AARES 2007

Experimental test of the effect of imposing a penalty on buyers in a specific market structure

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1. Introduction

This article examines one side of the Australian Federal Coalition Government's mandatory renewable energy target (MRET) policy (i.e. the presence of penalty in a specific market structure). The objective of this policy is to increase the market share of renewable energy technologies in the Electricity Supply Industry (ESI) in Australia. Renewable energy technologies are less emission intensive than conventional fossil-fuel electricity generation technologies. Therefore, the increased market share of renewable energy technologies is expected to result in reduced emissions from the electricity industry and corresponding improvements in environmental quality. The problem, however, is that renewable energy technologies are in general more expensive than conventional fossil-fuel generation technologies. The recent reforms of the ESI in Australia which resulted in the restructuring of the electricity sector and the introduction of competition in the generation and retail sectors have reduced the opportunities for renewable energy to be adopted by electricity generating companies due to the generally higher costs of producing electricity from renewable energy compared with the cost of electricity production from conventional non- renewable energy technologies.

One approach to achieving the goal of increasing the market share of renewable energy technologies in the ESI at least cost to retailers is to create a market for renewable energy certificates (RECs). Producers of renewable energy receive a certificate for each unit of renewable energy they produced and then sell certificates to retailers to recover costs of production of electricity from renewable energy. In Australia, electricity retailers are required to buy a certain amount of RECs from electricity producers that use renewable energy to generate electricity. If retailers do not have the required amount of RECs by a certain day, they have to pay a penalty for each certificate they are lacking. The structure of the Queensland REC market can be described as an oligopoly on the supply side and competitive on the demand side.

The effect of the penalty on the market outcome is not strongly developed in the literature. The closest approximation is to consider the effect of a price ceiling on market behaviour. Although the price ceiling is not exactly the penalty, it represents a constraint in the market and, thus, can give an idea of the way the market will behave. The results of this type of study were taken as a guide to understand the effect of imposing a constraint in the market. The

effect of a penalty in the REC market was examined by Schaeffer and Sonnemans (2000). Their study, however, was not concerned with the specifics of the market, such as market structure, but more with the influence of banking and borrowing[1] on investments and the price of green certificates.

The rest of the paper is organised as follows. Section 2 outlines the problem of the existence of a penalty in a market for RECs. Section 3 describes the methodology of the experiment. Section 4 discusses the results of the experiments. Section 5 summarises the major findings.

2. Review of the Literature

The REC market in Australia imposes a penalty on retailers and large consumers of electricity if they fail to acquire specified amounts of RECs for electricity they purchase. The behaviour of market participants in the presence of a penalty is important to examine. A penalty can be seen as the maximum price retailers and large buyers are willing to pay for RECs (Schaeffer and Sonnemans, 2000:410). In theory, in a competitive market, renewable energy electricity generators will submit their offers for RECs at their marginal costs. In practice, however, some participants (e.g. retailers and large consumers) have a mandatory demand for RECs. This means that producers of electricity from renewable energy know that there is a demand for RECs. Moreover, they know that if retailers and large consumers do not purchase the required amount of RECs, they have to pay a penalty. Renewable energy producers also know the level of the penalty. That knowledge could give producers an advantage by setting the price above marginal costs if they are given an opportunity to do so.

The situation in REC market is complicated by the potential of a small number of large producers to exercise market power. McLennan Magasanik Associates (2002) in their report entitled, "Modelling the Price of RECs Under the Mandatory Energy Target", noted some problems associated with the REC market in Australia. Among others, one of the problems mentioned was the possible exercise of market power by a small number of large RECs producers. The presence of one or two large renewable energy producers with a large market share can, in theory, lead to the price being higher than would occur in a competitive market.

[1] The RECs market with fixed demand and a varying supply of RECs can potentially have two extreme scenarios: zero prices for certificates if there is oversupply of RECs on the market or (2) maximum prices (set by the penalty) if there is shortage of RECs on the market. To avoid these scenarios the flexibility mechanisms can be used. Such mechanisms, namely banking and borrowing of RECs, were explored in Schaeffer and Sonnemans (2000).

These issues are difficult to examine using conventional economic models, such as simulation models, because these models cannot capture the behaviour of market participants. However, there is a possibility to examine these issues using experimental economics.

Despite extensive literature on the operation of the deregulated electricity market and experimental work on the operation of emission permit trading markets, there is a limited body of literature on the efficiency of the RECs markets. An interesting discussion on this subject is the paper by Schaeffer and Sonnemans (2000), entitled: "The influence of banking and borrowing under different penalty regimes in tradable green certificates markets - results from an experimental economics laboratory experiment".

The main issues Schaeffer and Sonnemans (2000) were concerned about were the level of compliance with the mandatory RECs, the price of RECs, and investments in renewable energy technologies. Banking and borrowing under different levels of penalty were the main focus of the experiment by Schaeffer and Sonnemans (2000). The following two main conclusions relevant to this paper were derived from the experiments about the role of a penalty were given by Schaeffer and Sonnemans (2000):

1. High penalties drive up prices in early periods, leading to over investment and a price crash in the later periods.

2. The average price of RECs was a little bit above the penalty level, which was caused by the relatively large share of the voluntary demand in the market.

Economic theory suggests that, in a competitive market, the level of maximum price allowed does not have an effect on the behaviour of participants, as long as the maximum price is higher than competitive equilibrium level. In the context of this research, this means that, if a penalty is considered as a price cap for sellers, as long as the level of the penalty is above the equilibrium level of the competitive price for RECs, it will not affect the behaviour of participants if the market is competitive.

However, an alternative theory of sellers' behaviour in competitive markets with non-binding price controls was suggested by Scherer (1970), and cited in Isaac and Plott (1981). He argued that sellers can adopt a collusive behaviour. The argument was that sellers could use the non-binding ceiling price as a focal point for tacit collusion to keep prices above the CE prices.

Isaac and Plott (1981), followed by Smith (1982), pioneered experimental research concerning price control and its effect on the efficiency of the market. The objective of the study by Isaac and Plott (1981) was to examine the behaviour of a competitive market under an imposed price control.

Isaac and Plott (1981) reported the main conclusion that under non-binding price control, market behaviour supports the competitive model rather than the "focal point" model. In non-binding price control experiments the mean price tends to be near the competitive equilibrium price, not the control price[2].

However, results of experiments by Schaeffer and Sonnemans (2000), indicated that the high price ceiling can serve as a focal point for suppliers to offer their product. The typical outcome of high-penalty sessions was that prices were higher than for a competitive equilibrium price. The results of the Schaeffer and Sonnemans (2000) experiment suggested that the "focal point" model is the best representation of the market especially in the case where banking is allowed.

Isaac and Plott (1981:459) proposed to include expectations, strategic behaviour and/or the availability of the market information to participants to be included in further research of price control.

3. Methodology of the Experiment

The rest of the paper adopted words "sellers" to represent "producers" and "buyers" to represent "retailers". That has been done for the sake of simplicity in the experiment. Subjects participating in the experiment might struggle with the notions of "retailer" versus "producers". The meaning of "sellers" and "buyers" is more familiar to the subjects.

This experiment examined the case of an oligopolistic supply side when the demand side (buyers) have value for certificates and asks the question of whether the enforced participation (i.e. imposing a penalty on buyers for non-compliance) puts them at a disadvantage compared with sellers, resulting in the price of certificates other than would be expected in a oligopolistic market. The sellers' knowledge that buyers will be subject to a penalty for non-compliance can give sellers an opportunity to set the price above the marginal costs of producing RECs.

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[2] Smith and Williams (1981) developed the Isaac and Plott (1981) experimental design further isolating any effects of a non-binding control on price convergence behaviour.

In the experiment, the strength of sellers' position was enforced by the possibility to exercise market power. That has been achieved by imposing a capacity constraint. In the experiment, three questions were asked of the observed results: (i) does the existence of penalty have any effect on price of RECs, (ii) can market power in the certificates market be exploited by the seller if given the opportunity, and (iii) if yes, is the resulting outcome serious enough to merit special consideration by regulators? Communication among participants was not allowed to exclude collusion between sellers.

The experiment used the following assumptions and rules: 1) in the experiment, a buyer has an obligation to buy one REC unit each period (if a buyer does not purchase the required amount of units, he/she faces a penalty); 2) the existence of the penalty is common knowledge to everyone in the market; and 3) trade in certificates in the experiment is conducted using a double auction. The theoretically derived estimates of oligopolistic outcomes were compared with the experimental results.

The number of subjects should be on the one hand large enough to answer the particular research question and to perform statistical analysis and, on the other hand, small enough to fit the budget. Since this research is aimed to test the effect of an oligopoly market, as an approximation of the REC market in Australia. The number of students to represent an oligopoly has been chosen as two (utilizing duopoly as an example of an oligopolistic market structure). The number for the competitive (demand side) of the market has been chosen as six. The reason is that

> *…competitive outcomes are almost always obtained in non-monopolized double auction markets with private incomplete information and stationary supply and demand conditions. It holds true for as many as four sellers* (Kagel and Roth 1995:393, see also Smith et al., 1982).

Therefore, six buyers seem to be large enough for approximating competition on the buyers' side using double auction as a trading instrument. The general set up of the experiment is shown in Figure 1. The boxes on the left hand side with arrows pointing into "Sellers" box are the different treatments on the seller side. The boxes on the right hand side with arrows pointing into "Buyers" box are the different treatments on the buyer side.

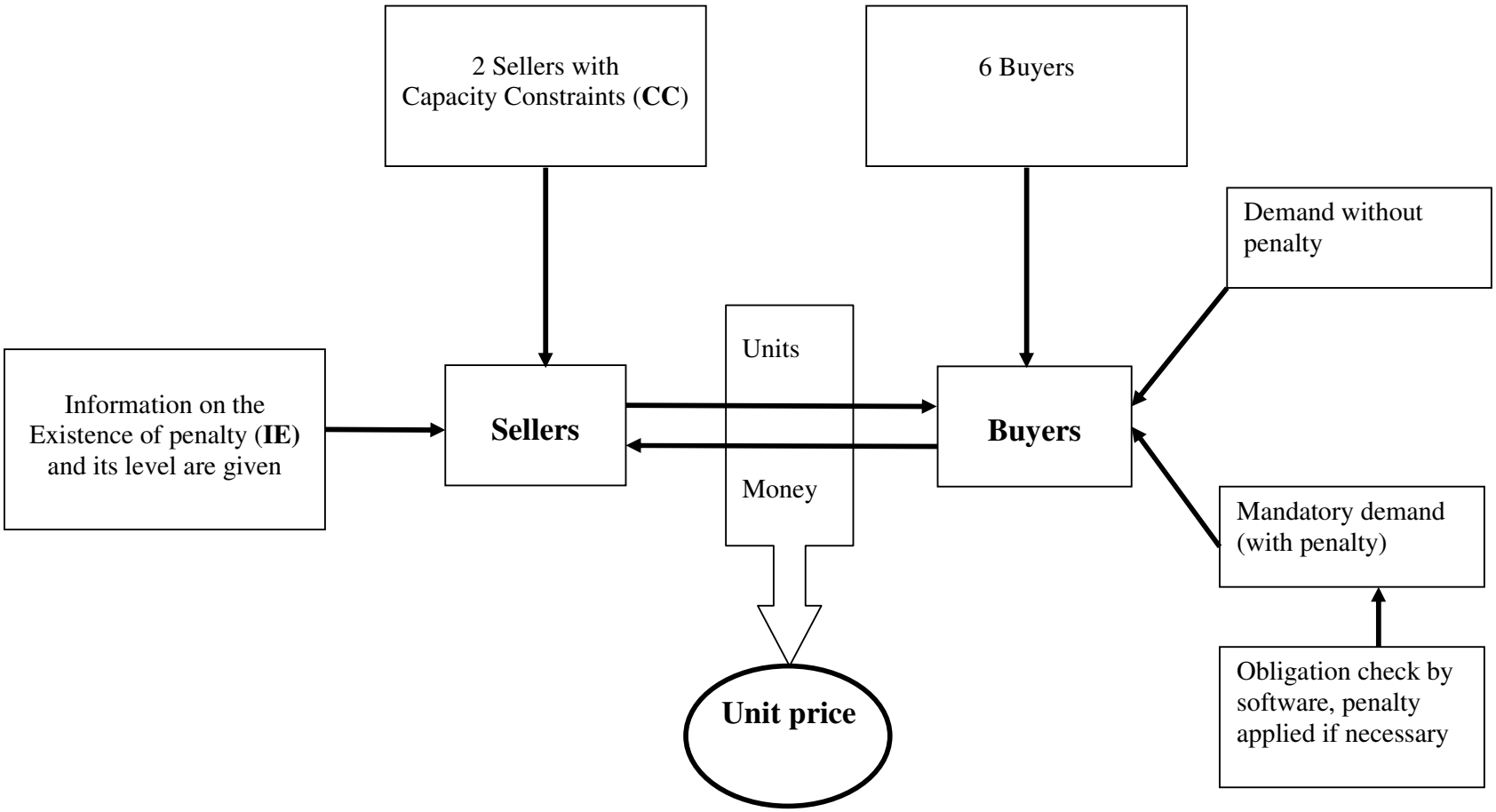


Figure 1. The general set-up of the experiment

Hypothesis 1:

This hypothesis tests the effect of enforced participation, i.e. the effect of the existence of a penalty on the buyers' side. It is hypothesised that when one part of the market is forced to participate for fear of incurring loss, they would be willing to accept much higher prices than otherwise. On the other hand, the presence of the penalty might induce aggressive behaviour on the buyers' side. If they know that they might lose money due to the penalty, they might adopt a strategy to bid very low to cover a possible loss in some other periods.

H_0: Price of units when the penalty is imposed on buyers[3] given an oligopoly market on the sellers' side = Price of units without penalty imposed on buyers in oligopoly market on the sellers' side.

H_1: Price of units when the penalty is imposed on buyers given an oligopoly market on the sellers' side ≠ Price of units without the penalty imposed on buyers given an oligopoly market on the sellers' side.

Hypothesis 2:

The experiment runs for many periods for each treatment. The effect of learning the policy due to playing several periods is tested by this hypothesis. The same market structure is used as in hypothesis one.

H_0: The trading behaviour in achieving a competitive equilibrium price does not change as market participants learn the policy

H_1: The trading behaviour in achieving a competitive equilibrium price does change as market participants learn the policy

Information given to participants

Subjects were not informed about the problems and context underlying the experiment, hence they did not know that they traded RECs. This was done in order not to impose the context of the experiment on participants. The knowledge of the context of the experiment might influence the strategies subjects chose due to their own perceptions about renewable energy.

[3] Buyers are in a competitive market, sellers are in an oligopoly market

If participants had this information, the decision making process could be distorted and thus reduce the validity of results.

Sellers were given individual costs for units of the product they produce. They were informed that buyers would have to pay a penalty if they did not buy a unit.

Two oligopolistic producers, shown in the Table 1 can choose to sell up to three units each. For each unit they sell they incur the cost for this unit. If they don't sell anything, they do not pay the cost of producing one unit. The supply function is usually symmetrical to the demand function (Smith and Williams, 1981 and Isaac and Plott, 1981). However, in this experiment sellers need to make a decision for a few units, the cost function has been simplified to reduce the information burden on subjects. The costs of the supply function are given as two numbers, laboratory (lab) lab$10 and lab$20 per unit. Table 1 shows costs for sellers.

Table 1. Laboratory firm costs.

	Units	**Production cost, lab$/unit**
Producer 1		
	1	10
	2	10
	3	20
Number of units supplied	***3***	
Producer 2		
	1	10
	2	10
	3	20
Number of units supplied	***3***	
Total number of units supplied	**6**	

Buyers were given individual values for units. They were aware of the penalty. The level of the penalty was known to all participants. During the sessions, one of the tasks of the experimental software was to check whether obligations were met after every period and to apply penalties if necessary.

Buyers profit is the difference between the price buyers pay for a unit in the auction and the maximum value they are given. In the treatment with penalty all buyers have an obligation to have one unit at the end of each period. A buyer not having a unit at the end of the period will pay a penalty. In this case this buyer will not receive a value for the absent unit. Speculative behaviour at the auction can increase profit if successful, but buyers will not receive a value for any additional unit. This type of speculation is possible due to the nature of the double

auction but it is not the focus of this research. Note, that paying the penalty is not in the interest of the buyers. Table 2 shows values for buyers.

Table 2. Laboratory buyers values.

	Units	**Value, lab$/unit**
Buyer 1	1	120
Buyer 2	1	100
Buyer 3	1	80
Buyer 4	1	60
Buyer 5	1	40
Buyer 6	1	20
Total number of units demanded	**6**	

The total demand is six units. The demand curve intersects the supply curve at the equilibrium price of $lab20 /unit. The equilibrium price is shown in Figure 2.

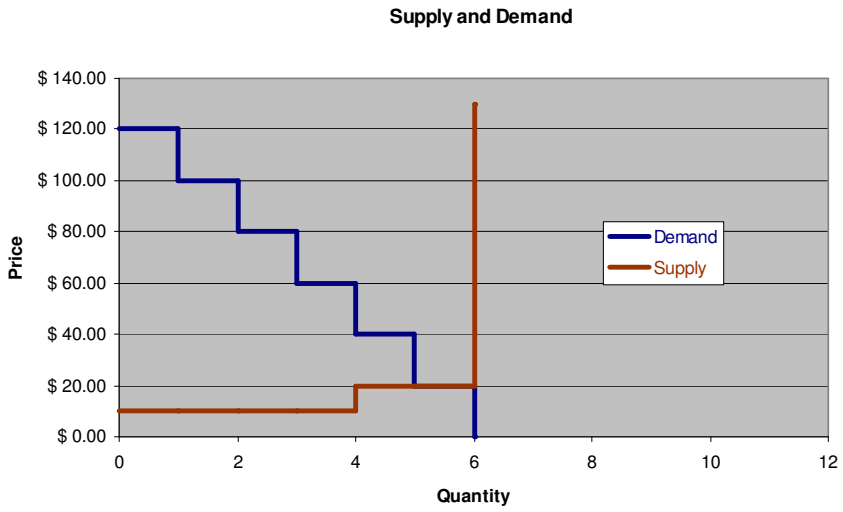


Figure 2. Equilibrium price in the experiment

The cost of each unit is the same for each firm (two units at $10/unit and one unit at $20/unit). At the competitive equilibrium price of $20, the total profit of oligopolistic firms is $40.

If one is to test the possibility of sellers to exercise market power, the specific parameters for subjects should give them an opportunity to exercise market power. In the experiment this is achieved by fixing the total supply by withholding a unit from sale to increase the equilibrium price. However, sellers were not made aware of the possibility of manipulating the market price by withholding units. Therefore they were expected to act as a) competitors or b) oligopolists by restricting output (if they work out this possibility).

The optimal output for each oligopolist[4] according to the Cournot equilibrium (where firms compete in quantities) would be $x_i = \frac{1}{n+1}$, where x_i is the output of i^{th} firm out of the total demand and n is the number of firms. If there are two producers making simultaneous decisions about quantities they are selling, the optimal output for each would be one third of the total demand, i.e. two units each[5].

If oligopolistic firms realise that by restricting output they can increase the equilibrium price of the unit, the optimal strategy for each firm would be to produce only two units. This would give the duopolists a total profit range between \$120 and \$200 because the equilibrium price would increase to the range between \$40/unit and \$60/unit (the intersection of demand and supply curves). The equilibrium price is shown in Figure 3.

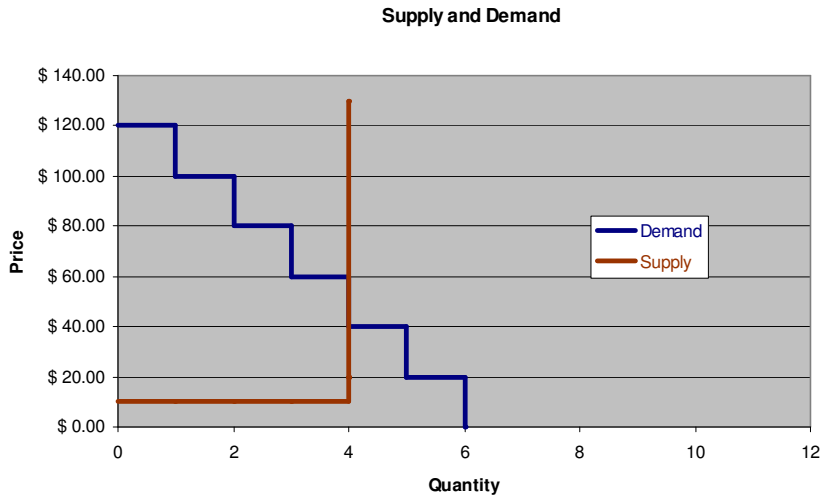


Figure 3. Supply and demand in the experiment if oligopolists restrict their outputs.

Within this context, the possibility to exercise market power further by the producer firm is to use knowledge of the existence of the penalty to sellers for not buying a certificate. The

[4] If it were a monopoly firm, the optimal output would be 3 units at lab\$60- lab\$80 price that would eventuate a monopoly profit of lab\$210.

[5] Oligopoly or duopoly in this experiment, can be seen within the game theory framework. It is assumed that the two firms behave in a way that will maximise their profit. There are three ways how duopolists can do it. First, they can collude explicitly. This option was ruled out in the experiment by not allowing any communication between market participants. Second, duopolists can use tacit collusion. In the experiment, there was no time to follow another firm's decision. Also, both firms have the same number of units and the same costs. There is no dominant firm among sellers. Third, firms could merge but it was not allowed in the experiment. Moreover, the firms did not face a "prisoner's dilemma" because the output of one firm could only meet exactly half of the demand and the prices one firm charged were not effecting the second firm's prices. Each of the oligopoly firms can only produce a fixed amount of output.

resulting contract price is expected to be near the high end (up to $60/unit) of the price range if producers are able to act aggressively, knowing that sellers will pay the penalty if they don't buy a unit. The penalty for this experiment is set at $80 unit.

4. Results

Participants

There were 18 participants, university students, both male and female of equal number, all aged a few years either side of 20. The recruitment of students took place at the University of Queensland by announcing the possibility for students to participate in a decision-making experiment among the students of economics courses. Contact details of the principal investigator had been given to students. Students were required to indicate their willingness to participate in the experiment by contacting the principal investigator. Interested students had been informed about place, time and date of the experiment.

Before the Experiment

Before the experiment started, participants were provided with the instructions. They were informed about the nature of the experiment but not about the exact purpose of the experiment, so the results would not be biased.

Participants had been required to sign a consent form after they read the "Instructions to Subjects", both to register their interest in participating and before the experiment was conducted. Participants were free to sign in just prior to the experiment if there was a shortage of participants. Two late participants were asked to remain in the computer laboratory as a reserve in case someone decided to quit the experiment. A fixed fee of $20/person was paid to these participants if no one withdrew.

This experiment took place electronically via networked computers, thus instructions and tests were in electronic form. Roles were assigned to subjects in an arbitrary way. The subjects had to answer a few questions at the end of the instructions to check whether they understood their roles. Before the actual experiment started five test periods were played. Although it was planned to have only two practice periods, the actual experiment has shown that two periods for practice is not enough for students to fully grasp their roles. Therefore the number of test periods was increased to five. The test periods did not influence the final earnings of the subjects as explained in the section above. At the end of the experiment, the budget of each

subject was converted into real money and given to the subjects. Participants' names were not recorded or published in the final results.

Trading Rules of an Experiment

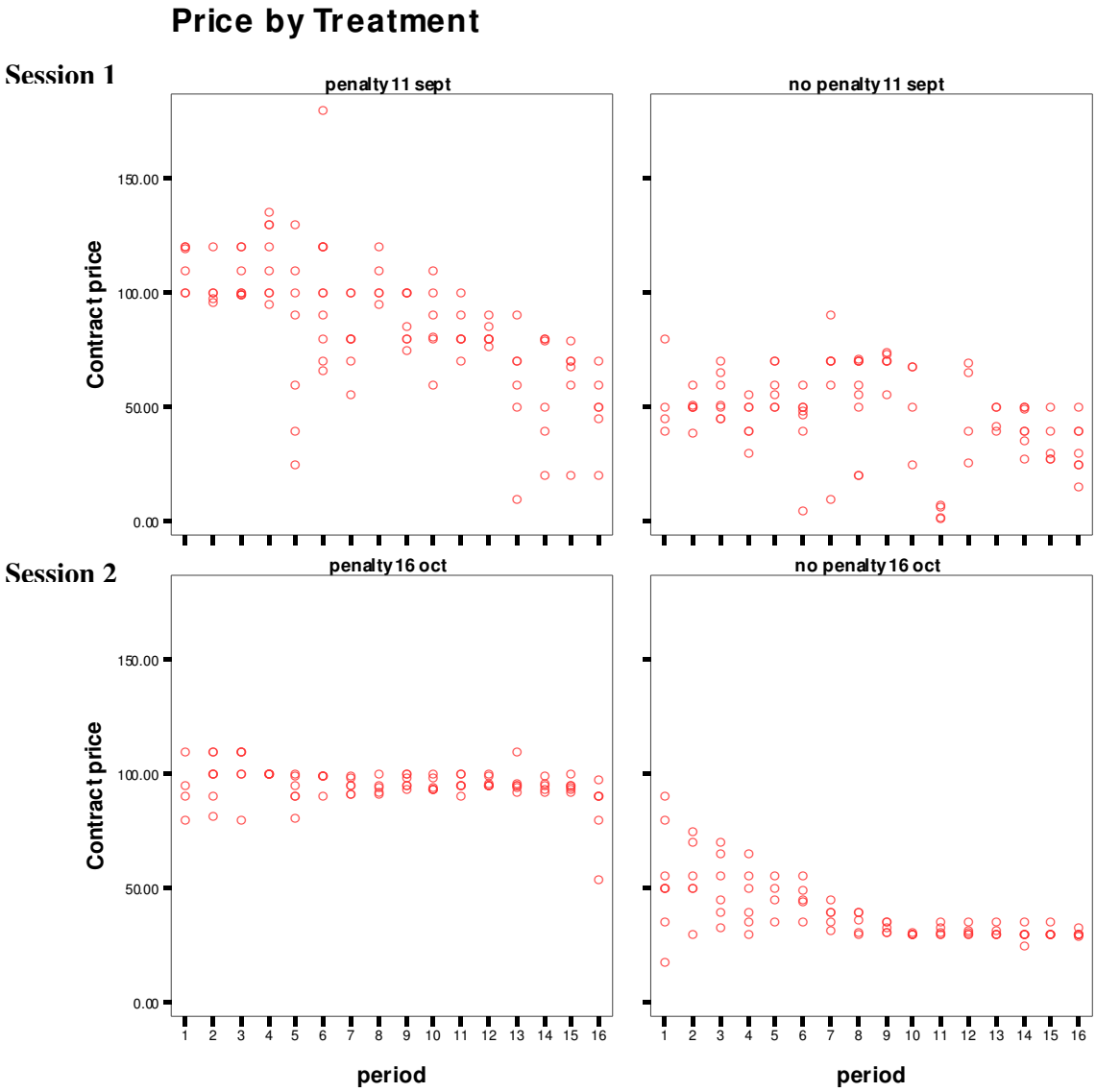
Trading rules were as follows: The market experiment was conducted as a multi period double auction. Any seller or buyer was able to bid at any time, any quantity, at any price subject to capacity and budget constraints. The market was set to be transparent.

Information on prices of offers and bids and the price of every transaction were shown to every subject. All subjects were given an initial budget of 1,000 laboratory dollars (lab$1,000). Their earnings was the difference between their budget at the end of the experiment and the initial budget. These earnings were then converted into real money.

Figure 4 shows the scatter plot of the contract price for one unit, by periods and by treatments. The first session of the experiment started by introducing the penalty into the market and then the treatment without the penalty was conducted. In the second session[6] of the experiment the order of treatments was altered. This was done to elicit the effect of the order of treatments. For illustrative purposes, Figure 4 shows the order for the second session that is the reverse of the actual order of treatments in the second session. The actual order of the second session was "no penalty" first and then "penalty" treatment second.

According to Figure 4, the presence of the penalty has an effect on prices. When the penalty was removed, the prices for the unit declined. In the second session, when the penalty was introduced, the prices jumped up and clustered around the level of the penalty, i.e. $80/unit.

[6] There were mostly different subjects and the session was run on a different day.



Source: Data from the experiment

Figure 4. Contract price for one unit by periods and by treatments, 2004.

During the penalty treatment in the first session, the average price of units declined by the end of the treatment (from about $100/unit to about $60/unit). The second treatment (no penalty) did not have the same effect. However, in the first treatment of the second session (no penalty), prices rapidly converged to about $40/unit by the 7th period.

It can be seen from Figure 4 that once sellers and buyers have been informed about the introduction of the penalty, the prices in the market increased markedly.

The penalty treatment of this experiment kept prices clustered around $100/unit. The clustering around $100/unit was expected. First, because the penalty is $80/unit and the minimum value for buyers was given at $20/unit. The price at $100/unit makes buyers indifferent between buying the unit or paying the penalty. However, many buyers have values more than $20/unit, thus it is in their interest to buy units at $100/unit and incur a smaller loss than otherwise would occur. For example, if a buyer has a value of one unit equal to $40/unit, and he/she buys a unit for $100/unit, his/her loss is $60/unit. Sixty dollars loss is less than paying $80/unit in penalty for not having a unit.

Table 3 shows the descriptive statistics for the experiments. Penalty treatments in both experiments have, on average, higher prices than no penalty treatments. However, the mean contract price of a penalty session of the second experiment is higher than the one for the first experiment. One of the sellers was the same as in the first experiment. One of the possible explanations is that this seller became more experienced in trading compared with the first experiment. That proposition, however, has been rejected after formal testing on the equality of means for experienced sellers versus an un-experienced one.

Table 3. Descriptive statistics of the experiments.

	N of contracts	Mean Contract price	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Session 1							
penalty 11	105	86.98	27.66	81.62	92.33	10.00	180.00
no penalty 11 sept	92	47.68	18.90	43.77	51.59	1.00	90.00
Session 2							
no penalty 16 oct	88	39.31	13.26	36.50	42.12	18.00	90.00
penalty 16 oct	92	95.52	7.59	93.94	97.09	54.00	110.00
Total	**377**	**68.35**	**30.53**	**65.25**	**71.44**	**1.00**	**180.00**

Source: Data from the first experiment.

The maximum possible number of contracts in each treatment (without considering the re-selling option) was 96 (6units x 16 periods). Sellers were exercising market power by withholding one or two units, especially when the penalty to buyers was introduced. The large amount (105) of contracts in the penalty treatment in session 1 was due to buyers' attempts to re-sell the units they acquired from sellers. This type of behaviour was diminished soon due to lack of time for such action. Buyers became more concerned with receiving a better price for the unit from sellers. Sellers, on the other hand, started to try to use their power and to

withhold some units from selling (only a few units were withheld). What noticeable is that sellers did not use their market power in no penalty 2nd session.

Table 3 shows that the maximum price for the unit was $180. As explained above, if the subject's value for one unit is $120 and the penalty is $80/unit, then subjects have to choose between two options when the seller offers the unit for $180. The first option is to not buy and to pay the penalty, which is a loss of $80. The second option is to buy the unit at the price of $180, and incur a loss of $60 ($120-$180). The loss in the second option is less than in the first one. The conclusion is that prices for units can be inflated and therefore they do not reflect the marginal cost of supply and cannot serve as a means of efficient resource allocation. Efficient resource allocation in this content means that high prices for units might attract higher investments in production of such units. Over investment can lead to collapsing prices as was shown in Schaeffer and Sonnemans (2000) experiment.

The theoretical competitive equilibrium price was $20/unit. However, since the sellers side was comprised of two firms, oligopolistic pricing was expected. The theoretical oligopolistic prices were between $40 and $60 per unit as explained earlier. The results have shown that the penalty affected the price increase above the expected oligopolistic prices. The mean contract price where the penalty was in place was about $87 and $96 per unit in the first and second sessions respectively. This means that the mark up ranged from 45% to almost 120%, averaging to 83% (Table 4).

Table 4. Divergence of experimental results from theoretical estimates.

	Experimental price, $/unit							
	"Penalty" treatment				"No penalty" treatment			
	Session 1		*Session 2*		*Session 1*		*Session 2*	
	87$/unit		96$/unit		48$/unit		39$/unit	
	Theoretical price, $/unit							
	40	60	40	60	40	60	40	60
Experimental price minus Theoretical price, lab$ (a)	47	27	56	36	8	-12	-1	-21
Difference (a) to theoretical price, % (b)	118%	45%	140%	60%	20%	-20%	-3%	-35%
Difference to the average theoretical price of $50, lab$ (c)	92%		74%		-4%		-22%	
Average for treatment to the average theoretical price of $50, lab$ (d)	83%				-13%			

Source: Data from experiments

In the treatments where the penalty was not introduced, prices converged to the average theoretical oligopolistic price in one session (almost zero difference) or to even lower than the average theoretical oligopolistic price in another session (average for that session was lower than theoretically predicted by 22%). The average experimental price for "no penalty" treatment was 13% less than theoretically predicted. This means that at times sellers did not exercise their market power. For "no penalty" treatments, the examination of the 95% confidence intervals for the mean price of units showed that the price for "no penalty" treatment lies within theoretically predicted prices with an exception of the lower bound at session 2. The low prices in the second session might be due to more competitive behaviour from the buyers' side who began to behave aggressively towards the end of the treatment. This suggests that the double auction market mechanism is a very effective one to achieve and maintain a competitive market outcome even in the duopolistic market structure.

Table 5 provides the results of a one way analysis of variance for testing the 1st hypothesis.

Table 5. ANOVA for Contract price

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	217829.914	3	72609.971	204.142	.000
Within Groups	132669.868	373	355.683		
Total	350499.782	376			

Table 5 shows that there is a significant difference in the mean contract price in different treatments. Thus, the null hypothesis is rejected and the conclusion can be drawn that there is

sufficient evidence that the mean price of units, when a penalty for non-compliance is imposed on buyers in a competitive market and where the supply side is oligopolistic, is significantly different to the mean price of units when a penalty for non-compliance is not imposed on buyers in a competitive market and where the supply side is oligopolistic.

In order to find out which treatment has the most effect on prices, the following tests for a difference, shown in Table 6, have been set.

Table 6. Tests for a difference (contrast coefficients)

Tests for a difference	Penalty 11 sept	No penalty 11 sept	Penalty 16 oct	No penalty 16 oct
1	-1	-1	1	1
2	-1	1	0	0
3	0	0	-1	1
4	-1	0	1	0
5	0	-1	0	1

The first test for a difference compares the means of the first session with the means of the second session. This test for a difference examines if there is any difference in the order of the treatments. The second test for a difference compares the penalty treatment from the first session with no penalty treatment from the same (first) session. The third test for a difference compares the penalty treatment in the second session with no penalty treatment in the same (second) session. The second and third tests for a difference are set to examine whether the penalty has an effect on price. The fourth and the fifth tests for a difference compare penalty and no penalty treatments in the first and second session respectively. Table 7 presents the results of the tests.

Table 7. Tests for a difference

Contract price	Test for a difference	Value of test	Std. Error	t	df	Sig. (2-tailed)
Does not assume equal variances[7]	1	.1742	3.71468	.047	262	.963
	2	-39.2962	3.34272	-11.756	185	.000
	3	-56.2036	1.62020	-34.689	137	.000
	4	8.5408	2.81377	3.035	122	.003
	5	-8.3666	2.42518	-3.450	164	.001

[7] The Levene's Test for Equality of Variances has shown that the variances are not equal in the two sessions. Thus, the test for non equal variances should be used although tests, assuming equal variance, or not assuming equal variances, produced similar results.

The test (Table 7) has shown that there are significant differences in contract prices due to the presence of the penalty (Figure 5) but not due to the order effect[8] (Figure 6). It is illustrated in Figure 5, where two box plots are presented for the prices in the two sessions.

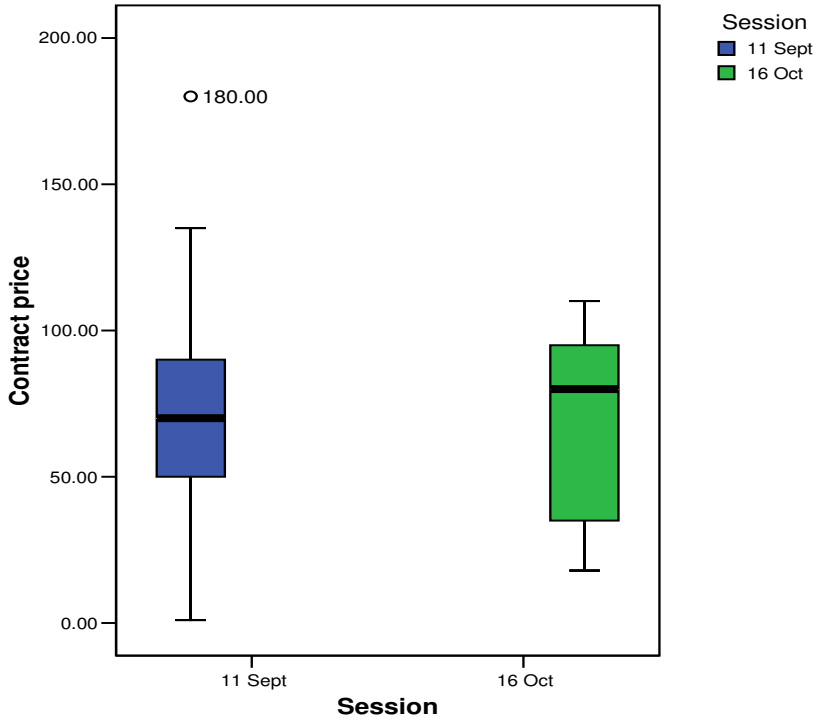


Figure 5. Box plots of price per session

The box plots summarise the median, quartiles and extreme values for the price variable, within clusters defined by a categorical variable, i.e. session. Each box within a cluster is defined by a second categorical variable, i.e. treatment (Figure 6).

The two sessions have similar prices: when we compare the effect of introducing the penalty to the market or the effect of removing the penalty from the market, the resulting average market price of units will be similar. In the context of oligopolistic supply side market structure if the penalty is introduced and then removed, the price of units will be lower compared with the situation when the penalty is introduced into the market that was functioning without the penalty. However, if a penalty free market existed before the

[8] An equality of means between sessions has been tested using the t-test for Equality of Means. This test has been performed to confirm the results obtained from the contrasts coefficients.

introduction of the penalty (session 2), the prices of units under "no penalty" treatment would be lower than after removing the penalty from the market (session 1).

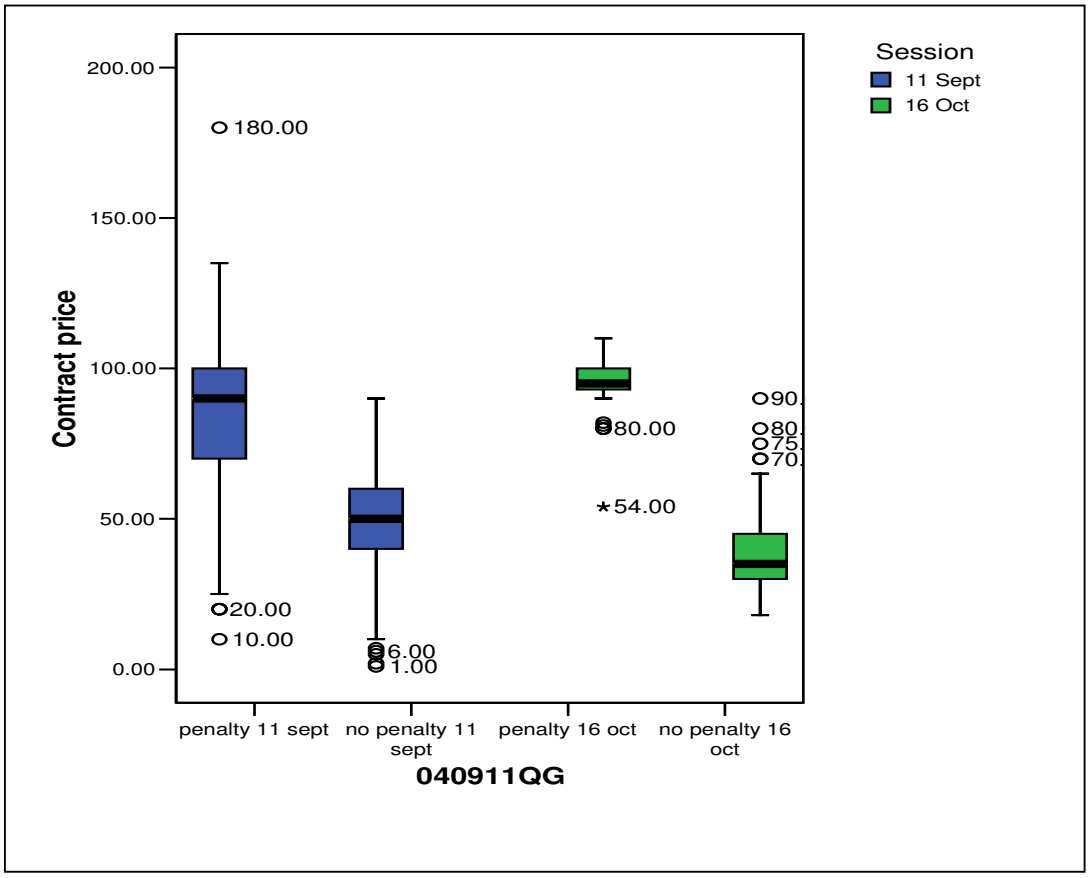


Figure 6. Box plots of price per treatment.

Figure 6, on the other hand, shows a significant difference in prices in different treatments.

The learning effect is also significant even after controlling for treatment. Table 8 presents Anova table testing the effect of periods.

Table 8. Anova test for the effect of period on contract price

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	70098.248	2	35049.124	46.749	.000
Residual	280401.535	374	749.737		
Total	350499.782	376			

The following analogy can be made: the longer the policy is in place, the closer the prices of RECs move to the competitive theoretical equilibrium due to the learning effect. The policy implication is clear – the policy should provide a stable environment for learning the rules and

market strategies to achieve a competitive outcome. It means that abolishing the MRET policy already in place, as proposed by Parer (2002), may not give the REC market enough time to learn the rules and to become efficient in achieving the renewable energy target in a least cost manner.

Table 9 provides the correlation coefficients for contract price, the number of periods and treatment. It shows that the contract price is negatively correlated with the period. This means that the contract prices for units declines during experiments as can be seen from the Figure 4 possibly due to the learning effect.

Table 9. Correlation coefficients (contract price, number of periods and treatment)

		Contract price	Period	Treatment
Pearson Correlation	Contract price	1.000		
	Period	-.280	1.000	
	Treatment	-.353	.014	1.000
Sig. (1-tailed)	Contract price	.	.000	.000
	Period	.000	.	.393
	Treatment	.000	.393	.
N	Contract price	377	377	377
	Period	377	377	377
	Treatment	377	377	377

The statistical tests performed were conducted to determine whether the penalty has an effect on price setting in the market. The results have shown that such an effect exists. The effect of the order in which the penalty was imposed was not significant. The impact of oligopoly on the supply side when the penalty is present is such that the prices for REC are likely to be in their higher range even if oligopolistic firm does not restrict it's output. The reason for a high price is the presence of a penalty that buyers would have to pay if they don't comply with their regulatory obligation. The knowledge of the level of penalty works as a starting point for sellers to sell their units.

5. Summary

The experiment was set up to test the issues expressed in the McLennan Magasinik Associates report (1999) and the report named "Modelling the Price of RECs Under the Mandatory Energy Target", also by McLennan Magasinik Associates (2002) whose (non-experimental) investigations expressed concern about, and indicated some evidence for, the existence of market power in the Australian REC market. A review of the relevant literature has suggested that the possible reason for high prices for RECs can be the presence of the penalty imposed on retailers for non-compliance. This aspect of the REC market design was examined in

order to elicit this effect. The importance of price control in the REC market was pointed out by Voogt et al. (2000), who stated that the penalty is needed to make a market for RECs work.

The effect of price control on the behaviour of a competitive market was investigated by Isaac and Plott (1981) and Smith (1982). Their research indicated that imposing the maximum price in a competitive market might cause divergence from the competitive equilibrium price. This means that the penalty as a maximum price might have an effect on the competitive equilibrium price of RECs. A penalty higher than this equilibrium price might affect the market price for RECs.

On the other hand, it was experimentally shown by Schaeffer and Sonnemans (2000) that the size of the penalty plays an important role in the RECs market. Their results supported the "focal" theory of the role of a high penalty as a price control. When the penalty was set high, the price of certificates was higher than the competitive equilibrium price. However, this result should be taken with caution. The Schaeffer and Sonnemans (2000) study combined voluntary and mandatory demands and they did not account for the effect of voluntary demand separately. This might be the reason why the price for RECs was higher than the equilibrium price in their experiments. The experiment described in this article aims to separate the effect of the presence of voluntary demand on price of RECs under a non-binding price control. In this experiment, the demand for units is mandatory (there is no voluntary demand) to make the results of the effect of the penalty specific for mandatory demand.

This experiment can be used to provide regulators with information concerning the likely effect of the penalty imposed on retailers in a duopolistic market structure on the supply side on the price for RECs. This can help to set optimal policy. The results showed that if the penalty is set higher than the competitive equilibrium price (at the intersection of supply of RECs and mandatory demand for them), there is a potential for price of REC being higher than competitive equilibrium and just under the level of penalty due to a) public knowledge of the existence of the penalty imposed on retailers for non-compliance, b) public knowledge of the level of penalty and c) market power of producers. Stylised experiment presented in this article highlighted that sellers' knowledge of the existence of the penalty and its level in the duopoly market pushed prices for REC higher than would occur in competitive market without penalty or without knowledge of the existence and level of the penalty. The level of penalty was used by sellers as a "focal" point for setting the price for the unit.

The advantage of this for the development of renewable energy technologies is obvious in the initial short run – investments in renewable energy technologies will be attractive for electricity producers. However, in the long run, overcapacity of renewable energy technologies compared with the required mandatory production of electricity from such technologies can reduce profit of electricity producers and lead to reducing returns on investments. This result was demonstrated by Schaeffer and Sonnemans (2000).

Another important result was that the market needs time to become efficient – the learning effect in such a market is very important. Therefore, abolishing the current policy too early would not allow the market to come to it's long-run equilibrium. An additional experimental test[9] including 4 sellers and 4 buyers was conducted by the author to investigate the effect of increasing competition on supply side. The results showed that increasing competition on supply side (from 2 to 4 sellers) does not eliminate the effect of presence of penalty – the prices for REC in the experiment were higher than theoretical prices. Further research is needed to elicit the effect of the market structure (i.e. duopoly on supply) when penalty is imposed on the buyers, e.g. the effect of knowledge of the level of penalty.

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[9] The set up of the experiment was the same as described in the paper but the number of sellers was larger and the number of buyers was smaller compared with this experiment.

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