

AMBIGUITY IN MARKETS: A TEST IN AN AUSTRALIAN EMISSIONS MARKET

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***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, Market efficiency, Emissions Trading*

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% 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 CO₂-e¹ 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.

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, 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. The next section 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. The

¹ CO₂-e is a way of describing different greenhouse gases in a common unit i.e. for any quantity and type of greenhouse gas, CO₂-e signifies the amount of CO₂ which would have the equivalent global warming impact.

section following that shows the methodology that is used to test for ambiguity in the considered markets, while we next provide the results of the empirical analysis. Finally, the paper presents the conclusion and examines the effects of ambiguity from both market and climate change mitigation perspectives.

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.

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 portfolio. 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 particularly 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.

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 Karpoff's (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.

Policy Issues

The effect on the environment of increases in anthropogenic CO₂-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 CO₂ 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.

Data and models

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.²

This paper has used as the price a mid-point between the bid and ask prices provided. Figure 1 shows the REC prices and Figure 2 shows the spread during this time period. Figure 3 shows the volume using data supplied by Next Generation Energy Solutions.

² AFMA website <http://www.afma.com.au/afmadata.html> has a complete description of these bids and offers

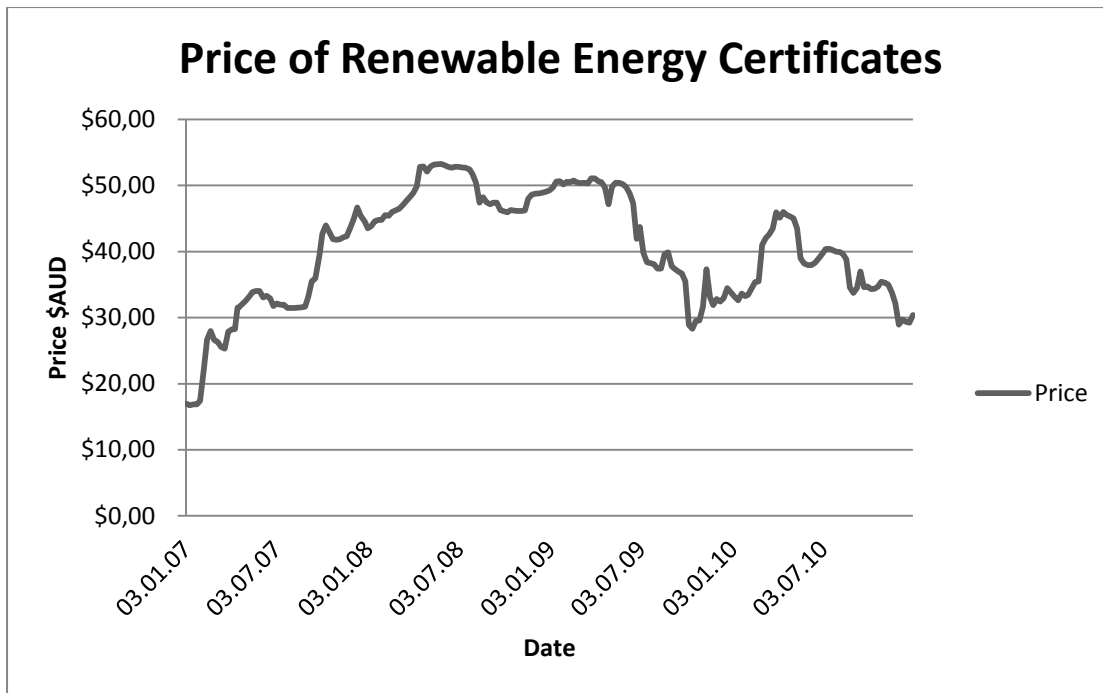


Figure 1: Price of RECs 1 January 2007 to 31 December 2010

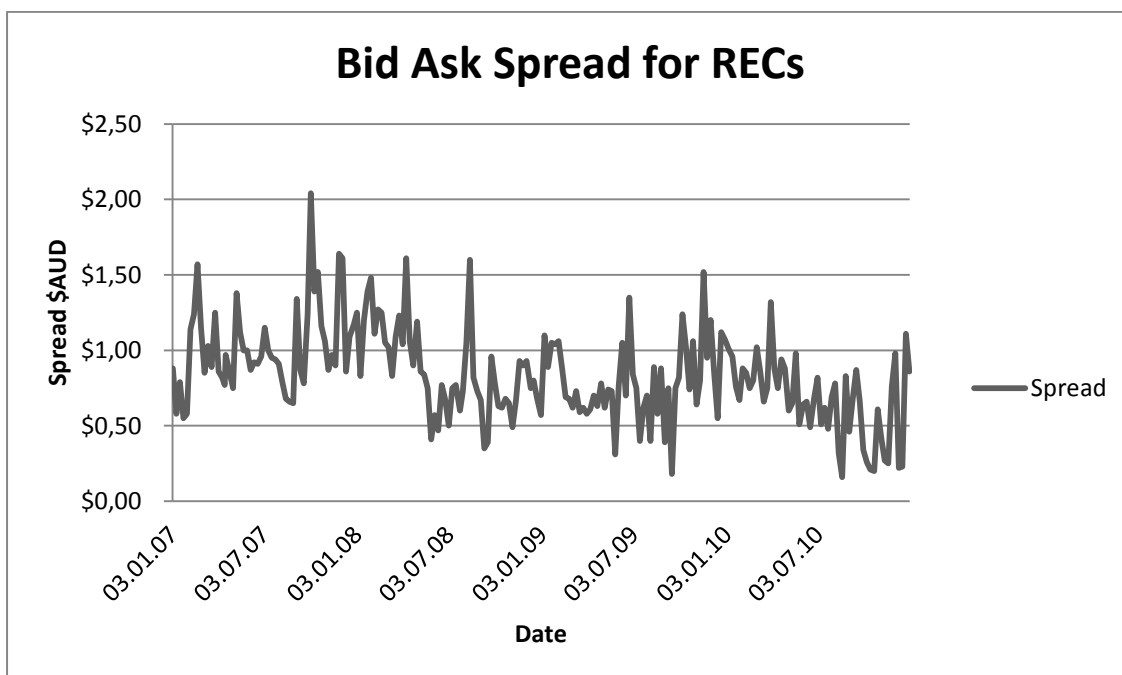


Figure 2: Bid-Ask Spread for RECs 1 January 2007 to 31 December 2010

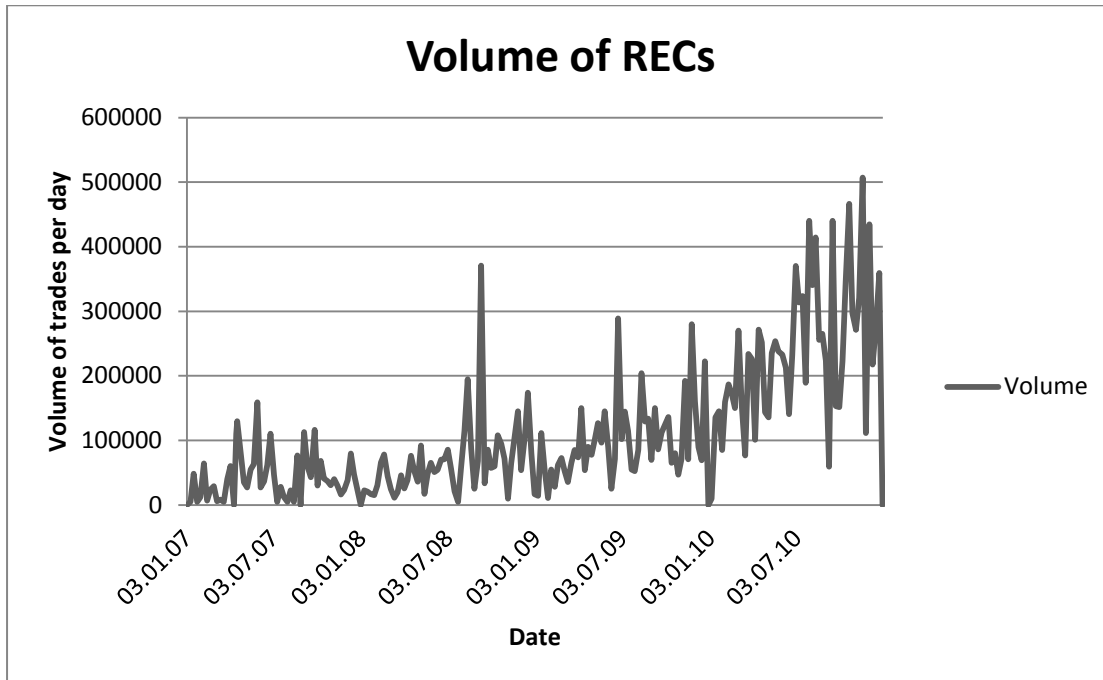


Figure 3: Volume of trades of RECs 1 January 2007 to 31 December 2010

Table 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 the next section.

Table 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 Spread³	0.02	0.02	0.01	0.8176	0.5986
Volume	113,023	76,584	105,053	1.5283	2.05334
Relative Volume⁴	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

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 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

³ Relative spread is the bid ask spread divided by the share price.

⁴ Relative volume is the volume divided by the share price.

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 2009 with expected implementation 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 Efficiency⁵, the MRET⁶, Point Carbon⁷ and the UNFCCC⁸. 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.

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 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

5 <http://www.climatechange.gov.au>

6 <http://www.orer.gov.au>

7 <http://www.pointcarbon.com>

8 <http://www.unfccc.int>

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: ρ_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.

Results

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:

H₀: Information events reduce the relative bid-ask spread vs

H₁: Information events do not reduce the relative bid-ask.

Table 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 2 reports the results for the conducted stepwise backward regression analysis where the optimal model determined is as follows:

$$\text{Relative Spread}_t = 0.0295 - 0.0043 \times \text{News} - 0.0097 \times \text{Green} + \varepsilon_t \quad (1a)$$

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 R² of 26.4%, indicating that about one-quarter of the variation in the relative spread can be explained by the model.

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:

H₀: Information events do increase the volume of trading, vs
H₁: Information events do not increase the volume of trading

Table 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 3 reports the results for the stepwise regression analysis with the relationship estimated as follows:

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

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 not 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 $R^2 = 0.214$.

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.

H₀: Information events do affect the REC prices, vs.
H₁: Information events do not affect REC prices.

Table 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 4 reports the regression analysis results with the final model suggesting the following relationship between Log Prices of RECs and the considered explanatory variables:

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

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.

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.

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 an 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

AMBIGUITY IN MARKETS: A TEST IN AN AUSTRALIAN EMISSIONS MARKET

Date	Delay	Garnaut	Green	News	Regulation	White
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

Date	Delay	Garnaut	Green	News	Regulation	White
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