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by

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THE INFLUENCE OF BANKING AND BORROWING UNDER DIFFERENT PENALTY REGIMES IN TRADABLE GREEN CERTIFICATE MARKETS – RESULTS FROM AN EXPERIMENTAL ECONOMICS LABORATORY EXPERIMENT

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INTRODUCTION[1]

The last years several studies have been performed on tradable green certificate (TGC) systems [2,3,4,5,6,7] These studies emphasise that at least from a theoretical point of view, TGC systems can be conceived as an efficient and effective way of stimulating renewables However, although some experience exist with TGC-markets (cf The Green Label System in the Netherlands) and other environmental benefit markets such as tradable SO_2-emission ceilings in the US, Package Recovery Notes[8] in the UK and CO_2 trading schemes within the oil companies of BP and Shell, these experiences are limited in scope and/or time and are operating in specific settings, which makes it difficult to say much in general about the actual efficiency or effectiveness of such systems in practice Quite a few environmental trading schemes will start in the near future, among which several TGC schemes, CO_2-emission rights trade and CO_2-emission reduction credit trade If we want to learn from these experiences, we will have to wait for a few years before we can start to analyse However, it would be convenient if more experience would be available sooner This would help policy makers to design these future schemes in a right way and to avoid mistakes that lead to inefficiency and/or ineffectiveness.

A way to get insight in the practical workings of a TGC-system is to make use of the skills and facilities of experimental economics In this article we will show the set-up and the results of an experiment in TGC-trade done in the laboratory of the Center for Research in Experimental Economics and Political Decision-Making (CREED) of the University of Amsterdam This experiment focussed on the differences in market dynamics if the obligatory demand part of the market has to deal with different non-compliance fines Also varying possibilities for 'borrowing' future certificates for compliance and varying possible levels of 'banking' certificates were taken into account

THE DYNAMICS OF A TGC MARKET

In Figure 1 the dynamics of a TGC market are shown.

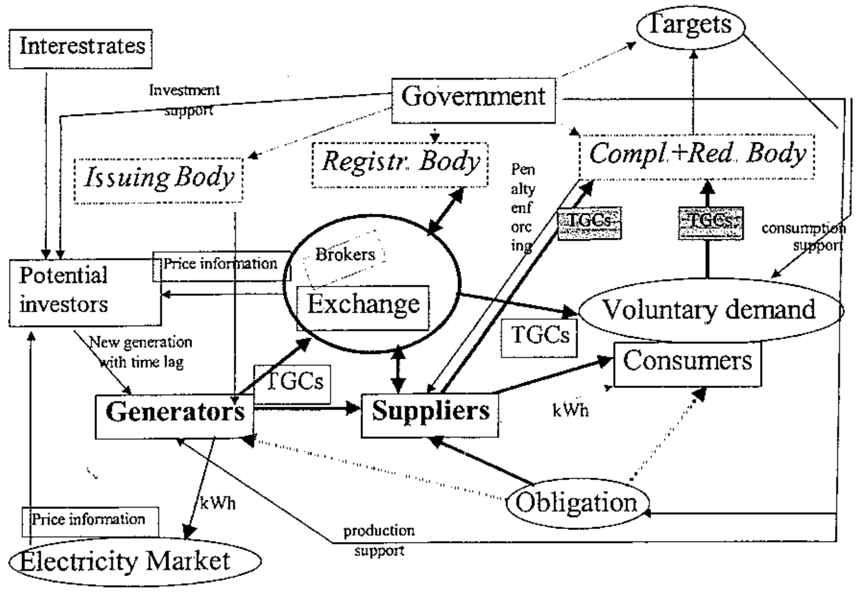

Figure 1 The dynamics of a TGC market

Producers of renewable-energy-sourced electricity (RES-E) receive their income from two markets: the electricity market and the TGC market. Electricity is produced and sold on the electricity market, either for general fixed tariffs (in a non-liberalised market) or for electricity market prices (in a liberalised market). On top off their income from the electricity market, RES-E producers will get TGCs for every standard unit of electricity produced (e.g. for every 1 MWh), which are issued by an Issuing Body. These TGCs can be sold to those actors with a demand. In most cases demand for TGCs comes from suppliers, either because of an obligation put on them by the Government or because they want to fulfil a demand from an obligation put by the Government on electricity consumers, or because they want to satisfy voluntary demand for green energy from customers. Voluntary demand from customers might be sustained by consumption support from the government, e.g. by an environmental tax rebate.

In the TGC market TGCs might switch hands several times, also because (new) actors might act as pure brokers or traders. A Registration Body will register these transactions. When fulfilling a demand, voluntary or obligatory, the TGCs have to be taken out of the market by a Redemption Body. The Redemption Body should also control whether obligations have been fulfilled, and if not, take care of applying a penalty. The functions of Issuing Body, Registration Body and Redemption Body could be integrated in one organisation, but could also be delegated to separate entities.

Transactions on the TGC-market should be sufficiently transparent to provide TGC price information. Potential investors will decide whether or not to invest in new renewable capacity based on this price information, together with price information from the electricity market. Positive investment decisions will not lead immediately to new production of RES-E and TGCs. Construction of new plants as well as getting the necessary construction permits will need some time. Once build, most new renewable capacity will have low marginal costs, meaning that they will be in production to the maximum of their capabilities. The new supply of TGCs, in combination with the (growing) obligatory demand and the price-dependent voluntary demand, will lead to new balances and TGC-prices, which, in their turn, will form the basis (together with price information from the electricity market) for the next turn of investment decisions.

The behaviour of investors is very important in this market. In a liberalised electricity market in combination with a TGC-system, investors have to cope with two insecure markets and corresponding prices, instead of with one secure price for electricity in a non-liberalised situation. This means that return on investment (ROI) criteria will be much higher than in a non-liberalised situation, and also that they will undertake a thorough risk analysis before deciding whether to invest. Apart from the electricity and TGC market risks, they will consider the regulatory risk (what are the risks of not getting my required ROI under the current regulatory framework), the political risk (what is the chance that the current regulations will be abolished by politicians, and what might be the effects for my ROI?), the technology risk (to what extent are the available renewable technologies "proven" and can I really count on the expected cash flow?) and the counter-party risk (are both parties in a deal trustworthy, i.e. to what extent do they have a good and long-standing financial reputation?). The assessment of the regulatory risk will be influenced by the firmness of the target/obligation and its level.

Not all investors will assess these risks in the same way, which will lead to a set of different ROI-criteria. There will be a distribution of ROI requirements around an average, which will certainly be higher than in the case of a more secure fixed feed-in tariff situation.

PENALTIES AND PRICE FORMING IN A TGC-MARKET

The equilibrium price of TGCs in a static obligation-only market, with market transparency and immediate adaptation of production to supply, can be seen in Figure 2.

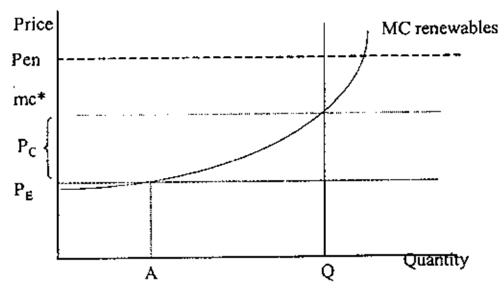

Figure 2 Equilibrium price of TGCs in a TGC-market with obligation

In this Figure $MC_{renewables}$ is the supply curve for renewable electricity in a country. If P_E is the electricity price, an amount A will come on the market without additional support. If the obligation is Q, the price needed is mc* The TGC price P_C is equal to the difference between P_E and mc*.

In a dynamic market with time lags between price information, investment decisions and start of production, the price might vary around this equilibrium. The level of the penalty can be expected to function as a maximum price (cost cap) in such a market: Obligatory actors will rather pay the penalty fine, instead of buying green TGCs at a higher price than the penalty.

There are different ways of setting a penalty The simplest form is a fixed fee per missing unit to be paid by non-complying obligatory actors. This approach for instance is proposed in Denmark and Belgium

Another way of setting penalties is to take the average market price of the compliance period, and multiply that with a factor above 1. This approach has the advantage that the penalty will always be higher than the market price, but will not be unnecessarily high This is the approach taken in the Texas TGC-regulation (although the absolute maximum in the US State is set at 5 $cents/kWh).

A more complicated approach is taken in the proposed Italian system The Issuing Body (the transmission operator GRTN) has the possibility to issue proxy ('uncovered') certificates for relatively high fixed prices that are not exactly known in advance. These certificates can be used by obligatory actors to meet their obligation. The Issuing Body has to re-buy an amount of certificates corresponding to the total of proxies issued in a certain year, from the market within three years after the issuing. This approach means that obligatory actors can always meet their obligation, either by 'real' certificates, or by 'proxy certificates' and that the penalty for non-compliance will be determined in Court on the basis of normal legal jurisdiction.

OPTIONS FOR FLEXIBILITY IN DEMAND

TGC-systems based on an obligation are characterised by the combination of an inelastic fixed demand and a varying supply (if only because of the yearly variation of wind supply, water supply and solar irradiation). Such systems are in principle unstable. If there is an oversupply, certificate prices will go to zero and if there is undersupply certificates will tend to go to the maximum (which is set by the penalty)

Apart from the varying climatic factors, another potential reason for instability on a TGC-market is the fact that it is initially a small market, while some technologies (e.g. off-shore wind parks, or large-sized biomass plants) come only on the market in certain minimum sizes. When these large projects come on-line, suddenly a large amount of certificates has to be absorbed by the small market. This will immediately lead to a downward pressure on prices.

To avoid market and price instability and to allow obligatory actors a reasonable flexibility in meeting the obligations, banking of certificates could be allowed. This means that 'left-over' certificates of one year can be used to meet an obligation in another year. Another possibility is to allow 'borrowing', which means that certificates from future years in one way or another can be used to meet the obligation

Banking of certificates

Banking of certificates can be regulated in two ways The validity period of a certificate can be extended to beyond the year of production, for a certain time period, or infinitively. Another way of regulating banking is to allow a certain percentage of the obligation to be met by certificates, issued in earlier years (ranging from a few % to 100%).

Borrowing certificates

There are several ways of regulating borrowing of certificates:

An investor could sell future certificates even before actually starting construction of the renewable energy project The Redemption Body could allow that these certificates are used for an obligation The advantage of this approach is that it will be easier to finance renewable energy projects The disadvantage is that some regulation has to be made in order to deal with projects that do not come on-line, e g because the developer goes bankrupt, while the future certificates (which will never be produced) have already been used for an obligation. A possible solution would be that if future certificates are used for an obligation, they have to be accompanied by a deposit sum equal to the penalty This sum will be returned to the obligatory actor as soon as the certificates are produced and immediately redeemed. A further extension of this idea is that any non-compliance penalty is redeemable, i e it will be paid back if the obligatory actor submits enough additional certificates in later years.

A simpler approach to regulate borrowing is to allow obligatory actors a leeway on their obligation, e.g. up to 50% per year. To achieve full compliance in the end, this leeway does, of course, not apply in the final target year.

Another way of regulating borrowing is to allow a settlement period, right after the end of every year. A settlement period will be needed anyway, if the obligation is calculated on the basis of the energy consumption of the year of compliance In that case the exact obligation per actor is only known after the end of the compliance period. Shortages can be settled in the settlement period, e g the first three months of the next year If also certificates issued in the settlement period can be used to comply with the obligation of the previous year, then borrowing exists de facto, up to a level of the relative production of renewable energy in the first three months of the year.

A fourth way of allowing borrowing is to have multi-year compliance periods This is the approach taken in the Kyoto commitments for greenhouse gas emission reduction. The compliance period of 5 years (2008–2012) effectively means that borrowing is allowed up to 100% in the years 2008–2011. A possible disadvantage of this approach might be that spot markets will only develop at the end of the multi-year compliance period, which might have a negative influence on market liquidity and price transparency during the earlier years of the compliance period

THE CONSTRUCTION OF THE LABORATORY EXPERIMENT

General set-up

The set-up of the experiment is visualised in the Figure 3:

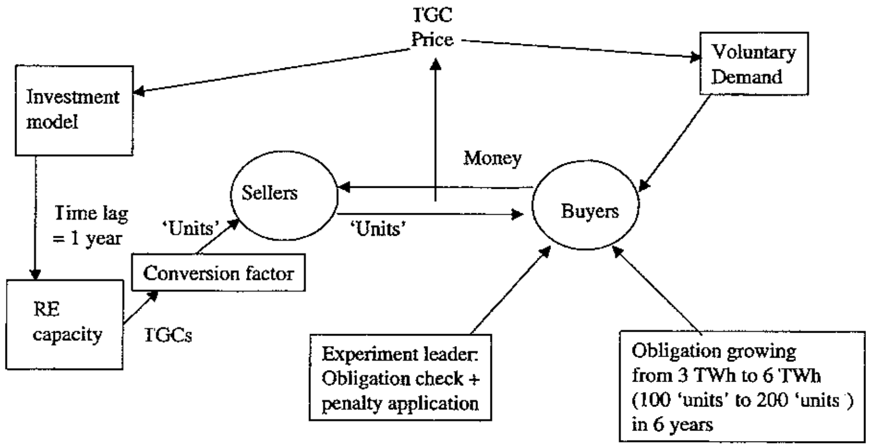

Figure 3 The general set-up of the experiment

The usual number of subjects (students of the University of Amsterdam) in each experiment was 12. Six subjects were (arbitrarily) assigned to play the role of a seller and six subjects were assigned the role of a buyer. Four of the buyers were 'buyers with an obligation', while two buyers did not have an obligation, representing the voluntary part of the market. At the start of each period (a 'year') buyers got a budget (different for buyers with an obligation and for buyers without an obligation). To simulate season-dependency of the supply of TGCs (because of different conditions of wind and solar irradiation) each period was divided in 4 sub-periods. Sellers got a number of 'units' at the start of each sub-period. After each full period buyers with an obligation had spent part of their budget on buying units (or on paying penalties) and sellers had earned money by selling units. Buyers without an obligation were told at the start of each period how much money they could get for each unit they would possess at the end of the period, up to a certain maximum number of units. If they were able to buy units on the market for a lower price than the value they could get for it, they would enlarge their total budget. Each session lasted for 6 trade periods. At the end of the experiment, the budget of each subject was converted into real money and given to the subjects. An experiment session lasted about 2 hours. One hour was dedicated to instruction, training and payment of the subjects. The duration of the proper experiment was one hour.

Trade

Trade between buyers and sellers took place electronically via computers connected to each other in a local area network. The size and prices of offers to sell as well as offers to buy were shown to every subject. Also the size and price of every transaction was shown to them. After each full trade period the average price was calculated and used as an input for the model that determined the voluntary demand. The maximum number of units for which buyers would receive money at the end of the following period depended on this average price in the market in the previous period and was calculated using a simple demand curve. The value of each of these the units always was a standard amount of money above the market price in the foregoing period. The average market price was also used as an input into the investment model.

Determination of the number of new units on the market

The number of units sellers got at the start of each period was determined by a software module. This software module calculated the number of units on the basis of installed renewable capacity.

Six different technologies are defined in the renewable capacity module[10]. In each period the capacity per technology was calculated (capacity in the year before + additional capacity following from the calculations in the investment model). Each of these technologies were characterised by an average number of production hours per year. The number of GWhs produced by those technologies that are not dependent on climatic factors (biomass) in each sub-period was 25% of the average yearly production. For those technologies that are dependent on climatic factors (wind and solar PV) historical statistics were used to determine the production in each sub-period. The amount of GWh was translated into homogenous 'experiment units' and given to the sellers.

The investment model

Each period an investment model calculated the addition of new renewable capacity. This model simulated the behaviour of investors as follows.

Per technology first a calculation was made of the internal rate of return of investing in that technology. This calculation was based on a cash flow analysis with a 15-year time horizon. Expenses were calculated on the basis of the level of the initial investment, yearly O&M costs and variable costs (variable O&M-costs and fuel costs). Income was calculated on the basis of the average number of production hours, the electricity price (in this experiment fixed at 3 eurocents/kWh) and on the TGC-price. The TGC-price taken in the calculations was the TGC-price in the foregoing period minus a small correction for price volatility in that period[11]. The investment model assumed this price to remain constant over a period of 15 years.

The Internal Rate of Return calculated in this way was converted into a share (number between 0 and 1) of potential investors taking a positive investment decision. This was done on the basis of an S-curve. The shape of this S-curve is based on statistics on the distribution of IRRs for investments in Danish wind turbines[12]. To account for the difference between the relatively secure income in the regulated Danish wind energy market and the more insecure combined market of a liberalised electricity market and a competitive TGC-market, this line was shifted to the right considerably, moving the average required IRR from about 11.5 % to 15%.

To determine the total capacity per technology to be added to the existing renewable capacity, the number between 0 and 1 determined by the S-curve was multiplied by a maximum additional capacity. This maximum was determined by a maximum growth rate (depending on the technology 25% or 40%) and the existing installed capacity. For technologies that were not present in the initial renewable energy capacity mix (e g offshore wind) a minimum in absolute terms was taken for the maximum additional capacity.

To simulate construction times and planning procedures, the new capacity was added one period after the period in which investment decisions were taken. So, the average TGC price in period 1 (2,3,4) was used as an input to determine investment decisions in period 2 (3,4,5) which led to additional capacity in period 3 (4, 5, 6).

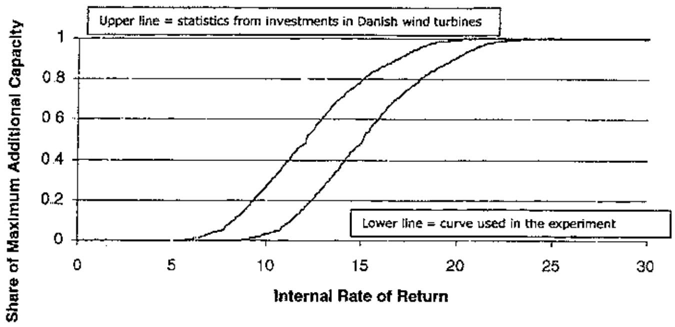

Figure 4. Relation between internal rate of return and share of maximum additional capacity

Initial experiment conditions

The experiment concerned an imaginary EU-country with an overall electricity consumption of 100 TWh. This is comparable to countries as Norway or The Netherlands The initial share of renewable energy in the electricity mix ('period 0') was 3 TWh. This amount is equal to the total obligatory demand in the first period (and known to the subjects as an obligation of in total 100 'units'). All subjects were told that the obligation would rise from a total of 100 units to a total of 200 units during the six periods of the experiment (6 TWh) This is equal to a growth rate of about 15% per period (which compares to going from 3% to 10% renewable electricity in 10 years). The voluntary demand as well as the investment decisions in the first period were based on a pre-determined TGC-price. This price was set by the experimenters and it was an estimation of the equilibrium price[14] The capacity in period 1 was augmented slightly to match total demand (obligatory and voluntary) with total production in the first period

Variables

Banking, borrowing and the level of the penalty were the three parameters for which the values were varied as shown in Table 1 Banking was either unlimited or not possible. Borrowing was either possible or not In the case it was possible the buyers with obligation had a leeway of 50% on their obligation in each period, except for the last period. For the level of the penalty three values were taken 25, 10 and 3 Eurocent/unit[13]. These values turned out to be equal to about 4, 1.5 and 0.5 times the equilibrium price[14] At first hand it might seem a little odd to take into consideration a penalty below the equilibrium price, since this would impose a cost cap at a level lower than the market price required to reach the obligations. However, it might well be that in several of the current TGC designs (possibly the UK and Denmark) the penalty/cost cap proposed is indeed below the equilibrium price. Therefore it was decided to include low-penalty sessions in this experiment.

Table 1. Experimental Variables

	Penalty	Banking	Borrowing
High	25 Eurocent/unit About 4 times equilibrium	Unlimited banking (unlimited validity period)	Maximum leeway on obligation of that period (except for last period)
Medium	10 Eurocent/unit About 50% above equilibrium price		
Low	3 Eurocent/unit About 50% below Equilibrium price	No banking (only valid in period of production)	No borrowing

Running the experiment

The experiment consisted of a total of 16 sessions The design was not complete, i.e. not all possible combinations of banking, borrowing and the level of the penalty were taken. Some of the interesting cases were replicated. The experimenter provided first a short explanation to the subjects and assigned roles to them in an arbitrary way. The subjects had to answer a few questions on paper to check whether they really understood their roles. Before the actual experiment started a test period was played. This test period did not have any influence on the final earnings of the subjects. Most subjects participated in the exeriment only once. Those few that participated twice did this in sessions with very different design conditions. During the sessions, one of the actions of the experiment software was to check whether obligations were met after every period and to apply penalties if necessary.

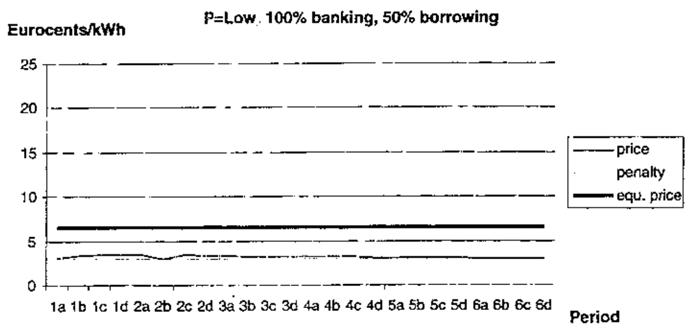

Figure 5 Typical outcome of low-penalty sessions

RESULTS

Low-penalty sessions

Figure 5 shows a typical outcome of a low-penalty run

The heavy solid line in this picture is the equilibrium price. The dotted line is the level of the penalty. The normal solid line is the TGC price over time.

What can be seen is that for most of the time the average TGC price is a little bit above the level of the penalty. Only in the last sub-periods the average price gets below the penalty level. How can this be explained? Because of the low TGC-prices there is a relative large voluntary demand Although at these price levels only around 2% of the electricity customers choose for green electricity, this is still substantial in a market that starts at about 3% of the electricity consumption Sellers are able to sell quite some units to the voluntary buyers at prices above 3 cents. Especially in cases where banking is possible, they do not care too much about not selling all their units since they can be stored anyway and offered for sale the next year Only in the last period, there is some oversupply with regard to the voluntary market, but since obligatory actors have a large demand just below 3 cents/unit, this accumulated oversupply can easily be sold in the last period for prices around 2 98 cents The oversupply with regard to the voluntary market is not building up very much, because of the low prices that induce hardly any new investments

In all the low-penalty sessions the level of penalty application (= the level of non-compliance) was very high. The average of non-compliance was far above 50%, in most sessions a little bit below 90% and in several periods up to 100% This means that the penalty functioned more or less as a tax. A non-effective tax, since almost no additional renewable capacity was installed. Low-penalty systems can be expected to induce large discussions on the question what to do with the penalty money (as is indeed the case in the UK and, to a lesser extent, in Denmark). It seems sensible that instead of introducing a low-penalty TGC system with an obligation, it is better to choose for a tax in a more straightforward way (e.g. to set up a renewable energy fund) or to choose for a system that is only based on voluntary demand.

High-penalty sessions

One way to avoid high non-compliance levels (and to decimate the administrative burden of penalty collecting), is to maintain a very high penalty level

Figure 6 shows a typical result of the high penalty sessions:

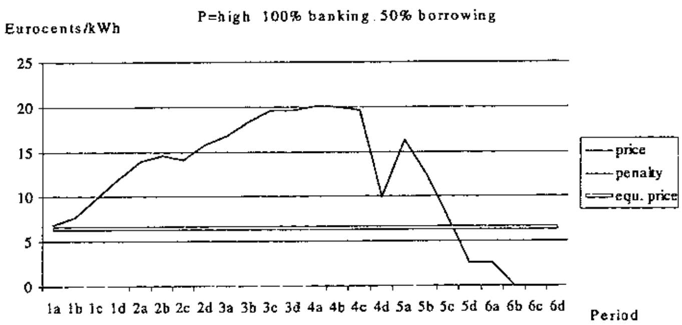

Figure 6. Typical outcome of high-penalty sessions

The upper line is the level of the penalty (at 25 cents). The heavy solid line is the equilibrium price. The normal solid line represents the TGC price development. What can be seen in this typical high-penalty session is that the high level of the penalty puts an enormous pressure on buyers to acquire units. They know that in the case they won't be able to buy enough units they will have to pay 25 cents of every unit they are lacking. Sellers know that and offer their units at very high prices. Especially in the case that banking is allowed they know that, even if they will not be able to sell all their units, they can store them and offer them on the market in the next period. Uncertainty on the part of the buyers with regard to the question how many units will be offered on the market leads also to a pressure for them to bank, if they can, in order to start with a buffer for the obligation of the following period. Both sorts of behaviour (tightening the market by suppliers and an over-demand on the part of the buyers) lead to very high prices in the first four periods. These high prices are fed into the investment model, and lead to massive investment in renewable capacity. An enormous overproduction is the consequence (up to more than 2 times the level of obligation in the final period) leading to a total collapse of prices in the last periods.

A development like this does not seem to be a very efficient way of promoting renewables. Because of the wrong market price signals, investments have been made in technologies that are far from cost-effective. Although the level of deployment in the final year is far above the target level, practically all the renewable energy plants turn out to be loosing money. The trust of industry in the TGC-mechanism would be seriously disturbed if such a scenario would happen.

The only non-typical high-penalty session occurred in the case that only borrowing was allowed. (Figure 7).

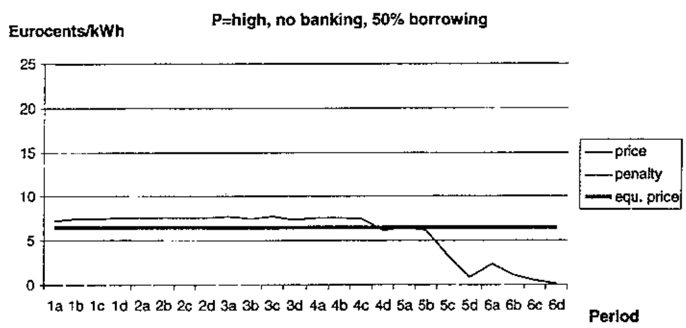

Figure 7 High-penalty session with borrowing and without banking

In this figure the heavy solid line is the equilibrium price. The upper line is the level of the penalty (25 cents) and the normal solid line is the development of TGC-prices. What can be seen is that the market is relatively stable for a long time at prices far below the typical high-penalty session level. Some overproduction occurred anyway, since the price, although stable for some periods, appeared to be a little bit higher than the equilibrium price. This still led to a crash in prices at the end, but since overproduction was less than 1 5 times higher than the obligation in the final year, the overproduction can be expected to be absorbed by growing demand in the future (assuming that the TGC-scheme would continue) much sooner than in the other cases of the high-penalty sessions.

The difference between the typical high-penalty sessions and the one with only borrowing is that borrowing relieves part of the high pressure (caused by the penalty) on the obligatory buyers. This had a downward pressure on prices, a much more stable market and less overproduction.

In addition the only-borrowing case was the case with the highest level of final compliance (100%) among the high-penalty cases. Compliance rates in the high-penalty cases were always close to 100% but in some of the cases were banking was not possible sometimes not all units were sold (sellers preferred to 'lose' a unit so now and then, instead of selling them below certain prices) and penalties had to be applied incidentally. Also in the cases with banking, when sellers did not offer all their certificates on the market, buyers were simply not able to buy enough certificates and had to pay a penalty so now and then

The high-penalty cases show clearly that the possibility of banking leads to higher TGC-prices in the first years, due to an increase of the pressure on obligatory buyers (voluntary demand of course was very limited in these cases) On the other hand, borrowing relieves some pressure from the buyers. Another lesson from the high-penalty runs is that the level of the penalty forms a strong price signal for the TGC-market

Medium-penalty sessions

In order to give a more appropriate price signal to the market, the penalty can be reduced to a level closer to the equilibrium price. Assuming that the equilibrium price was about 6 8 Eurocent/unit in our design of the experiment, we set the medium-level of the penalty at 10 Eurocent/unit, which is about 1 5 times the expected equilibrium price Figure 8 shows a typical result of the medium-penalty sessions:

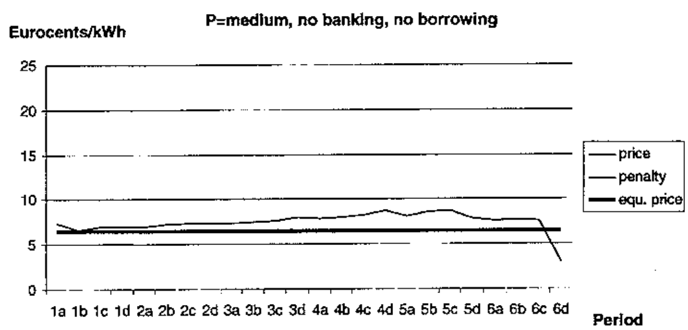

Figure 8 Typical outcome of medium penalty sessions

Again, the heavy solid line represents the equilibrium price, the upper line the level of the penalty (10 Eurocents/unit) and the remaining line is the TGC-price development. What can be seen is that the market is pretty stable over a long time, with a price a little bit above the equilibrium price, leading finally to some overproduction and a steep fall of prices at the very end It must be said that in most of the other sessions the overproduction was a little higher although less than in the high-penalty session with only borrowing) What is important is that these sessions show that a well-chosen level of the penalty indeed has a significant influence on the price-development and will bring the market closer to a stable market development. Also the compliance rates do not differ very much from the high-penalty cases

To relieve the pressure on the buyers even more, we did also a session with a medium penalty and only borrowing. This led to the 'perfect session' (Figure 9).

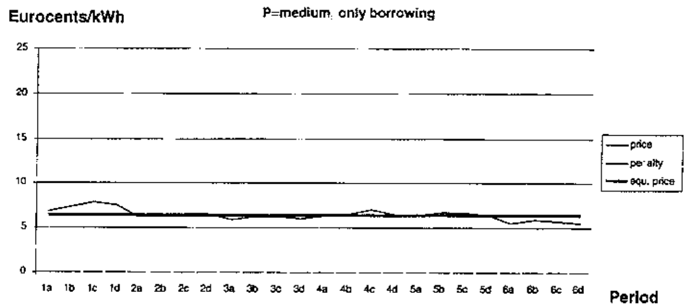

Figure 9 Medium penalty and only borrowing: the 'perfect session

In this session supply/production and demand matched perfectly. Apparently the average TGC-price of this session was the equilibrium price. There was only one negative aspect in this run (one that is shared with all cases in which banking was not possible). Because banking was not possible, the few units that were left over on the side of the sellers in the early periods, 'lost' their value, because they were not bankable. In the very last period some penalties had to be applied, but the number of penalties was 2 units lower than the units that had been 'lost' in earlier periods In other words, if (limited) banking had been possible, these units would not have been lost, and no penalties would have been applied in the last period.

This session was replicated with less superb results Analysis showed that the main difference in behaviour between the two runs was that the possibility of borrowing was used much less in the second run. Instead of a maximum of 32% (with regard to the obligatory demand) in the first run it was a maximum of 10% in the second. This replication teaches us that the same design does not always have to lead to the same outcome. Furthermore, although distribution of pressure on buyers or sellers can be built into the design, the actual pressure on buyers or sellers depend on the degree to which they want to make use of the possibilities the design provides.

CONCLUSIONS

An important conclusion of this experiment is that making use of experimental economics skills and facilities can add significantly to the understanding of environmental markets dynamics.

With regard to the experiment on TGCs the following conclusions can be drawn:

- The possibility of unlimited banking led to a significant market power shift in favour of the sellers. This resulted in prices far above the equilibrium price in the early periods of the experiment, which caused overproduction and a price crash towards the end of the sessions
- The level of the penalty is a strong price signal in a TGC-market High penalties lead to high pressure on buyers, which drives up prices in early periods, leading to over investment and a price crash in the later periods
- Penalties below the equilibrium price led to very low levels of compliance The average price was a little bit above the penalty level, which was caused by the relatively large share of the voluntary demand in the market. The low level of compliance turns the penalty almost into a straightforward tax
- The possibility of borrowing relieved pressure on buyers, especially if it was not combined with the possibility of unlimited banking. It stabilised the market and made, in combination with a medium-level penalty, a 'perfect' session possible
- The same design conditions do not always lead to exactly the same outcomes. However, the differences in outcomes between different designs is larger than the differences in outcomes under the same design.

POLICY IMPLICATIONS AND RECOMMENDATIONS

To draw conclusions with regard to implications and recommendations for TGC-designs, one should first reflect to what extent the outcomes of a laboratory experiment are related to real-world trading environments It is true that the design of an experiment is always a simplification of reality and cannot be generalised straightforwardly to reality. In real environmental credit markets for instance, actors will not fulfil only one role. They might act as buyer, producer and investor at the same time. Also other actors like brokers could enter the scene. Furthermore the development of derivative markets (call options, put options, futures etc.) could smooth the sharp edges of the extreme price developments as shown in the experiments to a large extent However, what is important to keep in mind, is that the experiment has shown that, all other things being equal, the change of one design parameter (e.g the allowance of unlimited banking, or not) has a significant influence on the market. Since only that parameter has been changed, the effect observed can only be related to this change. Therefore the conclusions of the experiment, at least in general terms, can be expected to hold in reality as well, although maybe tempered by the factors such as mentioned above Banking and borrowing are both meant to provide flexibility to the obliged actor. The experiment shows that this is indeed the case for borrowing Banking, however, provides also flexibility to the non-obliged actors (sellers) which can lead to marked inefficiencies. This reflection leads to the following set of TGC-design recommendations:

- Be careful with allowing unlimited banking. Banking is meant as a mechanism to allow some flexibility in compliance. Unlimited banking however allows strategic market behaviour which could lead to the wrong price signals.

- Be sure that the penalty is high enough, i.e higher than the equilibrium price. Penalties lower than the equilibrium price lead to high levels of non-compliance and turns more or less into a tax This will lead to political debates about what to do with the enormous amount of penalty money, how it should be recycled into society, etc. The price level of TGCs will be very stable (at that low level) in such a case. If that is the intention, than it would be better and more simple to introduce a low-level fixed-premium system, which would have the same effect on deployment without the complicated administrative hassle of a TGC-system
- Consider seriously allowing borrowing (up to a maximum level) in TGC-designs. The allowance of borrowing may reduce prices, stabilise the market and help to realise the theoretical potential of TGC-systems with an obligation to be an effective and efficient way of promoting renewables. The beneficial effects of borrowing in the experiment might be related to the value of a whole set of other parameters in the design of the experiment, which means that it cannot be concluded that allowing borrowing will be good for every TGC-system. But it is very well possible that it will beneficial. Since borrowing is not as popular as banking in discussions about the design of environmental markets, this is an important conclusion to be drawn.
- To avoid 'lost' certificates designers of TGC-systems should reflect on how to incorporate a limited form of banking. This form of banking should avoid providing the strategic opportunity for sellers to tighten the market. A possible solution might be to set the validity period of each certificate at one year after its issuance.

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8 A Package Recovery Note is a proof that a certain amount of waste material has been recycled These PRNs are used in the UK by waste material producing companies to comply to their obligation to recycle a certain percentage of their waste material. The PRNs are tradable. A spot market for PRNs exists and is managed by OM Environmental Exchange

9 The experiment was as part of the European Renewable Energy Certificate Trading Project (RECerT). This project is partially financed as an Accompanying Measure within the 5th Framework Program of the European Commission

10 These technologies were wind in coastal areas, wind inland, wind offshore, large biomass, small biomass and solar electricity

11 The correction was equal to half the standard deviation from the average price in the foregoing period

12 The statistics on the distribution of IRRs for investments in Danish wind turbines has kindly been provided by Poul-Erik Morthorst of Risoe National Laboratory

13 The experiement was designed in such a way that a penalty of n Eurocent/unit = n Eurocent/kWh

14 The equilibrium was estimated to be 6.8 Eurocent/unit on beforehand. This was done by calculating the unit production cost of the marginal technology with the average (15% IRR) investment criterion. During the experiment a 'perfect' run in which supply and demand matched perfectly, showed that the equilibrium price was a little bit lower (about 6.5 Eurocent/unit).