so does the price of electricity and vice versa with a fall in prices.

Therefore, our results suggest that during the second period from April 2007 to August 2010, the MRET and GGAS may be effective in their goals of encouraging activities relating to the reduction in greenhouse gas emissions.

4.6. Conclusions

We find that during the early years from 2004 to 2007, neither of the considered trading schemes had a statistically significant relationship with electricity prices. However, in the more recent period 2007-2010, according to a conducted cointegration analysis, they have become significant. The first periods' lack of relationship could be due to the higher emissions allowed and/or the fact that the market participants were still in the early learning stage of operations in a new market. The significant relationship during 2007-2010 found in this paper also confirms earlier results by Reinaud (2007), Bunn & Fezzi (2008), Zachmann & von Hirschhausen (2008), and Fezzi & Bunn (2009) obtained for the EU-ETS. Also, similar to those studies, our results are not clear cut. In particular, we find an elastic relationship between REC and electricity prices, while the relationship between NGAC and electricity prices remains relatively inelastic. Recall that based on earlier work on the Australian market, results for carbon pass-through ranged from 17 per cent to more than 300 per cent and are likely to be occurring here and affecting our results. Our examination does not yield unique results on the proportion of carbon pass-through. However, we provide a pioneer study in the sense that our results are based on actually observed carbon emission and energy prices in Australia. Note that our analysis only provides insights into the long-run relationship between the considered variables. A more thorough analysis of the short-run dynamics could be investigated using error-correction models or impulse response analysis. We leave such an extended analysis of the relationship between the considered variables to future work.

As noted by Tietenberg (2002), the most controversial and important aspect of marketable permit design is the initial allocation. This should be considered a major factor in the fall in the prices in the EU ETS in 2006 and a similar fall in the price of NGACs in 2007 when the market realised the high number of surplus certificates available. Passey et al. (2008) investigated the effectiveness of the NSW Greenhouse Gas Abatement Scheme with a focus on the governance issues and found that new low-emissions projects may have emissions that are not incorporated into the pool coefficient and hence increase emissions at the same time as creating NGACs.

The significant relationship between NGACs and RECs with electricity prices we observe during the second considered period may be due to the effectiveness of the scheme or may simply be a result of the cost pass-through that has also been found in European allowance markets. Similar to the EU ETS, the Australian schemes have not auctioned the allowances, and as such, there is as yet no great impact on the costs of the electricity generators associated with scheme compliance. Honkatukia et al. (2006) found that on average 75-95 per cent of the price changes in the EU ETS were passed on to the Finnish NordPool spot price for electricity, even though less than 50 per cent of that market is based on fossil fuels. Zachmann and von Hirschhausen (2008) also found that emissions prices were being passed through asymmetrically to electricity futures prices in Germany. They believe the two possible explanations for this may be either that as a new market it is still determining how to handle the new cost factor or that it may be an indication of the market power of German electricity generators. New entrants in the MRET have a zero baseline, which would improve the competitive advantage of existing producers suggested in the Zachmann & von Hirschhausen (2008) study. Neuhoff et al. (2006) discussed the distortions that can result from allocation of allowances to existing facilities, which is what has most likely occurred in the Australian schemes studied in this paper. They concluded that it is difficult to micromanage these allocations, and they are likely to end with inappropriate incentives to the recipients.

There is tangible evidence of an increase in investment in renewable energy sources (Figure 4.2).This may indicate that the relationship between NGAC and REC prices with electricity in recent years is due to a successful emissions trading scheme. However, contrary evidence that the relationship may be due to cost pass-through of opportunity costs can be found in the increased profits in the current financial year by many of the large energy companies in Australia. Future analysis of the cost and profit structures and investment levels in renewable resources of the major Australian energy providers may assist in determining if cost pass-through and subsequent high profit levels are occurring. Further, as discussed in the introduction there are other factors, in particular in relation to a reduction in emission for varying reasons, why certificate prices and electricity prices may correlate. These should be considered when analysing the results of this study in the second period. Australia's goal under the Kyoto protocol was to limit greenhouse gas emissions to 8 per cent above 1990 levels by 2012. However, the most recent figures from the Australian Bureau of Statistics (2009) show that at the end of 2007, it had risen to 9 per cent above 1990 levels. The energy sector had an increase of 55 per cent in carbon dioxide emissions between 1990 and 2007. Furthermore, the Australian Bureau of Agricultural and Resource Economics projections suggest that for the next 20 years, the share in energy production supplied by coal is anticipated to decrease; however, in terms of greenhouse gas emissions, there will be a continued increase. In light of these projections, the Australian emissions trading schemes do not appear at this stage to be successful in reducing greenhouse gas emissions. As discussed by Nelson et al. (2010), policy makers must take these issues into consideration when determining future subsidies to the large-scale energy retailers. A recent USA study by Carley (2011) found that their electricity producers are becoming less carbon-intensive and overall more sustainable. Even though this paper does not find this occurring in Australia, it does give some encouragement to the pursuit of the emission trading schemes to reduce the emissions.

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Chapter 5

Econometric analysis of Australian emissions markets and electricity prices

Abstract

Emissions trading schemes aim to reduce the emissions in certain pollutants using a market based scheme where participants can buy and sell permits for these emissions. This paper analyses the efficiency of the two largest schemes in Australia, the NSW Greenhouse Gas Abatement Scheme and the Mandatory Renewable Energy Trading Scheme, through their effect on the electricity prices from 2004 to 2010. We use a long run structural modelling technique for the first time on this market. It provides a practical long-run approach to structural relationships which enable the determination of the effectiveness of the theoretical expectations of these schemes. The generalised forecast error variance decomposition analysis finds that both schemes' emissions prices have little effect on electricity prices. Generalised impulse response function analysis support this finding indicating that when shocks are applied to electricity by the two schemes it returns to equilibrium very quickly. This indicates these schemes are not having the effect anticipated in their legislation.

Key Words: econometrics, electricity prices, emissions trading, market efficiency

5.1. Introduction

A major goal of financial markets is to ensure the efficient flow of funds between surplus units and deficit units. This should be achieved in a timely and cost effective manner so that those who can most efficiently use the funds will have access them. There has been a great deal of research conducted on different measures of market efficiency since Fama's study in 1970. While there are findings of anomalies Fama (1998) suggests that these are fragile and may disappear depending on which method of measurement is used. Fama states in the introduction to his 1970 paper that "the ideal is a market in which prices provide accurate signals for resource allocation: that is, a market in which firms can make production-investment decisions" (Fama, 1970, p383). Emissions trading schemes (ETSs) trade in a context where an ideal market is one in which those who can most efficiently reduce their emissions will be able to sell either their own surplus certificates or those they create. The overriding goal of emissions trading markets is to achieve a reduction in CO_2-e[19] in the most cost effective way. Garnaut (2011, Chapter 11) stated that "Under a carbon price, the market, rather than the government, will be making abatement decisions, which will ensure emissions reductions are delivered at lowest cost."

The question of whether or not a market has been efficient may be approached in two main ways. One way is to measure whether compliance has been achieved. The markets under analysis in this paper are the two largest and most actively traded emissions trading schemes in Australia during the period under analysis, January 2004 to December 2010. These are the New South Wales Greenhouse Gas Abatement Scheme (GGAS) and the Mandatory Renewable Energy Trading Scheme (MRET). The GGAS was closed in 2012 upon the commencement of the Federal Labor Government's carbon tax in order to reduce duplication. The MRET was split into two separate components in January 2011, the Large-scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Scheme (SRES). Using the level of compliance that has been achieved as the measure, it can be concluded that the

[19] A tonne of CO_2-e is a quantity of any greenhouse gas which has the same warming effect as a tonne of CO_2.

markets were efficient. The legislated CO_2-e reductions required under each scheme were achieved to a level of around 99% for the years under review in this paper. The other way of measuring efficiency is by determining if the schemes have had a price effect on the markets with which they have had the greatest connection. This paper aims to separate ETSs from other policies and determine if the markets themselves have contributed to a reduction in emissions in Australia. This paper will test this by determining if the ETS prices have had an effect on the wholesale price of electricity.

The electricity sector is chosen predominantly because this sector is the target for the MRET, the largest and most frequently traded ETS in Australia. The MRET goal is to encourage additional generation of electricity from renewable energy resources thereby reducing greenhouse gas emissions. This increased demand for these renewable energy sources would then assist in ensuring that renewable energy sources are ecologically and financially sustainable. The effect of price changes for renewable energy certificates, the certificates used in the MRET, are therefore most likely to be found in wholesale electricity prices. The expectation is that, as electricity producers move to using more renewable energy sources, the wholesale electricity price will increase. This is because the costs, as described in Figure 5.2 and explained later, indicate that using renewable energy sources is more expensive than using coal for the production of electricity. Therefore if the MRET is causing this change in energy source, the electricity price should increase. The GGAS has a similar link as the MRET to electricity prices and there remains an expectation that if it is working efficiently, it too would affect the electricity prices. The goal of the GGAS is to reduce greenhouse gas emissions through the use of benchmarks. The major participants in this scheme include retail suppliers, electricity generators and other suppliers of electricity to a customer and market customers. Additionally, certificate creation involved activities including those which reduce the consumption of electricity and production of electricity which results in reduced greenhouse gas emissions. In a similar way to the MRET we anticipate that if the GGAS is contributing to a change in

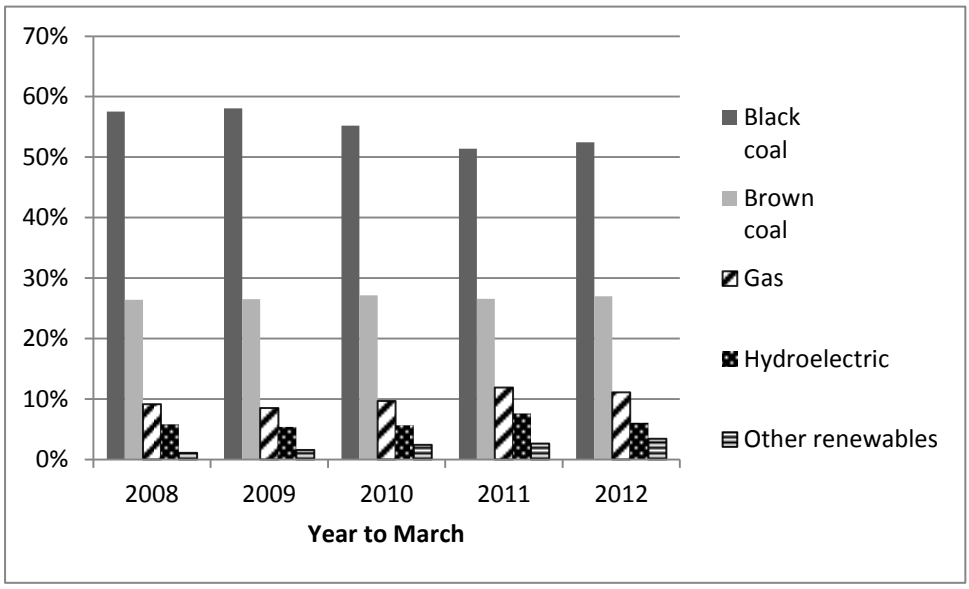
the energy sources used for electricity generation, then the cost of wholesale electricity would increase.

The electricity sector is by far the largest emissions sector in Australia, with annual emissions increasing by 49.1% from 1990 to 2011 as discussed in the Australian National Greenhouse Gas Accounts National Inventory Report 2010 (Australian Government, 2012a). Under the Kyoto Protocol, ratified by Australia in 2007, the allowed emissions for Australia were set at 108% of 1990 levels. While the electricity sector accounts for only a part of these allowable emissions, it produced 35% of Australia's emissions for the year to March 2012 (Australian Government, 2012a). After peaking in 2008–09 at 207.9 Mt CO_2-e, emissions in the sector fell to 193.1 Mt CO_2-e in 2011 (Australian Government, 2012b). The electricity sector involves electricity generation from fuel combustion and renewable sources such as wind and solar. We aim to establish whether emissions trading markets have had a long-term effect on wholesale electricity prices in the sector. In particular we want to determine causality. We have used a generalised forecast error variance decomposition (GVD) and generalised impulse response function analysis (GIRF) to determine this. These models are explained fully in our methodology and results in Section 4.

The growing global demand for energy has been beneficial for the Australian economy, due to the country's abundant coal, uranium and gas deposits. In 2012 Australia was the world's ninth-largest energy producer (Enerdata, 2013). Australia's electricity generation is dominated by fossil fuels with 430 Mt coal and lignite being produced in 2012. Coal exports earned $38,581million for the year to June, 2013 which accounted for 15.6% of Australia's exports for the year (ABS), 2013). Coals are the highest CO_2-e emitters of all energy sources and contributed around 79.2% of electricity generation in March 2012 (Australian Government, 2012a). The mining lobby is a very strong force in Australia, with coal mining employing around 229,100 full-time and 9,600 part-time workers and contributing to the strength of many rural communities. Under current production levels, black coal has

estimated economic demonstrated reserves of 111 years with brown coal at 539 years. Australia is the fourth-highest coal and lignite producer in the world and production increased at an average of 2.9% p.a. from 2000 to 2012. While the percentage of renewable energy used as a fuel source for electricity generation has increased, Figure 5.1 shows that this is still a very small proportion coming from a very low base.

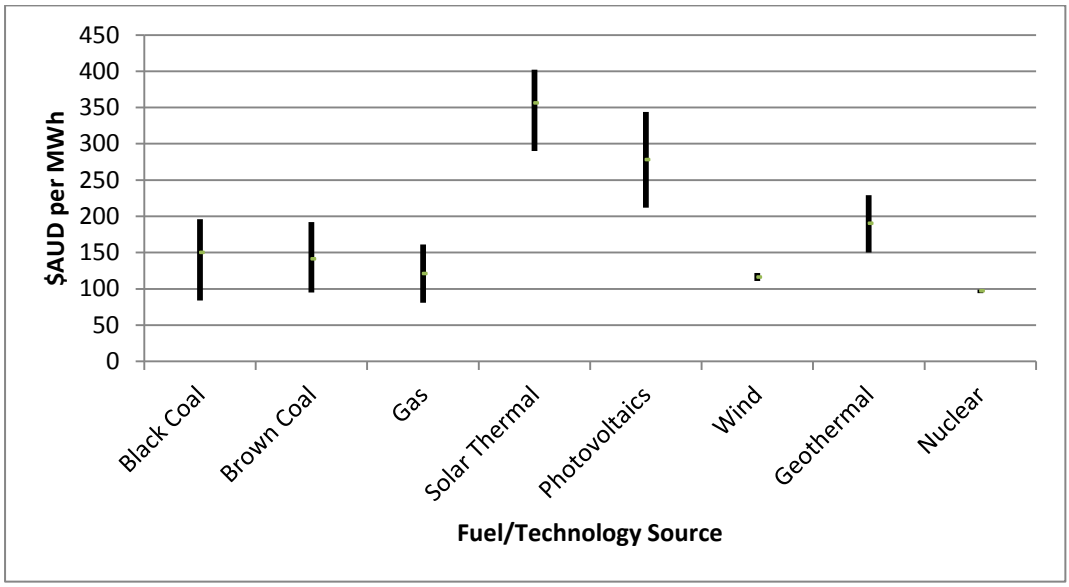
Figure 5.1: Electricity Generation by Fuel Source



Source: Australian Government, Energy in Australia 2011

In dollar terms, coal is the cheapest fuel source in Australia and is likely to remain so for many years to come. Australian Energy Technology Assessment (2012) showed the levelised cost of energy by technology in Australian dollars per megawatt-hour (MWh) to be approximately in the ranges shown in Figure 5.2 below.

Figure 5.2: Levelised Cost of Energy by Technology in $AUD per MWh in 2012



Source: Bureau of Resources and Energy Economics, Australian Government (2012)

Black Coal = supercritical pulverised black coal; with and without carbon capture and storage

Brown Coal = supercritical pulverised brown coal; with and without carbon capture and storage

Gas = combined cycle gas turbine; range includes south western interconnector system scale and with carbon capture and storage

Solar Thermal = solar thermal parabolic trough; range includes with storage, central receiver and central receiver with storage

Photovoltaics = range includes; non-tracking, single axis tracking and dual axis tracking

Wind = on shore

Geothermal = range includes hot sedimentary aquifer and hot rock

Nuclear = Gen 3+

The ETS endeavours to incorporate into the costs of production an amount attributable to the CO_2-e emissions that occur in generating electricity from non-renewable resources. It does this by reducing the amount of emissions allowed before penalties apply, and creating a market where the surplus and deficit units of the certificates can trade with each other. If this is done efficiently we

would initially expect the cost of electricity to increase due to the additional costs for producers. This will occur as they move towards renewable, more expensive sources of energy and away from the cheaper, high emitting fuels. It will also occur due to the increase in the cost of coal which will result from the additional cost to producers of purchasing emissions certificates. Over time renewable energy production is expected to become more efficient, leading to a decrease in costs and hence a decline in the cost of electricity.

The next section of this paper discusses the literature around market efficiency of ETSs with a focus on the use of electricity prices as a measure. It then provides descriptions of the GGAS and MRET in Section 3, along with the data used in our analysis. To our knowledge this paper is the first to use the methodology described in Section 4 for this type of analysis. This section also describes the results obtained. Finally in Section 5 the conclusions from our analysis are provided.

5.2. Materials and methods

5.2.1 Literature

Since the inception of the MRET in 2001, the GGAS in 2003 and the EU ETS in 2005, economists and energy specialists alike have been analysing the markets for their effects and efficiency. Nelson et al. (2012) undertook a literature review of economic studies on carbon pricing with an emphasis on their relationship with electricity prices in Australia. Their review, predominantly of studies done by economic modelling firms, found them to be inconsistent in their estimations of cost pass-through. If the Australian emissions trading schemes are affecting the cost of electricity we would expect a clear indication of cost pass-through. They also conducted a review of the literature on the EU ETS. Some of this literature is discussed below. Betz et. al. (2013) conclude that while there appears to be an efficient reduction in energy use overall from the various schemes in Australia it only occurs if

additionality is taken into account. Nelson et.al. (2012) found the level of pass-through in EU ETS to be dependent upon the emissions intensity of the market being studied.

In 2004 Sartzetakis measured the efficiency in emissions markets in a way which included considerations regarding the economic welfare of the society. Sartzetakis concludes that in the majority of situations these considerations are taken into account. However this conclusion is delivered with caution and assumes that efficient allocation of emission permits will always occur and that bureaucratic mechanisms may be more socially beneficial. Neuhoff et al. (2006) found the allocation of certificates in the EU ETS to have had a big impact on market efficiency, with planning for future allocations distorting current behaviour. This is of interest for this paper as it may provide some explanation of the results of our analysis. There have been many studies undertaken, predominantly in Europe, on the relationship between carbon prices, as measured by the prices of the various emissions trading certificates, and the price of electricity (Bunn and Fezzi, 2007; 2009). Other papers have included CO_2 in the policy mix (Keppler and Mansanet-Bataller, 2010) and the stock market (Oberndorfer, 2009). These papers provide the basis for our analysis.

Market imperfections were felt to have aggravated the effect of the European ETS on electricity prices. Honkatukia et al. (2006) found that around 75% to 85% of wholesale electricity price changes were passed on to the Finnish spot electricity price. Sjim et al. (2006) found cost pass-through to electricity prices in Germany using ordinary least squares (OLS) and autoregressive model of order 1(AR(1)). As both of these methods may be inconclusive when autocorrelations are present, the analysis was later refined by Zachmann and von Hirschhausen (2008) by using an error correction model (ECM) and an autoregressive, distributed lag model. They found an asymmetric cost pass-through between European allowances and wholesale electricity prices in Germany. The relationship for price rises was found to be stronger than for falls, indicating that increasing costs are more likely to be passed on than reductions. In 2013 Jouvet and Solier used a first order autoregressive model to determine the cost pass-through of CO_2 to marginal electricity spot prices in Europe. They found

the financial crisis affected the evidence during the second phase of the EU ETS. Their paper indicated power producers did not pass through the cost of carbon during 2009, but in some countries there was evidence of it occurring during the 2010–11 compliance year. Kara et al. (2008) used the VTT electricity market model and the TIMES energy system model and found that nuclear energy could limit the effect of carbon prices on electricity prices.

Bunn and Fezzi (2009) used a structural cointegrated vector error correction model (VECM) and found the carbon price to be an important and exogenous indicator of the electricity price in the United Kingdom. This method does not make *a priori* assumptions about exogeneity. This method was also used by Freitas and da Silva (2013) in a study of the effect of the second phase of the EU ETS on the Portuguese electricity system. Their analysis found carbon prices played an important role in the equilibrium price of electricity in the long run. In 2011 Cotton and Trück also used cointegration analysis to determine if there was a relationship between wholesale electricity prices and both GGAS and MRET from 2004 to 2010. The limitations discussed in their paper, which included other factors which may affect electricity prices and correlate with the certificate prices, should also be noted here. That is, that a reduction in emissions due to increases in energy efficiency and reduced emissions from industry etc., would have a similar effect to movements in the certificate prices and electricity prices. No relationship was found in their paper for the years 2004 to 2007 but this changed to a significant relationship in 2007 to 2010. The method used however does not clearly indicate which of the variables are endogenous and which exogenous and so Frietas and da Silva assume electricity is the endogenous variable. Pinho and Madaleno (2011) analysed the effect of nuclear power generation using the VECM and found it could limit the increases in electricity prices as a result of increased carbon prices. This paper and the study by Kara exemplify the importance of the sources of energy in the particular electricity market being studied. More recently Bertrand (2012) used VECM, Granger causality and impulse response functions to analyse the relationship between carbon and energy markets in Phase 2 of the EU ETS. Gas was found to be a driver for carbon prices in equilibrium; however their results in the short run were ambiguous. This

paper aims to rectify some of the problems in these earlier papers by using GIRFs and GVDs to determine the endogeneity and exogeneity of the variables (Koop et al, 1996).

5.2.2. The Schemes and Data

The GGAS covered emissions in the state of New South Wales (NSW). Its main goal was to reduce greenhouse gas emissions associated with the production and use of electricity. Due to changes in the federal government carbon reduction policies this scheme ceased operation in July, 2012. NSW has 42% of Australia's economically viable black coal resources and consumed around 26.7% of Australia's energy in 2011–12. The state is therefore a large contributor to the country's emissions. The scheme's benchmark participants included all NSW electricity retail suppliers, electricity generators who supply directly to large customers in NSW, and large market customers. There are also other companies who use over 100 gigawatt hours (GWh) who became benchmark participants. The NSW *Electricity Supply Amendment (Greenhouse Gas Emission Reduction) Act 2002* set a state greenhouse gas benchmark level on a per capita basis, commencing at a level of 8.65 tonnes of CO_2-e that has since reduced to 7.27 tonnes where it was set to remain until 2021. The NSW pool coefficient indicates the average emissions intensity associated with electricity sourced from the NSW grid and represents CO_2-e per MWh of electricity supplied from the pool of the major power stations that are the benchmark participants. These benchmark participants are liable to meet their shares of these emissions. If they exceed their allowed level of CO_2-e they must purchase certificates or pay a fine. Certificates may be created by reducing the greenhouse gas intensity of their generated electricity, reducing consumption, forest management for carbon sequestration[20] or reduction of onsite emissions due to industrial processes. Compliance was maintained at 97% and above after 2003 with the majority of non-compliance being made up in the following year. Daley and Edis (2011) state that this scheme delivered a greater level of reductions in Mt CO_2-e than the level required by the legislation for the period 2003 to 2011.

[20] Carbon sequestration is the process of carbon capture from the atmosphere and long term storage.

The MRET has been the only national scheme operating in Australia with the main goal of encouraging additional electricity generation from renewable sources. Its goal was to reach a level of 9,500 GWh extra renewable energy by 2010 (Department of Climate Change and Energy Efficiency, 2011). The Federal Labor Government proposed a cap and trade emissions trading scheme to be introduced on 1 July, 2014 to replace its new carbon price, which commenced in July 2012. If this proposal is adopted it will allow early linkages to international carbon markets. Under the MRET power generators and wholesale purchasers of electricity make up the liable parties to the scheme and are required to support the additional electricity generation from renewable sources. Certificates may be created for each whole megawatt-hour (MWh) of electricity generated by the power station from renewable sources in excess of the required baseline amount. The baseline is calculated on the amount of energy generated in 1997. Under the Commonwealth's *Renewable Energy (Electricity) Act 2000* Div. 2 S40, the required percentage of renewable energy for the liable parties has increased from 0.24% in 2001 to 5.62% in 2011. The scheme was expanded to ensure 20% of Australia's electricity supply comes from renewable energy sources by 2020. Compliance has been over 96% since the scheme commenced. Similar to the GGAS, fines are incurred for non-compliance. Daley and Edis (2011) show that the MRET scheme, like the GGAS, has achieved greater reductions in Mt CO_2-e than required by legislation over the period 2001 to 2010.

In 2010 legislation was passed to divide the MRET into two parts in order to improve efficiency for small-scale entities. This change came into effect in the beginning of 2011 and there is now a Large-scale Renewable Energy Target (LRET) and a Small-scale Renewable Energy Scheme (SRES). The LRET continues to use the same mechanism for determining the required number of certificates to be surrendered. The SRES allows liable entities to create certificates based on the amount of energy their small-scale technology produces or displaces. Due to the effect of this split on prices and volumes traded the data used finishes at the end of 2010 for both GGAS and MRET in order to maintain consistency.

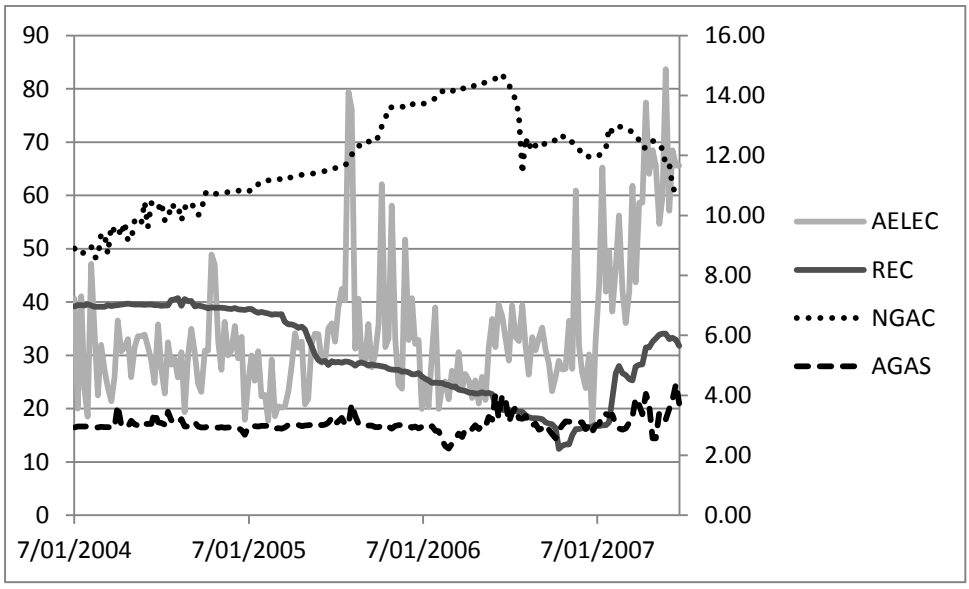
These markets have a relatively small number of trades compared with many of the financial markets. They have days where there are multiple trades interspersed with periods of no trades in a day. Early in the schemes' operations there were trading gaps which lasted some weeks. While this is no longer the case, again for consistency reasons, we have used a different approach to obtaining the weekly prices for our analysis and have not commenced the data until the beginning of 2004. Similarly, the futures trades had very light trading, limiting the ability to use it for analysis. Using weekly prices for GGAS and MRET we have obtained 365 observations for each variable. The Australian Financial Markets Association (AFMA) collects market participants' weekly views of the prevailing bid and offer prices for the GGAS certificates (NGACs) and the MRET certificates (RECs). The average of the bid and ask prices has been used. The adjusted gas (AGAS) and adjusted electricity (AELEC) prices have been obtained from the Australian Energy Market Operator (AEMO). The AEMO is the National Energy Market Operator and planner. The electricity prices are obtained from them as supplied from the National Electricity Market (NEM) which operates as the wholesale market for the supply of electricity to retailers and end-users. This data covers Queensland, New South Wales, the Australian Capital Territory, Victoria, South Australia and Tasmania.

The Victorian Wholesale Gas Market data is used as the source for the AGAS in our model as it is the most relevant data obtainable. It was not until September 2010 that the Short Term Trading Market started operation providing data from some other states.

In order to manage the extreme spikes that can be found in data on prices of electricity and gas we have adjusted the prices using a recursive filter algorithm. This was done by replacing all prices beyond the mean by plus or minus three standard deviations with the median of 16 observations around the replaced value. The log of the prices has been used to reduce variability and change the scale so that the elasticity values can be obtained directly from the parameter estimates. The data are divided into two periods. Period one extends from January 2004 to June 2007, and period two from July 2007 to December, 2010. The division and different econometric analysis, as discussed

below, enabled us to determine whether there was any change from the results of the effect of carbon prices on electricity prices found by Cotton and Trück (2011) and clearly determine any causality. Figures 5.3 and 5.4 below show the NSW Greenhouse Gas Abatement Certificates, the Renewable Energy Certificates, the adjusted Australian electricity price and the adjusted gas price for each of the two time periods. Table 5.1 provides summary statistics for these variables divided into the two time periods.

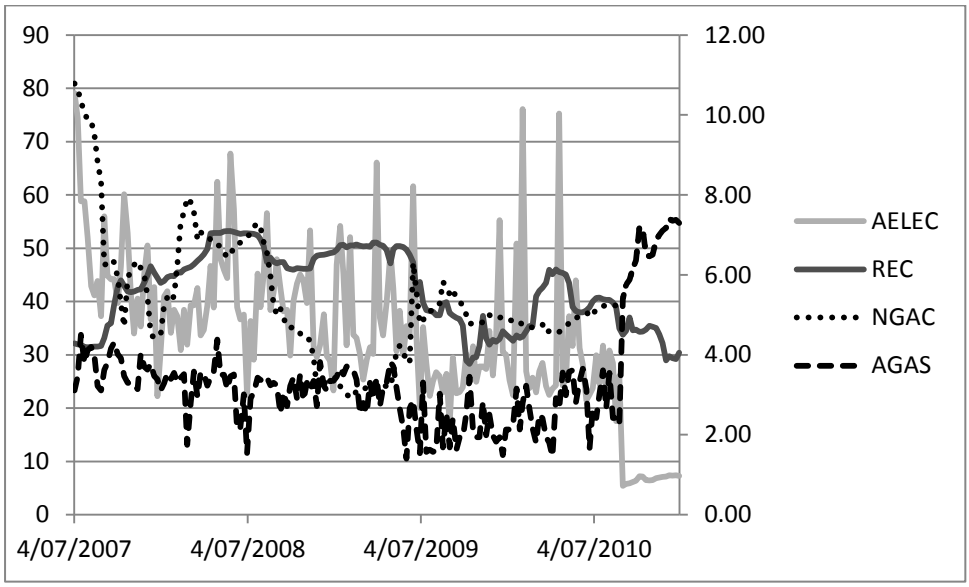
Figure 5.3: Data for time period one from January 2004 to June 2007



Source: Australian Financial Markets Association, price in Australian Dollars

Where: NGAC = NSW Greenhouse Gas Abatement Certificates; AELEC = adjusted Australian wholesale electricity price; AGAS = adjusted gas price; REC = Renewable Energy Certificates

Figure 5.4: Data for time period 2 from July 2007 to December 2010



Source: Australian Financial Markets Association, price in Australian Dollars

Where: NGAC = NSW Greenhouse Gas Abatement Certificates; AELEC = adjusted Australian wholesale electricity price; AGAS = adjusted gas price; REC = Renewable Energy Certificates

Table 5.1: Summary statistics for the NSW Greenhouse Gas Abatement Certificates, the adjusted Australian electricity price, the adjusted gas price and the Renewable Energy Certificates

Period 1: January 2004 to June 2007				
Variable	**NGAC**	**AELEC**	**AGAS**	**REC**
Median	11.95	31.48	2.99	28.72
Mean	11.85	34.49	3.05	29.86
Standard Deviation	1.58	13.19	0.30	8.32
Skew	-0.08	1.59	1.39	-0.28
Number of observations	182	182	182	182
Period 2: July 2007 to December 2010				
Variable	NGAC	AELEC	AGAS	REC
Median	5.16	33.19	3.24	43.47
Mean	5.50	33.96	3.33	42.15
Standard Deviation	1.57	14.68	1.33	7.23
Skew	0.88	0.32	1.51	-0.18
Number of observations	183	183	183	183

Source: Australian Financial Markets Association (NGAC and REC), Australian Energy Market Operator (electricity and gas prices) (2012), all prices in Australian Dollars

Where: NGAC = NSW Greenhouse Gas Abatement Certificates

AELEC = adjusted Australian wholesale electricity price

AGAS = adjusted gas price

REC = Renewable Energy Certificates

5.2.3 Methods

In this study we check for the hypothesis of a long-term relationship between AELEC, NGAC, REC and AGAS. We test the impact (if any) of NGAC and REC on the price dynamics of AELEC, and examine whether NGAC played a role or whether it was only REC that had any effect. In order to test this hypothesis, an over-identifying restriction of 'zero' on the NGAC series was imposed based on Pesaran and Shin's (2002) long-run structural modelling technique (LRSM)[21]. LRSM endeavours to estimate theoretically meaningful long-run (or cointegrating) relations by imposing on those long-run relations (and then testing) both identifying and over-identifying restrictions based on theories and a priori information about the economies in which they operate. For testing each restriction one should check the likelihood ratio statistic in each case to establish whether the null hypothesis that there are no restriction/s should be rejected or accepted.

It is well documented that a pre-condition for the application of cointegration and for testing long-run structural relationships is to ensure that all variables are I (1). All our series are non-stationary in their levels form and then become stationary after first differencing. We use the popular ADF, PP and KPSS units root test according to Dickey and Fuller (1979), Phillips and Perron (1988) and Kwiatkowski et al. (1992). Under the ADF and PP test, the series is assumed to be non-stationary and a failure to reject the null hypothesis implies that the series has a unit root. The KPPS test assumes that the series is trend stationary under the null hypothesis, with the alternative being that it is non-stationary. Next, to determine the order of the vector autoregressive model (VAR) we run the unrestricted VAR with eight lags and based on the Akaike Information Criterion (AIC) (Akaike, 1974) we select a VAR (4) for running the restricted VAR based on the Johansen cointegration technique (Johansen and Juselius, 1990; Johansen, 1991). Due to the nature of the data we use the unrestricted intercept and restricted trend model to capture the long-run relationship and the number of cointegrating relationships between the variables. The trace and maximum eigenvalue test indicates a single cointegrating relationship between all the variables. These results were common across both our samples (Jan 2004 – June 2007 and July 2007 – Dec 2010).

[21] The LRSM technique can be easily implemented in Microfit 5.0 software (Pesaran, H. and Pesaran B., 2009)

The identification of $\boldsymbol{\beta}$ (in $\Pi_y = \alpha_y \beta'$) requires at least *r* restrictions per each of the *r* cointegrating relations.[22] After selecting a single cointegrating relationship (r =1), we then normalise the AELEC by imposing the non-testable restriction of 1. This normalising restriction can be applied to the coefficient of any of the integrated variables that enter the cointegrating relation. However, since we are testing the impact of other variables on electricity it was only natural to impose the restriction on AELEC. However, in a more general case where r >1, the number of such "normalising" restrictions is just equal to r, which needs to be supplemented with a further $r^2 - r$ a *priori* restriction.

The LRSM procedure is a subsequent step after we estimate the VECM model and impose the identifying restriction of 1 on the cointegrating vector. Given that we have a model with $(\mathrm{AELEC}, \mathrm{NGAC}, \mathrm{REC}, \mathrm{AGAS})$ we impose the following over-identifying restriction on the $\boldsymbol{\beta}'$**.** The matrix $\boldsymbol{\beta}'$ can be used to impose all the restrictions necessary for the structural long-run relationship to be over-identified. So after normalising, we immediately impose the over-identifying restriction of 'zero' on the NGAC prices to see if the state greenhouse gas abatement scheme had any impact on AELEC.

The likelihood ratio statistic based on the chi-square distribution fails to reject the over-identifying restriction as the test statistic is less than the critical figure at the 95% confidence level. After this step we estimate the error correction equations of the individual variables, which are summarised below to conserve space.

We have used Granger (1969) causality tests which can be interpreted as within-sample causality tests and can be used to make inferences about causal relationships within the sample period only. In order to have a feel for the relative exogeneity or endogeneity of the variable (or what we call the short-run dynamics) we utilise the GIRFs and GVDs developed by Pesaran and Shin (2002) and Koop et al. (1996). In the variance decomposition analysis, variance of the forecast error of a particular variable is partitioned into proportions attributable to innovations (or shocks) in each variable in the

[22] Readers interested in more details should consult Pesaran and Shin (2002)

system, including its own. If a variable can be optimally forecast from its own lags, then it will have all its forecast variance accounted for by its own disturbances (Sims, 1982). The GIRFs examine how the shocks given to the residuals (innovations) of equations within the system of seven equations (one equation for each variable) impact on the variables involved at different time horizons. We use a bootstrap approach to calculate the upper and lower bound based on Pesaran and Pesaran's (2009) approach.

5.3. Results

For the first sample, January 2004 to June 2007, from the VECM the short-run two-period lag of AELEC are found to be significant in driving changes in AELEC themselves. This is an early sign that AELEC are not affected by changes in other variables in the short run. For the long-run component however, the error correction term is found to be negative and significant (-0.292, t = -3.14) thus indicating that AELEC are adjusting to their long-run equilibrium from the bottom, but we do not know at this stage exactly which variable is forcing this adjustment. The error correction equation for NGAC also shows that in the short run its price is driven by changes in its one lag price. We also find some weak endogeneity (significance of the error correction term) indicating that some movements in other variables are driving changes in NGAC prices to bring about an adjustment to long-term equilibrium. This might not be surprising as the NGAC was introduced not long prior to the start of the sample period and was not a very liquid instrument with some uncertainty surrounding its price. It could be that the electricity price had some influence on it. The size of the error correction term is found to be small and positive (0.0216, t = 2.27) thus showing a small adjustment in comparison to AELEC. The positive sign tells us that adjustments are coming from the top meaning the price overshoots and then adjusts back down towards its long-run equilibrium path.

The short-run deviations and the lags of all the variables play no role in the error correction equation for REC except for the first lag of the REC itself. This again tells us that REC is exogenous in the short run and this exogeneity persists in the long run, as indicated by the insignificant (-0.0069, t = -0.5047) error correction term. The error correction equation for AGAS gives us a similar result in terms of the short-run dynamics but the error correction term is found to be small and positive but significant (0.062, t = 2.486). It could be that gas prices are being driven by changes in electricity and NGAC and REC prices. Again, at this stage we cannot pinpoint exactly the variables that are driving changes in gas prices.

In the second period, July 2007 to December 2010, we find that all the endogeneity present in NGAC and AGAS disappears, REC remains exogenous and AELEC continues to show weak endogeneity. The coefficient of the error correction equation for AELEC is now larger and significant (-0.557, t = -5.466). This speed of adjustment is almost double that of the pre mid- 2007 period, telling us that prices are adjusting a lot faster to bring out long-term equilibrium. The wholesale electricity prices are determined by bids from the generators. Those with the lowest prices supply electricity bid first followed by the more expensive bids until the demand is fully met. The price is then determined by the price bid of the marginal supplier in the market. The Australian Industry Group (2011) suggests that the Global Financial Crisis which began in late 2007 to early 2008 depressed demand across the National Electricity Market. At this time there were also extreme weather conditions including drought which greatly reduced the ability of the low-cost generators to supply to the market. Many hydro generators and some coal generators who require large amounts of water were also affected by this, reducing their ability to supply the market. It is likely that these added pressures to the market have contributed to a smaller number of suppliers and a speedier impact of costs on the price of wholesale electricity.

The results of the GVDs shown in Table 5.2 & 5.3 are best interpreted by looking at the diagonal (in bold) where we can see the response of each variable when we introduce a shock to the variance of

one of the other variables. The first column tells us the number of weeks we go out of sample to measure the impact of the shock since its inception. If the majority of the shock is self-explained then the variable is deemed to be exogenous. This is an important extension from the error-correction results which is often missed where the significance of the error-correction term only indicates if a variable is weakly endogenous. This means that changes in other variables in the system are driving changes in the endogenous variables. In our VECM result, AELEC are being driven by changes in other variables but we do not know which specific variable is driving those changes. The GVDs give us a better insight into the relative endogeneity of the dynamics. Table 5.2 shows that the variance in AELEC is self-explained (93.38%) when own shocks are introduced in AELEC. As we move further out of sample to week three, approximately 80.26% of the variance is self-explained with only a fraction being explained by NGAC (2.29%) and REC (0.67%). AGAS tend to dominate or cause adjustments in AELEC to bring about long-run equilibrium. As we move further out of sample we can see the progressively increasing role that the variances of AGAS play in driving the variance of AELEC.

NGAC prices seem to play no role whatsoever in the price dynamics and REC seems to play a very minimal role. When we look at 15 and 25 weeks out of sample, nearly 37% and 43% of the variance in AELEC is being driven by AGAS. This is not surprising and it has been discussed earlier that the prices are dependent upon the costs incurred by the generators. Gas, as shown in Figure 5.1, contributes around 10% to the energy supplied. The NGAC prices initially have a slightly greater effect than REC prices but as we move further out of sample RECs seem to have a bigger influence than NGAC prices, where, for example, after 25 weeks approximately 3.5% of the variance in AELEC is being explained by the RECs. Based on this we can say that the carbon prices are having very little influence on AELEC and it is the changes in AGAS that seem to have a greater influence on AELEC.

Table 5.2: Generalised variance decompositions (Jan 2004 to June 2007)

Weeks	Variable Shocked	Response of AELEC	Response of NGAC	Response of REC	Response of AGAS
	AELEC				
0		**93.38**	0.34	0.21	7.07
1		**89.46**	1.70	0.20	8.64
3		**80.36**	2.29	0.67	16.78
5		**75.42**	1.83	1.29	21.45
10		**65.49**	1.23	2.23	31.05
15		**59.25**	1.03	2.83	36.89
25		**52.54**	0.89	3.47	43.10
	NGAC				
0		0.36	**99.23**	0.11	0.30
1		0.45	**98.32**	0.08	1.15
3		2.16	**95.00**	0.07	2.77
5		2.95	**92.49**	0.05	4.51
10		4.72	**88.20**	0.04	7.05
15		5.59	**86.11**	0.04	8.27
25		6.37	**84.23**	0.05	9.35
	REC				
0		0.23	0.11	**99.60**	0.06
1		0.27	0.69	**98.93**	0.10
3		0.12	2.09	**97.05**	0.73
5		0.08	2.63	**96.42**	0.87
10		0.07	3.34	**95.78**	0.81
15		0.08	3.70	**95.49**	0.73
25		0.11	4.03	**95.22**	0.64
	AGAS				
0		7.09	0.28	0.05	**93.58**
1		12.96	1.57	0.26	**85.20**
3		14.76	2.10	6.50	**76.64**
5		18.23	2.48	8.11	**71.18**
10		22.94	2.30	10.02	**64.75**
15		26.04	2.08	10.80	**61.07**
25		29.38	1.82	11.52	**57.27**

Where: Column 1; the number of weeks we go out of sample to measure the impact of the shock since its inception i.e. t = 0 is immediate (at inception), followed by 1 week, 3 weeks etc. Column 2; the variable which is shocked at time 0. Column 3 - 6; these measure the response in the price of the variable (column 3 AELEC etc. as indicated) to the shock in the variable in column 2, it indicates how much (percentage) change in its price occurs due to the shock immediately (t = 0) and then after the number of weeks indicated in column1.

The output in Table 5.3 paints a similar picture for the minimal role that NGAC and REC play in driving variances of AELEC in the second time period. The post-2007 period shows fairly strong exogenous behaviour in all variables, with all the variance being self-explained. The dynamics between AGAS and AELEC weakens as almost 90% of the variance in AELEC is self-explained in the first 5 weeks and this only drops to 80% as we gradually move to 25 weeks out of the sample forecast period. This indicates that gas prices have a minimal impact on electricity prices on a short and long out-of-sample horizon. The AGAS prices show even higher exogeneity in which 90% of the variance is self-explained throughout the out-of-sample period. Unlike some other studies that have found a closer link between carbon prices and electricity, our study fails to establish such a link.

Table 5.3: Generalised variance decompositions (July 2007 to Dec 2010)

Weeks	Variable Shocked	Response of AELEC	Response of NGAC	Response of REC	Response AGAS
	AELEC				
0		**94.95**	0.51	0.05	4.48
1		**94.20**	1.53	0.12	5.16
3		**91.46**	3.11	0.69	4.74
5		**90.79**	3.07	1.28	4.86
10		**88.36**	3.00	2.44	6.20
15		**86.25**	2.94	3.43	7.38
25		**82.34**	2.81	5.27	9.57
	NGAC				
0		0.54	**98.99**	0.04	0.44
1		0.26	**98.36**	0.18	1.20
3		0.65	**97.56**	1.10	0.69
5		1.02	**97.03**	1.48	0.46
10		1.34	**96.34**	2.05	0.27
15		1.44	**96.09**	2.27	0.20
25		1.53	**95.87**	2.45	0.14
	REC				
0		0.05	0.04	**99.89**	0.02
1		0.02	1.40	**98.11**	0.47
3		0.08	1.51	**97.81**	0.60
5		0.17	2.64	**96.63**	0.56
10		0.51	3.69	**95.40**	0.39
15		0.66	4.09	**94.92**	0.33
25		0.77	4.40	**94.54**	0.28
	AGAS				
0		4.49	0.42	0.02	**95.07**
1		3.95	0.37	0.89	**94.78**
3		3.10	2.46	0.68	**93.76**
5		3.84	2.12	0.54	**93.50**
10		5.66	1.79	0.38	**92.17**
15		6.64	1.62	0.29	**91.45**
25		7.66	1.43	0.20	**90.71**

Where: Column 1; the number of weeks we go out of sample to measure the impact of the shock since its inception i.e. t = 0 is immediate (at inception), followed by 1 week, 3 weeks etc. Column 2; the variable which is shocked at time 0. Column 3 - 6; these measure the response in the price of the variable (column 3 AELEC etc. as indicated) to the shock in the variable in column 2, it indicates how much (percentage) change in its price occurs due to the shock immediately (t = 0) and then after the number of weeks indicated in column1.

The information contained in the GVDs can be equivalently represented by graphs of the generalised impulse response functions. We break the impulse response function analysis into two elements, with Figures 5.5 and 5.6 looking at the impact of a shock in each individual variable and the response profile of the entire cointegrating vector. This approach, although available in standard econometric packages like Microfit 5.0, is not readily utilised but interesting results could be obtained to see if a single variable has an important bearing on the entire system (i.e. the cointegrating vector). The upper and lower bounds show the bootstrap confidence interval of impulse responses at the 95% confidence level. This helps us gauge which variable causes a bigger impact on the system as a whole even though this is not captured in the GVDs.

In Figure 5.5 shocks to electricity prices initially have a downward impact on the cointegrating vector but within a few weeks prices tend to increase before declining and then ultimately reaching a steady state equilibrium after approximately 14 weeks out of sample. In Figure 5.6, shocks to AELEC have a sharp negative impact and then decrease further and reach a steady state much faster than in Figure 5.5. These findings could be interpreted as meaning that electricity prices had a bigger impact on the cointegrated system prior to 2007 with no positive impacts between 2007 and 2010. Similar movements are observed with shocks to NGAC prices. As shown in Figure 5.5, initially there is a positive impact on the cointegrating vector and then the system gradually continues on a downward path with some persistence before returning to equilibrium after approximately 14 weeks out of sample. In Figure 5.5 the shock from NGAC is vastly different, with the remaining prices collectively declining and staying below “zero” for approximately 2 weeks and then returning to equilibrium in about half the time (approximately 7 weeks) in comparison to shocks in electricity prices. This tells us that in the latter half of the sample NGAC prices did not have a huge bearing on the dynamics of the estimated model. Another interesting observation from Figures 5.5 and 5.6 is that overall the system takes 14 weeks to reach equilibrium in the 2004–2007 period and approximately 7 weeks in the 2007–2010 period. This illustrates that in recent times, shocks to electricity and emission trading

scheme prices tend to cause only minor distortions in the very short run before settling to a steady state equilibrium.

Figure 5.5: Impulse response functions of the cointegrating vector to shocks in individual variables (Jan 2004 – June 2007).

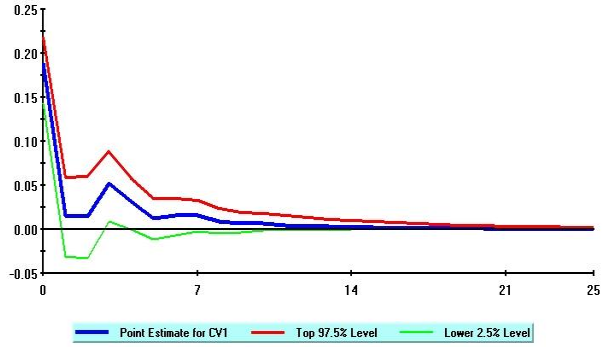
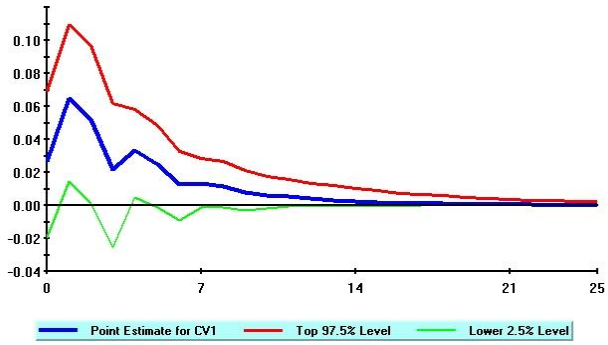
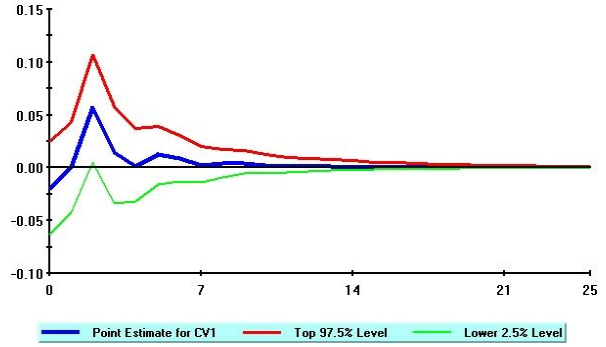
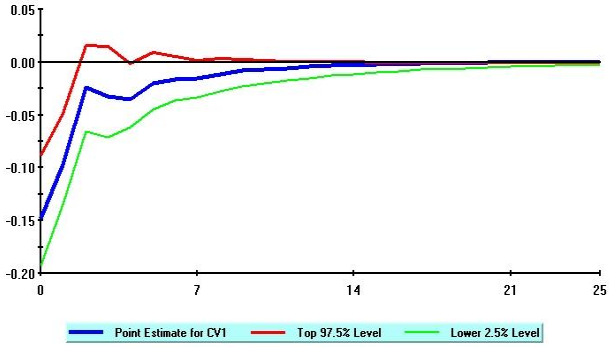
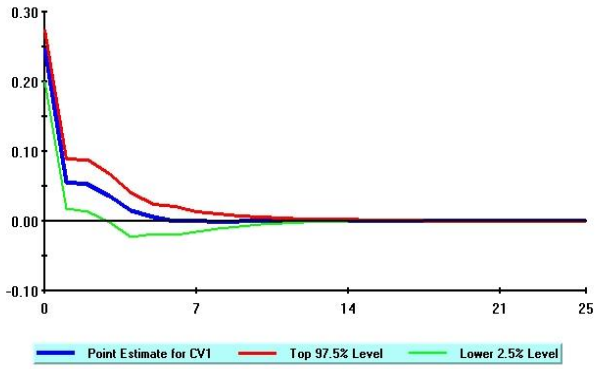
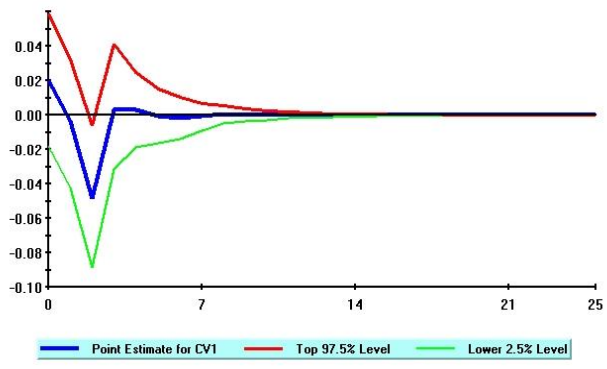
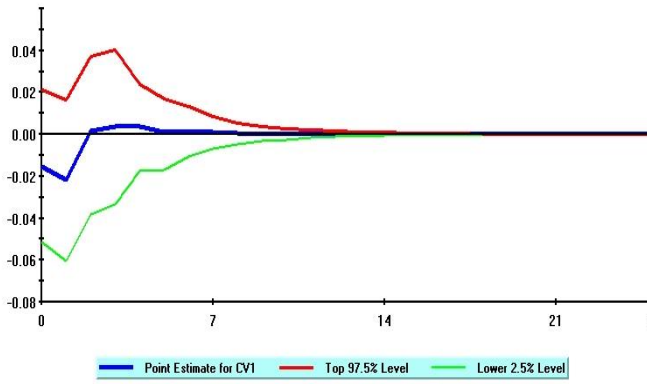
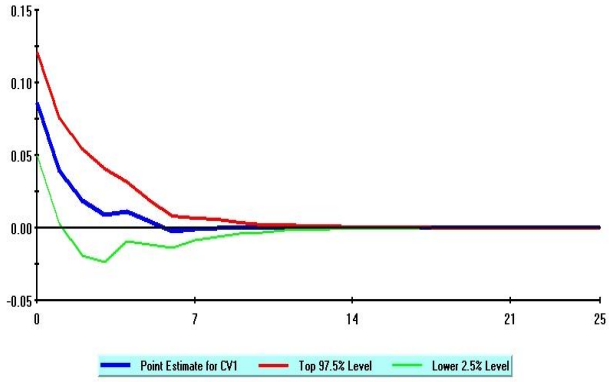
Shock to AELEC	**Shock to NGAC**
	
Shock to REC	**Shock to AGAS**
	

Figure 5.6: Impulse response functions of cointegrating vectors to shocks in equation (July 2007 to Dec 2010)

Shock to AELEC	**Shock to NGAC**
	
Shock to REC	**Shock to AGAS**
	

Figures 5.7 and 5.8 show the dynamic response of each variable when a one standard deviation shock is introduced in each of the residuals of the variables. For example, in the upper left panel of Figure 5.7, we can see that "own" shocks to AELEC die out quickly but prices reach a higher steady state equilibrium, indicating an increasing cost of electricity. The impact is almost 'zero' on the rest of the variables and this is supported by the small role that AELEC plays in explaining the forecast error variance of other variables shown by the results in the GVDs. Shocks to NGAC do however have some impact on AELEC but they return to "zero" within 3.5 weeks and then continue on a downward trajectory before settling at an equilibrium below 'zero'. Shocks to AGAS have lasting positive effects on AELEC which is not surprising given the strong association between the two during the first sample period. This however is not the case in Figure 5.7 where shocks to AGAS do not feed through to AELEC but rather AGAS prices reach a higher steady state equilibrium.

In Figure 5.7, "own" shocks to NGAC and REC tend to cause lasting effects on their own prices (they settle at a much higher steady state) with very minimal impact on other variables. This is supported by the exogeneity shown by NGAC and REC in error correction results together with the out-of-sample exogeneity found in the GVDs analysis. Similar to results in Figure 5.5, shocks to AELEC die out very quickly and all other prices (the combined effect is captured in Figure 5.5 by the response of the cointegrating vector) return to equilibrium in approximately 7 weeks.

Figure 5.7: Impulse responses functions of individual variables to shocks in equation (Jan 2004 to June 2007)

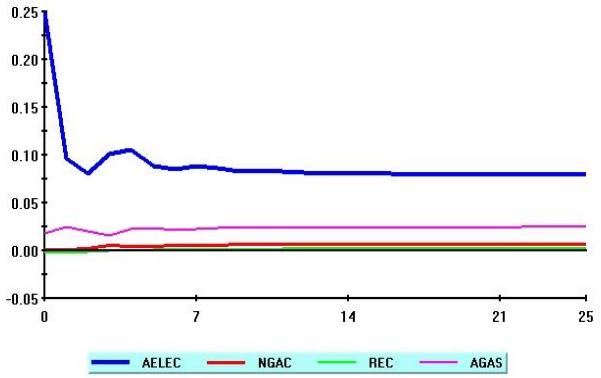
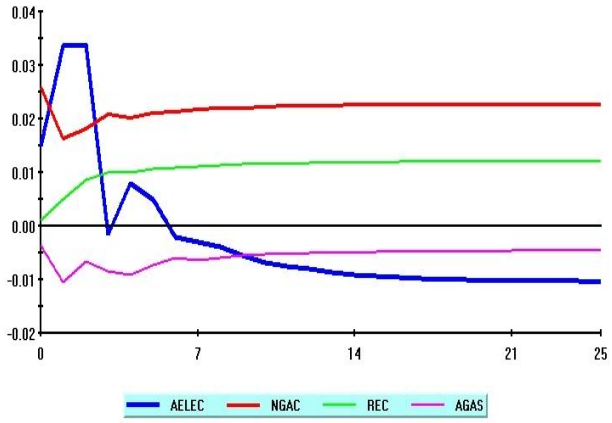
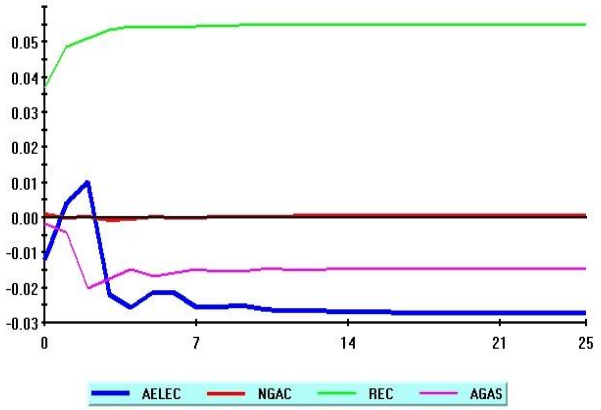
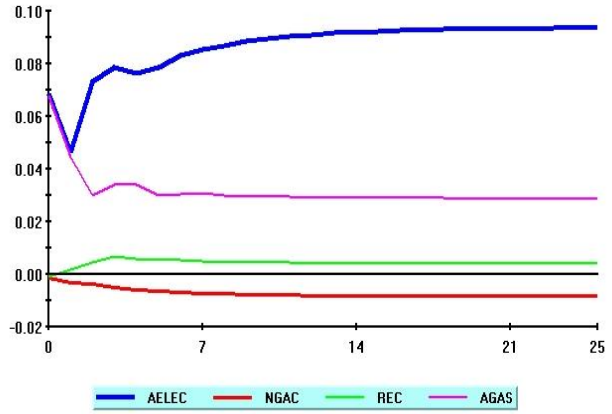
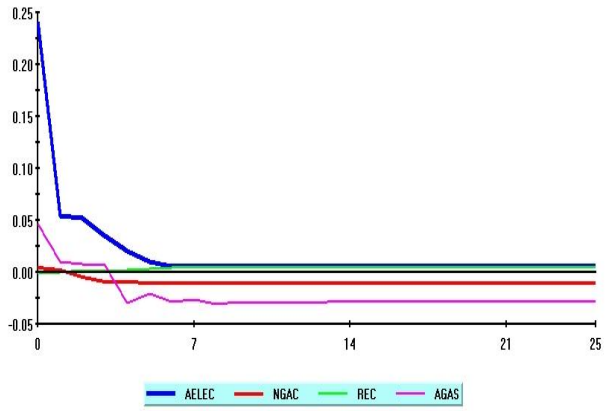
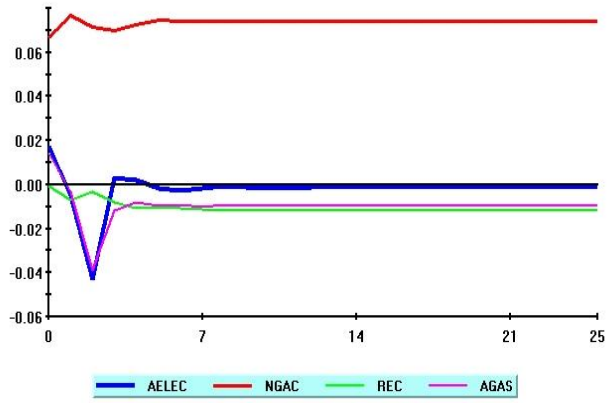
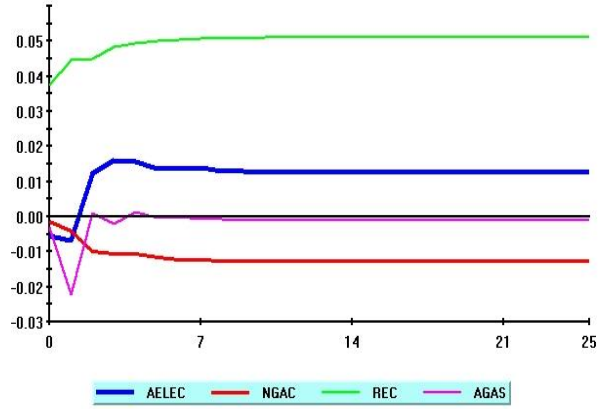
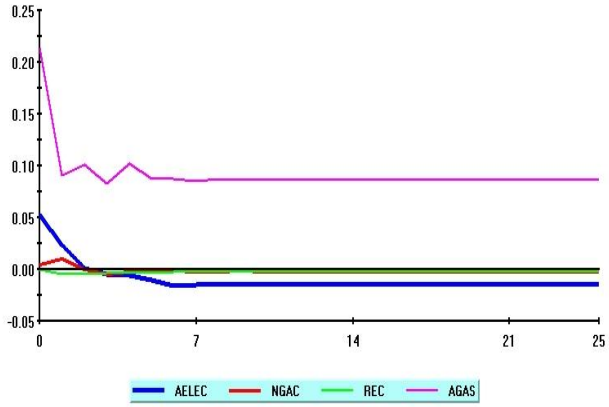
Shock to AELEC	**Shock to NGAC**
	
Shock to REC	**Shock to AGAS**
	

Figure 5.8: Impulse responses functions of individual variables to shocks in equation (July 2007 to Dec 2010)

Shock to AELEC	**Shock to NGAC**
	
Shock to REC	**Shock to AGAS**
	

5.4. Discussion

Much of the initial analysis undertaken is similar to earlier studies of the relationship between carbon prices and electricity prices in Australia and internationally. In this paper we are testing for a long-term relationship as was done by Bunn and Fezzi (2007) and others, and as is discussed in the literature section, Section 2.1. The LSRM methods used may be inconclusive when autocorrelation is present which is highly likely when using time series data. Zachmann and von Hirschhhausen (2008) and others improved on earlier studies and addressed the problems of autocorrelation by using ECM and VECM and this forms the initial part of our analysis. We find that while we can see that electricity is adjusting to its long-run equilibrium we want to determine in this paper which variable/s is/are forcing this to occur. In our early analysis it appears to be the electricity itself. We use GIRFs and GVDs for the first time on this type of market and they provide us with an understanding of the relative exogeneity or endogeneity of the variables. A shock to the variance of one of the variables is introduced so that we are able to see if electricity is driven by these other variables. This methodology enables a better understanding of which variables play a role. The GIRFs determine how the shocks given to the residuals impact on each of the variables. Here we can determine how long the effects of the shocks last and as such the importance of the long-term effect of each variable on the prices of the other variables. The findings, as shown in Section 3 above, give a first clear insight of how short term the effect is of shocks by the other variables on electricity prices. As discussed in the conclusion, the indication is that neither of the schemes has had significant effect on the electricity prices.

These results provide some empirical evidence to endorse earlier research which suggests some problems with Australia's emissions trading schemes. That is, if we expect that increases in the certificate prices should increase the electricity prices if the scheme is operating efficiently, then this is not occurring. This premise though may not be as simple as it seems and other factors may be

affecting electricity prices as noted in the literature review. Griffiths et al. (2007) note the climate change conflicts in Australian policy that are caused by differing targets set individually by the states and federal governments. In line with our earlier discussion they state that 'green and other environmental groups have been marginalized as large corporations seek to influence the design and structure of any carbon tax or emissions trading scheme'. Further they conclude that 'part of the resilience of the coal industry in Australia has been its effective ability to lobby governments to attract resources and desirable policy outcomes.' The results of this lobbying may provide some understanding of the results we find in this paper. Further evidence of the lack of any long-term relationship can be seen in the Department of the Environment National Inventory (Australian Government, 2012c). In this report the authors state that electricity generation emissions increased by 49% from 1990 to 2012. In the period 2009–2010, during the second period of our analysis in this paper, the report shows a slight decrease in the CO_2 emissions from coal for electricity generation by fossil fuels. It is worth understanding though that in 2012 around 90% of all coal consumed in Australia was used for electricity generation.

When looking at the MRET and GGAS we tend to see parallels with the EU ETS which is by far the larger and more highly traded scheme. Ellerman and Buchner (2007) explain that when the emissions data were released in Europe in April and May 2006, they revealed that the allowances for emissions exceeded the actual emissions by around 80 million tons or four per cent of the EU ETS cap. This revelation of the over-allocation of allowances explains the fall of EUA prices at this time. Not all countries who were participants in the EU ETS, and not all sectors covered by the scheme, were over-allocated. However, the overall effects of the price fall, and the resulting increase in uncertainty and concern, were widespread. This type of uncertainty may also be contributing to the lack of impact on electricity prices by the Australian emissions trading schemes analysed in this paper.

5.5. Conclusion and Policy Implications

This paper captures the dynamics between the price of electricity, the NSW greenhouse gas abatement certificates, the mandatory renewable energy certificates and the price of natural gas. Our findings show that there is a long-term relationship between the variables in both the samples. On further analysis however, the short run-dynamics indicate that NGAC and REC play a minimal role in explaining movements in electricity prices. The interactions between NGAC and electricity are stronger in the first half of the sample but then dissipate in the second period. This paper has separated the emission reduction schemes from other policies and has found that neither the GGAS or MRET certificates affect the electricity prices. So even though compliance requirements were met for both schemes during the period under analysis, schemes appear not to have been contributors to these emission reductions. While these results differ from earlier studies in Australia, and most international scheme analysis, there are other indications that vindicate our findings. The continued high level of use of coal as an energy source in Australia indicates little to no actual change to lower emission alternatives. Because of coal's importance to Australia's export income, both of the major political parties have failed to introduce policies which increase green energy and reduce the use of coal. While we do see in our results in the first time period an effect of gas prices on electricity prices, the proportion of gas relative to coal as a fuel source in Australia has not increased significantly. Our findings indicate that a policy requiring a greater proportion of green energy as a source of energy production will be required before the certificate prices will affect the electricity price. Nelson et. al. (2013) concluded that the ongoing uncertainty in the RET policy prevented it from operating efficiently. The introduction of the carbon price on July 1, 2012 may have provided the required change, however the new federal government has introduced legislation to cease the operation of this carbon price. Where Australian policy goes from here, and the likelihood of it legislating for greater use of green energy, is as yet unknown.

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Chapter 6

Ambiguity in markets: a test in an Australian emissions market

Abstract

Research suggests that ambiguity not only reduces the desirability to trade but also the overall effectiveness of financial markets. This paper tests the hypothesis that information related to climate change mitigation in Australia reduces the ambiguity surrounding investor participation in Australia's largest emissions trading scheme. This market was chosen due to the high level of ambiguity surrounding government policy and the ability to determine the factors likely to reduce ambiguity. We use government announcements and international and locally significant events as sources of information. From this we find that information does reduce the level of ambiguity, as shown by reduced bid-ask spreads and increased relative trading volume.

Keywords: ambiguity, emissions trading, financial markets

6.1. Introduction

The definition of ambiguity in the Oxford English Dictionary refers to wavering of opinion, hesitation, doubt and uncertainty. The concept of ambiguity was first applied to financial markets by Easley and O'Hara (2009, 2010) and Routledge and Zin (2009). These studies created models that showed that a reduction in ambiguity increased market participation. The inverse relationship between ambiguity and market participation has potential implications for market efficiency, as Routledge and Zin (2009) imply that ambiguity reduces efficiency as characterised by market liquidity measures and market effectiveness. They refer to effectiveness as a measure of importance to gauge the impact of ambiguity. The level of uncertainty regarding climate change policy in Australia is very high and provides an excellent backdrop to investigate ambiguity and its effect on market participation and efficiency. The Labor Party won the federal election in Australia in 2007 and ratified the Kyoto Protocol on 3 December 2007, giving a strong indication that it wanted to act on climate change mitigation. The ratification of the Kyoto Protocol meant a commitment to limiting greenhouse gas emissions to 105% of 1990 levels. However, there has remained a high level of uncertainty regarding the long term policy direction of the federal government.

Business leaders have been trying to resolve the uncertainty. At the sixth Australia-New Zealand Climate Change and Business Conference held in Sydney on 11 and 12 August, 2010, the resounding opinion from all the business sectors was for a clear carbon price to be determined. This call has been reiterated on numerous subsequent occasions. The business leaders represented at the Conference, including participants from Origin Energy, the Murray-Goulburn Co-operative, the Australian Farm Institute, National Australia Bank, Insurance Australia Group and KPMG, all agreed that reducing greenhouse gas emissions by at least 15% from 2000 levels by 2020 would be economically beneficial and this statement was communicated in their Conference Communique (Climate Change and Business Centre, 2010). This view has continued with the presentation by

Tennant Reed, Principal National Advisor of Public Policy for the Australian Industry Group at the 2013 Carbon Expo stating that 'Policy/budget vagaries are damaging' (Carbon Expo Australasia 2013). In late 2011, legislation for a carbon tax was passed. The legislation applied to approximately 500 of the highest emitting companies in Australia and came into force on 1 July 2012. The Labor Government stated that the tax will be replaced by a carbon pollution reduction scheme (CPRS) on 1 July 2015. It was also intended that a full two-way link would be established at the most three years later with the European Union Emissions Trading Scheme (EU ETS). However, the Liberal/National Coalition ousted the Labor Government in the federal election in September 2013. The new government repealed the carbon tax in July 2014 and appears unlikely to introduce a CPRS.

There are several different markets for abatement and carbon in Australia. Australia has a number of environmental emission reduction schemes set up by the state governments and operating mostly independently of each other in Victoria, New South Wales, Queensland and the Australian Capital Territory. While these schemes may indicate a strong desire at a state level to reduce $C0_2$-e[23] emissions, the requirements for emitters covered by each scheme are different, with many participants regulated under more than one scheme.

In this study we empirically investigate the Mandatory Renewable Energy Target Scheme (MRET). The MRET is Australia's largest and only national renewable energy trading scheme and is also the most liquid emissions trading scheme with the highest volume and number of trades. The scheme began on 1 January 2001, with the goal of encouraging the generation of additional energy from renewable resources, thereby reducing greenhouse gas emissions. The MRET acted as a complement to the carbon tax and, therefore, MRET participants were likely to have a long term perspective on climate policy information. Uncertainty for those participating in the MRET comes from possible changes to both Australian and international policy direction about climate change mitigation.

[23] CO_2-e is a way of describing different greenhouse gases in a common unit i.e. for any quantity and type of greenhouse gas, CO_2-e signifies the amount of CO_2 which would have the equivalent global warming impact.

We focus on measuring market efficiency, using the bid-ask spread and volume as indicators, through information asymmetry and liquidity, respectively. Another metric, effectiveness, in an emissions trading market would be measured by the reduction in emissions found in the particular country or region during the period of the market's operations. While the net impact and therefore effectiveness of the considered scheme is beyond the scope of this paper, the Australian Governments' 2012 National Inventory Report to the UNFCCC (2012) shows that emissions levels from the energy sector increased by 44.2% from 1990 to 2012 .

This paper examines whether more certainty in long-term government policy direction, and enacting of legislation at the federal level, reduces ambiguity and increases efficiency. The focus of this paper is on domestic action which is where the federal government has the most power through law. Easley and O'Hara (2009) demonstrate that the legal system affects participation in markets by contributing to the level of ambiguity. This link is examined in this paper by including changes in the regulations, including any changes to market rules, surrounding climate change policy and their announcements in Australia as indicators of information in the market. Focusing on this market is beneficial since other broader markets would be affected by a greater diversity of regulatory, and even general, information issues that would make it more difficult to measure the effect on uncertainty, ambiguity and efficiency.

The remainder of the paper is organised as follows: Section 2 reviews the literature on the effects of ambiguity in financial markets, information provided by the bid-ask spreads and policies surrounding the issue of climate change. It then explains the data used in this study, including the measures used to indicate information in this study. Section 3 shows the methodology that is used to test for ambiguity in the considered markets, while Section 4 provides the results of the empirical analysis. Finally, Section 5 presents the conclusion and examines the effects of ambiguity from both market and climate change mitigation perspectives.

6.2. Literature

Much of the literature surrounding investment decisions is based on utility maximisation theory, which asserts that the consumer attempts to get the greatest value possible from the least amount of expenditure in order to maximise the total value derived from their available dollars (Stigler, 1950). According to theory, investors do this by considering the amount and probability of the return. Early work by Savage (1954) proposes an alternative to simple probabilities by suggesting people have a 'degree of belief' about an event, whereby a person will have a general preference for one event over another, even if they have the same prize and same probability of occurring. Drakopoulos (1992) looked further back at Keynes' views on consumer behaviour from 1937, where he rejected the utility maximising model. Keynes believed consumption depended on both objective and subjective factors. On the spending side he included factors such as enjoyment, short-sightedness, generosity, miscalculation, ostentation and extravagance. The motives for saving included precaution, foresight, calculation, improvement, independence, enterprise, pride and avarice. These additional components all suggest that consumer behaviour is influenced by factors other than simple probabilities and expected outcomes. Dow and Werlang (1992) distinguish between risks and uncertainties in investment decisions. They suggest that 'an agent gambling on the toss of a coin about which he knows nothing may behave qualitatively differently from when he knows whether the coin is biased and if so by how much' (p. 197). They suggest that the agent's behaviour will reflect uncertainty aversion or, as it is termed in this paper, ambiguity aversion.

6.2.1 Ambiguity

In 1961 Ellsberg looked at the difference between quantifiable uncertainty, or risk, and unmeasurable uncertainty where the probabilities of events are unknown. Unmeasurable uncertainty was tested in what is known as the Ellsberg Paradox. Ellsberg (1961) undertook an

experiment which showed that when given the choice, individuals tend to prefer a known probability to an unknown one. Recognising the multiple interpretations or inexactness of probability in decision-making has led to research into ambiguity.

Ambiguity can lead to lower pricing, extreme preferences for reductions in ambiguity or even non-participation. For example, Sarin and Weber (1993) find that an ambiguous asset induces some psychological discomfort. They study bidding situations such as oil leases and mineral rights, where the object of the sale involves ambiguous probability, due to a lack of information or prior experience in the particular site. They find that the bid prices and market prices of the ambiguous assets are consistently below those of the unambiguous assets. Bossaerts et al. (2010) find that these ambiguity-averse investors have an indirect effect on prices because these investors perceive an increase in the per capita amount of risk that is to be shared among the marginal investors. The ambiguity-averse investors will always choose to hold an unambiguous portfolio no matter the cost of such a portolfio. Easley and O'Hara (2005) find that mispricing from ambiguity also induces non-participation. They suggest that not only will investors avoid the unknown distribution, as shown in the Ellsberg Paradox, but they will act in a pessimistic way and assume the odds will not go their way. Easley and O'Hara suggest that seemingly irrelevant events can lead ambiguity-averse investors to exit a market and this phenomenon may explain why markets appear to overreact. Their paper has a government policy implication, since they suggest that regulations that rule out unlikely outcomes can play an important role in keeping ambiguity-averse investors in the market.

If ambiguity-averse investors stay in a market they may be affected by a general mood in the market, and they may also assign large weights to seemingly low-probability occurrences. A general contagion among investors is demonstrated by Ford et al. (2006) who use Choquet expected utility theory (CEU) to argue that attitudes towards uncertain outcomes lead to general swings in the market, depending on levels of optimism or pessimism. The CEU model 'allows for taking into

account a fuller array of behaviours under uncertainty' (Chateauneuf and Cohen, 2000, p.297). Ford et al. (2006) suggest that ambiguity-averse investors place more weight on extreme outcomes, and particulalry pessimistic ones, exacerbating these swings. They also suggest that both herd and contrarian behaviour among informed traders can be rational when their market is affected by ambiguity, suggesting that there are situations where it is rational for informed traders not to trade.

Ambiguity may lead to a decrease in the optimal exposure to a risky asset and affect asset pricing. In a review article, Guidolin and Rinaldi (2013) find that the level of investment in international stocks may be less than optimal and that there tends to be overinvestment in familiar assets. The recent global financial crisis provided some insight into behaviour around uncertainty, since, during this period, many securities which in normal circumstances were regularly bought and sold were simply not traded. There may also be an ambiguity premium in asset pricing, as Ui (2011) suggests that limited market participation and larger equity premiums occur when ambiguity is present in the market. Guo (2013) suggests that this phenomenon is also present in credit spreads. Guo finds that an incorporation of the ambiguity aversion may be present in the debt market. Guo links extremely high credit spreads to an ambiguity premium that has been ignored in traditional bond pricing models.

6.2.2 Bid-Ask Spread, Volume and Price

The way uncertainty is incorporated in the market microstructure literature also provides some insight into ambiguity. In equity markets, Copeland and Galai (1983) demonstrate that the dealers' objective is to maximise profits by setting their bid-ask spread at an optimal level. If they set the spread too wide then they will lose revenue from the liquidity traders but will minimise losses from the informed traders. Alternatively, if the spread is too narrow then the dealers will benefit from the increased trading from liquidity traders but will suffer from an increase in the potential for losses

from informed traders. Copeland and Galai conclude that the uncertainty surrounding who is trading results in the dealers setting a wider spread. This is true in particular when there is greater volatility of the stock being traded, when the price levels are higher and when there is a lower volume of trading. Venkatesh and Chiang (1986), among others, confirm the theory that dealers widen the spread when they believe there is an increase in the advantage possessed by informed traders.

The volume of trading also gives some insight into who is trading and information flows. For example, in Karpoffs' (1987) review of research on price and volume relationships, he finds that volume is positively correlated with the magnitude of the price change. He shows that price provides insight into the market evaluation of the information, while volume is a measure of the disagreement between participants in the market. The author suggests that volume is highest when all investors are either optimists or pessimists. A more recent study by Balduzzi et al. (2001) finds significant and persistent increases in trading volume after announcements in the US treasury market. The authors also look at surprise announcements where an increase in the volume of transactions occurs after a pause. The pause most likely indicates that the market processes the announcement before reacting. They find that the bid-ask spread initially widens after news then reverts the pre-announcement level, suggesting that the uncertainty of the news announcement is reflected in the bid-ask spread. Bomfin (2003) finds a similar occurrence in the stock market in New York, where surprise announcements can temporarily double the size of the bid-ask spread.

Uncertainty related to a lack of trading may provide evidence of information in the market. Easley and O'Hara (1992) suggest that a lack of trading will lead to a smaller spread as market makers assume that there are fewer informed traders in the market and it is therefore safer for them to trade. In contrast, in derivative markets, Routledge and Zin (2009) find that where the appropriate probability distribution about the future cash flows is uncertain, the market maker becomes

uncertain about the consequences of derivatives trading. In this case, market makers typically increase the bid-ask spread and reduce liquidity because of the increase in uncertainty.

In summary, this literature indicates that the bid-ask spread is a valuable measure of uncertainty that fluctuates in size when market participants are processing new information. Volume changes, however, can be interpreted in several ways, since an increase in volume indicates a reaction but can also indicate disagreement. For market participants that may be ambiguity-averse, reactions may be swift around changes as they exit a market.

6.2.3 Policy Issues

The effect on the environment of increases in anthropogenic CO_2-e emissions has resulted in many governments trying to slow and reverse climate effects. A report on climate change governance for the World Bank by Meadowcroft (2009) listed five main difficulties for existing governance mechanisms. These are fossil fuels, scientific uncertainty, distributional and equity linkages, long time frames and global implications. Fossil fuels, which include coal, petroleum products and natural gas, made up around 95% of Australian energy consumption in 2010 according to Energy Update 2011, a report by the Australian Bureau of Agricultural and Resource Economics (Australian Government, 2011). Australia's dependence on these fossil fuels goes beyond consumption, since metallurgical coal is Australia's largest commodity export, providing 54% of world trade in that product. Australia exports around 67% of domestic energy produced. Australia relies on coal exports because of the income they earn, and because the industry provides over 94,000 jobs. Grubb and Neuhoff (2006) argue that the heavy industry lobbying around allocations within an emissions trading scheme in the EU makes it different from any other type of market. In Australia, the size of the industry and the lobbying are even more extensive, given its greater size relative to the economy as a whole.

Policies such as subsidies and incentives can encourage development and shifting from fossil fuels and this can reduce uncertainty in the industry. Sato et al. (2007) show that a clarification and continuation of the EU ETS provides incentives to the energy-intensive industries to develop longer term technology-related investments. The authors also argue that such incentives would decrease emissions and reduce uncertainty. In Australia, Riedy (2003) notes that there are many subsidies for both fossil fuel production and consumption that encourage their continued use. Clearly, such subsidies are directly opposed to incentives to reducing the consumption and use of fossil fuels. Reidy suggests that the removal of these incentives has the potential to improve economic performance and the effectiveness of greenhouse abatement measures. This will require a resolution of the direction of support by the government.

The possibility that sanctions could be imposed on Australia due to lack of action on climate change increases market uncertainty. A number of countries, including the US and EU nations, may penalise those countries they believe are not taking sufficient action on climate change by imposing tariffs. This may affect Australia's export markets for coal and gas. Chevallier (2010) looks at the impact of news regarding Australian emissions trading schemes on electricity prices. His findings suggest that news providing greater confidence about environmental market mechanisms decreases spot prices in electricity markets. This empirical relationship reinforces the role that government can play in convincing all parties of the benefits to greener businesses and earlier action against climate change.

The Intergovernmental Panel on Climate Change (IPCC) (2013) states that climate change occurs largely as a result of human activity, however, there remains uncertainty regarding the tipping points at which radical changes in climate patterns will occur and cause permanent changes. The distributional impact of climate change is also uncertain and this raises a number of equity issues both domestically and internationally for governments.

Climate change evolves over decades, centuries even, making managing it very difficult and also contributing to uncertainty. In part due to the cumulative and delayed effects of emissions already in the atmosphere, stopping emissions immediately will not prevent global temperature increases, and the role of governments will necessarily include adapting to these ongoing warming patterns. Contributing to the political confusion, the long time frame around climate change does not fit well with the three or four-year electoral cycle for most governments in Australia. The short political cycle affects policy decisions as the costs of emissions reductions will be borne today, but the benefits will not be evident until decades in the future and more immediate political problems tend to be addressed first.

Global implications are not specifically discussed in this paper. However they are a significant issue for the government, due to the need for climate change policy to be enacted on an international level with flow-on effects to domestic policy. The tendency to wait and see what others may do before implementing any programs may have adverse effects, both economically and environmentally. 'The tragedy of the commons', first discussed by Hardin in 1968, in which self-interest plays a significant part in the abrogation of individual responsibility for a global problem, can be found in the climate change issue. The size of the two largest economies, the US and China, implies that there is likely to be little action elsewhere until they lead international action.

The lack of universal action ensures that some companies can lobby and try to delay costly actions while others might wait before acting. Grubb and Neuhoff (2006) verify uncertainty in this industry when discussing future allocations of permits in the EU ETS. They suggest that companies will delay investment decisions until they can obtain more knowledge about future prices and allocation levels, thereby making better decisions. Further, they state that in the presence of uncertainty, risk aversion, or ambiguity-aversion, is likely to reduce investment. Jotzo and Pezzey (2007) go further to state that this uncertainty is in fact an obstacle to commitments to emissions reductions and that by

reducing uncertainty, significant increases in global abatement could occur. The wait and see scenario is tested in an experiment by Fuss et al. (2008), using bifurcating price trajectories to mimic the uncertainty surrounding climate change policy. In this experiment the investor faces two possibilities, one where the government commits to long-term carbon reduction policies and the other where the government completely opts out of any commitment. They show that the investor would wait and see as long as the option value exceeds the losses incurred due to rising expenses from CO_2 emissions. The longer the time before investment, the less information the investor has about the probabilities of government action in either scenario. This finding confirms the understanding that ambiguity in the market will induce inaction and a trading reduction.

Another avenue of research involves examining the effect of targets on participants. Lester and Neuhoff (2009) provide evidence of the importance of outcome-based targets in climate change policy. They state that while it may be difficult to effectively break down large overarching climate change emissions reduction targets, it is important to set some form of short-term target to achieve better structure for organisations to participate in. The literature identifies the difficulties surrounding ambiguity in existing markets and how uncertainty has been measured in market microstructures. The difficulty in setting government policy increases the uncertainty about how to respond to climate change. In this study, the two streams of literature are combined to examine how ambiguity affects the MRET market.

6.3. Data and models

6.3.1 The Mandatory Renewable Energy Target Scheme

The Office of the Renewable Energy Regulators (ORER) Annual Reports state that the MRET had 5,726 trades in their Renewable Energy Certificates (RECs) in 2007, 8,519 in 2008, 12,676 in 2009

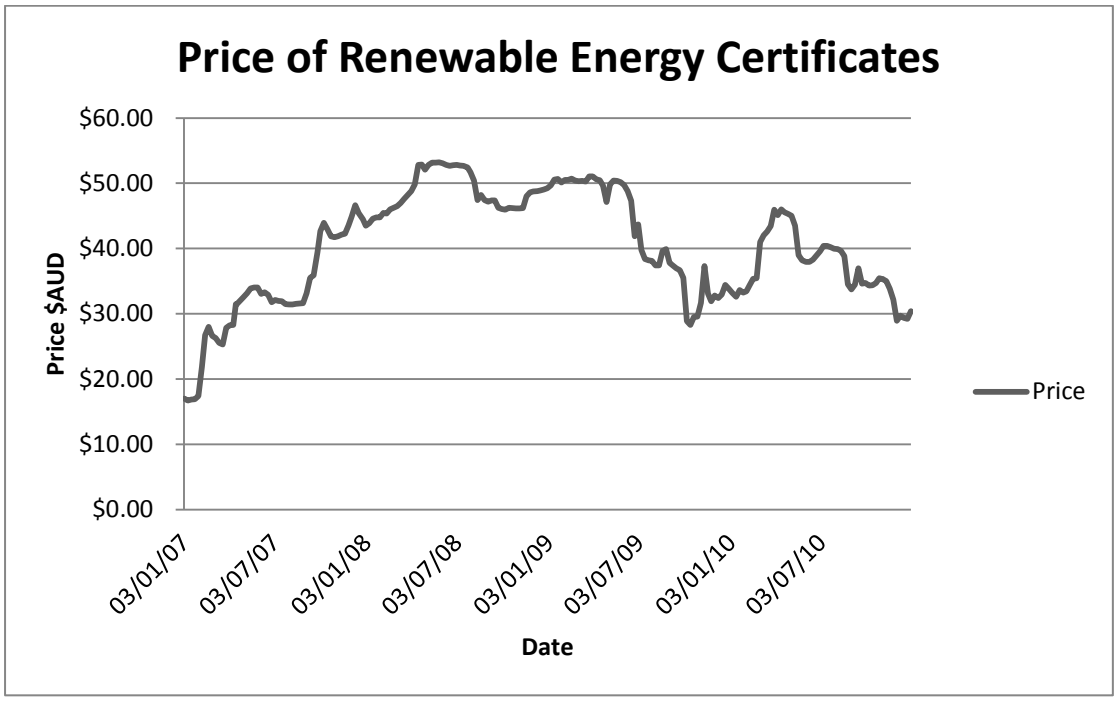
and 10,710 in 2010. Due to the relatively small number of trades, it is difficult to obtain data on regular trading. The major provider of trade data, Next Generation Energy Solutions, has data on approximately 80% of the trades in RECs and we use their data to determine the level of trades in the market. However, as trading was extremely light in the early years of the MRET, this study only uses data beginning in 2007. The study period ends on 31 December 2010 due to changes in the scheme that severely alter its structure and render any comparison to the earlier period difficult. The changes were a result of legislation introduced in June 2010 that split the RECs into two parts on 1 January 2011: the Large-scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Target Scheme (SRES). The aim of these changes was to ensure greater certainty for households, large-scale renewable energy projects and small-scale renewable energy installers.

> The period analysed includes 209 weekly observations. Weekly bid-ask spread and price information was obtained from the Australian Financial Markets Association (AFMA). They collect the data in the following way: [They send] a form to market participants each Wednesday, seeking their view of the prevailing bid and offer prices for the contracts as at 4pm on Wednesday afternoon. It is important to emphasise that prices are not quotes to actually trade, but an assessment of the prevailing prices from a range of organisations on both sides of the market.[24]

This paper has used as the price a mid-point between the bid and ask prices provided. Figure 6.1 shows the REC prices and Figure 6.2 shows the spread during this time period. Figure 6.3 shows the volume using data supplied by Next Generation Energy Solutions.

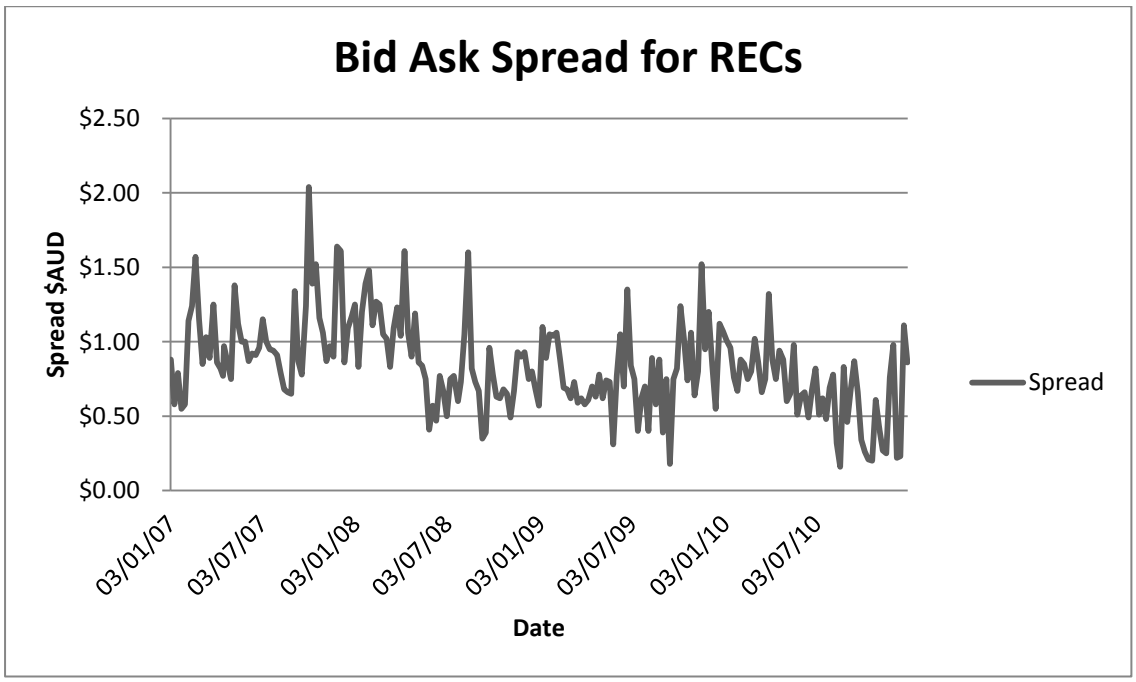
[24] AFMA website http://www.afma.com.au/afmadata.html has a complete description of these bids and offers

Figure 6.1: Price of RECs 1 January 2007 to 31 December 2010



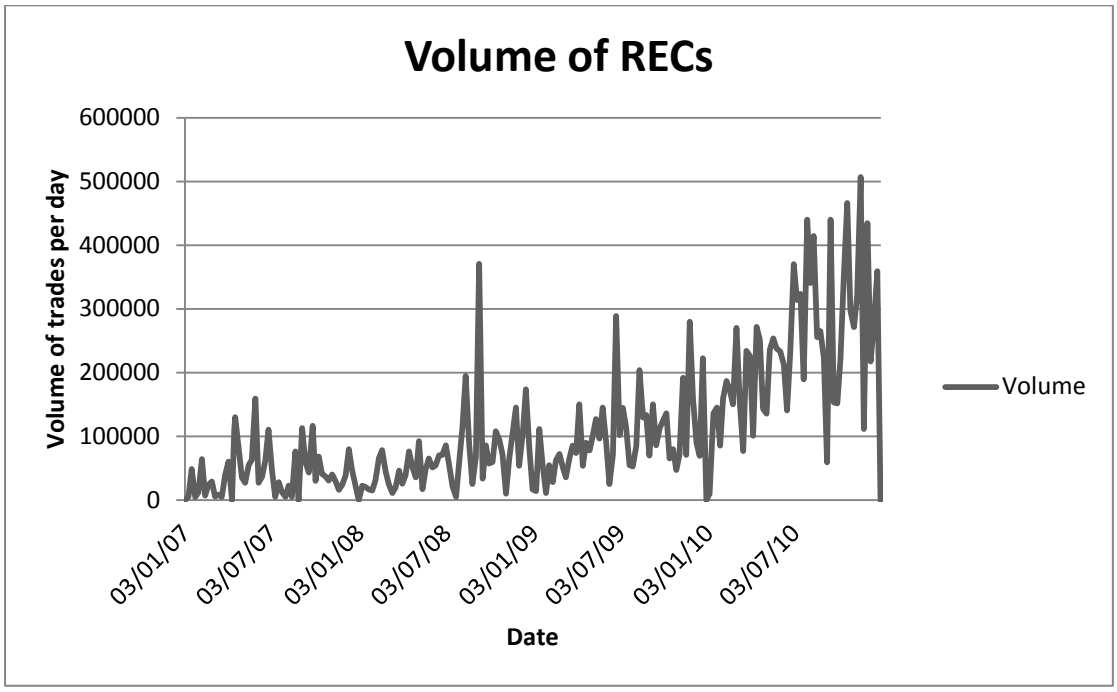
Source: Australian Financial Markets Association 2012

Figure 6.2: Bid-Ask Spread for RECs 1 January 2007 to 31 December 2010



Source: Australian Financial Markets Association 2012

Figure 6.3: Volume of trades of RECs 1 January 2007 to 31 December 2010



Source: Next Generation Energy Solutions, 2013

Table 6.1 below provides summary statistics for the REC price, log of price, spread, relative spread, volume, relative volume and log of relative volume. It is obvious that bid-ask spreads in the considered market, are substantially higher than for many other financial markets, with relative spreads around 2% on average and spreads being greater than $1.50 for several of the weeks in the considered time period. The REC data exhibits some skewness in volume, suggesting high levels of variability. Price is used as a control variable to ensure variations in the stock price do not influence results that compare the relative spread and volume. In addition, the natural log of the price and relative volume are used in order to control for non-stationarity which is discussed in Section 4.

Table 6.1: Summary statistics for the weekly price, log of price, spread, relative spread, volume, relative volume and log of relative volume for the Renewable Energy Certificates from 1 January 2007 to 31 December 2010.

Series	Mean	Median	Standard Deviation	Skewness	Kurtosis
Price	40.29	40.38	8.61	-0.4164	-0.4315
Ln Price	3.67	6.25	0.24	-1.1137	1.8065
Spread	0.84	0.82	0.31	0.5003	0.962
Relative Spread[25]	0.02	0.02	0.01	0.8176	0.5986
Volume	113,023	76,584	105,053	1.5283	2.05334
Relative Volume[26]	2,970	1,812	2,985	1.7738	3.293
Ln Relative Volume	7.46	7.50	1.18	-2.4846	9.1054

Note: The number of observations for all series is 209

6.3.2 News

There are a number of distinct news items that we identify and use in this study after reviewing the history that led to the development of the MRET market. The introduction of a federal scheme has been an ongoing process since 2004 when the ministers of the states and territory governments set up the National Emissions Trading Taskforce to look into a cap and trade scheme to cover all of Australia. While at that time a federal scheme was considered likely to be implemented, the states and territories commenced their own individual schemes due to the lack of federal action. The initial discussions by the federal government regarding an emissions trading scheme for Australia began with the Prime Ministerial Task Group instigated by the Howard Coalition Government on 10 December 2006. The final report was presented on 31 May 2007 which outlined a proposed Australian domestic emissions trading scheme along with complementary policies, aiming to reduce emissions while remaining economically competitive. On 30 April 2007 the then Federal Labor

[25] Relative spread is the bid ask spread divided by the share price.
[26] Relative volume is the volume divided by the share price.

Opposition and the state and territory governments commissioned an independent study to be undertaken by Professor Ross Garnaut. At the end of September 2008 the final report for the Garnaut Review was issued. This was a significant step and is listed as a separate exogenous variable in the models in this paper. The report outlined an emissions trading scheme with complementary measures to lower the costs of emission reductions and to correct some noted market failures. It also made clear a global commitment would be critical to any ability to achieve necessary emission reductions to achieve the goals of the Kyoto Protocol.

On 24 November 2007 the Australian Labour Party was elected to government, replacing the Coalition. On 3 December 2007 they established the Department of Climate Change and Energy Efficiency, appointing Dr Martin Parkinson as Secretary. In July 2008 this department released a Green Paper that outlined the CPRS as part of the federal government's future climate change strategy. We classify this event as an exogenous information event in our models.

After receiving over 1,000 submissions to the Green Paper, the government released the final version of the CPRS in a White Paper in December 2008. The release of the White Paper is also classified as an exogenous event in our models. The CPRS legislation was introduced to Federal Parliament on 14 May 2009. It was passed in the House of Representatives on 4 June 2009. It was rejected in the Senate on 13 August 2009, introduced again on 22 October 2009 suffering a further defeat on 2 December 2009. The scheme was deferred in early May 2010 with expected implementaton on 1 July 2011. This deferral is included as a separate exogenous dummy variable due to the impact it had on the emissions trading market. The deferral was not anticipated by the market. However, the later delay in April 2010 caused much less disturbance and is listed only as a news item and not a separate variable. Jotzo and Betz (2009) analysed the features and opportunities of this scheme and detail many inconclusive issues. The government was still assessing whether or not to include agricultural emissions from 2015 onwards, the level of free allocations of

permits to emissions-intensive, trade-exposed industries and possible links with the New Zealand Emissions Trading Scheme.

The news items chosen for this study include the items from the above list of reports and other items we believe may have affected the MRET. There is a total of 65 items, and their details are reported in Appendix 1. All legislative changes that affected market ambiguity such as effects on regulation, were reported separately. There were 19 such events over the period. It is worth noting that many of these regulatory changes were pre-empted in news releases and included in the general news. We have included as separate items the release of the Green Paper, the Garnaut Report, the White Paper and the initial delay in the CPRS. The information came from publicly available information on both government and other news websites. These websites include the Australian Government Department of Climate Change and Energy Efficiency[27], the MRET[28], Point Carbon[29] and the UNFCCC[30]. As the information is received on a daily basis and the data we are using is weekly, we have taken a dummy to indicate a news item during the previous week. Any item received on the day the data is taken, is included as news for the following week, as our analysis indicates a stronger relationship between the considered dependent variables and the occurrence of news two days after the announcements. This delay is believed to be indicative of the market processing the information.

6.4. Methodology

The news events discussed above are used as explanatory variables in a regression analysis, examining REC spread and volume on the MRET market. We investigate the hypothesis that the

[27] http://www.climatechange.gov.au
[28] http://www.orer.gov.au
[29] http://www.pointcarbon.com
[30] http://www.unfccc.int

majority of new information provided, in particular by government bodies, reduces uncertainty in the markets and thereby reduces the level of ambiguity. Uncertainty will be measured using the bid-ask spread and we hypothesise that the spread will decline with the release of new information. Furthermore, using the same logic, we hypothesise that volume will increase as ambiguity is reduced with releases of information.

In addition, the prices of the RECs will be used to determine if there is any effect from the news releases. The hypothesis is that news releases will indeed be new information to the market and thus we will expect a reaction, either positive or negative, and this will affect the price. If there is a price reaction this will provide support for the view that the news is indeed informative and thus we would expect changes in levels of ambiguity.

Natural logs of both relative volume and price are used to mitigate the wide price dispersion. The regression model is shown in equation (1).

$$\rho_{t,} = \alpha + + \beta_3 \text{Delay} + \beta_4 \text{Garnaut} + \beta_5 \text{Green} + \beta_6 \text{News} + \beta_7 \text{Regulation} + \beta_8 \text{White} + \varepsilon_t \quad (1)$$

Where: $\rho_{t,}$ = the dependent variable of interest at time t

α = intercept

β_i = coefficient for the independent variable i

Delay = first delay of the CPRS variable

Garnaut = release of the Garnaut report variable

Green = release of the Green paper variable

News = general news items variable

Regulation = regulatory changes variable

White = release of the White report variable

ε_t = error term at time t

Unit root tests were conducted using the Augmented Dickey Fuller test statistics for stationarity (Dickey and Fuller 1981). We were able to reject the hypothesis of a unit root at levels for the log of relative volume, log of price and relative spread. The relative values are the actual values divided by the price. These tests were undertaken in order to reduce the likelihood of spurious regression which can occur due to non-stationarity.

The models for each dependent variable are estimated using stepwise regression, applying backward elimination. Thus, for each dependent variable, we start with all candidate variables, testing the deletion of each variable based on model comparison to the current model. In each step, the variable (if any) that improves model performance the most by being deleted is excluded from the model. The procedure is repeated until no further improvement to the model is possible. Hereby, the adjusted R square and F statistic are used to determine the significance of each model.

6.5. Results

6.5.1 Bid-Ask Spread

We are interested in testing whether the majority of new information provided, in particular by government bodies, reduces the level of ambiguity in the market. In a first step, we use the relative bid-ask spread for the RECs as a proxy for ambiguity and examine the following hypothesis:

H_0: Information events reduce the relative bid-ask spread vs

H_1: Information events do not reduce the relative bid-ask.

Table 6.2: Regression Analysis Results for LHS Variable Relative Spread

LHS Dependent Variable: Relative Spread				
Number of Observations: 209 after adjustments				
Variable	**Coefficient**	**Standard Error**	**t Statistic**	**Probability**
Constant	0.0292	0.0010	28.6329	0.0000
News	-0.0043	0.0013	-3.2960	0.0012
Green Paper	-0.0097	0.0012	-7.8716	0.0000
Adjusted R-squared	0.2640			
F Statistic	38.3032			
Prob. (F-statistic)	0.0000			

Table 6.2 reports the results for the conducted stepwise backward regression analysis where the optimal model determined is as follows:

$$\text{Relative Spread}_t = 0.0292 - 0.0043 \times \text{News} - 0.0097 \times \text{Green} + \varepsilon_t \qquad (1a)$$

Where: Relative Spread_t = relative spread at time t

Green = release of the Green paper

News = general news items

The results illustrate that several of the considered variables were removed by the iterative procedure, since they were not statistically significant or did not significantly improve the model's explanatory power. However, the coefficients of the two remaining explanatory variables, news and green paper, indicate a negative effect on the relative spread. This finding supports the first hypothesis that information reduces uncertainty and ambiguity in this market. Note that for news items we do not distinguished between good or bad news, but consider additional news simply as an indication of more information in the market. The negative coefficient indicates that more news reduces the relative spread. Similarly, the release of the Green Paper provided the market with a strong indication of future policy and is associated with a reduction in the relative spread. The F

Statistic indicates the model is highly significant with an adjusted R^2 of 26.4%, indicating that about one-quarter of the variation in the relative spread can be explained by the model.

6.5.2 Relative Volume

In a second step we use trading volume as a proxy for ambiguity in the market and apply stepwise regression, using the same explanatory variables as for the relative price spread. We would expect news items to be associated with increases in volume, if the news reduces uncertainty and ambiguity and thereby enhances additional trading in the market. Thus, we test the following hypothesis:

H_0: Information events do increase the volume of trading, vs

H_1: Information events do not increase the volume of trading

Table 6.3: Regression Analysis Results for LHS Variable Log of Relative Volume

LHS Variable: Log of Relative Volume				
Number of Observations: 209 after adjustments				
Variable	**Coefficient**	**Standard Error**	**t Statistic**	**Probability**
Constant	6.4303	0.1631	39.4356	0.0000
Delay	1.0695	0.2774	3.8556	0.0002
Green Paper	0.6193	0.2836	2.1834	0.0301
Adjusted R-squared	0.2140			
F Statistic	29.3203			
Prob. (F-statistic)	0.0000			

Table 6.3 reports the results for the stepwise regression analysis with the relationship estimated as follows:

$$\text{Log Relative Volume}_t = 6.4303 + 1.0695 \times \text{Delay} + 0.6193 \times \text{Green} + \varepsilon_t \qquad (1b)$$

Where: Log Relative Volume_t = log of the relative volume at time t

Delay – first delay in the start of the CPRS

Green – release of the Green Paper

Again, in this model several of the considered variables are deemed to be statistically insignificant, and are therefore excluded from the model. The delay and green paper indicate positive effects on the relative volume that support the tested hypothesis, i.e. information will increase the volume by reducing the ambiguity in the market. The delay, even though it was an indication of a deferral of a policy that the market may have previously thought was occurring, still contributed to an increase in volume. This may be an indication that any information, where there was previously some uncertainty, is seen to reduce ambiguity for market participants. The Green Paper is again seen as an indicator of information in a similar way as for the bid-ask spread. The model is statistically significant as can be seen by the F statistic and explains approximately 21% of the variation in trading volume with an adjusted coefficient of determination R^2 =0.214.

6.5. 3 Price

We also examine whether additional information will have a significant impact on observed REC prices. Therefore, REC price is being used as the dependent variable and a stepwise regression is conducted to test the following hypothesis.

H_0: Information events do affect the REC prices, vs.

H_1: Information events do not affect REC prices.

Table 6.4: Regression Analysis Results for LHS Variable Log Price

LHS Variable: Log Price				
Number of Observations: 209 after adjustments				
Variable	**Coefficient**	**Standard Error**	**t Statistic**	**Probability**
Constant	3.5673	0.0242	147.4443	0.0000
News	0.1513	0.0312	4.8512	0.0000
Green Paper	0.2620	0.0401	6.5376	0.0000
Delay	-0.2393	0.0391	-6.1146	0.0000
Adjusted R-squared	0.2727			
F Statistic	26.9911			
Prob. (F-statistic)	0.0000			

Table 6.4 reports the regression analysis results with the final model suggesting the following relationship between Log Prices of RECs and the considered explanatory variables:

$$\text{Log Price}_t = 3.5673 + 0.1513 \times \text{News} + 0.262 \times \text{Green} - 0.2393 \times \text{Delay} + \varepsilon_t \qquad (1c)$$

Where: Log Price_t = log of price at time t

News = general news items

Green = release of Green paper

Delay = first delay of the CPRS

The news items, the Green Paper and the first delay have significant coefficients that indicate they have an effect on the price. As the news items have not been divided into positive and negative events, initially, we do not have a clear hypothesis for the sign of the coefficient. However the coefficient is positive, indicating that during the considered time period news releases have led to an increase of the price on average. The positive coefficient for the Green paper dummy variable,

indicates that overall, prices were positively affected by the release of the Green paper. The coefficient on the delay variable is negative, which may be due to the possibility of lower compliance requirements which would reduce the likely demand for certificates.

The release of the Green Paper is statistically significant with positive coefficients in all models. This significance is most likely due to its release not long after the 2007 election of the Labor Party to federal government, after 11 years of the Liberal/National Coalition being in power. During the years of the Coalition Federal Government the climate change policy had not been a significant part of their policy platform. The Labor Government also ratified the Kyoto Protocol soon after coming to power which was another indication that they, and as such the Green Paper, were serious about climate change mitigation and the positive reaction indicated a reduction in uncertainty and ambiguity.

6.5.5 Summary of Findings

We have identified some events that do not provide information to the market and have no effect on ambiguity. Two variables, Regulation and White Paper, are not statistically significant in any of the models and they have therefore been omitted from the final specifications. This lack of significance of the White Paper may be because it was the final version of the Green Paper and did not provide a lot of additional information. Regulation events were also expected through the news items and as such did not have new information for the market.

We find that exogenous variables are related to both the relative bid-ask spread and relative volume. Supporting our hypotheses, we find that the explanatory variables are negatively related to the relative spread and positively related to the relative volume. Our results, therefore suggest that significant information events reduce ambiguity in the market. We also examine the relationship

with the price and find that news events are rather associated with a positive price reaction, with only the delay variable having a negative coefficient. We conclude that the negative price reaction in our sample may increase ambiguity while the other news events are associated with a positive price reaction, thereby adding value to the MRET market since it resolves uncertainty about the market.

6.6. Conclusion

We examine whether information related to climate change mitigation in Australia reduces the ambiguity surrounding investor participation in Australia's largest emissions trading scheme, the Mandatory Renewable Energy Target Scheme (MRET). We find that the dissemination of news, especially around key regulatory releases, decreases the bid-ask spread and increases volume in the MRET market. We interpret these results as evidence that ambiguity in markets can be reduced through information. In the considered MRET, a price reaction is also in indicator of participants' evaluation of the sustainability of the scheme, such that an increase in prices indicates that perceptions of the market's importance as an instrument of reducing greenhouse gas emissions may have increased. Conversely, a reduction in the price is associated with uncertainty and an increase in ambiguity.

Our results support findings by Easley and O'Hara (2010) who suggest that in the case of uncertain events, regulation can moderate the effect of ambiguity and increase participation and ultimately welfare goals in financial markets. Easley and O'Hara (2010, pp. 1843–44) indicate that during a market's development stage, 'the role of ambiguity seems particularly significant, as even sophisticated investors elsewhere may feel unsophisticated when it comes to investing in unfamiliar settings'. The MRET falls into the 'developing market' category and demonstrates the role of regulation in addressing ambiguity.

Science-related uncertainties drive some of the ambiguity in this market. In particular tipping points, the speed at which technology can improve, and the economic impacts of addressing climate change, are uncertainties in emissions markets. The additional manmade uncertainties relating to regulation are affected by government policy. Consistent with Fuss et al. (2008), we find that policy makers are failing to provide the necessary long-term signals to ensure emitters will commit to investments into emission-reducing technology and emission-reducing energy sources. Our findings emphasise the need for clear policy direction from the Australian federal government. The suggestion by Lester and Neuhoff (2009) of setting annual milestones and monitoring can be incorporated into any Australian federal government policy to provide information and some stability and incentives for participants, while reducing uncertainty. Long-term government policy can improve the efficiency in this market by eliminating ambiguity about government action.

We suggest some areas where future work on ambiguity could be undertaken. Further analysis of trading since the commencement of the split in the RECs could examine the effect of the introduction of the carbon tax. Such an analysis would also accomplish a comparison of the effects of news on price spreads and trading volume, to determine if the new legislation provided a less ambiguous trading environment for participants. Clearly, the change to a Coalition federal government in 2013 and the new climate change policy direction would also be of interest to analyse. We leave this analysis to future work.

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Appendix 1

The table below shows all the dummy variables used in the analysis in this paper. The dummies for general news items (news) and regulatory changes (regulations) are from 1 January 2007 to 31 December 2010. The first delay of the CPRS (Delay) is taken from 15/4/09, the Garnaut Report (Garnaut) is taken from 1/10/08, the Green Paper (Green) from 9/7/08 and the White Paper (White) from 11/12/08.

Date	Delay	Garnaut	Green	News	Regulation	White
6/06/2007	0	0	0	1	0	0
25/07/2007	0	0	0	0	1	0
1/08/2007	0	0	0	0	1	0
29/08/2007	0	0	0	0	1	0
5/09/2007	0	0	0	1	0	0
3/10/2007	0	0	0	0	1	0
28/11/2007	0	0	0	1	0	0
5/12/2007	0	0	0	1	0	0
12/12/2007	0	0	0	1	0	0
19/12/2007	0	0	0	1	0	0
23/01/2008	0	0	0	1	0	0
27/02/2008	0	0	0	1	0	0
5/03/2008	0	0	0	1	0	0
26/03/2008	0	0	0	1	0	0
9/04/2008	0	0	0	1	0	0
16/04/2008	0	0	0	1	0	0

23/04/2008	0	0	0	1	0	0
30/04/2008	0	0	0	1	0	0
7/05/2008	0	0	0	1	0	0
14/05/2008	0	0	0	1	0	0
28/05/2008	0	0	0	1	0	0
4/06/2008	0	0	0	1	0	0
18/06/2008	0	0	0	1	0	0
25/06/2008	0	0	0	1	0	0
9/07/2008	0	0	1	1	0	0
24/07/2008	0	0	1	1	0	0
6/08/2008	0	0	1	1	0	0
3/09/2008	0	0	1	1	0	0
10/09/2008	0	0	1	1	0	0
17/09/2008	0	0	1	0	1	0
24/09/2008	0	0	1	0	1	0
1/10/2008	0	1	1	1	0	0
8/10/2008	0	1	1	0	1	0
15/10/2008	0	1	1	0	1	0
22/10/2008	0	1	1	1	0	0
29/10/2008	0	1	1	0	1	0
5/11/2008	0	1	1	0	1	0
19/11/2008	0	1	1	1	0	0
3/12/2008	0	1	1	1	0	0
11/12/2008	0	1	1	1	0	1
17/12/2008	0	1	1	1	0	1

24/12/2008	0	1	1	1	0	1
7/01/2009	0	1	1	1	0	1
14/01/2009	0	1	1	0	1	1
4/02/2009	0	1	1	1	0	1
25/02/2009	0	1	1	1	0	1
4/03/2009	0	1	1	1	0	1
11/03/2009	0	1	1	0	1	1
18/03/2009	0	1	1	1	0	1
25/03/2009	0	1	1	1	0	1
1/04/2009	0	1	1	1	0	1
8/04/2009	0	1	1	1	1	1
15/04/2009	1	1	1	0	0	1
22/04/2009	1	1	1	1	0	1
29/04/2009	1	1	1	0	1	1
6/05/2009	1	1	1	1	0	1
13/05/2009	1	1	1	1	0	1
27/05/2009	1	1	1	1	0	1
3/06/2009	1	1	1	1	0	1
10/06/2009	1	1	1	1	0	1
24/06/2009	1	1	1	1	0	1
1/07/2009	1	1	1	1	0	1
19/08/2009	1	1	1	1	0	1
26/08/2009	1	1	1	1	0	1
21/10/2009	1	1	1	1	0	1
9/12/2009	1	1	1	1	0	1

16/12/2009	1	1	1	1	0	1
30/12/2009	1	1	1	1	0	1
6/01/2010	1	1	1	0	1	1
21/01/2010	1	1	1	1	0	1
28/01/2010	1	1	1	1	0	1
3/03/2010	1	1	1	0	1	1
24/03/2010	1	1	1	1	0	1
5/05/2010	1	1	1	1	0	1
19/05/2010	1	1	1	1	0	1
24/06/10	1	1	1	1	0	1
8/07/2010	1	1	1	1	1	1
30/09/2010	1	1	1	1	0	1
14/10/2010	1	1	1	1	0	1
21/10/2010	1	1	1	1	0	1
18/11/2010	1	1	1	1	0	1
2/12/2010	1	1	1	0	1	1
23/12/2010	1	1	1	0	1	1

Chapter 7

7. Conclusion

Australia has had a wide variety of programs associated with the mitigation of greenhouse gas emissions and potential climatic change. The major programs are outlined in Chapter 2. We can see that Australia was one of the first countries in the world to operate an emissions trading scheme under the Mandatory Renewable Energy Target Scheme (MRET) which was introduced in 2001, nearly four years before the much better known EU ETS. The EU ETS commenced by operating on behalf of the twenty-eight European Union countries. This increased by three in 2008 to include Iceland, Liechtenstein and Norway who are European Free Trade Association members. This is in stark contrast, size and coverage wise, to the MRET which operates only in Australia. The main aim of the MRET is to encourage the additional generation of electricity from renewable energy sources. The baseline requirements of the participants in the scheme increased from 2001 to 2010 with the original aim to generate an extra 9,500 GWh of energy from renewable sources by 2010. The first main scheme to align with the MRET was the Victorian Renewable Energy Scheme (VRET) which covered all electricity retailers and large wholesale purchasers of electricity in Victoria. It commenced trading in 2007 but transitioned into the MRET at the end of 2008. The other schemes introduced in the different states of Australia did not all operate in conjunction with this scheme and were mostly independent. The other early emissions trading scheme was the NSW Greenhouse Gas Abatement Scheme (GGAS) which commenced in 2003. The goals of this scheme were to decrease the level of CO_2-e greenhouse gas emissions per head of state population. While it was created under an amendment to the Electricity Supply Act 1995, it was not as specific to electricity production as the MRET. Aligned to the GGAS was the Australian Capital Territory Greenhouse Gas Abatement Scheme (ACT GGAS) which commenced in 2005. Another scheme which commenced in NSW in 2009, the NSW Energy Savings Scheme (ESS), was also established under the Electricity Supply Act 1995. This scheme aimed to assist households and businesses to reduce electricity

consumption in order to complement the MRET goals. Similarly, Victoria introduced their version of this scheme in 2009, but its main goal was for business to reduce greenhouse gas emissions. The Queensland 13% Gas Scheme had the aim of expanding the Queensland gas industry and to reduce greenhouse gases. It commenced in 2005 and placed targets on the percentage of electricity in Queensland to be sourced from gas. In July 2012, a federal carbon pricing mechanism was introduced, which is usually referred to as the carbon tax. It levied a tax on approximately five hundred of the largest carbon polluting companies in Australia. The government's plan was to transition this scheme into a national carbon pollution reduction scheme (CPRS) in 2015. Links to the EU ETS were also discussed as a goal for this CPRS.

Climate change has been a controversial issue in Australian politics with a number of leadership changes in both the major political parties as a result of this issue. As such there have been a number of changes during the last ten years with many of the above schemes no longer in operation. The GGAS ceased in July 2012, the ACT GGAS in June 2012 and The Queensland 13% Gas Scheme in December 2013. Changes in state and federal governments brought about a number of reviews and changes in 2012 and 2013. The NSW ESS was reviewed with changes to commence from 2014, and the similar Victorian scheme is currently under review. Both the MRET and VRET are still in operation but are also under review. In 2011 the federal Labor Government split the MRET into two parts: one for small-scale emitters and one for large-scale emitters. With the Liberal/National Coalition winning office in 2013 there are many more changes likely. The current government has issued a green paper for community consultation which proposes direct action with businesses to determine the actions to reduce emissions at least cost. They have also repealed the carbon tax. While we would expect different philosophies from different political parties, it is clear from the changes in leadership made by both major parties in recent years, due to the issue of climate change that their approaches are, to at least some extent, driven by votes. If this is indeed the case, it is incongruous how different their approaches are and with this in mind a survey of exactly what the Australian voting public wants was conducted.

The survey was conducted online and covered 1,000 participants representing the Australian electorate in relation to gender, age and state in which they lived. While not used as a requirement for participation, we also found that they were a good representation in terms of education levels and employment status. Voting intentions for the major political parties, with unsure voters divided evenly across the parties, were measured against the 2010 federal election results and were also found to be similar. This range of participants was important to enable an informed indication of the whole population's views. Previous surveys were mostly undertaken in Europe and the USA and those that were conducted in Australia, such as Akter and Bennett (2011) were limited to a small region only. The designed questionnaire drew in part on a survey conducted by Lee and Cameron (2008) in the USA and their use of information within the survey, to ensure that all participants were clear on exactly what was being asked. In our survey, information was provided on what was meant by a cap and trade scheme and a carbon tax for the purposes of the survey questions.

The current federal government does not appear to have climate change mitigation as a priority, yet the survey finds over 70% of participants believed preventing climate change was a very important or important issue, both globally and locally. Further, and perhaps more significantly for the government, the survey finds that over 50% want Australia to act on climate change irrespective of whether other countries do or not, with an additional 32.9% wanting action if there is international agreement.

As indicated earlier, there have been continual changes in climate change mitigation policies. If, as it appears, there is consensus that action should be taken, what action do the public want? The survey indicates a policy mix to be the most popular, with no policy second, a cap and trade scheme third, and a carbon tax last. It is important to note that, within the 'no policy choice', 43% of respondents chose this option as they only wanted action if there was international action. It is curious, given these results, that the Labor Party introduced a carbon tax. The now present federal Liberal/National Government campaigned strongly on eliminating the carbon tax if elected. Clive Bean and Ian

McAllister, in *Julia 2010: The Caretaker Election*, look at the demographics of the major political parties. They show the Liberal/National Party coalition demographics are mostly male, either under 25 or over 65, work in non-manual jobs and live in a rural situation. Not surprisingly, given the trade union involvement in the Labor Party, they are less likely to be union members and more likely to be self-employed. McAllister also finds Liberal and Labor voters are equally likely to have a university degree. The survey in this thesis found voting intention to indicate a desire for a policy mix among Liberal voters. If the connections between demographics and policy preferences indicated in our study have remained the same since the 2010 election, the following results should be of interest to the Liberal Government. Almost 65% of those aged between 18 and 30 believe Australia should proceed on climate change policy irrespective of whether other countries do or not. Of those 65 and above, 48.67% want climate change policy to proceed if there is international agreement. Only 9.36% of the younger age group and 20.67% of the 65 plus age group indicated climate change policy should not proceed at all. These, and other findings in the conducted survey, provide information regarding the policy preferences of the Australian public which could be useful for policy makers.

Having undertaken the study of the schemes that have been, and are, in operation in Australia, the analysis then proceeded to determine how efficient the major schemes have been. This analysis is conducted in Chapter 4 and 5 of the thesis. As discussed, the two main climate change mitigation programs were the MRET and the GGAS emissions trading schemes. We measured efficiency in the basic sense of the degree to which they produced the desired effect. The largest sectoral contribution to greenhouse gas emissions in Australia has been from the energy sector, which, in itself, is dominated by electricity generation. To examine the efficiency of these schemes, we tested for an effect of the prices of the certificates in these schemes on wholesale electricity prices. The expectations for an efficient scheme would be an increase in wholesale electricity prices as a result of an increase in the certificate prices. This would arise as, during the period under analysis, renewable energy sources were more expensive than non-renewables such as coal. Therefore, as companies move towards more renewable sources due to the requirements under these schemes,

wholesale electricity prices would be expected to rise. Also, certificate prices would be likely to increase, due to an increase in demand for certificates on the part of scheme participants wanting to meet their obligations. Initially we tested using a structural, cointegrated vector error correction model (VECM) in an approach, similar to studies undertaken by Bunn and Fezzi (2009) and Pinho and Madaleno (2011) for the European EU ETS. While the conclusions suggest a relationship with electricity prices, the paper also concludes that a more thorough analysis of the short run dynamics would be valuable.

Therefore, further analysis was undertaken in Chapter 5, where we used generalised forecast error variance decomposition analysis and generalised impulse response function analysis to better determine the long- and short-run dynamics of the relationships. The lack of any real relationship found in the updated analysis indicated a need to determine why this might be the case. While carbon emission and electricity markets are not typical financial markets, the similarities with typical markets are significant enough to apply finance theory to an understanding of their efficiency.

The lack of any real relationship found in the updated analysis indicates a need to determine why this might be the case. A common concern from business has been the uncertainty surrounding climate change mitigation policy in Australia. The Australian Bankers' Association states on its website: "Governments will need to provide consistent leadership and long-term guidance to companies and individuals, so that the market and the community understand the actions they must take to contribute to Australia's response to climate change." Further, Andy Hoffman, Professor of Sustainable Enterprise at the University of Michigan, states on The Conversation website that "despite having endured the hottest summers on record, more bush and forest fires and record floods, climate change remains a 'wedge issue' on both sides of the Pacific". In Australia, while the Labor Party was in federal government, a price on carbon was introduced through the Clean Energy Legislation. In 2013 the Coalition won the federal election with a policy to abolish this carbon tax in order to reduce prices of goods affected. They also merged the Departments of the Environment

and Climate Change and planned to close the Clean Energy Finance Corporation, the Climate Change Authority and the Climate Commission, claiming this would yield savings of $20 billion over four years.

This mixed political landscape in the US and Australia means continued regulatory uncertainty for businesses over the pricing of carbon emissions and energy policy more broadly. This is a critical issue for business, particularly those in the energy, resources and manufacturing sectors looking to make infrastructure investments that can last decades. This indicates that uncertainty surrounding policy is not only an Australian issue. The well-researched, but relatively untested, behavioural finance theory of ambiguity, see, e.g., Easley and O'Hara (1992, 2005, 2009, 2010), Routledge and Zin (2009), was deemed appropriate to apply to this market in light of this continued regulatory uncertainty. We analysed trading volume and bid-ask spread against information events related to Australian and international news and policy on climate change. As anticipated, we found these events increased volume and decreased the bid-ask spread. This indicates that as information is received by the market, it reduces the ambiguity and hence increases the relative efficiency. Both volume of trades and bid-ask spread are common indicators of market efficiency in most financial markets. The significant results indicate that much of the lack of trading in the carbon emission markets considered in this thesis is a result of this ambiguity. As a consequence, one could argue that ambiguity is also likely to be a contributing factor to the lack of efficiency of the scheme as measured earlier. The conducted study is therefore of significant interest to Australian and international researchers, market participants and policy decision-makers with regards to the impact of ambiguity and uncertainty on the efficiency of carbon trading.

The research conducted in this thesis has implications for future policies for the mitigation of climate change in Australia. We find a desire for action by the general public with a preference for a policy mix or cap and trade scheme. The current federal government may consider its climate change mitigation policy to be a mix. However, as discussed at the end of Chapter 2 the policy direction is

not clear. This lack of clarity is found to most likely be a major reason for the lack of effectiveness and efficiency of the existing emissions trading schemes. The econometric methods used to test the efficiency of these schemes are new to these markets, in Australia and internationally, and allow us to determine the lack of efficacy. The findings in this thesis provide information on the emissions trading markets in Australia which should be considered by policy makers, in Australia in particular, but we also believe they have broader significance.

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