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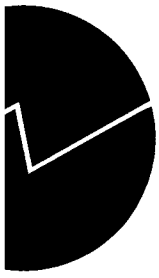

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Experimental Economics and the US Tradable SO_2 Permit Scheme: A Discussion of Parallelism

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Abstract:
In the US tradable SO_2 permit scheme 97.2% of the permits are allocated to the affected utilities on an annual basis. The remaining 2.8% are traded at an auction conducted each year by the US Environmental Protection Agency (EPA) along with permits offered for sale by the permit holders. In addition, permits are traded on a complementary private permit market. In this paper we review a set of experiments that preceded these developments and tried to predict auction and, to some extent, market behaviour. The reviewed experimental efforts concluded that the auction prices would tend to be downward biased and thus underestimate the true marginal cost of emissions control. Also, one paper forecasted a divergence between the auction price and the corresponding permit market price level. A comparison with available empirical data serves to falsify several of these predictions. Indeed, the practical relevance of the EPA auction's experimentally alleged properties is negligible. Hence, parallelism - the degree of transferability of experimental results to real-life settings - is questioned.

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1. Introduction

The main purpose of this paper is to discuss the practical relevance of experiments conducted with reference to the US tradable SO_2 permit scheme. This discussion utilises the concept parallelism, i.e., the extent to which both the experimental designs as well as the laboratory results transfer to the relevant realistic setting. The background for these experiments as well as a precise outline of the paper follow in sections 1.1.-1.3.

1.1. The Clean Air Act Amendments (CAAA)

The most innovative feature of US 1990 Clean Air Act Amendments is the market-based approach to reduce sulphur dioxide (SO_2) emissions from 18.9 million tons per annum (mta) in 1980 to 8.9 mta by the year 2000. This policy objective is to be achieved by means of tradable allowances/permits[1]: given an overall cap on emissions, the individual emission sources are granted complete flexibility as to the manner in which they choose to adhere to the legislation. The binding constraint is for the individual generating plant to possess allowances that cover its emissions. This is achieved either by investing in abatement technology and/or purchasing permits. These may be bought at the US Environmental Protection Agency's (EPA) annual auction or the now operating market in tradable SO_2 allowances. The first auction of this kind was conducted in 1993 whereas the allowance market commenced the year thereafter[2].

The programme consists of two phases. The first was implemented on January 1, 1995 and is to last for 5 years. The second phase begins on January 1, 2000. The former affects 110 of the highest emitting electric utility units in the US, although other plants have the option to participate (opt in) as well. During the second phase the programme is expanded to include most existing fossil-fired electric generating units.

The initial permits were allotted to the affected units free of charge (grandfathering) based upon emissions observed within the time range 1985-87. Permits are distributed on an annual basis. They are dated by years and may be used in that year, alternatively «banked» and used in any subsequent year within the phase period. The first emission rights were issued in 1992, albeit none were valid for use prior to the commencement of phase I.

Starting in 1993 the Chicago Board of Trade conducts annual auctions on behalf of the EPA. These enable post-1985 market entrant the possibility to purchase permits. Also, price signals are generated which is believed by the EPA to encourage trading or to 'make the market'.

To supply the auction with permits, the EPA withholds 2.8 per cent of the total annual allotment. Eighty per cent of these are available for auction purposes (the rest being offered for direct sales to power producers at a fixed cost of US$ 1500)[3].

There are two parts to this auction: a spot auction as well as an advance auction. Both are sealed bid, discriminative two-sided auctions, i.e., consisting of both bids to buy as well as offers to sell. After

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[1] The Amendments refer to permits as allowances. In this paper the words permits, allowances, and rights are used synonymously.

[2] The Chicago Board of Trade (CBOT) has a home-page on the Internet which provides extensive and continuously updated information concerning the 1990 CAAA, the EPA auctions, and the operating spot and futures markets in tradable allowances. Confer the Internet-address as follows: http:/www.cbot.com/

[3] Private permit holders may also tender permits for the sale at the EPA auction. Nonetheless, the EPA does not offer these before going short on their own withheld permits. The EPA returns proceeds and unsold private permits from the auctioning on a pro rata basis to those units from which they were originally withheld. Proceeds from the direct sales are also returned to the private permit holders in a similar fashion.

being submitted, bids are ranked from highest to lowest based on the bid price, whereas the offers are ordered in an ascending manner. Afterwards the lowest offer is matched with the highest bid, where the latter also constitutes the factual trade price. EPA offers privately tendered allowances upon going short on its own stocks.

1.2. Tradable emission permits experiments

Prior to the commencement of the allowance auctions and markets considerable efforts were devoted to the experimental explorations of these institutions. Indeed, some of the laboratory evidence was taken into account when drafting the CAAA auctions and markets legislation. Such work was warranted insofar the auction procedure chosen by the EPA diverted from conventional auction procedures. Thus, initially there was considerable ignorance as regards its behavioural properties. Moreover, the interaction between the auction and the developing allowance market was investigated experimentally.

A clear or accurate price signal is characterised by being indicative of the optimal marginal abatement cost in the industry affected by a tradable permits scheme. Such signals are essential to achieving the cost and dynamic efficiency objectives of such an arrangement. This criterion tends to attract little explicit attention in the policy documents. It is implicit, however, in the substantial attention paid to problems of thin markets and banking: the former may cause volatile prices not representative for optimal marginal emission control cost. Banking is commonly proposed as a remedy facilitating less permit price variance (Muller and Mestelman, 1993).

The issue of accurate permit prices has figured dominantly in the mentioned experiments. Auction prices reflecting utilities' equilibrium marginal abatement costs would assist the implementation of a complementary market in permits. Also, such price signals might contribute to a rational planning of abatement (to wit, investments in proper technology) by firms.

1.3. Outline of the paper

The paper's objective is to, first, discuss the concept of parallelism in experimental economics.This term refers to, in brief, the experiment's «closeness» to natural situations and the extent to which experimental results transfer to a corresponding non-experimental setting (Davis and Holt, 1993).

Second, we provide a summary of the experimental work conducted with regard to the CAAA tradable emission scheme. This is discussed relative to available data from EPA auctions and complementary permit markets. The focal point of this discussion is the permit price signal issue and the interaction between the auction and the permit market.

Third, an assessment of the relationship between the experimental results and the existing empirical data on the operating marketable SO_2 allowance scheme in terms of parallelism concludes the paper.

2. Parallelism in experimental economics

2.1. Definitions and dimensions of parallelism

Vernon L. Smith (1982) states that «the fundamental objective behind a laboratory experiment in economics is to create a manageable microeconomic environment in the laboratory where adequate control can be maintained and accurate measurement of relevant variables guaranteed». He proceeds to list a number of precepts which he deemed sufficient in order to exercise control over an experimental setting. One of these precepts is termed parallelism. It is characterised as a sufficient

condition for the transferability of experimental results to field/real-life environments, and is defined as follows:

«Propositions about the behaviour of individuals and the performance of institutions that have been tested in laboratory microeconomies apply also to nonlaboratory microeconomies where similar ceteris paribus conditions hold»

Smith's definition concerns the behavioural aspects of agents or institutions. In the following we shall adopt the term behavioural parallelism to describe this phenomenon.

A more general connotation of parallelism is that of policy implications or policy guidance. Charles Plott (1987) discusses these dimensions of the term, some of which are reproduced below:

- Shifts in the burden of proof: experimental results can influence an ongoing policy debate. «The objective of the experiment is to establish the need for proponents of the other side of the argument to prove or disprove something before a policy discussion can proceed in their favour» (ibid., p. 205). The extent of parallelism thus hinges on the effectiveness of experimental data in exerting influence upon a policy debate.

- Potential design; prepolicy research: sometimes economic problems require novel types of organisation and decision processes. In such cases history supplies no data, and experimental predictions consequently constitute the information set underlying the eventual policy decision. In this context parallelism consequently refers to the link between experimentally developed designs and their practical implementation.

Yet another interpretation is provided by Davis and Holt (1987), namely that of design parallelism. This is matter-of-factly used to indicate «closeness» to natural situations. A high degree of design parallelism obtains when laboratory settings are constructed to resemble scale models of the target market or institution.

In practise this definition does not easily allow for a succinct operationlisation. However, when designing an experiment on a tradable permit scheme involving both an auction procedure as well as a complementary market, a laboratory setting exhibiting both an auction and a market would have a higher degree of design parallelism than a design which included an auction procedure only[4].

The recommended degree of design parallelism depends upon the purpose of the experiment. Theory falsification is often proposed as a prominent goal of experimental analysis (see, e.g., Popper (1959)). This would require a specification of the laboratory setting which rather accurately satisfy the conditions of the theory.

However, in a policy guidance context dealing with possibly novel institutions the quest for falsification is not necessarily an obvious research strategy. The appropriate task is to provide information that policy makers consider relevant import to a decision making process. A «high» degree of design parallelism is a probable requisite in this regard as well.

[4] Critics might argue that this conjecture does not hold if the market in the former experimental design is unrepresentative of the real-life permit market. An appropriate riposte is to assert that design parallelism exhibits a lexicographic property: an experimental design including both a market and an auction exhibits a higher degree of design parallelism than an experiment incorporating but one of these institutions.

2.2. Empirical properties of parallelism

Smith considers the validity of parallelism is considered an empirical matter: the appropriate way to falsify behaviour parallelism with respect to some particular aspect of behaviour is to show that some replicable experimental property of a theory/institution is contradicted by available field data. Similarly, design parallelism is low when the experimental design imprecisely resembles the characteristics of the relevant real-life setting. Whereas design parallelism may be evaluated ex ante, behaviour parallelism can only be falsified/corroborated ex post.

We conjecture that the two notions of parallelism are linked in a particular manner. A «high» degree of design parallelism is a priori correlated with the practical transferability the experiments' behavioural properties. Alternatively, if the laboratory design differs significantly from the modelled market, then the probability of obtaining precise experimental predictions is likely to be small.

3. Review of papers on the 1990 CAAA allowance auctions and markets

SeveNral of the reviewed papers are based on theoretical underpinnings published elsewhere, see e.g. Cason (1993) and Cronshaw and Kruse (1991). These are disregarded in order to focus on sheer experimental evidence deriving from laboratory microeconomies.

Below a short reproduction of the experiments is provided. The focus is upon the experimental design as well as results regarding the EPA auction's properties and the auction and permit market prices. A more detailed review can be found in the Appendix.

3.1. Cason and Plott: «EPA's New Emissions Trading Mechanism: A Laboratory Evaluation»

This experiment evaluated the EPA auction institution for trading SO_2 allowances relative to the more commonly observed uniform call auction[5].

In total 12 sessions were conducted for 24 market periods. Eight of the sessions implemented the EPA auction rules while four implemented the uniform price auction. The EPA auction experiments did not include any mandatory units in order to focus on the incentives of the voluntary units offered for sale.

When testing each auction procedure the experimenters made use of two different types of environments. In one aggregate demands and supplies were constant for several periods (the constant aggregate case), in the other the demands and supplies of each individual were drawn randomly each period (the random draws case).

In the EPA auction sessions the different bids determined the different transaction prices, and in the uniform price sessions the midpoint of the market-clearing price interval determined the (common, uniform) price.

The primary conclusion is that the EPA auction rules create strong incentives for both buyers and sellers to underreport their true cost of emissions control to the auction, thus leading to a downward price bias and extracting less gains from trade compared to the uniform call auction[6].

[5] This auction is conducted in the following manner: the auctioneer aggregates and arrays all bids and asks as revealed demand and supply schedules, and all trades occur at a uniform price where these schedules intersect. Only the bids and asks near the margin affect the uniform transaction price. This form of auction is common on exchanges world-wide for securities that have low trading volume.

Additional results concerning permit prices are the following:

- Prices of the uniform price auction are closer to the competitive equilibrium prices and are higher than the market clearing prices of the EPA auction[7].

- Value and cost relevation are greater under the uniform price auction than under the EPA auction. Also, the uniform price auction prices convey more accurate information and are more responsive to changing conditions that the EPA auctions prices where the market clearing price reacts more slowly to unexpected parameter changes.

3.2. Franciosi, Isaac, Pingry, and Reynolds: «Extension of Research into Marketable Emissions Permits»

This experiment was conducted on behalf of the Oak Ridge National Laboratory's Energy programme in order to serve as input to the drafting of the marketable SO_2 allowance scheme. It focused on the interaction of the EPA auction with the complementary market for permits.

In this experiment each period was divided into two markets, conducted sequentially. First, subjects were given the opportunity to trade permits in a computerised double auction similar to an ordinary asset market. Subjects submitted bids and offers through the computer network. Their screens displayed outstanding bids and offers, which they could accept at any time.

After the double auction, subjects were permitted to submit a series of sealed bids for the permits offered in the revenue neutral auction. Simultaneously, subjects were required to surrender a fraction of their holding to the revenue neutral auction. They might tender additional permits for this auction as well. The submitted bids effectively corresponded to the subjects' demand schedule. The market clearing price was determined by the intersection of this demand curve with the supply of permits. Sellers received the average revenue generated by the auction for each unit they sold.

As for the results, in general there is a divergence between the revenue neutral auction and the double auction. In the most efficient session the revenue neutral auction prices lie substantially below the double auction prices. The double auction prices themselves are generally substantially below the competitive price. In the least efficient the mean prices from the revenue neutral auction track the double auction fairly well, although the lowest winning bids are below both. In general, prices are well below the competitive level, thus understating marginal abatement costs. Hence, prices in the revenue neutral auction and double auction markets do not always convey the same information, and neither is an accurate indicator of marginal abatement costs.

3.3. Cronshaw and Kruse: «An Experimental Analysis of Emission Permits with Banking and the CAAA of 1990»

The reported experiments investigate, first, the issue whether the marketable permit programme is potentially functional. Functionality here relates to potential reduction in system abatement cost

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[6] A tentative motivation: sellers receive the bid price of a specific buyer, and their asking price determines their trading priority. Sellers with the lowest asking prices receive the highest bids; consequently, sellers have an incentive to submit offers that underrepresent their true costs of emission control. Also, bid prices tend to be understated, cf. the well-known result from Vickrey (1961) that buyers have an incentive to under-reveal demand in discriminative auctions in which they pay their bid price.

[7] Cason and Plott define the market clearing price as the final transaction price at the margin when the auctioneer intersects the revealed supply and demand arrays. This is considered the most significant price signal insofar it reveals the marginal terms of trade buyers and sellers must in order to be included in the market transactions.

relative to the benchmark command and control approach. Second, it is considered whether prevailing market prices bear any systematic resemblance to market clearing prices.

The features of the experiments may be summarised as follows: Allowances are grandfathered to existing «affected units» (five types of firms, distinguishable by reference to abatement cost schedules). Once allocated, the permits can be applied to cover a period's emissions (the experiments cover a twelve period time span), banked, or traded. The auction includes both mandatorily and voluntarily tendered permits[8]. There exists no aftermarket. The mandatory amount of allowances are available at an offer price of zero. Additional permits are traded conditional upon the mandatory permits having been sold. The bids are ranked from high to low, and vice versa with the offers. The proceeds from the auctions are returned to the firms.

It is shown that a perfect foresight competitive equilibrium exists, and that this achieves the minimum abatement cost. This implies a specific competitive equilibrium (CE) permit price which is equal for each period. If actual emissions in one period should differ from the amount corresponding to the CE level, then there is a new CE price from the current period to the end of the experiment. These prices are optimal after some given history, and are termed «adapted». Adapted CE prices for each period of each market experiment is calculated, and reflect the number of permits available from banked stocks and allocations to be received in the remaining periods of the experiments.

Transaction prices are compared with the adapted CE price for each period. In each case the adapted CE price falls over time due to large stocks of permits. (Compared with the 12 period system optimum, too many permits are banked.) The prices observed in the market respond to changing market conditions as reflected by the falling adapted CE price in 4 of the 5 experiments. Also, the prices observed relate to the marginal abatement cost at an optimal system allocation, albeit they are not demand revealing.

Below a brief summary of the experiments' designs and main predictions is provided.

Table 1. Summary of the reviewed experiments' designs and main predictions

	Experimental design:			***Predictions:***	
	Auction + aftermarket	Mandatory permits	Direct sales of permits	Permit prices	Auction's resp-onsiveness to changing ec. con.
Cason & Plott	No, only EPA auction	Only privately offered permits are analysed	No	Downward price bias; understated abatement costs	Bad
Franciosi et al.	Yes	Yes	No	Auction prices below market prices	Bad
Cronshaw & Kruse	No, only trade at the EPA auction	Yes	Yes	(Decreasing) prices indicative of abatement costs	Good

[8] Also, the experiments allow the subjects to purchase permits at a high fixed price of 500 laboratory dollars, which compares with the highest marginal cost of any firm of $240. This aspect of the laboratory market corresponds to the direct sale property of the CAAA: utilities have the opportunity to buy permits from the EPA for US$ 1500 (adjusted for inflation).

4. Analysis of empirical EPA auctions data and allowance market prices

4.1. Tradable permit prices[9]

4.1.1. Spot auction prices

So far six auctions have been carried out. The permit prices from the annual spot auctions are reproduced below.

Table 2. Bid prices

	1993[10]	1994	1995	1996	1997	1998
Highest	450	400	350	300	121.02	228.92
Lowest	0.26	24	1	39	0.02	56.91
Clearing	131	150	130	66.05	106.75	115.01
Average winning	156	159	132	68.14	110.36	116.96

The clearing prices from 1993-1995 are significantly higher than the 1996 level. The highest bid prices show a decreasing tendency over time (the same pattern is observed in the advance auctions). Also, the clearing (intersection of permit demand and supply) and average winning prices appear to converge. This pattern is not altered by the introduction of the allowance market, which commenced March 1994. The range between highest and lowest bid seems to decrease over time in a similar fashion.

4.1.2. Market prices

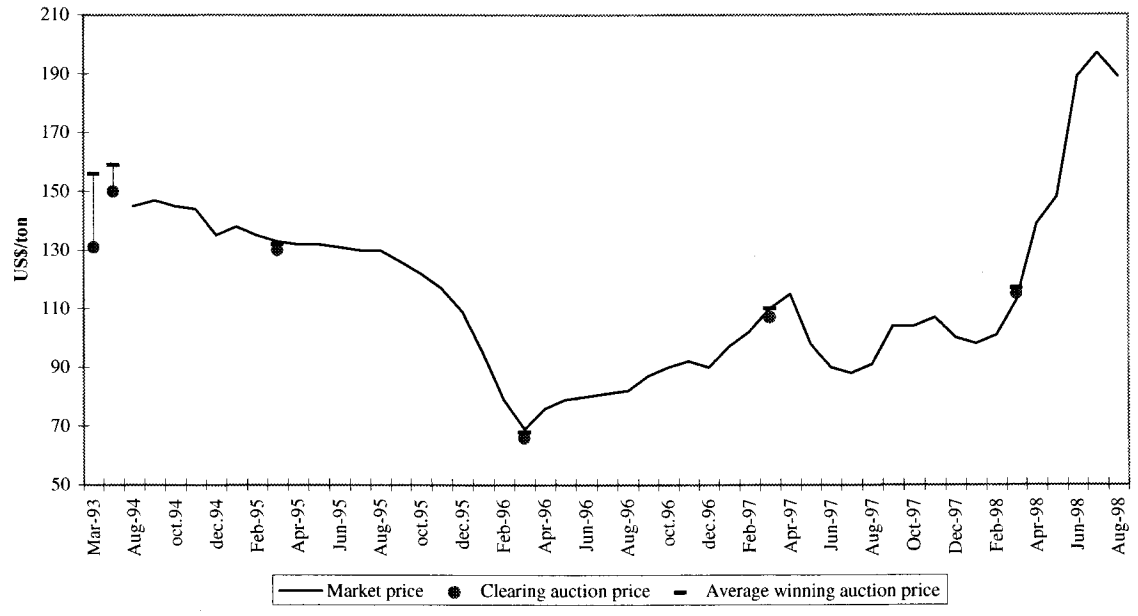
Two monthly price indices constructed by brokerage firms are available; the Cantor Fitzgerald Monthly Price Index (MPI) as well as the Emission Exchange's index. The former covers a longer time span of the market trades, and is the one chosen for comments. This index is based in equal parts on the following factors:

- The average of the highest sulphur dioxide allowance bids weighted by allowance volume.
- The average of the lowest sulphur dioxide allowance offers weighted by allowance volume.
- The weighted average of actual trade prices determined from trades consummated during the prior trading period that settle within the following 6 months[11].

Below the MPI for the period spanning August 1994-August 1998 is depicted. Average winning and clearing prices from the spot auctions are included in the figure.

[9] All prices are denoted in US$/ton SO_2.
[10] 1993 average winning prices are not weighted.
[11] A trading period, for the purposes of the MPI, is defined as the period beginning with the 25th day of the previous month and ending with the 24th day of the month in which the MPI is published.

Figure 1. Auction and market prices[12]



The most noticeable fact is the apparent correspondence between the auction price levels and the MPI recorded at the same time. Since the introduction of the market, the realised clearing prices in the EPA auction (only 4 observations) have to a large extent mirrored the permit market price.

It is difficult to evaluate whether the realised prices are equal to marginal abatement cost. Nevertheless, in so far as aggregate trading volumes increase, it is likely that prices become more indicative since greater extent of trading to some extent reflect the utilities' rational adoption to the new legislation.

4.2. Behavioural properties of the EPA auction

The EPA auction was designed specifically for the US SO_2 tradable permit scheme. Hence the theoretical and empirical behavioural properties of this particular auction procedure were scant at the time of implementation.

One issue in this regard is the extent of trades occurring at the auction in excess of trading in the permits mandatorily offered. The following data indicate that the number of privately tendered permits have declined and constitute but a minuscule proportion of total permit sales.

[12] All auction prices are spot auction prices. 1993 average winning price is not weighted.

Table 3. Permits offered and sold at EPA spot auctions

Year	Number of privately offered permits	Privately offered permits that were sold	Total number of permits sold at the EPA auction	Sales of privately offered permits as % of total sales
1993	95,010	10	50,010	0.019 %
1994	58,001	0	50,000	-
1995	8,306	600	50,600	1.185 %
1996	8,000	0	150,000	-
1997	0	0	150,000	-
1998	0	0	150,000	-
Total:	169,317	610	600,610	0.101 %

Source: US Environmental Protection Agency

Active trading in the permit market commenced spring 1994. It is noticeable that the amount of privately offered permits declined dramatically at the two auctions which coincide with the operation of a complementary market. Also, the percentage of the privately tendered permits succeeding in being sold is low. Equivalently, the permit market may be seen to adversely affect the sellers' incentives to tender permits at the EPA auction.

By means of comparison, through December of 1997, over 3,300 transfers moving 49.3 million permits have taken place in the complementary permit market. 30 percent of these allowances were transferred between economically distinct organisations, 25 times the aggregate spot auction trading volume.

5. An assessment of experimental and empirical data with regard to parallelism

Below we evaluate the experimental and empirical data on the SO_2 tradable permit scheme with reference to parallelism. First, focus is directed onto the issue of design parallelism. Second, we investigate whether the behavioural predictions deriving from the reviewed experiments are corroborated by the available empirical data.

5.1. Design parallelism

The empirical data clearly suggests a strong degree of interaction between the EPA auction and the complementary market in tradable permits. The role of the auction rather obviously changes after the introduction of the market. The trading volume observed at the auction declines and the extent of trading in privately offered permits is - for all intents and purposes - equal to zero. In short the market disciplines the auction.

This aspect is not incorporated in Cason and Plott's paper where the experimental design is confined to auctions only. The conclusions arrived at regarding seller incentives is not obtained through an analysis of the potential impact of an aftermarket in permits. This low degree of design parallelism works to prohibit a discussion of how the auction's behavioural properties may change when a complementary permit market is introduced. Indeed, the empirical data indicate that the practical relevance of the alleged sub-optimal properties of the EPA auction procedure are negligible.

Empirically, the complementary market in permits has proved to diminish the auction's role as a price discovery process. Relatively more information is inherent in the permit market price as the permit

market witnesses the emergence of increasingly sophisticated transactions occurring in the allowance market, such as allowance swaps, fuel bundling, futures, forward contracts, and options trading[13]. This tendency underlines the need for an inclusion of an aftermarket in experiments on the CAAA. Any conclusions as to downward biased permit prices in auctions need to be checked against the impact of a complementary market in allowances. The Franciosi et al. paper in this regard exhibits a satisfactory degree of design parallelism through their analysis of an aftermarket. The Cronshaw and Kruse paper focuses on trade at the EPA auction only.

The empirical data indicate a very stochastic pattern of permit demand and supply. In particular, the supply of allowances grows steadily over time. The reviewed experiments' designs do not include this aspect of the tradable permit scheme to any satisfactory degree. Although Cason and Plott examine the responsiveness of the EPA auction to changes in underlying economic conditions, no conjecture of a trend in demand and supply as a result of these changes is incorporated into the analysis.

An additional aspect of experimental design is the choice of the subject pool. All the conducted experiments have relied on subject pools consisting of business and economics students. Most of these have been unlikely to take an active part in the operation EPA auctions and the complementary allowance market. This is true for all the papers reviewed in section 3. The extent to which this yields different results from a treatment involving realistic cannot be known in the absence of field tests or lab tests using real agents as subjects.

5.2. Behaviour parallelism

The most important feature of the interaction between the two trading institutions is the extent to which the market disciplines the auctions. In practise this yields a convergence between the prices in the market place and the EPA auction. This is not observed in the paper by Franciosi et al. However, the logic underlying this empirically corroborated convergence is as follows: assuming the allowance market is competitive and is functioning smoothly, the market-clearing price would reflect the underlying marginal abatement/control cost and changes in output- input substitution, investments in new technology and the like (and disregarding speculation in future permit price changes). Agents would behave irrationally if a completely different price would obtain at the auction. It is reasonable to expect that also the latter is indicative of the parallel market price, hence the marginal abatement cost, although this may not lend itself to any empirical confirmation.

Nevertheless, these aspects are disregarded in the both the Cason and Plott as well as the Cronshaw and Kruse paper. The observed divergence in auction/aftermarket prices in the Franciosi et al. is not rationalised either.

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[13] An example of an allowance swap, the exchange of allowances of different vintages or years between two parties, occurred in October 1995. Allegheny Power transferred a total of 20,200 vintage 1996 and 1997 allowances to Duke Power Company. Duke Power in return transferred 20,000 1995 allowances to Allegheny Power. Assuming no cash was exchanged, this swap would demonstrate that the market valued 1995 allowances at a premium over 1996 and 1997 allowances (the premium here represented by the extra 200 allowances received by Duke Power).
An example of fuel bundling, combining the sale of fuel with allowances, was recorded in November of 1995. Peabody Coal Sales Co. transferred 2,195 vintage 1995 allowances to Big Rivers Electric Company, presumably in conjunction with the delivery of coal. Fuel bundling is often done to help the utility comply with the Clean Air Act by providing allowances to offset the burning of higher sulphur coal.
Also, both forward contracts and options to buy occur in the allowance market. In a forward contract, a purchaser can contractually agree to buy a number of allowances for delivery in the future at an agreed upon price. In an option to buy a transaction, a party can negotiate to buy the right to a specific number of allowances over some time period.

Cason and Plott predict a downward price bias, i.e., the auction price will be lower than the market price and hence understate the true cost of emissions control. Also, they find that EPA auction prices are experimentally shown to be relatively unresponsive to changes in the underlying economic conditions.

The empirical data seem to falsify these predictions. First, any divergence between the auction spot price and the permit market price is minuscule. Second, there is no reason to assume that, as the trading volume in the market continues to expand, the market price is not indicative of the industry's marginal abatement cost. Also, the market conditions have changed dramatically during the time of its operation. This consequent change in prices, however, have transferred directly into changed price levels realised at the auction.

By the same token, the paper by Franciosi et al. predicted auction prices below the market level. This result has not been corroborated by the empirical evidence.

The behavioural predictions deriving from Cronshaw and Kruse differ from the other papers. The auction prices are predicted to fall and be responsive to changes in the relevant market conditions. Moreover, they are forecaster to relate to the marginal abatement cost at an optimal system allocation. This is corroborated by the factual workings of the permit market. However, in this experiment 33% of the permit allotment is relinquished for the auction, the provided interpretation being that the experiment deals with allowances that could potentially be traded. In practice the trade in permits in addition to the mandatory units have been minimal.

References

Cason, Timothy N (1993): Seller Incentive Properties of EPA's Emission Trading Auction, *Journal of Environmental Economics and Management* **25**, 177-195.

Cason, Timothy N. (1995): An Experimental Investigation of the Seller Incentives in EPA's Emission Trading Auction», The American Economic Review, September, 905-922.

Cason, Timothy N. and Charles R. Plott (1996): EPA's New Emissions Trading Mechanism: A Laboratory Evaluation, *Journal of Environmental Economics and Management* **30**, 133-160.

Cronshaw, Mark and J. Brown Kruse (1991): Temporal properties of a market for emission permits with banking, Department of Economics, University of Colorado, Boulder, March.

Cronshaw, Mark and J. Brown Kruse (1992): An Experimental Analysis of Emission Permits with Banking and the CAAA of 1990, Working Paper 1992-05-26, University of Colorado, Boulder.

Franciosi, R., R. Mark Isaac, David E. Pingry, and Stanley S. Reynolds (1992): Extension of Research into Marketable Emissions Permits. Final report to Oak Ridge National Laboratory.

Muller, R. Andrew and Stuart Mestelman (1993): Tradable emission permits: Policy implications from laboratory markets, Working paper, McMaster University, Hamilton, Ontario, Canada, March.

Plott, Charles (1987): "Dimensions of parallelism: some policy applications of experimental methods" in Roth (ed.): *Laboratory experimentation in economics. Six points of view*, Cambridge University Press.

Popper, Karl R. (1959): *The Logic of Scientific Discovery*, London: Unwin Hyman.

Smith, Vernon L. (1992): Microeconomic Systems as an Experimental Science», The American Economic Review, December, 923-954.

Vickrey , W. (1961): Counterspeculation, auctions, and competitive sealed tenders, *Journal of Finance* **16**, 8-37.

Appendix

The reviewed experiments' designs and results

a) Cason and Plott

Four kinds of comparisons are reported in terms of efficiency, the extent of truthful relevation of underlying values and costs, the accuracy of price information, and responsiveness to changes in underlying market conditions.

Experimental environments, procedures, and design

In total 12 sessions were conducted for 24 market periods. Eight of the sessions implemented the EPA auction rules while four implemented the uniform price auction. The EPA auction experiments did not include any mandatory units in order to focus on the incentives of the voluntary units offered for sale. In both cases the experimenters made use of two different types of environments. In one aggregate demands and supplies were constant for several periods (the constant aggregate case), in the other the demands and supplies of each individual were drawn randomly each period (the random draws case). Each session employed eight students drawn from upper division economics classes at University of Southern California.

In the EPA auction sessions the different bids determined the different transaction prices, and in the uniform price sessions the midpoint of the market-clearing price interval determined the (common, uniform) price.

The random draw case sessions employed experienced students only, i.e., these had previously participated in the constant case EPA auctions. However, although the experiment varies with both experience and the constant version random draws environments, the key treatment variable of interest - the trading institution - is not confounded.

Models and theoretical predictions

General models from auction theory do not exist which capture the characteristics of the EPA auction. Nevertheless, Cason and Plott do manage to produce a set of predictions based on their understanding of the theoretical properties of both institutions.

To summarise, predicted behaviour is similar on both cases: predicted price in the constant aggregate environment under EPA auction rules is at the bottom of the competitive price interval. In the random draws environment the EPA auction price may be less sensitive to underlying value and cost variation, but also here the price levels are predicted to lie in the competitive price interval. In the uniform price auction, theory predicts that buyers and sellers reveal values and costs at the margin, implying prices in the competitive price interval and near 100% efficiency.

Results

The primary conclusion is that the EPA auction rules create strong incentives for both buyers and sellers to under-report their true cost of emissions control to the auction, thus leading to a downward price bias and extracting less gains from trade compared to the uniform call auction. The most important results concerning permit prices are the following:

- Prices of the uniform price auction are closer to the competitive equilibrium prices and are higher than the market clearing prices of the EPA auction. The mean absolute deviation of market

clearing price from the CE price interval midpoint (=230 cents) is 20.5 cents in the EPA auction and is 8.6 cents in the uniform price auction.

- Value and cost relevation are greater under the uniform price auction than under the EPA auction. Also, the strategic behaviour induced by the latter causes it to be unresponsive to underlying economic conditions: the uniform price auction prices convey more accurate information and are more responsive to changing conditions that the EPA auctions prices where the market clearing price reacts more slowly to unexpected parameter changes.

- In the EPA auctions the market clearing prices are below the competitive equilibrium in both the constant aggregate and random draws environments, and the average price is below the competitive equilibrium midpoint in the constant aggregate environment. (These qualitative features are consistent with theory.)

Cason and Plott state that the choice of the EPA auction rules may have been motivated by an intuition that these could imply increased returns to the initial allowance holders, mainly large investor-owned electric utilities. This hypothesis, however, is refuted by laboratory evidence where seller profits are no higher in the EPA auction than the uniform price auction, and indeed are lower in the EPA auction in the constant aggregate environment.

b) Franciosi, Isaac, Pingry, and Reynolds

Experimental setting

The experiment consisted of a series of three 12-period sessions and focused on the interaction between a mandatory revenue neutral auction and a continuos private complementary market. Each period, subjects were given the opportunity to trade permits in a computerised double auction similar to a conventional asset market. In this auction subjects submitted bids and offers through the computer network. Their screens displayed outstanding bids and offers, which they could accept at any time. After the double auction, subjects were permitted to submit a series of bids for the permits offered in the revenue neutral auction. Participants were permitted to transmit more than the mandatory number of permits to the revenue neural auction; sellers received the average revenue generated by the auction for each unit they sold. Once all bids were submitted, the bids were ranked, permits transferred and cash balances updated. Subjects were trained in preliminary sessions in which they followed self-paced instructions presented by the computer followed by four trading sessions.

Results:

- Cost savings (efficiency): The most relevant index of the efficiency of these markets is the percentage of total available cost savings which were realised in each sessions relative to the command-and-control equilibrium. Comparatively speaking, the perfect foresight competitive equilibrium (PFCE) exhibits cost savings equal to 32.7%. The obtained average cost savings were 26.4%.

- Permit use and banking: The extent to which the laboratory markets were able to capture the potential gains from banking was tested. In (PFCE) 40 permits are used in each period. This requires aggregate banking of 20 permits per period in each of the first four periods, and an aggregate drawdown of 10 banked permits in the following 8 periods. However, once overbanking or underbanking has occurred, the PFCE allocation of permits across the remaining periods may not be the best. The best allocation, given that permit use has already occurred, is called the adapted competitive allocation (ACE).

- The experiment showed a very substantial over-use of permits during the early periods of the experiment and under-use during the later periods. Some of the under-use in the later periods simply balances the over-use in the beginning, but it is noteworthy that average permit use is even below the ACE use for 5 of the last 6 periods. The data clearly suggest that the laboratory market was unable to capture the potential gains from banking.

- Prices: In trading emissions programmes, prices are expected to convey information about the marginal cost of pollution abatement. The experimenters thus set out to acquire data on whether prices in the laboratory reveal the costs facing the subjects and the extent to which the prices in the two markets convey the same information. (The ACE price is an indicator of the marginal abatement cost facing the firms).

In the least efficient session the mean prices from the RNA track the double auction prices fairly well, although the lowest winning bids are below both. In general, prices are well below the ACE, thus understating marginal abatement costs. Re the most efficient session: the RNA prices lie substantially below the double auction prices. The double auction prices themselves are generally substantially below the ACE price. Hence, prices in the RNA and double auction markets do not always convey the same information, and neither is a good indicator of marginal abatement costs

c) Cronshaw and Kruse

Experimental design

The features of the experiments may be summarised in the following manner:

- Allowances are grandfathered to existing «affected units» (five types of firms, distinguishable by reference to abatement cost schedules). Once allocated, the permits can be applied to cover a period's emissions (the experiments cover a twelve period time span), banked, or traded. At the end of the experiments the unused permits have no redemption value. Permits are going to be traded by discriminative auction exhibiting both mandatory and voluntary components. The experiments disallows trade outside the auction, i.e., there exists no aftermarket.

- Mandatory units: 33% of the permits are relinquished to the auction, as opposed to the real-life 2.8% figure. One interpretation is that the experiments deal only in allowances that could potentially be traded. Also, the experiments allow the subjects to purchase permits at a high fixed price of 500 laboratory dollars, which compares with the highest marginal cost of any firm of $240.

- In the discriminative auction the mandatory amount of allowances are available at an offer price of zero. Additional permits are traded conditional upon the mandatory permits having been sold. The bids are ranked from high to low, and vice versa with the offers. The proceeds from the auctions are returned to the firms of the proceeds. This experimental design corresponds to the factual EPA auction procedure.

Theoretical benchmarks

In the experiments, which were conducted at the University of Colorado at Boulder using upper division undergraduates, minimum abatement cost is achieved by reallocating permit usage so that marginal abatement cost is equalised across firms and across time. This may be achieved by means of banking and trading, and provides a 33% cost reduction relative to the command and control approach (firms effectively emitting in accordance with permit allotment). Overall performance indices are constructed which gauge the laboratory performance relative to the mentioned benchmarks.

Furthermore, it is shown that a perfect foresight competitive equilibrium exists, and that this achieves the minimum system abatement cost. This implies a specific competitive equilibrium (CE) permit price which is equal for each period. If actual emissions in one period should differ from the amount corresponding to the CE level, then there is a new CE price from the current period to the end of the experiment. These prices are optimal after some given history, and are termed «adapted». Adapted CE prices for each period of each market experiment is calculated, and reflect the number of permits available from banked stocks and allocations to be received in the remaining periods of the experiments.

Cronshaw and Bruce note that the theoretical properties of the emission allowance discriminative auction institution are not well established. Hence the predictive power of the CE price in the experiments is considered uncertain.

Results

As regard the five experiments which including the opportunity to trade in addition to banking showed a cost reduction index - the proportion of maximum possible abatement cost savings actually achieved - ranging from 29.9% to 70.9%. The mean index of the five experiment sample is 56.3%. A null hypothesis that the mean cost reduction index is non-positive against the alternative that the mean is strictly positive is rejected, whence it is suggested that the laboratory markets were functional in terms of reducing system abatement cost.

Cronshaw and Kruse construct a method for evaluating the proportions of the cost savings which derived banking and trading respectively. It was found that the discriminative auction (qua trading) captured 38.8% to 75.7% of the obtained cost reduction.

Moreover, transaction prices are compared with the adapted CE price for each period. In each case the adapted CE price falls over time due to large stocks of permits. (Compared with the 12 period system optimum, too many permits are banked.) The prices observed in the market respond to changing market conditions as reflected by the falling adapted CE price in 4 of the 5 experiments. Also, the prices observed relate to the marginal abatement cost at an optimal system allocation, albeit they are not demand revealing.

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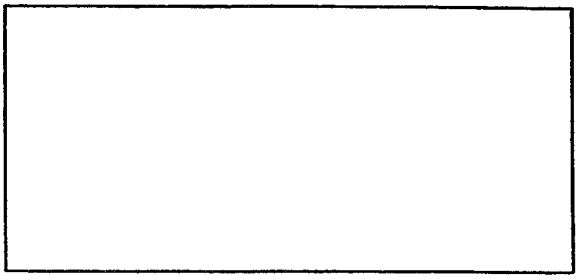

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