Breaking collusion in auctions through speculation: an experiment on CO2 emission permit market
Mougeot, M.; Naegelen, F.; Pelloux, B.; Rullière, J.-L.

Citation for published version (APA):
Breaking Collusion in Auctions Through Speculation:  
An Experiment on CO2 Emission Permit Market

Michel Mougeot\textsuperscript{a}, Florence Naegelen\textsuperscript{a},  
Benjamin Pelloux \textsuperscript{bc}, Jean-Louis Rullière\textsuperscript{b}

December 2009

\textsuperscript{a} CRESE University of Franche-Comté, Avenue de l’Observatoire F - Besançon 25030 cedex,  
France Email: michel.mougeot@univ-fcomte.fr, fnaegele@univ-fcomte.fr
\textsuperscript{b} GATE, CNRS and University of Lumiere Lyon 2, 93 chemin des Mouilles, 69130 Ecully, France.  
Email: pelloux@gate.cnrs.fr, rulliere@gate.cnrs.fr
\textsuperscript{c} CREED, University of Amsterdam, Roetersstraat 11, 1018 WB Amsterdam, The Netherlands. Email:  
b.pelloux@uva.nl

This research has been made possible by a financial support from the Mission Climat, Caisse des Dépôts et Consignation, Paris, France. Any opinions, findings, and conclusions or recommendations in this material are those of the authors and do not necessarily reflect the views of the Mission Climat, Caisse des Dépôts et Consignation. The authors are grateful to Anaïs Delbosc, Sylvain Boschetto, Sylvain Ferriol for the software and the help and would like to thank Jacob Goeree and Charles Holt as well as participants of the ESA 2009 American meeting in Tucson for their useful comments. The remaining errors are the authors’ sole responsibility.
Abstract:
The European Emission Trading Scheme (EU-ETS) has chosen to adopt an auctioning procedure to initially allocate CO2 emission permits. Free allocation of permits becomes an exception for the third phase (2013-2020) and firms have to buy all their permits on the market or via auctions. The ability of bidders to collude is a key concern about the design of the auction format. To counter the bidding ring, the auction can be open to bidders without compliance obligations (speculators). This paper aims at studying experimentally speculation as a collusion breaking device in two different auction mechanisms: the uniform price sealed bid auction and the ascending clock auction. Our results suggest that a uniform sealed bid auction open to speculators should be chosen from a revenue maximization point of view. In this mechanism, compliance agents are adopting an outbidding strategy toward speculators. This strategy significantly increases the seller’s revenue, compared to the more collusive clock auction. In this one, on the contrary, bidders accommodate speculators, letting them buy permits in the auction and buying their necessary permits on the secondary market. However, as opening the auction to speculators deteriorates efficiency, the regulator faces a trade-off between these two objectives.

JEL-Code: D44; C92, Q52, Q58

Keywords: Auctions, Collusion, Speculation, Cheap Talk, Laboratory Experiment, Emission Permits
I – Introduction

In 2005, the European Union initiated the implementation of the first CO2 emission trading scheme. This European Emission Trading Scheme (EU-ETS) was designed to cap emissions from power generation and much of heavy industry. It forms the central piece of European policy on climate change and is the main instrument to enable European countries to comply with their objectives of the Tokyo protocol. Based on a cap and trade principle, the EU-ETS is the world’s largest carbon trading market: the European carbon market accounts for over 80% of the global carbon market transactions (about 90 billions in 2008). Its liquidity has improved continuously from 260 million tons during the first year (12% of the total allocation of allowances) to 2.75 billion tons in 2008 (130% of the allowances)\(^1\). The aim of such a mechanism is to achieve emissions reduction at the lowest overall abatement cost. The cap corresponds to the overall emission reduction objective and is set on the emissions of the installations covered by the scheme. The permits allocated to firms can be freely traded on the market. Hence, the EU-ETS puts a price on carbon and creates incentives for the reduction of CO2 emissions.

A crucial issue for a cap-and-trade policy such as EU-ETS is the initial allocation of allowances. In the first phase (2005-2008), permits were mainly allocated to firms at no cost in a way related to historical outputs (i.e. to past emissions levels). Whereas firms favor the maintaining of this grandfathering process, economists recommend the introduction of a costly auctioning mechanism\(^2\). In the preliminary phase, European countries could use auctions for at most 5% of the overall allocation. In phase II (2008-2012), at most 10% of the permits could be auctioned, inducing a strictly positive price for carbon emission permits.

However, as the price effects of a cap and trade mechanism are unaffected by whether permits are grandfathered or auctioned, this free allocation has resulted in substantial windfall profits for the firms covered by the scheme. The opportunity cost of a permit (i.e. the price on the market) being the same under grandfathering or auctioning, firms transfer a proportion of the marginal production cost increase to consumers regardless of the form of the initial allocation but depending on the market structure\(^3\). As the effects of the two mechanisms of initial allocation are identical from an efficiency point of view, rent extraction matters. Whereas rent accrues to shareholders of the compliance firms (i.e., the producers that must surrender each year a number of permits corresponding to their emissions to their government) under grandfathering, it can be obtained by taxpayers when permits are auctioned under the condition that auction revenues are oriented toward the reduction of distortionary taxes. When the transfers from consumers to the government have positive social value, i.e., when there is a loss incurred by the society in raising additional revenues to finance government spending, social welfare is greater when permits are auctioned.

Based on these rent distribution arguments, the European Union has limited\(^4\) free allocation of permits to an exception for the third phase of the EU-ETS (2013-2020). Firms from the electricity sector will have to buy all their permits on the market or via auctions. The share of permits freely allocated to firms in the other industrial sectors will have to decrease from 80% in 2013 to 30% in 2020. In a similar way, ten North-eastern American States opted

---

\(^1\) See Charpin (2009)
\(^2\) See for instance Cramton and Kerr (2002) or Hepburn et al. (2006). According to Cramton and Kerr, powerful vested interests in the energy sector are lobbying the permits to be allocated on a grandfathering base.
\(^3\) Hence, though they received free of charge permits, firms in the power sector have increased electricity prices. For instance, in Germany, RWE got a windfall profit of $6.4 billions in the phase I of EU-ETS.
\(^4\) See amended directive 2003/87/EC
for a cap and trade system since September 2008 through the adoption of the RGGI (Regional Green Gas Initiative)\textsuperscript{5}.

The European Commission mentions efficiency – i.e. allocating allowances to firms who attach the greatest value to them – as the main objective of the auctioning of permits\textsuperscript{6}. From this point of view, how to design carbon permits auction? The setting is characterized by a fixed supply of identical permits and by multi-unit demands. Whereas economic theory provides important results on the comparison of the common auctions formats in the case of the sale of a single indivisible unit or of unit demands in the case of multi unit auctions, there is no general game-theoretical solutions for the sale of multiple units when bidders demand more than a single unit. First, there are a variety of auction formats. The seller can decide to sell the permits by using a sealed bid, an ascending bid or an ascending clock auction. The pricing rule can be uniform, discriminatory or based on the Ausubel-Vickrey principle\textsuperscript{7}. Moreover, the auction access can be either restricted to the “compliance” agents, or be open to all current participants on the secondary market, including “non compliance” agents, i.e. banks and financial institutions.

The ability of bidders to collude appears as a key concern for the design of pollution permits auctions as it affects both the efficiency and the revenue of the auction. First, it depends of the format of the auction. Second, it depends of the agents participating in the auction. To illuminate the EU-ETS pollution permits auction design, we have conducted experiments in such a way to analyse how the presence of speculators can be used as a collusion breaking device in two auction formats differently sensitive to collusion and how it affects the auctions performances.

Introducing bidders who have no use value for the allowances but who can speculate by reselling on the secondary market can affect the industrial agents’ strategies in the auction. As in Burtraw et al. (2009), we find that the sealed bid uniform auction gives higher revenue, and that the introduction of speculators enhances this result, contrarily to the ascending clock auction. The latter gives rise to lower revenue and to a shift of the permits obtained in the auction from the high costs producers to the speculators. This is the consequence of different patterns of strategies of the bidders in the two formats.

The paper is organized as follows. Section 2 reviews briefly both the theoretical and experimental literature on auction and speculation. In section 3, we outline the experimental design. Section 4 presents the basic theoretical predictions and discusses the main statistical and econometric results and section 5 concludes.

\textsuperscript{5} See Holt and al. (2007)
\textsuperscript{6} Maximizing the revenue is the second objective of the government when designing an auction procedure. In general, an efficient auction is also a revenue maximizing auction. However, there are exceptions. For instance, a first price auction can be more profitable but less efficient than a second price auction when the bidders’ values are drawn from different distributions. In the same way, a reserve price raises the revenue of the seller but may have a detrimental effect on efficiency.
\textsuperscript{7} See Krishna (2002) for a description.
2. Previous Literature.

According to Klemperer (1999), it is hard to achieve efficient outcomes in multi-unit auctions. The Vickrey sealed-bid auction and the Ausubel ascending auction are efficient in private values contexts. However, in both mechanisms, each bidder has to pay for each permit an amount equal to the externality she exerts on other bidders, and it is a weakly dominant strategy to bid according to her true demand. But implementing these auction formats does not result in a unique price signal for the carbon and can be considered as unfair because high-value bidders are often required to pay less than low-value bidders.

In sealed-bid auctions, there is a single round in which buyers can submit multiple bids at different prices. With pay-your-bid pricing, the highest bids for the \( n \) auctioned permits obtain allowances at their own bid price. With uniform pricing, the bidders with the highest bids obtain allowances at a unique price equal to the highest rejected price. Whatever the pricing rule, strategic behavior leads to inefficiency. With discriminatory pricing, each bidder attempts to guess the clearing price and bids slightly above. Then, in this procedure, bids are well below true values. With uniform pricing, buyers have an incentive to shade their bids for all units except for the first one. Because of this demand reduction strategy, this auction format results in an inefficient outcome. Moreover, there is no clear ranking between pay-your-bid and uniform price auctions. However, the latter has the benefit that every winner pays the same price.

These mechanisms have a corresponding open format. Ascending auction can be conducted with demand schedule or with an electronic clock. As for the sealed-bid format, these procedures are not efficient because bidders shade their bids to lower the price. The most popular is the English clock auction in which the bidders submit in each round the quantity they are willing to buy at the price specified by the clock. This price is increased if the total quantity bid exceeds the supply of permits. The increase continues until there is no excess demand and the permits are allowed at the prior price (and rationed for bidders who reduce their demand in the last round).

As the strategy spaces are complex and as multiple equilibria exist in multi-unit auctions, economic theory does not provide a clear evaluation of these different formats in terms of efficiency, revenue or sensibility to collusion. As a consequence, the design of permits auctions has been often based on experiments. Porter et al. (2009) have tested three mechanisms to maximize revenue and efficiency in the sale of nitrous oxide emission allowances by the Commonwealth of Virginia. Since September 2008, the RGGI organizes quarterly permits auctions in a uniform price, single round sealed bid format. This mechanism has been chosen on the basis of a report of Holt, Shobe, Burtraw, Palmer and Goeree (2007). The research of Holt et al. (2007) uses experimental methods to identify the auction mechanism that performs best along an expended set of performances measures: efficiency, price discovery, guard against collusion and/or market manipulation, government revenue. Experiments were conducted with participants recruited from the undergraduate population at the University of Virginia.

The main result from the experiments was that all auction formats are “reasonably” efficient. Moreover, the revenues for the two single rounds, sealed bid formats (discriminatory and uniform price) were at least as high as those for the multi-round formats. Then, the main

---

8 See Krishna (2002) for a description.
9 See Krishna (2002)
10 Ausubel and Cramton (1996)
12 See also Burtraw, Goere, Holt, Myers, Palmer and Shobe (2009)
recommendation of this research is that the RGGI should use a uniform price sealed bid auction because this design performs very well as a price discovery mechanism. As the price of a permit is a signal of the economic cost of reduction in emissions, it is important that the auction provide accurate price signals. Moreover Holt et al. (2007) show that the clock auction performs less well as promoting price discovery and facilitate collusion.

These proposals have been criticized by Cramton (2007) who recommends an ascending clock auction instead of the uniform-price sealed bid auction. According to Cramton, the main advantage of the clock auction is price discovery: bidders can learn about the other bidders’ demand from the dynamic process and condition their bids on this information. Cramton considers that the experiments of Holt et al. (2007) used a non standard clock format that did not include the price discovery features essential to obtain the benefits of a clock auction, i.e. at each round the excess demand should be made public. On the other hand, whereas Holt et al. (2007) conclude that the clock auction facilitates collusion, Cramton thinks that collusion is unlikely because the market is only moderately concentrated and because collusion is illegal. However, according to Krishna (2002), while bidding rings are illegal, they are widely prevalent. Several other experimental papers consider explicitly collusion in multi object auctions.

Hence, the ability of bidders to collude constitutes a major issue for the design of pollution permits auctions. Collusive bidding results in inefficient outcomes and seller’s low revenue. Moreover, a collusive auction outcome generates biased price signal for carbon. It is well known that collusive agreements are easier to sustain in ascending auctions than in sealed bid auctions. Burtraw et al. (2009) have tested the ability of bidders to explicitly or tacitly collude in three auction formats. Using laboratory experiments, they conclude that the clock auction facilitates collusion, both because of its sequential structure and of the focus on only one dimension of cooperation (quantity) rather than two (price and quantity).

To counter the bidding ring, the seller can set a reserve price. But a more efficient tool could be to open the auction to other bidders than firms with compliance obligations. As financial institutions are not subject to greenhouse gas emission regulation, they only buy permits to make money when selling these permits on the secondary market. An evident advantage is given by an increasing size of the market in order to get closer to the competitive state and to increase the liquidity of the market. But more crucially, it gives rise to speculation, i.e. buying units in the auction to resell them to bidders with high values in the spot market. The presence of speculators may affect other bidders’ strategies, either by inducing them to bid more aggressively to obtain units (which enhance revenue) or by affecting incentives to reduce demand to obtain a lower price. In a complete information theoretical setting, Pagnozzi (2009) puts in evidence three effects resulting from the possibility of resale. Two effects make demand reduction more profitable for bidders. First, resale can correct inefficient allocations and makes demand reduction less costly for the higher value bidders, as they can buy in the resale market the units lost to a speculator. Second, it is more costly to outbid lower-value competitors who bid more aggressively when they can resell. The third effect of increasing competition, i.e. having to share the units with speculators, makes demand reduction less profitable for some bidders. Thus, the presence of speculators may not increase the seller’s revenue, depending on the fact that high value bidders accommodate speculators or not. In a context of uniform price auction with constant marginal valuations and common knowledge valuations, Pagnozzi (2009) shows that the seller should attract speculators only when bidders are relatively symmetric. However, the existence of bidders without compliance obligation may also have an effect on the ability of

---

13 See Brown, Plott and Sullivan(2009), Sherstyuk and Dulatre (2008)
industrial bidders to collude. Indeed, it is more difficult to engage in bidding ring with agents belonging to another sector. Moreover, the speculators’ objectives differ from those of firms with compliance obligations. As a consequence, the seller may try to break collusion by opening the auction to financial actors.

To analyze the impact of speculators in the different bidding formats, we have introduced them in the experimental protocol of Burtraw et al. (2009) that we adapted. Contrary to Pagnozzi’s theoretical analysis, this protocol allows us considering the dynamic aspect of the game due to the bankability of permits and assumes private information about permits valuations.

3 – Experimental Procedures.

To investigate our various auction designs either with or without speculators, we ran a set of four different experimental treatments using 144 undergraduate students (inexperienced; with no specific knowledge in auctions experiments and auctions theory) recruited in groups of 18 from ITECH (Institut Textile Chimique) and Engineering School of Lyon (Ecole Centrale de Lyon). All the experimental sessions were performed at GATE (Groupe d’Analyse et de Théorie Economique, University of Lyon, France) in September 2009. Participants were paid €5.00 for showing up and engaged in an experiment lasting about 1 hour and 30 minutes including instruction time. They were paid according to their performance over the whole experiment and their average final payoff was about €18.00 - €19.00, which seemed more than sufficient to motivate them. During the experiment the payoffs were given in the fictitious “Experimental Currency Unit” (ECU) which was changed into Euro after the experiment by an exchange rate of 2 ECU for €1. Payment was anonymous. Each subject participated only once.

A neutral language was used in the instructions, avoiding words like carbon permits, coal and gas industries, bankers or speculators. The experiment consisted of four treatments with 36 participants each. One session used 18 participants who were randomly assigned to one of the three groups (6 subjects by group). These groupings are never changed.

Our design is based on Burtraw et al. (2009) but the main modification is the introduction of speculators as described below. Overall, our experiments contain 3 types of players: high emitters (e.g., coal industry – type $C$), who need 2 permits per unit produced, low emitters (gas industry – type $G$) who are required 1 permit per unit produced and non emitters (speculators – type $S$) who cannot produce and therefore have no use value for a permit. Each industry player (either type $G$ or $C$) was endowed with 5 units of production and could as a consequence produce a maximum of 5 units of product per period. To reach their full production level, low and high emitters then need 5 and 10 permits, respectively. For each producer, five production costs were randomly determined at the beginning of the experiment and stayed the same for the whole session. These costs were drawn from a uniform distribution within the interval [2, 6] for high emitters and the interval [5, 10] for low emitters. Production units were used in a coherent way so that the lowest cost was used to produce the first unit, the second lowest to produce the second unit, and so on... As in Burtraw et al., each unit produced is sold at a fixed and known price of 12 ECU. Speculators can only make profit by buying permits either during the auction or on the spot market and reselling them on the spot market.

Each session consists of a total of 12 periods. The structure of the game for one period is the same as in Burtraw et al. (2009). It starts with a pre-play communication using an electronic chat room. Whatever the treatment, this chat room lasts for 1 minute prior to the

14 The instructions and the whole set of experimental data are available from the authors upon request.
auction. However, contrary to Burtraw et al. (2009), we did not allow for communication between rounds in our treatments using the multi-round ascending price English clock auction. Communication was anonymous but labelled so that the type of the sender (e.g., C, G or S) was indicated in front of each message. After the minute of communication, the auction started. Depending on our treatments, we considered two types of auction designs: the sealed-bid auction with uniform price and the multi-round ascending price English clock auction. In the uniform price auction, types C and G bidders had to indicate the maximal value they wanted to pay for a permit for each one of their production unit. On the other hand, speculators had to indicate the quantity of permits they wanted to buy and at which price. All bids were then ranked according to their price and the auction price was determined by the price asked for the first unit after the cap, either the 31st or the 21st depending on treatments (see Table I below). The ascending clock auction started at the reserve price of 2 and the price was increased by an increment of 0.15 as long as the total demand for the current price exceeded the cap. Bidders could not increase their demand of permits between auction rounds and if total demand was below the cap, the remaining permits were distributed to the bidders who reduced more their demand.\textsuperscript{15}

Once the auction was over, people were authorized to trade on a spot market. Each participant could then send a buy and/or a sell order, indicating in each case, a price and a quantity. Orders were not constrained in terms of price as soon as it was above the reserve price, but we told participants during the reading of the instructions that it was rather sensible to enter a higher price for the sell order than for the buy order. The intersection of the demand and supply curves formed by the bid and ask prices, determined the spot price. After transactions took place, types C and G players had to decide on the number of production units they wanted to activate. They knew they would receive 12 ECU for each active unit. Once again, subjects were not constrained in their decisions and could incur deficits with respect to compliance standards.

As in Burtraw et al. (2009), compliance periods were spanning multiple periods. Every 3 periods, we confronted the number of permits required for the produced units summed over the 3 periods (remember that high emitters were required 2 permits for each unit produced while low emitters needed only one) with the number of permits hold by the producer at this particular moment. So producers could incur temporary permit deficits in non-compliance periods without being penalized or save permits for future periods. At the end of period 3, 6, 9 and 12, any deficit in permits was penalized at a rate of 9 ECU for each missing permit. At the end of the last period (period 12), the non used permits have no value and participants knew it beforehand.

At the end of each period, we provided feedback to the participants. They saw a screen indicating their buying and selling activities (quantities and prices) for the current period, both during the auction and on the spot market. They could also see their current stock of permits and the current number of permits required according to their type and production decisions during the on-going compliance periods. In the case of periods 3, 6, 9 and 12, the possible penalties were indicated. Their cumulated payoff for the experiment was also shown. Throughout the whole experiment, a reserve price of 2 ECU was imposed for a permit, so that at no point in time it was possible to buy or sell a permit below this price. It should be noticed that permits were bankable so they are valid for the whole duration of the experiment. In all our treatments, the cap was fixed at 2/3 of the total number of permits needed for a maximal

\textsuperscript{15} Obviously, this is not the case for the first auction round where nobody reduced his demand. It is therefore possible that not all the permits are sold during the auction if the total demand is below the cap at the reserve price. We will see that this happened several times in our experiments.
production. This is coherent with a cap and trade policy which aims at limiting polluting emissions, based on the produced quantities.

Table I is showing the basic features of our four treatments. As you can see, the number of players is fixed (e.g., 6 players whatever the treatment) but the types of players composing the market is not constant. We opted for a 2x2 design where we crossed the auction format (either clock or uniform) with the presence or absence of speculators. This allows us not only to study the impact of the auction format on collusion (as in Burtraw et al. (2009)) but also to see what is the impact of the presence of speculators, and if this impact differs according to the auction format.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>CI</th>
<th>Ul</th>
<th>CS</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>Players</td>
<td>3G / 3C</td>
<td>3G / 3C</td>
<td>2G / 2C / 2S</td>
<td>2G / 2C / 2S</td>
</tr>
<tr>
<td>Auction Format</td>
<td>Clock</td>
<td>Uniform</td>
<td>Clock</td>
<td>Uniform</td>
</tr>
<tr>
<td>Permits Needed For Maximal Production</td>
<td>45</td>
<td>45</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Permits Being Sold During the Auction</td>
<td>30</td>
<td>30</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

4 – Results

Before considering the experimental results, we can consider the theoretical equilibrium price of a permit $p$ as a benchmark. It is obtained in a static model without speculators and with price takers under assumptions identical to those of the experimental procedure.

4.1. Theoretical benchmark.

According to these assumptions\(^\text{16}\), a low emitter’s profit is equal to $\Pi_g = 12 - p - c_g$ and is positive if $12 - p > c_g$. Then, the expected supply of a low emitter depends on the permits price and is given by

$$ S_g(p) = \begin{cases} 
0 & \text{if } 12 - p < 5 \\
5 \int_5^{12 - p} \frac{1}{5} dc_g = 7 - p & \text{if } 5 < 12 - p < 10 \\
5 & \text{if } 12 - p \geq 10 
\end{cases} \quad (i.e. p > 7) \quad (i.e. 2 < p \leq 7) \quad (i.e. p \leq 2) $$

In the same way, a high emitter’s profit is equal to $\Pi_c = 12 - 2p - c_c$ and is positive if $12 - 2p > c_c$. Then, the expected supply of a high emitter is

\(^{16}\) See Goere et al. (2009) in a different setting
If we denote $D_g(p)$ and $D_c(p)$ the demand of permits from low and high emitters, we have $D_g(p) = S_g(p)$ and $D_c(p) = 2S_c(p)$. Assume that the number of permits is capped at 30. The permits price is such that

$$30 = 3D_g(p) + 3D_c(p) = D(p)$$

with

$$D(p) = \begin{cases} 
45 & \text{if } p \leq 2 \\
51 - 3p & \text{if } 2 < p \leq 3 \\
96 - 18p & \text{if } 3 < p \leq 5 \\
21 - 3p & \text{if } 5 < p \leq 7 \\
0 & \text{if } 7 < p 
\end{cases}$$

The competitive price of a permit is then equal to $11/3$. At this price, a low emitter produces if her cost is lower than $25/3$. Her demand of permits, as well as her production, is equal to $10/3$. In the same way, a high emitter produces if her cost is lower than $14/3$. Her demand of permits is equal to $20/3$ and her production is equal to $10/3$. Then the whole production is equal to 20 units.

In the auction, a low emitter is then assumed to acquire $10/3$ permits whereas a high emitter is assumed to acquire $20/3$ permits at a price $p_a$ of $11/3$. The auction revenue is equivalent to 110. Since the auction allocates permits optimally, there is no activity on the spot market.

### 4.2. Experimental results.

To analyze the experimental results, we consider only the last 6 periods (over 12) of the experiment. It is well known that experimental auctions give rise to learning. This may be all the more true in our design as subjects also have to understand the spot market and the production decisions. Keeping only the second half of the experiment allows us to reduce this confusing element. The data analysis will be done in order to study the differences in the levels of collusion between treatments and the impact of the presence of speculators through different criteria which are the auction price, the auction or seller’s revenue, the permit holding patterns, as well as the activity on the spot market, the production decisions and efficiency levels.

Concerning the auctions performances, we observe different patterns. Figure 1 shows the distribution of auction prices for each treatment. The two top panels correspond to the two clock auction treatments, without (CI) and with speculators (CS). We can first notice that, on average, 70% of the auctions end at the reserve price of 2 (69.4% and 80.6% respectively for CS and CI), which could be consistent with a very high level of collusion facilitated by the chat room. Even more striking is the fact that the price went beyond the second round of the clock auction only once to reach 2.3 in the CI treatment. This result is consistent with the study of Burtraw et al. (2009) who also found the clock auction more collusive. The introduction of speculators only alters slightly this result. A Wilcoxon rank sum test is not rejecting the equality of medians between the CI and CS treatments ($p > 0.1$) so the
introduction of speculators did not impact significantly the prices in the clock auction. The picture is however different when we consider the uniform auction. Even if the treatment including only compliance agents yields a majority of auctions ending at the reserve price (52.8%), the presence of speculators shifts the distribution to the right with only 8.3% of reserve prices. This difference appears highly significant (Wilcoxon rank sum: \( p < 0.01 \)).

The auctions prices are shown in Table 2, which contains the average auction and spot prices per treatment. It must be noticed that the average auction prices reached in our four treatments are far below the theoretical prediction of 3.66. The maximum, a price of 3.2, is obtained twice in the US treatment.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Avg. Auction Price</th>
<th>Avg. Spot Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS</td>
<td>2.163</td>
<td>2.950</td>
</tr>
<tr>
<td>CI</td>
<td>2.033</td>
<td>2.279</td>
</tr>
<tr>
<td>US</td>
<td>2.571</td>
<td>2.697</td>
</tr>
<tr>
<td>UI</td>
<td>2.258</td>
<td>2.284</td>
</tr>
</tbody>
</table>

These prices result from the ability of the auction to raise revenue for the seller. This is an important question when designing the CO2 permits auctions, as the public authority prefers a design that maximizes its revenue, besides goals such as efficiency or the minimization of price volatility. We use a random effects generalized least squares model with an AR1 error term and regressed revenues (normalized according to the number of
permits auctioned, either 20 or 30 depending on treatments) on dummies reflecting the presence of speculators, the format of the auction, an interaction term between the two, on the normalized Walrasian revenues and on a constant. The results of this estimation are shown in Table III.

Table III: Econometric Analysis of Auction Revenue

| Normalized Revenue          | Coefficient | P>|z| |
|-----------------------------|-------------|-----|
| Speculators                 | -9.005      | 0.000 |
| Uniform                     | 14.429      | 0.001 |
| Speculators * Uniform       | 11.589      | 0.026 |
| Walrasian Normalized Revenue| -0.549      | 0.074 |
| Constant                    | 102.31      | 0.000 |

N 144
Wald $\chi^2$ 184.21

Firstly, we can notice that the three dummies appear significantly. As expected, the auction format matters: the fact that the auction is uniform has a positive and very significant impact on revenues. More surprisingly, we see a negative and again very significant coefficient for the speculators dummy. This is due to the CS treatment and its conjunction of collusive prices and a limited number of permits bought in some rounds of the auction. This last observation is explained by the fact that producers considerably reduce their demand and accommodate the quite aggressive strategy of the speculators. This leads to miscoordinations on the total quantity demanded on the first round of the auction so that, in some cases, less than 20 permits were sold at the reserve price. Finally, the coefficient of the interaction term is positive and significant. This reflects the fact that our US treatment yields the highest revenues. The introduction of speculators in a fairly competitive auction seems to be the best solution as far as government’s revenues maximization is concerned. The lower the collusion during the auction, the more positive is the impact of the presence of speculators on the revenues. We obtain a result similar to Pagnozzi (2009) when the bidders are symmetric: the presence of speculators increases the revenue when the bidders do not accommodate.

To assess the significance of differences of revenues between treatments, we perform both Wald Chi$^2$ tests based on the previous regression and Wilcoxon rank sum tests. Table IV shows the results of these tests, which are almost all very significant. The tests between treatments with the same types of agents both show a clear superiority of the uniform auction in terms of revenues as indicated by the second and third rows of the table. Moreover, as suggested by the positive and significant coefficient of the interaction term in our regression, the auction revenue in the US treatment is also significantly higher than in the UI treatment. Finally, the difference between the CS and CI treatments is given significant only by the Wald Chi$^2$ test.
Table IV: Pair-Wise Revenue Comparisons
(p-values appear in parentheses, where *** indicate significance at the 0.01 level)

<table>
<thead>
<tr>
<th>Results</th>
<th>Wald $\chi^2$</th>
<th>Wilcoxon Rank Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue US &gt; Revenue UI</td>
<td>16.87 ***</td>
<td>3.636 ***</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Revenue US &gt; Revenue CS</td>
<td>104.09 ***</td>
<td>-5.156 ***</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Revenue UI &gt; Revenue CI</td>
<td>10.72 ***</td>
<td>-3.796 ***</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Revenue CS &lt; Revenue CI</td>
<td>16.70 ***</td>
<td>-1.494</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.135)</td>
</tr>
</tbody>
</table>

These experimental results recommend the design of a sealed bid uniform auction open to no use value agents, i.e. speculators, for several reasons. The first reason is the same as Burtraw et al. (2009). We find that when there are only producers participating in the auction, the sealed bid auction with uniform price gives higher revenues. The second one is specific to our experiment. The introduction of speculators in the uniform auction weakens collusion, in line with the idea that in general, the more competitive an auction is, the higher is the outcome for the auctioneer.

These first tests suggest that the presence of agents with no use value does not prevent collusion during the clock auction but has a significant impact on the outcome of the uniform auction. However, the low level of price in the CS treatment, indicating a high level of collusion, does not mean that speculators did not play an important role during the auction. This role can be considered through the distribution of permits among agents. Figure 2 shows the average number of permits bought during each auction by the different types of agents. We can observe a dramatic change in the type of permits holders following the introduction of speculators in the clock auction. Indeed, one speculator bought on average $5.35$ permits in our CS treatment, meaning that these agents held more than the half of the emitted allowances after the auction. This strong position is obtained mainly at the expense of high emitting industries as their average number of permits bought during the auction is divided by more than three, moving from the CI to the CS treatment. Together with our first results, it can indicate that speculators easily outbid compliance agents during the clock auction and obtain a lot of permits at a very low price.
The sealed bid uniform price auction exhibits a different pattern. Even if speculators get a quite large share of the auctioned permits, their impact is less dramatic than in the clock auction. They obtained on average 2.60 allowances in the US treatment, which is less than a half of the permits bought in the CS treatment. It also appears that low and high emitters share quite evenly this 'burden', as their average permits holding decreases to a similar extent.

The previous results concerning prices and distributions of permits in the auction leads to the conclusion that compliance agents adopt two different strategies when agents with no use values are introduced in the ascending clock and the sealed bid uniform auctions. In the former, they accommodate speculators. Producers reduce notably their demand during the auction. This demand reduction has two consequences. First, it leads to a reduction of the auction price. Second, it lets speculators do their job, i.e. to buy permits at a low price during the auction to resale them at a higher price on the spot market. Producers reduced demand so much that in 50% of the auctions of the CS treatment, total demand at the reserve price did not reach the offer of 20 permits, so that not all allowances were sold\(^{17}\). It seems that producers accept to let the permits in the hand of speculators and that this coordination is facilitated by the intrinsic collusive nature of the clock auction, where bidders focus on only one dimension, the demanded quantity. Coordination is less easy to sustain in the uniform auction, where bidders have to coordinate on both the price and quantity dimensions, as shown by higher price levels and a more equal distribution of permits among the three types of agents. In the latter auction, producers do not accommodate speculators whose outbidding strategy is more costly. Instead, they buy a significant share of the permits during the auction.

These different patterns of permit holding between treatments should be reflected on the spot market, that we consider now, both through the volume of transactions and the prices. Figure 3 exhibits the average volume of exchange for the last 6 periods of each treatment. Because speculators capture a huge share of the permits sold during the auction in the CS treatment, we expect a high volume of exchanges in this treatment, conditional on the fact that

\(^{17}\) See also below, in the econometric analysis of revenue

Figure 2: Permit Holding
compliance agents are still willing to produce. This is indeed the case with on average 13 permits changing of owners, from speculators to producers. In line with the permit holding findings, we observe a significant difference in the number of exchanged allowances on the spot market between our two treatments including speculators (Wilcoxon rank sum: \( p < 0.01 \)). Because of the stronger position of producers after the auction, less trade is necessary on the spot market in the US treatment compared to CS.

![Figure 3: Exchanged Quantities on the Spot Market](image)

Even without speculators, the spot market could have worked as a coordination device, so that collusion could have been maintained over time in the auction phase. But the sessions without speculators exhibits very low volumes of exchange on the spot market. Remarkably, no trade occurs in 41.7% (respectively 47.2%) of the rounds in the CI treatment (respectively in UI treatment). The underlying explanation may be that an efficient allocation has already been achieved during the auction so that little reallocation of allowances is needed afterwards.

From Table II, we can also see that speculators efficiently exploit their quasi-monopolistic position on the spot market in the CS treatment. The average spot price is equal to 2.95, far above the mean auction price of 2.16. This is however not the case for the US treatment where the auction and the spot prices are closer. According to our previous results, the scenario is close to perfection for the speculators in the CS treatment. As the more collusive nature of the clock auction does not make their outbidding strategy too costly, they buy a lot of permits at a very low price during the auction, which generates high profit perspectives on the spot market. When getting on it, the speculators can ask for high prices that the compliance agents must accept if they want to produce and to comply with their obligations. The willingness to maintain collusion in the auction is costly to the producers, to the sole benefit of speculators. The story is different in the US treatment. Because coordination is harder in the uniform auction, permits are more expensive in the auction. Speculators cannot obtain a quasi-monopolistic position on the spot market and, as a consequence, get a lower price than in the CS treatment (see table II supra).
Finally, we can consider the impact of the auction format and of the presence of speculators on the decision of production and more precisely on the relative levels of production of low and high emitters. According to the theoretical model, when the number of permits is capped at 20, each low and high emitter should produce 3.33. Considering the experimental results, we must first notice that producers are producing more than the theoretical level, but less in the presence of speculators than without them: they produce on average 3.52 in the S treatments versus 3.79 in the I treatments. This difference is marginally significant according to a Wilcoxon rank sum test (\( p = 0.078 \)).

More precisely, we show in Figure 4 the mean production level per low and high emitter for each treatment. We see that the high emitters are producing on average half a unit less than in the US treatment (3.06 vs 3.57), owing to the difficulties they encounter to buy permits in the CS treatment. This difference is marginally significant (Wilcoxon rank sum: \( p = 0.075 \)). The difference is in the opposite direction for the low emitters (4.01 in CS vs 3.46 in US) who are producing significantly less in the uniform case (Wilcoxon rank sum test : \( p < 0.05 \)). The presence of speculators has an impact on production levels, and then on the level of emissions.

The results concerning production decisions may be linked to efficiency. If the auction is efficient, permits must be allocated to the producers with the highest permit values and production decisions made accordingly. However, the experiment induces a dynamic game in which producers could incur temporary permit deficits in non-compliance periods without being penalized or save permits for future periods. Therefore, production decisions are based on the permits obtained in the auction and/or in the spot. Moreover they depend on previous and future decisions. Comparing the value of permits used at each period for production with the theoretical value gives only an indication of a temporary possible misallocation, the overall misallocation having to be considered on the whole game, i.e., the 12 periods.
Table V shows the mean allocative efficiency over the 12 periods. It is very close to 1 for the treatments without speculators and lower than one for the treatment with speculators, whatever the auction format. Then allocative efficiency is greater in the absence of speculators.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Avg. Efficiency 12 periods</th>
<th>Avg. Efficiency Periods 1 to 6</th>
<th>Avg. Efficiency Periods 7 to 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS</td>
<td>0.858</td>
<td>0.757</td>
<td>0.959</td>
</tr>
<tr>
<td>CI</td>
<td>1.037</td>
<td>1.027</td>
<td>1.047</td>
</tr>
<tr>
<td>US</td>
<td>0.867</td>
<td>0.750</td>
<td>0.984</td>
</tr>
<tr>
<td>UI</td>
<td>0.991</td>
<td>0.926</td>
<td>1.056</td>
</tr>
</tbody>
</table>

All along the periods, we observe different patterns in the use of permits linked to production decisions in the different treatments, because of the possibility of deficit and banking. As shown in Figure 5, allocative efficiency is greater in the last 6 periods and the greater allocative efficiency is observed for the ascending clock and uniform auctions without speculators. Coefficients greater than 1, observed essentially in the clock auction without speculators indicates that producers have used more permits than authorized by the cap, incurring penalties. However, there is compensation between the 12 periods.

![Figure 5: Mean Efficiency (Rounds 1 - 12)](image)

5 –Conclusion

The laboratory experiment we conducted shows that introducing speculators in auctions matters and that speculation plays a significant role in the CO₂ initial emissions auctions as a means to increase the auction price and the seller’s revenue. In the terms of
Pagnozzi (2009), speculators are welcome in this market. However, the impact of speculators on the revenue, efficiency and allocation of permits depends heavily of the auction format, as well as the activity on the spot market. The uniform price auction leads to higher revenue with a lower activity of speculators, contrarily to the ascending clock auction.

In the sealed bid auction with uniform price, opening the auction to non compliance agents leads to higher prices. Is it because speculators weaken collusion? A priori, in this mechanism, collusion is less likely to appear, as shown by the theoretical literature, by Burtraw et al. (2009) and by our experiment results in the absence of no-use value agents. Compliance agents seem to adopt outbidding strategies when speculators participate in the auction. Consequently, as competition increases, their demand reduction strategy is weaker. This behavior leads to higher revenue for the seller.

In the ascending clock auction, opening the auction to financial institutions results also in higher prices but the effect is less important. With or without speculators, a great number of permits are sold at the reserve price. In this a priori more collusive auction, the price is significantly lower than in the sealed bid format whatever the participating agents. Compliance agents seem to accommodate non compliance bidders. They reduce their demand and let speculators buy permits in the auction and they buy their necessary permits on the spot market. This behavior leads to a lower auction price and to a lower seller’s revenue.

In other respects, we show that the presence of speculators has an impact on production levels and then on pollution. In the two formats, the level of emission is lower when non compliance bidders participate in the auction because high emitters reduce their production. Moreover, we show that allocative efficiency is greater when the auction is not open to speculators.

Then there is a trade-off for the public authority. On the one hand, from a revenue point of view, these experimental results recommend the design of a sealed bid uniform auction open to agents having no use value for permits i.e., speculators 18. On the other hand, the participation of speculators deteriorates efficiency. Then, if a sealed bid auction should be preferred according the two goals, the participation of the speculators works in opposite directions from the objective of revenue maximization and from the objective of allocative efficiency. Our results must however be considered cautiously because the experiment does not explore all the complexity of the market. For example, the question of different vintages is not considered here. The allowances of different vintages can be sold in separate auctions or in simultaneous ascending auctions. In our model, the product market price is fixed. However, depending on the activity sector of the firms, the cost of the permits could be transferred differently on the downstream product prices. So the bidders could adopt different strategies in the auction. Further research will consider these issues.

---

18 This is also the conclusion of the Charpin (2009) Report for the EU-ETS
References


