An Experimental Economic Analysis of Carbon Trading Options for Australia

John Tisdell
Australian Rivers Institute, Griffith University
Kessels Road, Brisbane, QLD 4011, Australia

Corinne Grainger
Australian Rivers Institute, Griffith University
Kessels Road, Brisbane, QLD 4011, Australia

Paper presented at the 2008 NZARES Conference
Tahuna Conference Centre – Nelson, New Zealand. August 28-29, 2008.

An Experimental Economic Analysis of Carbon Trading Options for Australia

John Tisdell and Corinne Grainger

Australian Rivers Institute

Griffith University

Kessels Road, Brisbane, QLD 4011, Australia

Abstract

Australia is currently developing a carbon emissions trading program. The Garnaut report recommendations include options for emissions trajectories, coverage, permit allocation, inter-temporality, governance and compliance. This paper reports the results of a series of economic experiments in which we explored spot and future markets given high and low levels of carbon credit reductions. The results provide important insights to the current debate in Australia and highlight the importance of well crafted market design.

Keywords: Carbon trading, emissions trading, future markets

Introduction

Markets for pollution control have been advocated as a means to efficiently manage emissions. In particular the use of cap-and-trade schemes (referred to as emissions trading schemes in this paper) for the control of carbon pollution and other greenhouse gasses have increased in popularity. Several emissions trading programs are currently in operation, such as the EU Emissions Trading Scheme, the US Acid Rain and Reclaim programs, and the NSW Greenhouse Gas Reduction scheme. Australia is now developing a national carbon emissions trading scheme in order to reduce its carbon emissions.

In the recent reports released in relation to this scheme, the Garnaut Review (2008) and the governments Green Paper (2008), a number of institutional options have been discussed, including the emissions trajectory, coverage, permit allocation, inter-temporality, governance and compliance. This paper tests in a laboratory setting two of the policy options discussed in the Garnaut Review (2008); emissions trajectory and inter-temporality.

Previous experimental research has examined a number of aspects of carbon markets. The majority of this experimental research relates to the examination of, type of market institution (revenue neutral auctions versus double auctions versus discriminative price auctions) (Cason 1993, 1995; Cason and Gangadharan 1998; Cason and Plott 1996; Franciosi et al. 1993; Ledyard and Szakaly-Moore 1994), market power (Brown-Kruse et al. 1995; Carlen 1999, 2003; Cason et al. 2003; Godby et al. 1998; Ledyard and Szakaly-Moore 1994) and compliance behaviour (Cason and Gangadharan 2006a; Murphy and Stanlund 2006; Murphy and Stranlund 2007) in an emissions trading scheme[1]. However little attention has been paid to the role of the emissions trajectory or futures markets in an emissions trading scheme.

In this paper we examine how different emission trajectories and spot and futures markets, may effect an emissions trading scheme in terms of compliance and market efficiency. As well as testing the effects of two of the policy options discussed for the proposed Australian scheme this research adds to the current experimental literature on compliance within an emissions trading scheme.

Compliance behaviour within an emissions trading scheme is a critical factor in the success of a scheme and differs significantly from that under a command-and-control situation (Murphy and Stanlund 2006; Murphy and Stranlund 2007). Previous research suggests that within an emissions trading scheme, compliance is not only linked to the enforcement strategy but also to different aspects of the market design.

Murphy and Stranlund (2006) examine compliance behaviour within an emissions trading scheme. They find that compliance choices are influenced by both a direct effect from the enforcement strategy as well as an indirect market effect. Further, Cason and Gagadharan (2006b) examine the interaction between banking and compliance decisions and find that where banking is allowed compliance is decreased.

[1] Muller and Mestelman (1998) provide a good overview of the experimental literature related to emissions trading.

These previous studies suggest that interactions between various policy options within an emissions trading program play an important role in determining compliance behaviour.

We design an experiment based on the proposed Australian scheme. In our design permits are able to be traded into spot and future markets. This is crossed with treatments for a stringent and relaxed reduction in the emissions cap over time. The next section provides an overview of literature surrounding the two options. We then provide our experimental design. Lastly we report our results from the experiments.

Literature

The objective of an emissions trading scheme is to provide the incentive for firms to reduce emissions to a given level in an efficient manner. For example, Australia has committed to reducing emissions by 60% of 2000 levels by 2050. However, due to the long term nature of climate change and the time lags involved in technological development and uptake, the emissions cap is generally proposed in terms of a reduction schedule rather than a significant singular reduction in emissions (Stavins 2007; Wigley et al. 1996). A number of studies have examined the effect of various reduction schedules on the cost of technological change or mitigation (Goulder and Mathai 2000; Grübler and Messner 1998; Jaffe et al. 1999, 2002; Manne and Richels 1997, 2004; Richels and Edmonds 1995; Schneider and Goulder 1997; Wigley et al. 1996). It has been argued that the trajectory chosen to achieve the final level of stabilisation is of as much importance in determining the costs of mitigation, as the actual level of final stabilisation (Richels and Edmonds 1995).

A number of studies (Manne and Richels 1997; Richels and Edmonds 1995; Wigley et al. 1996) have argued for gradual reductions in concentrations in C02 in the near term with more stringent reductions in later periods. Three reasons for a gradual reduction away from business as usual have been proposed. First, the positive marginal productivity of capital means that the further in the future the reduction falls, the smaller the contribution must be now. Second, sudden changes in the configuration of current capital stock will be costly without adequate time to adjust. Finally, over time the efficiency and availability of abatement technology will improve and hence in the long term the costs of mitigation will be lower. This finding is upheld by Manne and Richels (2004) where they find that including learning-by-doing into their model does not change the outcome that a gradual transition away from business as usual is superior to aggressive near term cuts.

In contrast, while acknowledging that there exist a number of possible emission reduction schedules, the Garnaut Review (2008) states that as long as the final level of emissions is equal there is no strong evidence to distinguish between paths. We test the effect of a stringent and relaxed reduction in permits on compliance and market efficiency.

To our knowledge, Ben-David (2000) is the only other published experimental study to examine the effect of a declining cap on an emissions trading scheme. Ben-David (2000) examines the effect of uncertainty regarding the timing of as well as the magnitude of a one off decline in emission allowances on technological change and price stability. Ben-David (2000) finds that uncertainty in emissions allowance reductions results in no change to market prices but states that this is likely to be from the interaction with technological uptake. Unlike the scenario examined by Ben-David, in the scheme proposed for Australia, emissions reductions will not be highly uncertain with measures in place in order to reduce the uncertainty of timing and magnitude (see Garnaut 2008). Further, our design examines the effect of a continuous reduction in emission permits, as it is unlikely that only a one-off reduction will be imposed.

The second design feature we examine is the role of futures markets. In markets for pollution such as greenhouse gases, inter-temporal flexibility plays a large role in ensuring market success (Stavins 1998; Stern 2007). Often firms are required to make long term decisions regarding emissions and technological uptake, however, uncertainty surrounding the future price and supply of permits may reduce the effectiveness of such decisions. Hence, compliance over time may be smoothed by providing greater certainty surrounding future prices (Stern 2007).

Futures markets have long been used in the commodity market to reduce the risk associated with uncertainty in future prices. Where long term decisions must be made, futures markets reduce uncertainty by providing information on the future price and timing of delivery. This future price is a reflection of expectations for future demand and supply, where markets are functioning efficiently (Burns 1983; Garnaut Review 2008). Thus, futures markets aid efficiency at three levels. They improve liquidity by providing certainty of price, enhance pricing efficiency or the degree to which prices reflect supply and demand, and they decrease transaction costs by reducing the cost of searching and acquiring the asset (Burns 1983). We investigate the effect of liquidity on compliance, and the degree of pricing efficiency achieved by the futures markets.

A number of greenhouse gas emission schemes currently operating have provisions for future trading (for example, EU ETS, US Acid Rain program) and reports, such as the Garnaut Review (2008) and Stern Review (2007) have acknowledged the use of futures markets as a way to improve market efficiency. However, very little literature exists examining the role of futures markets in a carbon trading scheme (see Maeda 2001; Truck et al. 2006). While a vast body of literature exists for future trading in commodity and asset markets, emission permit markets differ significantly from these markets. Emission permits do not provide a future stream of dividends or utility and the only purpose of holding an emission permit is for compliance with regulation (Maeda 2001).

In the experimental literature, Muller and Mestelman (1994) and Godby et al (1997) investigate a futures market particular to a design proposed in a Canadian nitrous-oxide trading scheme. In this design shares are able to be traded for future periods and each share provides the holder with a given number of coupons (or permits). In Godby et al (1997), uncertainty in emissions was introduced to the design. Muller and Mestelman found that by including the share market, market efficiency and compliance were improved. However these studies were highly specific to the Canadian scheme.

By contrast, we investigate the effects of a futures market based on the Australian proposal. Further we examine the interactions of high and low emissions trajectories with spot and futures markets. The next section of this paper reports our experimental design.

Experimental Design

Given the current literature on emission trading schemes, we posed the following questions:

1. Are markets able to adjust to period by period declining permit stocks?
2. Does the rate of decline in carbon permits impact on compliance?
3. Do futures markets produce better results than simple spot markets in terms of compliance and market activity?

The experimental design (given in Table 1) examined high and low abatement trajectories with a spot versus a futures market. A total of 12 experimental sessions were conducted at Griffith University, with 8 subjects in each session. In each of the sessions, subjects traded emission permits in a posted offer market, and made decisions regarding their level of emissions and hence compliance.

Table 1: Experimental Design

	High Reduction (HR)	**Low Reduction (LR)**
Spot Market (SM)	3 sessions 10 periods	3 sessions 10 periods
Futures Market (FM)	3 sessions 10 periods	3 sessions 10 periods

In order to minimise biases, the emissions decision was framed as a decision regarding production of a good and emissions permits were labelled simply as permits. However, in context, units produced by subjects are equivalent to units of emissions and each permit equates to a right to produce one unit of emissions.

Subjects were informed that they were the producer of a fictitious good and that they could produce this good up to a maximum production level. Subjects were told that for each unit of their good they produced they would earn their value of production. They were also given a stock of permits and informed that for each unit they produced they were required to hold a permit. Subjects faced random auditing and if found to have less permits than their production they would face a fine. Subjects were informed that their aim was to maximise their earnings taking into account their earnings from production, trade and any fines they may receive. .

Subjects were endowed with an initial allocation of permits that they could trade in the market and were informed that each round the number of permits they would receive in their initial allocation would decline by a given number (depending on which treatment they were in). Under treatments with a ‘high reduction’ the initial allocation of permits was reduced by 7 permits each round, compared to a reduction of 4 permits each round in the 'low reduction' treatments. In both treatments, subjects started round 1 with an initial allocation of 90 permits. The allocation of permits each round is given in Table 2**.**

Table 2: Initial Allocation of Permits for each Round

Round	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Low	90	86	82	78	74	70	66	62	54	50
High	90	83	76	69	62	55	48	41	34	27

In the first stage of the experiment, subjects were able to trade their permits in a posted offer market that was open for four minutes. Offers to sell (asks), posted by subjects were displayed on a trade table accessible to all subjects and subjects were able to purchase permits from any of the available offers to sell. In the treatments with a futures market, subjects were able to post offers to and purchase permits from any future periods. In the spot market treatments subjects were only able to trade in the current period. Once the market closed, subjects were asked to submit a decision regarding their level of production. Subjects earned a given marginal benefit for each unit of production and all subjects were constrained by a maximum production at 100 units. Subjects were endowed with differing marginal values in order to provide gains from trade.

In all treatments subjects faced a penalty if found to be non-compliant. In order to be compliant subjects were required to hold permits equal to or greater than their production. In all treatments subjects were audited depending on a 40% probability of being audited and if found to be non-compliant fined. The fine structure was determined by setting the expected value of the fine equal to the equilibrium price in that period.

Table 3 shows the marginal values and expected distribution of permits after trade. As the allocation of permits declines permits redistribute to higher value players. In the case of a high reduction in permits this moves the market from a highly competitive market to a duopsony with only two buyers. Table 4 shows the expected price of permits and penalties for each period. As the allocation of permits (supply) falls the price was expected to increase, with the high reduction treatment increasing at a greater rate.

Table 3: Player Characteristics and Expected Distribution of Permits at End of Trade.

		Low										**High**									
Player	**Marginal Value**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	40	20	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0
2	60	100	88	56	24	0	0	0	0	0	0	100	64	8	0	0	0	0	0	0	0
3	80	100	100	100	100	92	60	28	0	0	0	100	100	100	52	0	0	0	0	0	0
4	100	100	100	100	100	100	100	100	96	64	32	100	100	100	100	96	40	0	0	0	0
5	120	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	84	28	0	0
6	140	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72	16
7	160	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
8	180	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table 4: Equilibrium Prices and Associated Penalties for Non-Compliance

	Period	1	2	3	4	5	6	7	8	9	10
Low	Equilibrium Price	50	50	70	70	70	90	90	90	90	110
	Penalty	125	125	175	175	175	225	225	225	225	275
High	Equilibrium Price	50	70	70	90	90	110	110	130	130	150
	Penalty	125	175	175	225	225	275	275	325	325	375

Experiment procedures

Each experimental session consisted of eight participants. Experiments were carried out at Griffith University in Brisbane, Australia using The Experimental Software System (TESS). Participants were recruited from the University's student population through a web-based recruitment system. On arrival at the experiment, each participant was randomly assigned to a computer, provided with a set of instructions, and asked to complete a quiz to ensure they understood the experiment. Once participants answered all the questions correctly, they received a password enabling them to access the experiment.

Computer screens showed participants the marginal value of their good, the maximum number of goods they could produce and their allocation of permits. Each period commenced with an onscreen posted offer market. At the conclusion of the market a decision box appeared in which participants entered their production decision. Participants were audited at random and fined when appropriate.

Each experimental session consisted of eight participants. Participants were paid $A10 for agreeing to participate and showing up on time and were then given an opportunity to earn additional money in the experiment. Total earnings ranged from $A12 to $A45. In accordance with standard experimental economics procedures and protocols, earnings were paid in cash at the end of each experiment. Each experimental session lasted approximately two hours.

Results

The experimental data was analysed using random effects model assuming autoregressive one covariance structures. The analysis that follows focuses on levels of compliance and market activity.

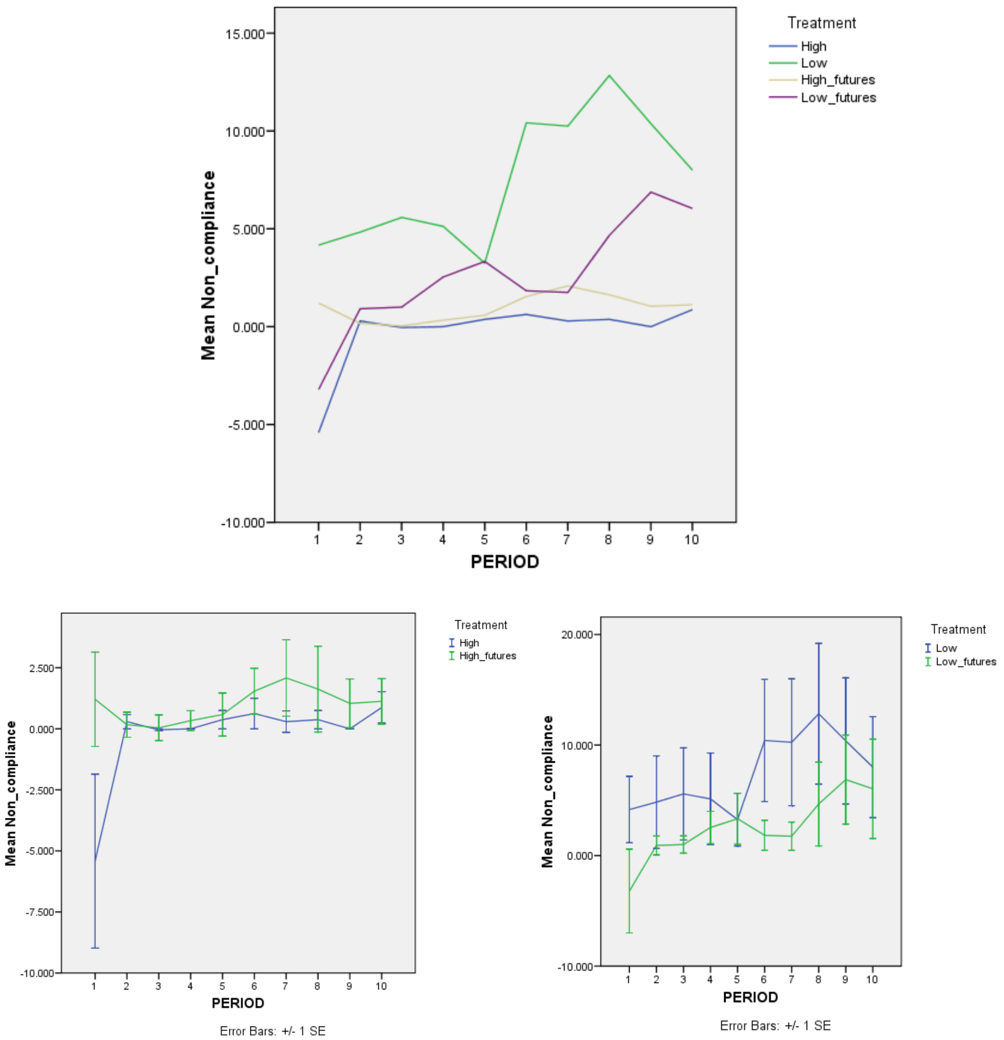
Levels of Compliance

Table 5 and the associated Figure 1 show the analysis of non-compliance for all treatments across the 10 periods. When the level of production exceeds the number of permits held a player is non-compliant. There is a significant interaction between the level of permit reduction (high_low) and the type of market (spot_futures) in explaining non-compliance (p=0.024). Figure 1 suggests that futures markets increases compliance compared to spot markets given low levels of permit reduction. With high levels of permit reduction, futures market compliance was less than spot market compliance. Overall, non-compliance is greater given low levels of permit reduction compared to high levels of permit reduction.

Table 5: Random Effects Model of Non-Compliance

Treatment	Coef.	Std. Err.	Z	P>|z|	95% conf. Interval	
high_low	-10.73278	16.35035	-0.66	0.512	-42.77887	21.31332
spot_futures	38.89661	16.35035	2.38	0.017	6.850514	70.9427
interaction	-52.16541	23.12288	-2.26	0.024	-97.48543	-6.845393
constant	18.82627	11.56144	1.63	0.103	-3.833737	41.48628
Wald = 16.46 p = 0.0025						

Figure 1: Mean Non-Compliance through Periods



Market Activity

The other important dimension to compliance is market activity. Table 6 summarises the panel data analysis of market prices. The results show that market prices were higher under the high level of permit reduction consistent with expectations (p = 0.022). Figure 2 shows the increase in market prices as the supply of permits declines for high and low treatments.

Table 6: Random Effects Model of Market Prices

Treatment	Coef.	Std. Err.	z	P>|z|	95% conf. Interval	
spot_future	-7.43048	9.022032	-0.82	0.410	-25.11334	10.25238
high_low	20.70647	9.022032	2.30	0.022	3.023613	38.38933
Constant	91.98258	7.813309	11.77	0.000	76.66878	107.2964

Wald = 5.97 p = 0.2015. Interaction not significant and so excluded.

Figure 2: Mean Price of Permits through Periods for the High and Low Reduction Treatments

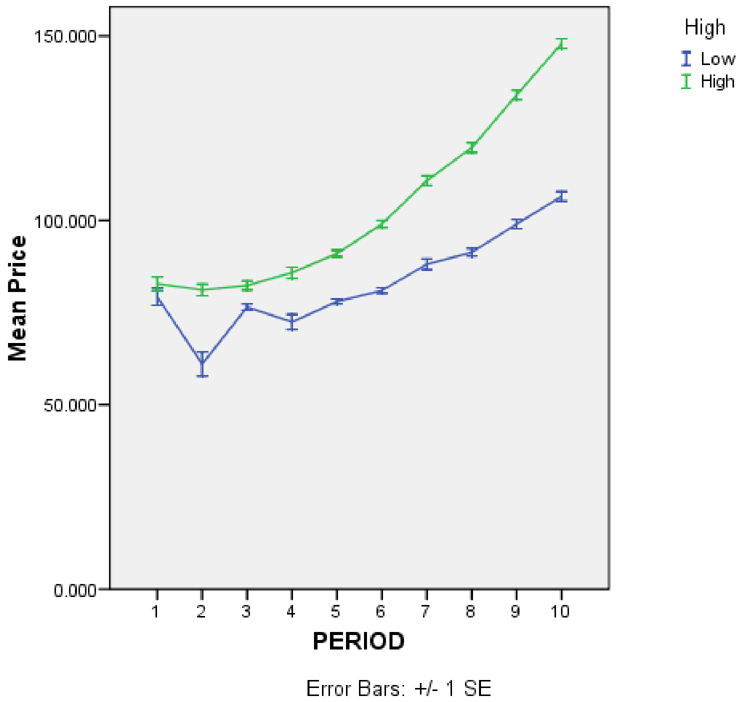


Figure 3 graphically compares the realised permit prices in the experiments with those modelled across the four treatments. It can be seen that in all treatments the realised mean permit price closely approximated the modelled permit price.

Figure 3: Mean Modelled Price of Permits and Mean Permit Price in all Treatments

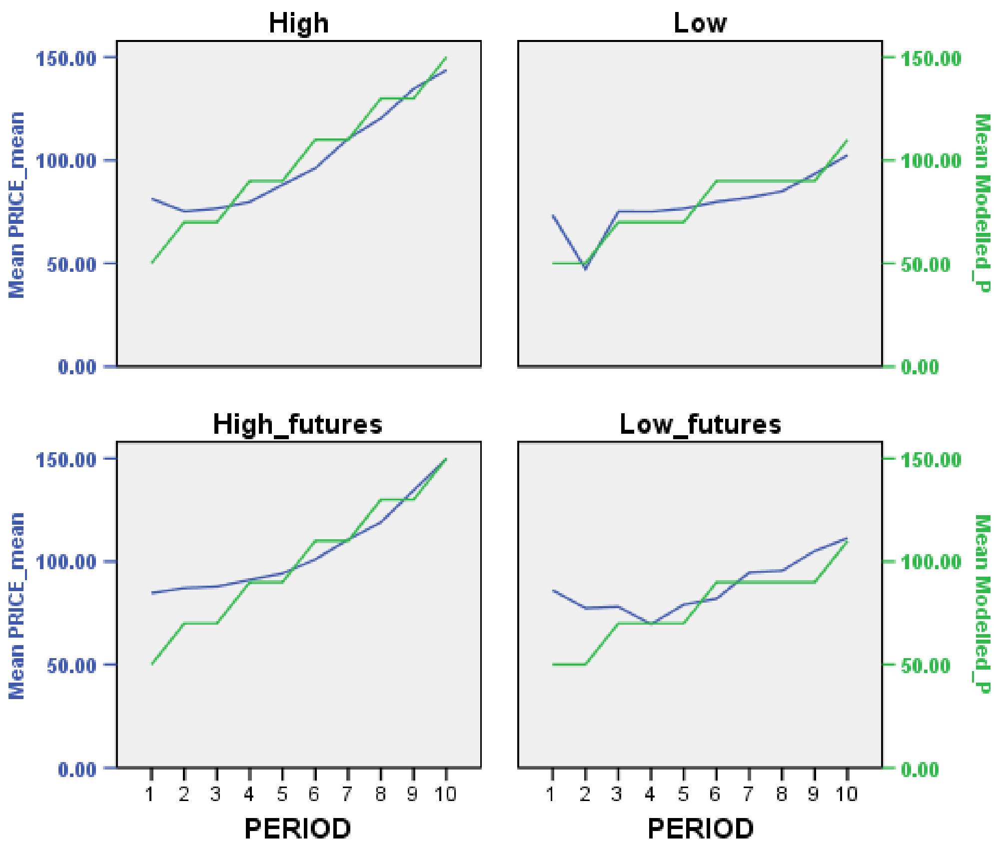


Table 7 and Figure 4 summarise the difference between mean spot and forward prices under a high and low reduction. When faced with a high level of permit reduction players underestimated the value of future permits. The realised spot prices in high reduction markets were significantly greater than the future prices into the same period reflecting the risk premium associated with future trading (p values range 0.00 to 0.043). The differential increased through time. Overall, in low reduction markets forward and spot prices were not significantly different suggesting that the low reduction did not induce a risk premium[2].

Table 7: Random Effects Model of Market Prices

Mean Prices	**Futures Market, Low Reduction**				**Futures Market, High Reduction**			
Round	**7**	**8**	**9**	**10**	**7**	**8**	**9**	**10**
Spot Price	93.36	95.44	104.94	109.32	112.60	120.44	135.88	154.26
Forward Price	92.50	94.88	93.75	111.42	110	110	122.50	132.90
p-value	0.934	0.924	0.023	0.740	0.015	0.000	0.043	0.000

[2] The exception to this was a significant difference between spot and future prices in period nine.

Figure 4: Mean prices for spot and forward trades with a high and low reduction

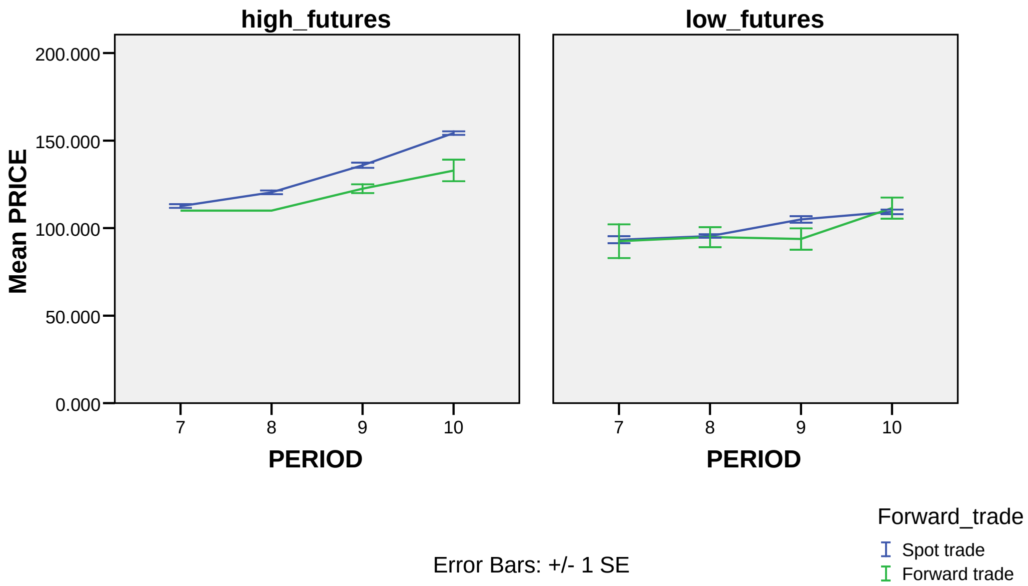


Table 8 and Figure 5 show the analysis of quantities traded by market type across periods. There was no significant difference in the average quantity traded between the low and high reduction treatments (p = 0.098). Spot markets resulted in higher average quantities traded compared to future markets (p= 0.016).

Table 8: Random Effects Model of Market Quantities

Treatment	Coef.	Std. Err.	z	P>|z|	95% conf. Interval	
spot_future	3.025735	1.255851	2.41	0.016	.5643127	5.487157
high_low	-2.080926	1.255851	-1.66	0.098	-4.542349	.3804962
constant	11.99493	1.087599	11.03	0.000	9.863281	14.12659

Wald = 5.97 p = 0.2015. Interaction not significant and so excluded

.

Figure 5: Mean Quantity of Permits Traded through Periods within the Spot and Futures Treatments

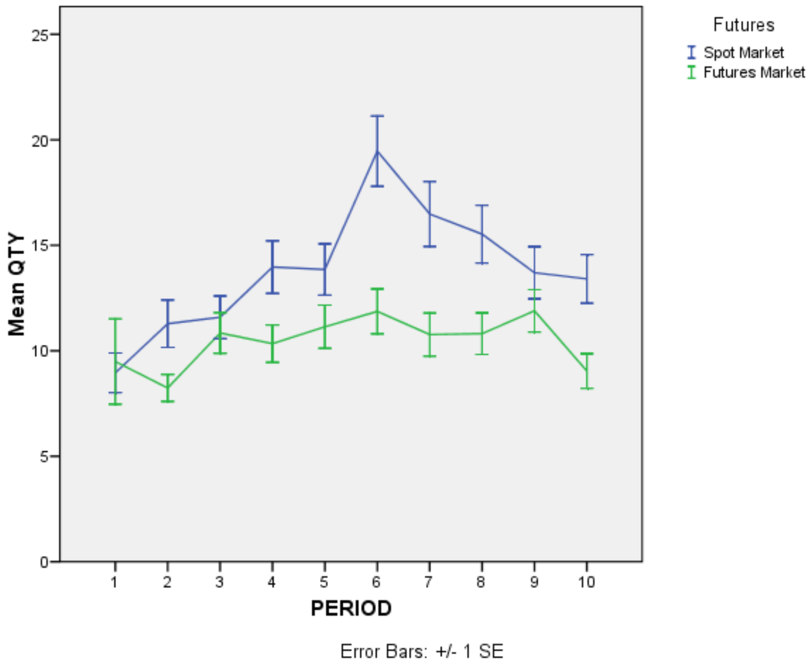


Figure 6 shows the modelled and actual quantities traded. The quantity traded in all markets was less than optimal. This can be seen in the future markets in particular.

Figure 6: Modelled and Actual Trade Volumes

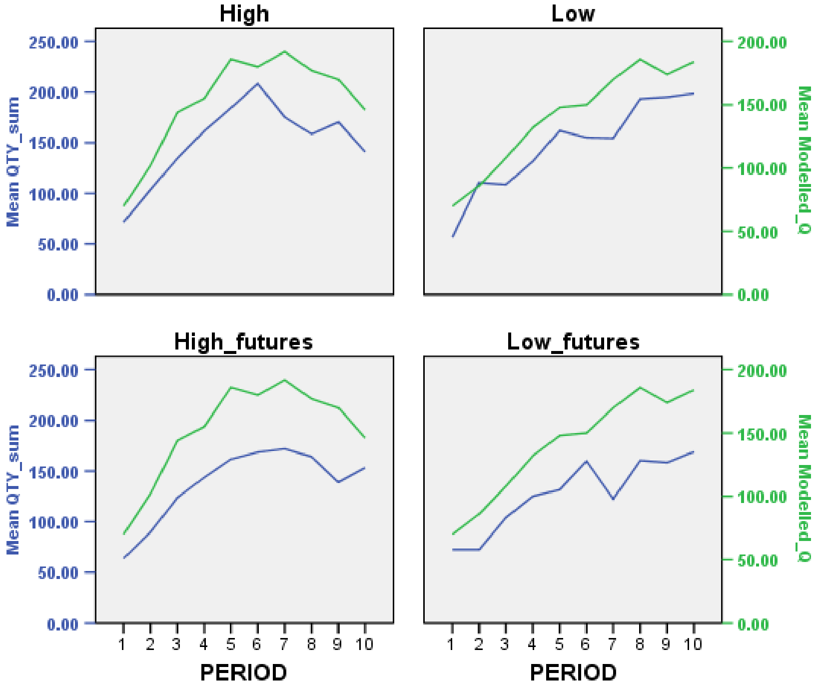


Table 9, and the associated Figure 7, summarises differences in spot and future quantities traded in/into the last 4 periods. Within the low reduction markets, the size of spot trades was not significantly different to the future trades. This, combined with the fact that the spot and future market prices were not significantly different within low reduction markets, suggests that players felt confident in future trading in low reduction environments.

Table 9: Difference between Mean Spot and Forward Quantities Traded Under a High and Low Reduction

Mean Quantity	**Futures Market, Low Reduction**				**Futures Market, High Reduction**			
Round	**7**	**8**	**9**	**10**	**7**	**8**	**9**	**10**
Spot Qty	11.68	10.83	12.35	10.84	10.94	10.82	11.85	8.36
Forward Qty	6.67	11.38	11.50	7.92	2.00	5.00	7.00	6.70
p-value	0.250	0.891	0.815	0.366	0.000	0.000	0.442	0.522

.

Figure 7: Mean Quantities Traded in Spot and Forward Trades with a High and Low Reduction

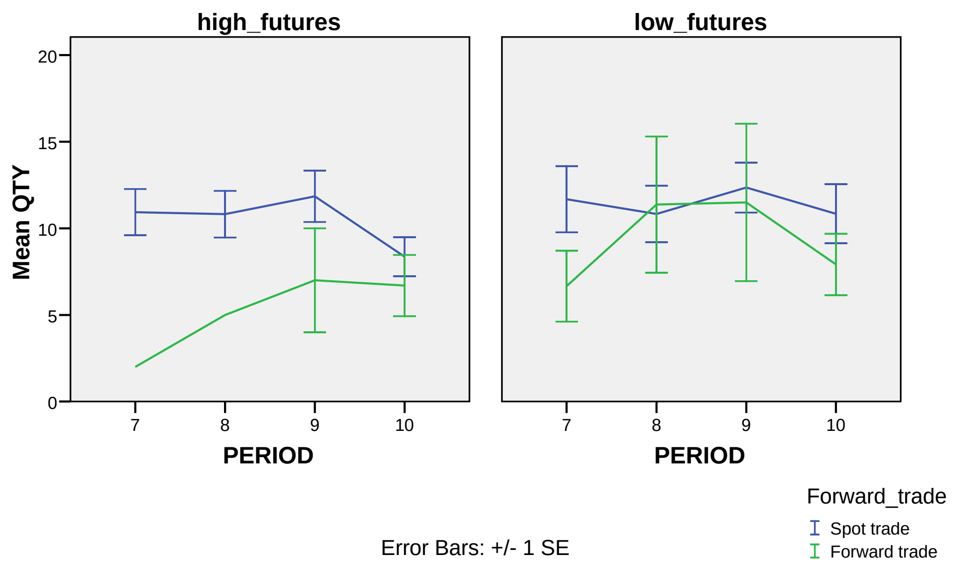
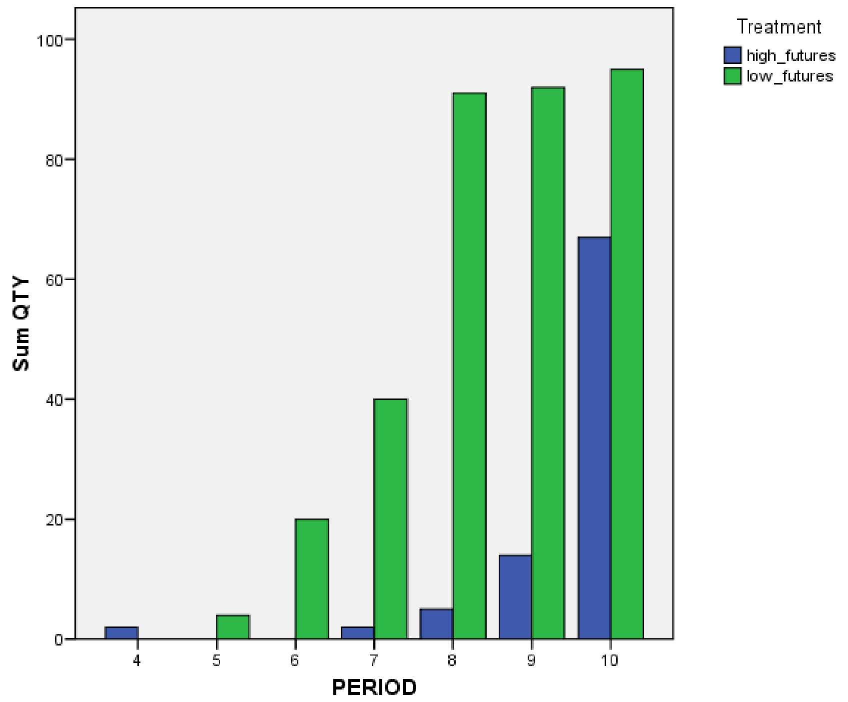


Figure 8 shows the spot and future quantities traded by nature of permit reduction. Future trades into earlier periods were low but increased significantly in latter periods. The total volume traded in futures low reduction markets was significantly greater than in futures, high reduction markets.

Figure 8: Volume of Future Trades in the High and Low Reduction Treatments



Discussion and conclusions

We expected that a high level of permit reduction would lead to lower compliance and greater use of futures markets. This was not the case. The high level of permit reduction led to higher levels of compliance and fewer futures trades than occurred in the low level permit reduction treatment experiments. One possible explanation is that higher levels of reduction led to greater uncertainty and higher levels of risk aversion which in turn led to greater compliance and less future trading. Future trade prices underestimated the realised spot prices. With market maturity, future market activity and convergence of spot and future trade prices may improve.

Low permit reductions led to better predictions of future trade prices but less compliance compared to high permit reductions. In this case, futures markets were found to be effective in improving compliance. Future trade prices were consistent with the realised spot prices and future trades made up a greater proportion of traded permits.

The policy implications of these results are that if the authority is concerned with achieving an emission target quickly, high rates of permit reduction with spot markets should be considered. Based on the experimental data, there should be high rates of compliance and limited need for futures markets during the initial phase. If a low emissions trajectory is adopted then it should be implemented with a futures market option. Higher rates of non-compliance could be expected.

The findings of this work are based on experimentation. Further research is required to explore operational and field specific implications.

References

Ben-David, S., Brookshire, D., Burness, S., McKee, M, Schmidt, C. (2000) Attitudes towards risk and compliance in emissions permit markets. Land Economics, 76: 590-600.

Brown-Kruse, J., Elliot, S., Godby, R. (1995) Strategic Manipulation of Pollution Permit Markets: an Experimental Approach. Department of Economics Working Papers, McMaster University.

Burns, J.M. (1983) Futures Markets and Market Efficiency. In Futures Markets: Modelling, Managing and Monitoring Futures Trades. M.E. Streit (ed.), Basil Blackwell Publisher Limited, Oxford.

Carlen, B. (1999) Large-Country Effects in International Emissions Trading: A Laboratory Test. Working Paper, Department of Economics, Stockholm University.

Carlen, B. (2003) Market Power in International Carbon Emissions Trading: A Laboratory Test. MIT.

Cason, T. (1993) Seller incentive properties of EPA's emission trading auction. Journal of Environmental Economics and Management, 25: 177-195.

Cason, T. (1995) An experimental investigation of the seller incentives in the EPA's emission trading auction. The American Economic Review, 85: 905-922.

Cason, T. and Gangadharan, L. (2006a) An experimental study of compliance and leverage in auditing and regulatory enforcement. Economic Inquiry, 44: 352-366.

Cason, T. N. and Gangadharan, L. (1998) An experimental study of electronic bulletin board trading for emission permits. Journal of Regulatory Economics, 14: 55-73.

Cason T. N. and Gangadharan, L. (2006b) Emissions variability in tradable permit markets with imperfect enforcement and banking. Journal of Economic Behavior & Organization, 61: 199-216.

Cason, T.N., Gangadharan, L. and Duke, C. (2003) Market power in tradable emission markets: a laboratory test-bed for emission trading in Port Phillip Bay, Victoria. Ecological Economics, 46: 469-491.

Cason, T.N. and Plott C.R. (1996) EPA's new emissions trading mechanism: a laboratory evaluation. Journal of Environmental Economics and Management, 30: 133-160.

Department of Climate Change (2008) Carbon Pollution Reduction Scheme: Green Paper. Commonwealth of Australia.

Franciosi, R.., Isaac, R.M., Pingry, D.E. and Reynolds, S.S. (1993) An experimental investigation of the Hahn-Noll revenue neutral auction for emissions licenses. Journal of Environmental Economics and Management, 24: 1-2.

Garnaut Review (2008) Garnaut Climate Change Review: Draft Report. Commonwealth of Australia.

Godby, R., Mestelman, S. and Muller, R.A. (1998) Experimental Tests of Market Power in Emission Trading Markets. Working Paper, McMaster University.

Godby, R., Mestelman, S., Muller, R.A. and Welland, J.D. (1997) Emissions trading with shares and coupons when control over discharges is uncertain. Journal of Environmental Economics and Management, 32: 359-381.

Goulder, L.H. and Mathai, K. (2000) Optimal CO2 abatement in the presence of induced technological change. Journal of Environmental Economics and Management, 39: 1-38.

Grübler, A. and Messner, S. (1998) Technological change and the timing of mitigation measures. Energy Economics, 20: 495-512.

Jaffe, A.B., Newell, R.G. and Stavins, R.N. (1999) Energy Efficient Technologies and Climate Change Policies: issues and evidence. Resources for the Future Inc, Washington D.C.

Jaffe, A.B., Newell, R.G. and Stavins, R.N. (2002) Environmental policy and technological change. Environmental and Resource Economics, 22: 41-69.

Ledyard, J.O. and Szakaly-Moore, K. (1994) Designing organisations for trading pollution rights. Journal of Economic Behaviour and Organisation, 25:167-196.

Maeda, A. (2001) Domestic Greenhouse Gas Emissions Trading Markets: Forward Pricing and Banking Impacts. Interim Report IR-01-048, International Institute for Applied Systems Analysis.

Manne, A. and Richels, R. (1997) On stabilizing CO2 concentrations: cost-effective emission reduction strategies. Environmental Modelling and Assessment, 2: 251-265.

Manne, A. and Richels, R. (2004) The impact of learning-by-doing on the timing and costs of CO2 abatement. Energy Economics, 26: 603-619.

Muller, R.A. and Mestelman, S. (1994) Emission trading with shares and coupons: a laboratory experiment. Energy Journal, 15: 185-212.

Murphy, J. and Stanlund, J. (2006) Direct and market effects of enforcing emissions trading programs: an experimental analysis. Journal of Economic Behaviour and Organisation, 61: 217-233.

Murphy, J. and Stranlund, J. (2007) A laboratory investigation of compliance behaviour under tradable emissions rights: implications for targeted enforcement. Journal of Environmental Economics and Management, 53: 196-212.

Richels, R. and Edmonds, J. (1995) The economics of stabilizing atmospheric CO2 concentrations. Fuel and Energy Abstracts, 36: 459-459.

Schneider, S.H. and Goulder, L.H. (1997) Achieving low-cost emissions targets. Nature, 389: 13-14.

Stavins, R.N. (1998) What can we learn from the grand policy experiment? Lessons from SO2 allowance trading. Journal of Economic Perspectives, 12: 69-88.

Stavins, R.N. (2007) A U.S Cap-and-Trade System to Address Global Climate Change. The Hamilton Project, The Brookings Institute.

Stern, N. (2007) The Economics of Climate Change: The Stern Review. Cambridge University Press, Cambridge.

Truck, S., Borack, S., Hardle, W. and Weron, R. (2006) Convenience yields for CO2 emission allowance futures contracts. . Discussion Paper 2006-076, Humboldt-Universitat zu Berlin.

Wigley, T.M.L., Richels, R. and Edmonds, J.A. (1996) Economic and environmental choices in the stabilization of atmospheric CO2 concentrations. Nature, 379: 240-243.