The impact of the delay between energy generation and REC creation in MRET

A laboratory investigation on the performance of the Australian Renewable Energy Market

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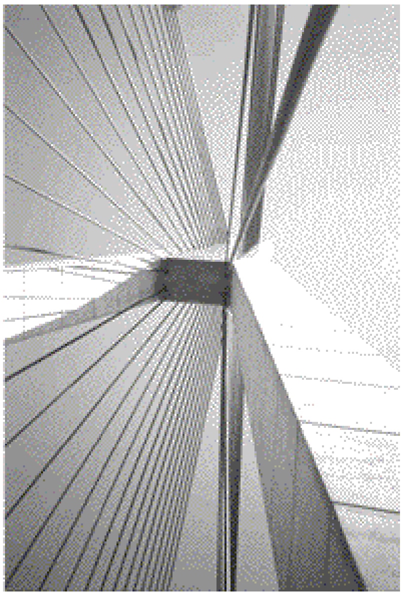

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EXECUTIVE SUMMARY

The centrepiece policy of the Australian Government in respect of supporting renewable energy generation is the Mandatory Renewable Energy Target (MRET), implemented by way of a tradeable Renewable Energy Certificate (REC).

Each REC represents proof of the generation of one Megawatt Hour (MWh) of electricity from an eligible form of renewable generation.

In summary, generators produce RECs, retailers purchase RECs and then acquit a targeted number of RECs to the Australian Government annually. Failure by a retailer to supply the target of RECs is penalised at a tax effective rate of $57 per REC short[1]. Thus the retailers in effect are collecting a subsidy from electricity consumers, and passing it to renewable energy generators via a market mechanism. The policy intent was to use a market to minimise the cost of meeting the target quantity of energy.

Two features of the MRET market are discussed in this report.

- Firstly, that while both retailers and generators can bank RECs from year to year, only retailers face a "hard[2]" annual target with a penalty for non compliance. This asymmetry in the market means that retailers face considerable risk from being non-compliant. In the experiments discussed in this report, retailer participants were consistently paying well above "rational" prices for RECs, despite their supposed market dominance. We suggest that this is due to the risk asymmetry, which places generators in a comparatively stronger position than a simple market share analysis would imply. ***This would also imply that the assumption that this market architecture will lead to least cost implementation of the target may be badly violated in the real MRET market, and other markets with similar architecture.*** This would match with evidence that the forward price for NSW Greenhouse Gas Abatement Certificates (another scheme with a similar market architecture) is at or above the time adjusted value of the penalty, indicating that the retailers prefer to pay over the penalty rate in order to be 'compliant' – which in economic terms is irrational behaviour.
- Secondly, a most unusual feature of the real MRET market is that a delay measured in years can exist between when energy is generated and when the associated certificate is created and becomes visible to the market. It has been proposed to reduce this delay to 12 months. In this report we experimentally investigate the impact of existing rule, and an alternative where certificates are created "instantly". ***This simple rule change dramatically alters the performance of the market – with prices rising markedly and the distribution of benefits altering.***

We also suggest that prices are strongly influenced by the level at which the non-compliance penalty is set, not by the underlying cost of supplying the renewable energy, although these experiments were not configured to specifically test this matter.

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[1] The penalty rate is fixed at $40, however as a penalty, it is not a tax deductible expense, hence the effective penalty rate for is found by adjusting for the 30% corporate tax rate, giving $57 per unit short.

[2] There are some flexibility mechanisms in the MRET market, allowing retailers to be slightly non-compliant in a particular year.

INTRODUCTION

The centrepiece policy of the Australian Government in respect of supporting renewable energy generation is the Mandatory Renewable Energy Target (MRET). Commencing operation in 2001[3], MRET requires all electricity retailers and direct large consumers to source additional energy from "new"[4] renewable energy sources, rising from an initial 300GWh per annum (2001) to an eventual 9500GWh per annum (2010), and remaining at that level until 2015. Compliance against the scheme is verified by way of a tradeable certificate, called a Renewable Energy Certificate (REC). Each REC represents proof of the generation of one Megawatt Hour (MWh) of electricity from an eligible form of renewable generation.

In summary, generators produce RECs, retailers purchase RECs and then acquit a targeted number of RECs to the Australian Government annually. Thus the retailers in effect are collecting a subsidy from electricity consumers, and passing it to renewable energy generators.

One unusual feature of the MRET market is that a considerable delay (of up to the remaining life of the scheme – currently 9 years) can exist between when a MWh of energy is generated and when the associated REC is created. It is not until the REC is created that it becomes "visible" to other market participants. Having been created, the generator participant can then chose when to sell that REC.

A government review of the scheme in 2003 recommended that this rule be altered (Tambling, Laver et al. 2003), and the Australian Government has announced a proposed change to reduce the allowed period to one year from the time of generation.

This paper experimentally investigated two versions of the MRET institution – one where the existing MRET rules applied (that is, RECs can be created anytime before the end of the market), and an alternative where RECs are created "instantly" when the underlying energy is generated.

We find that this simple rule change dramatically alters the performance of the market – in particular overall societal welfare (meaning achieving the targeted quantity of renewable energy at least incurred cost) is promoted under the "instant create" case, but the distribution of the benefits is substantially altered, and market prices are substantially higher – thus generators in fact receive a larger subsidy than required.

We suggest that the prices prevailing in the market to have less to do with the supply/demand balance than with strategic behaviour by generators knowing that retailers face a penalty rate and annual compliance process.

That is, we suggest that prices are influenced more by the level at which the penalty rate is set, rather than by the genuine costs of supplying the targeted quantity of renewable energy.

This implies that the current MRET style institution (at least in the absence of an efficient forward market) will NOT deliver the targeted quantity of renewable energy at least cost to electricity consumers.

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[3] MRET was formally established under The Renewable Energy (Electricity) Act 2000 and the Renewable Energy (Electricity) (Charge) Act 2000.

[4] The scheme definitions are such that additional generation above a "baseline" from existing "old" renewable energy plants also counts.

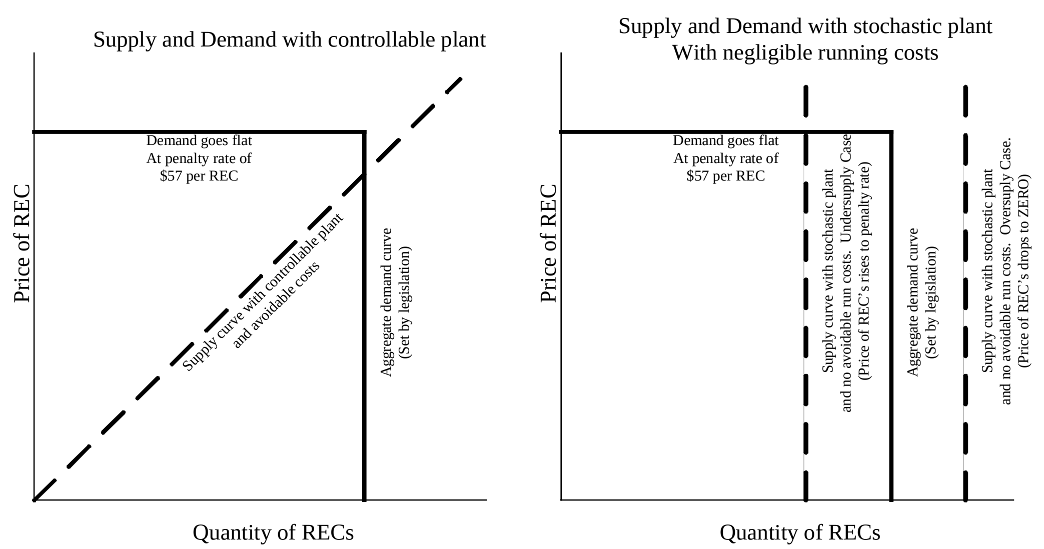
MODELS

Market participants in many markets can make short-term adjustment to changes in prices, however in the MRET market no such short-term adjustments are possible. As (Chupka 2003) points out, the demand for RECs from retailers is driven by their sales of electricity to end-use consumers, and thus is essentially non-controllable from the perspective of the retailers. In economic terms, the demand curve is vertical, up to the $57 per REC penalty rate, at which point it becomes horizontal.

It is also important to note that in the short term the supply of RECs is relatively inelastic – at least in so far as RECs are being generated from renewable sources with a stochastic output (such as wind farms or solar power). Many of the key forms of renewable energy are high capital expenditure (CAPEX) and low operational expenditure (OPEX) – that is – once the plant is constructed the costs are fully sunk, and operational (and controllable if the plant is has control over operation) costs are minimal. For these producers, it is rational to sell RECs for any positive price, regardless of the annualised cost of production. Other REC producers, such as hydropower, biomass and certain other forms of "renewable" energy are controllable, and have non-trivial operating costs. Having such producers in the market is a key element of ensuring that the market has an achievable equilibrium position.

Consider a REC style market that consisted either ONLY of stochastic plant with high CAPEX and zero OPEX, or only of a single form of controllable plant with a linear rising marginal production cost. In the stochastic case such a market would have near vertical supply and demand curves, and would be prone to enormous price volatility between the penalty rate ($57 per REC tax adjusted in the real MRET market) and zero. This is contrasted with the case of a controllable plant in figure 1.

Figure 1 - Conceptual Supply and Demand in the MRET market



MRET as a policy tool

The motivation for using a market was to deliver the targeted quantity of renewable energy at minimal societal cost. Markets have proved a powerful tool for achieving a reduction in the cost of meeting stated policy objectives - (Ellerman, Joskow et al. 2003) conducted a review of a range of environmental markets, and concluded that a cost reduction of in the order of 50% compared to the use of “command and control” type regulatory arrangements was achieved from the application of a market mechanism. However to achieve the cost minimisation goal requires the market to reach an equilibrium price that provides both:

- The correct incentive for investment in new generation – to the point of meeting the target and,
- Driving appropriate use of the existing generation plant.

Considering the MRET market design leads to some questions as to the likelihood of the market in fact operating to minimise the cost of the environmental target, due to the lack of information about the amount of generation that has already occurred. The lack of this information – stemming from RECs not being visible to the market although the production (and cost) of the underlying energy has already occurred - means that generators have incentive to attempt to over-generate and under-reveal.

The Supply and Demand Parameterisation

We consulted with professional REC traders to develop a realistic scenario of the known and probable generation plant within the MRET market.

The parameterisation is summarised in Table 1 and Table 2 below.

Table 1: Demand Characterisation – Annual and cumulative target by period

Period	Target	Cumulative Target
2000	300 MWh	300 MWh
2001	1,100 MWh	1,400 MWh
2002	1,800 MWh	3,200 MWh
2003	2,600 MWh	5,800 MWh
2004	3,400 MWh	9,200 MWh
2005	4,500 MWh	13,700 MWh
2006	5,600 MWh	19,300 MWh
2007	6,800 MWh	26,100 MWh
2008	8,100 MWh	34,200 MWh
2009	9,500 MWh	43,700 MWh
2010	9,500 MWh	53,200 MWh
2011	9,500 MWh	62,700 MWh
2012	9,500 MWh	72,200 MWh
2013	9,500 MWh	81,700 MWh
2014	9,500 MWh	91,200 MWh

Table 1 shows the target for “RECs” (representing MWh of certified renewable energy) for all electricity retailers (taken as a group.) These targets match the targets specified in the actual Mandatory Renewable Energy Target Market. In the real MRET, the target is then allocated between electricity retailers on the basis of their market share of electricity sales. In our experiment, the target is split equally in each period between two retailer participants.

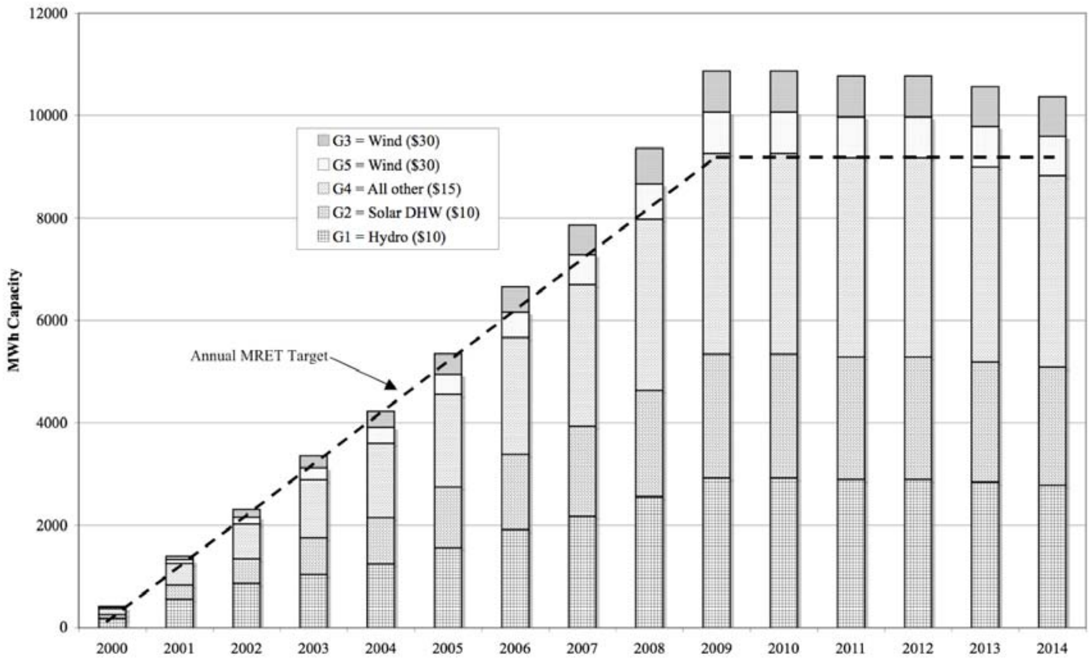
Table 2: Supply Characterisations by participant and in total by period

Period	(1) G1 = Hydro ($10)	(2) G2 = Solar DHW ($10)	(3) G4 = All other ($15)	(4) G3 = Wind ($30)	(5) G5 = Wind ($30)	(6) Supply Cap.	(7) Potential Over Supply (Supply minus Target)	(8) Cum. Supply	(9) Cum. Over Supply	(10) Supply from G3+ G4+G5
2000	176	78	121	16	16	407	107	407	107	152
2001	554	277	422	66	66	1,385	287	1,792	392	554
2002	864	475	680	140	140	2,299	500	4,091	892	961
2003	1,030	718	1,139	234	234	3,355	754	7,446	1,646	1,607
2004	1,251	899	1,447	313	313	4,223	823	11,669	2,469	2,072
2005	1,559	1,188	1,807	396	396	5,346	846	17,015	3,315	2,599
2006	1,910	1,478	2,279	493	493	6,653	1,053	23,668	4,368	3,265
2007	2,183	1,746	2,765	582	582	7,858	1,058	31,526	5,426	3,929
2008	2,557	2,080	3,337	693	693	9,360	1,260	40,886	6,686	4,724
2009	2,920	2,417	3,927	806	806	10,876	1,376	51,762	8,062	5,539
2010	2,920	2,417	3,927	806	806	10,876	1,376	62,638	9,437	5,539
2011	2,893	2,394	3,890	798	798	10,773	1,273	73,411	10,710	5,486
2012	2,893	2,394	3,890	798	798	10,773	1,273	84,184	11,983	5,486
2013	2,838	2,348	3,816	783	783	10,568	1,068	94,752	13,051	5,382
2014	2,783	2,303	3,742	768	768	10,364	863	105,116	13,914	5,277

Table two shows the supply side parameterisation. Notice that there are two participants playing the part of wind generators – this was done to ensure that there was some additional competitive pressure at the top of the supply curve. This is of less importance in the current experiment (where in most periods there are three generator participants at or above the margin), however in other experiments conducted in this research program, all using the same supply side parameters, there are occasions where the wind generator was on the margin, and hence it was split between two players. This issue does not affect the interpretation of this experiment.

More details about the supply side characteristics are provided in Section 3. The overall supply capacity (columns 1-5 in Table 1 above) and the target in each period (Table 2 above) is shown graphically in Figure 2 on the following page.

Figure 2: Supply and demand characterisation



A simple supply/demand view of price paths

It is critical to note that G2, G4 and G5 are uncontrollable – that is – they are forced to generate to their supply capacity each period. For these participants it is rational to sell units at ANY positive price, since their costs are sunk. Thus despite their apparent costs, they should be prepared to bid at slightly above zero.

Thus it is supplier G1 (hydro, cost $10/MWh) and G3 (“other”, cost $15/MWh) that present the driving force for market performance.

Notice that for the first 4 periods, the cumulative over-supply is less than the capacity of G3 + G4 + G5 (see columns 9 and 10 of Table 2). Since G4 is controllable, and G3 and G5 are not, G4 represents the marginal generator. Thus in the event that all generators are running, it would be reasonable to expect prices to be close to $15/REC for the first 4 periods.

After the 4th period, sufficient generation has occurred to ensure that with G1, G2, G4 and G5 running that the target will be met in each year. At this point, to meet the cost minimisation objective of the market (that is, achieving the set quantity at the lowest cost), G3 should turn off (since G3 is a higher cost unit ($15/MWh) than G1 ($10/MWh), which should continue to run.)

For G3 to have commercial reason to switch off, the price should fall below $15/REC – and be close to the production cost of G1 ($10/REC).

Thus, a simplistic analysis on the assumption that decisions are made purely on available price information would suggest that prices should be around $15/REC for periods 1-4, and decline after that to around $10/REC.

A more game theoretic perspective of possible price paths

However, recall that the market structure is such that generators can bank both MWh and RECs from year to year, while Retailers face a hard “annual acquittal” target. The market is thus asymmetric, in that:

- Retailers face a high cost of non-compliance, and are rationally fearful of being charged the penalty rate.
- Generators do not face any immediate cost in withholding RECs from the market from period to period, minus the opportunity cost of keeping it.

Generators may thus realise that withholding creation of RECs causes prices to rise towards the penalty level, even though an actual position of over-supply (of MWh generated) may exist in a given period). This is a profitable strategy in early periods since unsold over-production in one period can be rolled forward into the next. However, since generators as a group cannot know how much production has occurred, the “hidden oversupply” would grow larger in each period, and ultimately the withholding strategy should fail – as “long” generators would rush to market to sell RECs created on energy produced in previous periods before the end of the market, and the prices could be expected to decline. Potentially an absolute oversupply could exist by the end of the market, in which case prices should decline towards Zero.

Thus we hypothesise that the combination of annual targets on the retailers with indefinite delay in creation and banking for the generators would mean that generators as a group would tend to over-produce RECs under such a market institution, since the price prevailing in the market may not accurately reflect the true supply/demand balance, and no upper-limit information on production is available.

Once over-generation has occurred, given that the costs are sunk, the incentive upon generators is to sell the associated RECs at any positive price to attempt to recoup at least some of the generation cost. Thus once the market has discovered that an over-supply exists the price can be expected to fall rapidly as an oversupply of RECs seeks to meet a vertical demand curve.

Thus, on this analysis, one would expect prices to commence well above the equilibrium (of $15/REC in period 1), and continue at a high price until later periods, at which time the prices would decline sharply.

We suggest that providing the market the information about actual generation production levels by requiring RECs to be created instantly when energy is produced, should remove the attraction of this strategy, since generators would be able to see when an oversupply was occurring, and make production decisions accordingly.

However, this provides an alternative problem, in that the two controllable generators will have some ability and incentive to ensure that the supply/demand balance is tighter. Thus the combination of additional information and a vertical demand curve will actually lead to increased market power of incumbents.

By this line of thought, we would expect that if the RECs are being instantly created that quantity produced will be lower, but that prices will be higher, and stay higher for longer, as compared to the delayed create case.

In both cases, the above line of analysis would suggest that prices would be well above the equilibrium price.

Some notes on the role of the forward market

In the real MRET an active forward contract market is a critically important aspect of the operation of the scheme. It is the forward market that provides the revenue protection required by individuals to make investments into renewable plant – and thus in many respects the forward market is the most important market aspect for achieving the desired policy objective of new investment into renewable generation plant.

This is significant in the current context since it is sometimes argued that whatever problems exist in the spot market architecture of MRET (such as the indefinite banking and the information problem around the timing of REC creation that are discussed in this laboratory investigation) can be overcome through the price signals from the forward market.

As noted by (AFMA 2003) this appears to put considerable faith in the forward market to correct underlying difficulties in the spot market design.

The MRET legislation essentially created a tradeable instrument and a registry. At no point in the legislation is forward trading of RECs mentioned. The importance of the forward market was however highlighted in a number of submissions to the Australian Government review of the MRET scheme in 2003, particularly (AFMA 2003; ANZ Infrastructure Services 2003; Babcock and Brown 2003), and ultimately the resulting review report (Tambling, Laver, Oliphant and Stevens 2003) also noted the importance of the forward markets, without making any particular recommendations.

Conceptually though the argument that an unstable spot market can be assisted to equilibrium by the forward market is correct and supported by a considerable volume of experimental economics work[5]. Thus we note that some of the questions raised by the results in this paper about the performance of the spot market for RECs may be overcome – or ameliorated to some degree – in the real world from the existence of an active forward market for RECs, and this is a fruitful area for follow-on experimental research.

[5] Experimental work done by Porter, D. and V. L. Smith (2003), and Smith, V. L., G. L. Suchanek and A. W. Williams (1988) among others have shown spot markets for assets are susceptible to price bubbles, even in cases where the market is for assets with a common and uniformly known value As theoretically demonstrated by Allaz, B. and J.-L. Vila (1993) and experimental confirmed by others such as Brandts, J., P. Pezanis-Christou and A. Schram (2003) the existence of a forward market can assist overcome these asset bubbles by providing additional information to the market participants.

Hypotheses

Taking the above, we make the following hypotheses for laboratory evaluation between an "*instant creation"* and a "*delayed creation"* case:

Hypothesis 1: Total MWh generation across all generators in the "delayed creation" case will be higher than in the "instant creation case", and hence will be in "over-supply" compared to the quantity of production targeted by the "policy". Accordingly the overall societal cost (being the total cost of energy generated) will be higher in the "delayed creation" case than in the "instant creation" case, simply because in the delayed creation case generators as a group will tend to over-produce, and this extra production incurs a cost.

Hypothesis 2: Prices in the "delayed creation case" will be high (at or near the penalty rate) in early periods, and will then be significantly lower on average in later periods.

Hypothesis 3: Prices in the "instant create" case will be higher on average in later periods than in the "delayed create" case.

An experiment was conducted to test these hypotheses, and we now proceed to discussing the experimental implementation and results.

The experiment used a computer network-based market of 5 generators (the supply side) and 2 retailers (the demand side), who participate in a market for "Units" (representing RECs) over 15 annual periods (described as the years 2000 to 2014). The experiment was implemented using Java – with clients running as applets inside web-browsers. The experimental software is an extension of an experimental platform specifically developed at our laboratory.

To ensure no expectation bias the experiments did not refer to "renewable energy" or to "RECS" – instead using the neutral term "units" which could then be traded.

Each experimental year comprises 360 experimental days. The entire experiment (15 years each of 360 days) takes approximately 50 minutes to run – thus each year (compliance period) lasts approximately 3 minutes.

Treatments

Two treatments were conducted:

- "*Delayed Creation"* Case – A parameterisation of the market where supply was modelled off actual supply in the MRET market, and where generator participants could chose at what point to create "units" up until the end of the experiment.
- *"Instant Create"* Case – The same parameterisation of the market as for the delayed create case (in terms of the supply and demand), however participants no longer had the ability to chose when to create "units" – they were instantly created as energy was produced.

Experimental Environment

Supply Side

The supply side of the market is represented by "Generators", which are defined to have a production capacity (in MWh) and production cost (in $/MWh) in each period. As each experimental day ticks the "MWh output" for each generator rises (unless they have "switched off" their generator), and their bank balance is decreasing at their production cost multiplied by their generation output on that day. Each generator participant was given a cash endowment such that if they simply ran their generator throughout the experiment, without selling ANY output, their bank balance would be $E0 at the end of the experiment. In practical terms this removed the ability of the generators to go bankrupt during the experiment. In the *instant create* case, once MWh have been generated, they are immediately converted to units. In the *delayed create* case participants can chose when to convert their MWh to units

Once the generator participant holds units, they may sell these in the market. If these units are sold at above the production cost, then the participant makes a profit.

For each generator participant there are several controllable parameters. After discussions with people who are active in the MRET market, a set of parameters (in terms of costs and capacities in each period) was prepared. These parameters represent a realistic scenario for the real MRET market – given currently constructed, announced and expected plant.

The key parameters for each generator are as follows:

Table 3: Key Parameters for Generator Participants

Parameter	Characteristic	Valid Values
Generation Capacity	The "MWh" generation capacity each experimental year for the generator. This value is divided by 360, to provide a daily capacity. Each day the generator is running their MWh balance increases by this amount.	An integer value, one defined for each year of the experiment.
Generation Cost	A $/MWh production cost, specified for each year of the experiment. If the generator is running, their production that day is multiplied by this per-unit cost to prepare a daily run cost. This is then deducted from the generator participants' bank accounts.	A float value, defined for each year of the experiment. In this experiment, each generator had a constant cost throughout.
REC Creation Choice	If true, a generator participant may chose when to convert MWh to Units (which may then be sold). In this experiment, this parameter is set to TRUE for all participants in "Delayed Create Case" and FALSE for all participants in the "Instant Create Case".	TRUE/FALSE
Control Generation Choice	Some generators can control whether to run their plant or not. (For example, hydro generators can control their run hours), other types of plant (such as Solar Cells or Wind) are essentially uncontrollable, and just run continually subject to weather conditions.	TRUE/FALSE If True, the participant can control if their generator runs each day.

In all 12 sessions (6 sessions of each treatment) there were 5 generator participants. Participants G1 and G4 could control the operation of their generator, while the other generator participants were "uncontrollable" and would just generate throughout the experiment. This distinction is to reflect that in the real market some renewable generation plant (such as Hydro Electricity) can control their output, whilst others (such as Solar Cells) simply produce according to the amount of sunlight in an uncontrollable manner.

An example, drawn from a particular experimental year (the year 2005) is in Table 4 below. Cost and controllability for each participant remain constant throughout the experiment, and the generation capacity rises each period. The increases in capacity are in line with advice we received from active REC traders as to the current and committed generation plant.

Table 4: Values of Key Parameters – example for experimental year 2005

	Represents	Generation Capacity (MWh) in 2005	Run Cost in 2005 ($/MWh)	Control Operation
Generator 1	Hydro	1,559 MWh	$10.00	Yes
Generator 2	Solar DHW	1,188 MWh	$10.00	No
Generator 3	Wind	396 MWh	$30.00	No
Generator 4	All Other (Inc Landfill)	1,807 MWh	$15.00	Yes
Generator 5	Wind	396 MWh	$30.00	No

This table could be repeated for each "year" of the experiment, with costs being held constant, but with the projected capacity of each generation form increasing. Taken together the total supply model is shown in Figure 2.

Demand Side

Retailers have an annual compliance target which increases at each experimental year (as shown in Figure 3). Retailers are fined at the rate of $e57 per unit short at the end of each period if they do not meet their compliance target for that period. The retailer target is modelled off the actual MRET targets. Retailers are given an initial cash endowment such that if they did nothing (and hence were non-compliant each period for the full value of their target) their closing balance would be $e0. This removes any practical likelihood of retailer participants going "bankrupt" during the experiment.

For this experiment two identical retailers were configured, each being allocated half of the MRET target in each period. The retailer participants were drawn at random from the subject pool each session.

It may be suggested that two retailers are insufficient for a competitive outcome, and that we should have used three or more retailers to reduce the potential for retailers to engage in monopsonistic behaviours. Several factors were at play in our decision to proceed with only two retailers. Firstly, our hypotheses are such that we are expecting generators to force prices higher than the efficient market prices. Thus, if the two retailers are able to exercise any market power, then this will be contrary to our expected finding, and hence if we still find that generators are able to inflate prices we may be confident that the "rush to trade" due to the retailers facing an annual non-compliance penalty effect is outweighing any market power effect on the supply side.

Secondly in the real MRET market there are a small number of large retailers, and a larger number of very small ones. There are a number of reasons to believe (compliance issues aside) that in the real world the retailers would be able to exert downward pressure on the REC prices.

Thirdly, in previous trial experimental runs (not written up) where we compared the two retailer cases against cases with more retailers, in this form of "compliance" market, where the retailer participants are forced to be compliant each period, there has been little evidence of collusion or other non-competitive behaviour. It is suggested that this is due to the high penalty applying to attempting collusion and being unsuccessful in being compliant at the due date.

Market Mechanism

Participants were able to trade each period by way of a continuous double auction. Any participant could send bids/offers at any time. Any participant could accept the "best bid" or "best offer" at any time. Any bids/offers older than 10 experimental days were deleted. The parcel size in each year was not alterable by the participants. It was selected such as to require that each participant (on average) would need to trade around 10 times in each year. This was done to provide there to continual activity in the market.

In some previous software trials where participants had the ability to set parcel size it was noted that generators would consistently offer large parcels, whist retailers would bid for smaller parcels. Since the market mechanism used did not permit the partial fulfilment of bids or offers this meant that trading volumes collapsed while prices were crossed due to large differences in bid / offer quantities on each side of the market. This problem is avoided through fixing the parcel size.

Units were of indefinite life and were bankable across periods (units created or purchased this year could be used in any subsequent year).

Again, to ensure that we could rely on the market mechanism implementation, a number of trials were run where participants were simply "gifted" units each period, with no banking or borrowing. Under this circumstance the circumstance is a straight double auction for known value goods, and we observer fast and reliable convergence to the simple case equilibriums. Thus we have some confidence that the actual software implementation of the mechanism is performing well.

An example of a generator and a retailer participant screens as used shown in Figures 3 & 4.

Figure 3: Example Generator Participant Trading Screen

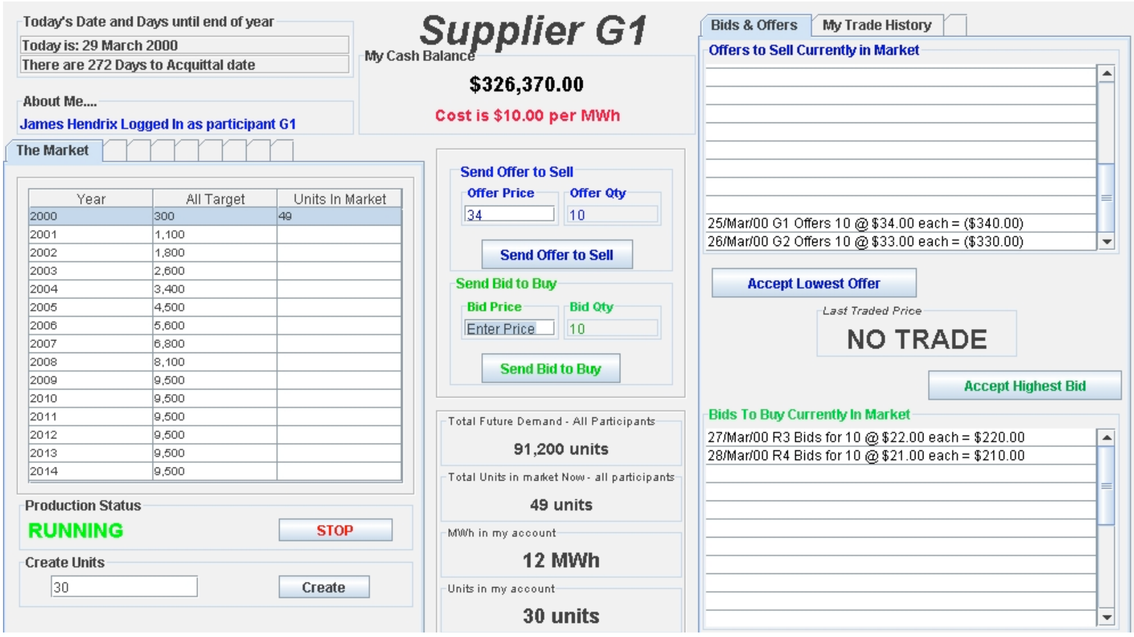


Figure 4: Example Retailer Participant Trading Screen

Procedural Details

A total of 2 training sessions and 6 experimental sessions of each scenario were conducted over 4 weeks in March/April 2006 using a cohort of 14 final year & post-grad university students.

The students were randomly assigned to a participant (G1 – G5, R6, R7) before each session. Over time all students participated as both retailers and generators in one particular scenario. There was no mixing of participants between the scenarios. This is summarised in Table 5.

Table 5: Summary of sessions, parameters and participants

Treatment	Scenario	Subject Experience
Instant Create	"Units" created instantly with MWh generation for all generator participants	2 x Training Sessions of Instant Create 6 x Experimental Sessions of Instant Create
Delayed Create	All participants were able to generate MWh, and then later convert these to "Units" for sale.	2 x Training Sessions of Delayed Create 6 x Experimental Sessions of Delayed Create

Participants were paid in real cash, in proportion to their "experimental cash" holdings at the end of the experiment. Typical remuneration was around $25 per session, plus a showup fee of $10.

KEY FINDINGS:

A significant difference exists in the prices evolving post 2005 in each case. This may be seen in Figure 5.

Figure 5: Average 10 trade prices

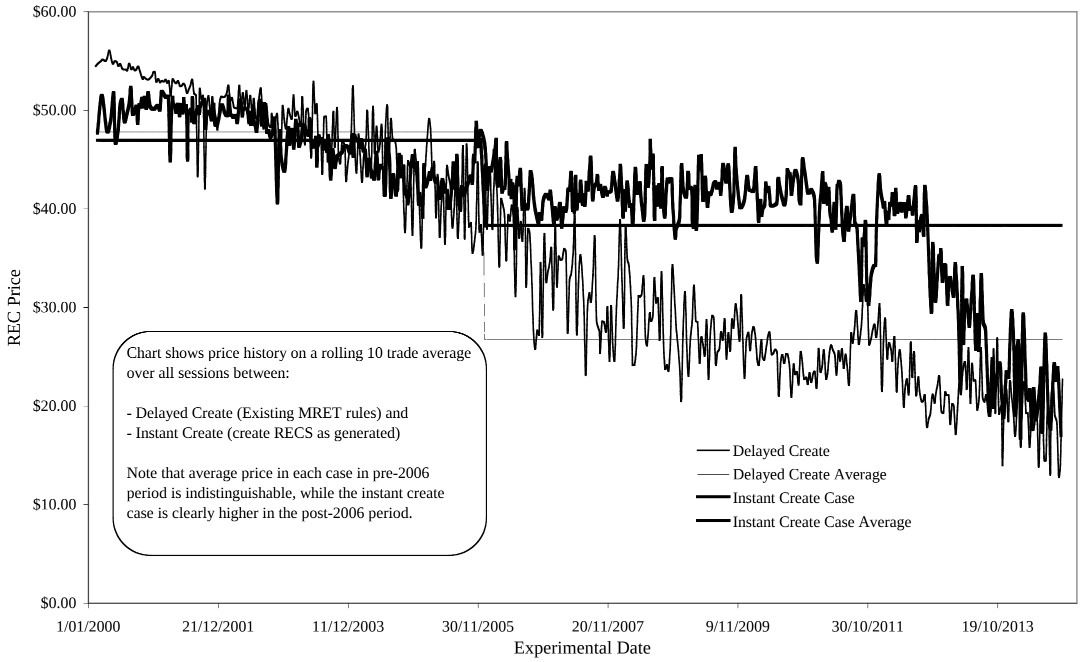


Figure 5 shows price history across all experimental sessions on a 10 trade average over all sessions between:

- Delayed Create Case (Existing MRET rules) and
- Instant Create Case.

The horizontal lines indicate the average prices in the “early” period (2000-2005) and “later” period (2006-2014) for each of the two treatments. Note that average price in the early period is slightly (but significant at the 1% level) higher under the *Delay Create* case (T=4.51, $t_{\alpha/2(0.005)}$ = 2.326), while *Instant Create* treatment average is considerably (and significant at the 1% level) higher than the *Delayed* Create treatment in the later period (T=57, $t_{\alpha/2(0.005)}$ = 2.326).

Our hypotheses are tested as follows:

Result 1: Total generation cost cannot be distinguished between the treatments at 95% confidence

Given the provided supply resources, minimising the societal cost requires that one or both of participants G1 and G4 (who represented Hydro and "Other", who are controllable in operation) would switch off their plant for some fraction of the experiment. Since G4 is a higher cost plant ($15/MWh generated) than G1 ($10/MWh generated) the minimum cost process is for G1 to operate continually, and for G4 to operate only just enough to meet demand in each year the retailers targeted demand. Under that circumstance, the minimum cost of production (while still meeting the retailer targets in each year) will be $e 1,336,008. The worst case – where all generators (including G1 & G4) run continuously (despite the fact that this leads to over-production compared to the targeted quantity) incurs a production cost of $e 1,544,712. There is thus a 15% difference between the best and worse case societal cost, and any given experimental session will fall between the two.

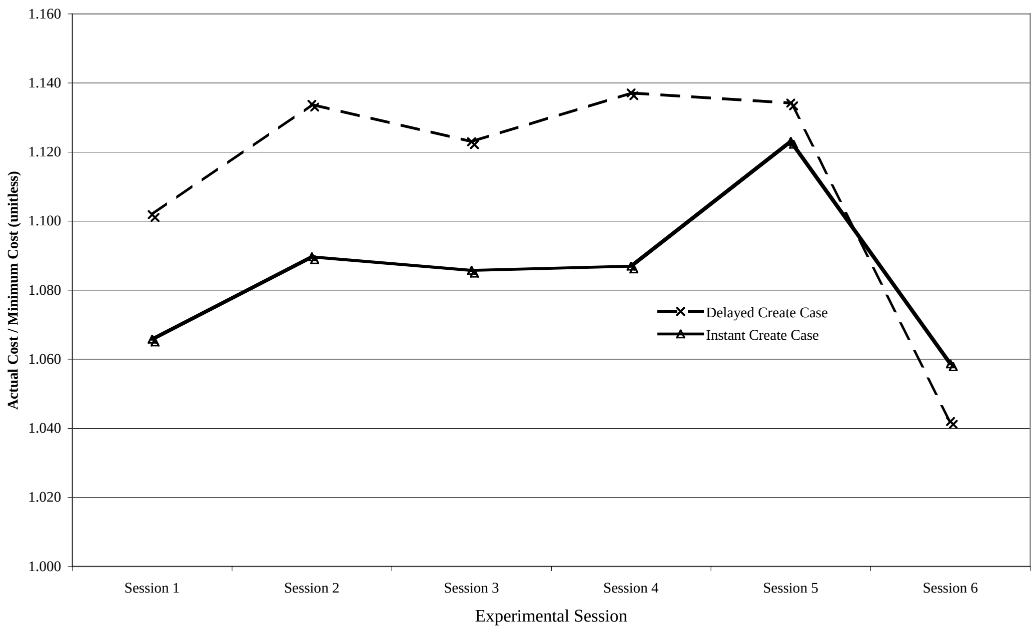
Let us define the ratio of actual cost: minimum cost in each session Instant Create treatment as being I_s and in the Delayed Create treatment as D_s, where s represents the session number. Thus we express our results in Table 6.

Table 6: Actual Generation Cost to Minimum Possible Cost

Actual Generation Cost Incurred in $E			Ratio of Actual : Minimum Cost		
	Delayed Create Case	**Instant Create Case**		**Delayed Create Case** ***(D_s)***	**Instant Create Case** ***(I_s)***
Session 1	$e 1,472,122	$e 1,423,943	Session 1	1.102	1.066
Session 2	$e 1,514,811	$e 1,455,735	Session 2	1.134	1.090
Session 3	$e 1,500,298	$e 1,450,532	Session 3	1.123	1.086
Session 4	$e 1,519,183	$e 1,452,202	Session 4	1.137	1.087
Session 5	$e 1,515,244	$e 1,500,463	Session 5	1.134	1.123
Session 6	$e 1,392,063	$e 1,414,353	Session 6	1.042	1.059
			Mean	$\overline{D}$ = 1.112	$\overline{I}$ = 1.085
			σ	0.037	0.023

A graphical representation of the ratios D_s and I_s is shown in Figure 6.

Figure 6: Actual generation cost by session and treatment as ratio of minimum possible cost



It appears to the eye that the total societal cost in the delayed create case is higher than in the instant create case. However this difference fails to be significant under a two-tailed t-test for significant difference of means at the 95% level, as follows:

H0 : That $\overline{D} = \overline{I}$ at 5% significance level

H1: That $\overline{D} \neq \overline{I}$ at 5% significance level

We find:

- $\overline{D}$ = 1.112 (σ = 0.037, n=6)
- $\overline{I}$ = 1.085 (σ = 0.023, n=6)

Using a 2-sided t-test, we cannot reject this H0 at the 95% confidence level.

For $\alpha/2$ = 0.025 the critical T value = 1.86

Actual t metric = 1.54

Note however that H0 would be rejected at the 90% confidence level.

Conclusion – Hypothesis 1:

Total generation cost (i.e.: societal cost) incurred in the "instant create" case cannot be distinguished from that under the "delayed create" case at the 95% level, although it *remains probable (at the 90% level) that a difference does exist. A further experiment is warranted.*

Result 2: Prices in the "delayed create" treatment are high early, and low later.

Support:

As a visual examination of Figure 5 suggests, prices under the delayed create treatment tend to be high in earlier periods, and then collapse in the second half of the experiment. This visual impression is confirmed in the statistical analysis.

Formally, we will consider if a statistical difference in the average prices evolved exists in the "later" period of the "delayed create" treatment as compared to the "earlier" period. We consider the "earlier" period to be 2000-2005 and "later" periods to be the period 2006-2014. If we let $\overline{P}_{Dt}$ represent the average price in the delayed treatment case for period *t* then:

H0: $\overline{P}_{D[1 \le t \le 6]} = \overline{P}_{D[7 \le t \le 15]}$, at a 1% significance level

H1: $\overline{P}_{D[1 \le t \le 6]} \neq \overline{P}_{D[7 \le t \le 15]}$, at a 1% significance level

We find:

- *Delayed Create* treatment 2000-2005 (Earlier period)

  Average Price $\overline{P}_{D[1 \le t \le 6]}$= \$47.81 (σ = 7.72, n=2192)

- *Delayed Create* treatment 2006-2014 (Later period)

  Average Price $\overline{P}_{D[7 \le t \le 15]}$= \$26.77 (σ = 9.09, n=3422)

Using a 2-sided t-test, we may reject this H0 at the 99% confidence level.

For $\alpha/2$ = 0.005 the critical T value = 2.58

Actual t metric = 92.84

Since t >> T, we can strongly reject the null hypothesis at the 1% level.

Conclusion – Hypothesis 2:

Prices in the later period of the "delayed create" treatment are significantly lower than in the earlier period. This is probably due to a higher level of generation in earlier periods, leading to a relative (although disguised to the participants) oversupply in later periods.

Result 3 : Prices in the "instant create" case are higher on average in later periods than in the "delayed create" case.

Support:

We recall our third hypothesis, being:

Hypothesis 3: Prices in the "instant create" case will be higher on average in later periods than in the "delayed create" case.

Formally, we will consider if a statistical difference in the prices evolved exists in the "later" period for each treatment. We consider "later" periods to be the period 2006-2014. If we let $\overline{P}_{Dt}$ represent the average price in the delayed treatment case for period t and $\overline{P}_{It}$ represent the average price in the instant create treatment for period t, then we may state the hypothesis as follows:

H0 : $\overline{P}_{D[7 \le t \le 15]} = \overline{P}_{I[7 \le t \le 15]}$, at a 1% significance level

H1: $\overline{P}_{D[7 \le t \le 15]} \neq \overline{P}_{I[7 \le t \le 15]}$, at a 1% significance level

We find:

- *Delayed Create* treatment Post 2005 (Later period)

  Average Price $\overline{P}_{D[7 \le t \le 15]}$= \$26.77 (σ = 9.09, n=3422)

- *Instant Create* treatment Post 2005 (Later period)

  Average Price $\overline{P}_{I[7 \le t \le 15]}$ = \$38.39 (σ = 9.04, n=3715)

Using a 2-sided t-test, we may reject this H0 at the 99% confidence level.

For $\alpha/2$ = 0.005 the critical T value = 2.58

Actual t metric = 54.1

Since t >> T, we can strongly reject the null hypothesis at the 1% level.

Conclusion – Hypothesis 3:

There is a very significant difference in the prices evolved between the two treatments in later periods. It appears that generators can use the extra information from the REC registry to inflate prices towards the penalty rate for longer than is the case under the "delayed create" treatment.

CONCLUSIONS

The MRET market architecture is relatively unique in providing a “pressure to trade” on the demand side, and allowing the supply side to bank indefinitely. The primary conclusion of this experiment is that the architecture places considerable power with the generators in earlier periods, which is attenuated somewhat as the market progresses under the “delayed create” REC rule due to supplier over-production. Under the alternative market rule of “instant create” the additional information is used by generators to constrain production and keep prices high.

Under both treatments, prices are consistently above the economically efficient level of around $10-15 (a price at which new entrants would be dissuaded, and the most expensive marginal controllable plant would have price incentive to turn off).

The general pattern of prices (starting and remaining above the efficient level, but with a consistent downward path) suggest that the annual target on retailers combined with indefinite MWh and REC banking on the part of generators creates a lop-sided market architecture favouring the generators, particularly in earlier periods. This experiment was not configured to particular examine if the annual target is the cause of this pattern, and so we can only speculate at this time.

The ability of generators to “delay” creating RECs clearly is a significant institutional rule choice. It probably leads to over-production on the part of supplier, however the alternative of “instant” REC creation appears to favour generators by enhancing their ability to constrain supply. The decision on this rule has a major impact on the prices that evolve in the market. It is with interest that we note that the Australian Government has announced (following the recommendations of (Tambling, Laver, Oliphant and Stevens 2003) to reduce the permitted delay in the MRET market to 12 months between generation and REC creation. From our experiment, we would expect this change to lead to a reduction in over-supply in later years, and a rise in REC prices relative to what may have occurred had the rule remained unchanged.

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