FURTHER EXPERIMENTAL INVESTIGATIONS INTO MARKETABLE EMISSIONS PERMITS

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ABSTRACT

This paper examines the results of experiments designed to study various aspects of tradable emissions permits as set forth by the Clean Air Act of 1991. In particular, this paper develops an understanding of some of the results that we attained in our experimental work in this area at the Universities of Arizona and Colorado. In these experiments subjects acted as managers of firms that must trade emissions permits. After an initial allocation of permits, subjects were allowed to trade them in both an "informal" double auction and a "formal" revenue neutral auction or in some sessions just the "formal" auction. Further, some sessions allowed subjects to hold permits across rounds for later use (intertemporal banking of permits), while others did not.

The results show, when faced with only one arena in which to trade permits, subjects are able to lock on to the efficient trading price and come close to the efficient intertemporal allocation of permits. However, when we introduce the double auction mechanism to a setting with banking, results change dramatically. Now there are arbitrage possibilities across markets and permits become an asset. Price becomes very unstable across markets and periods, and it may show signs of bubbling and crashing as other assets have done in experimental markets. Further research in this area is outlined to understand more of the dynamics of these influences on the efficient solution predicted by theory.

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I. Introduction

The 1991 Clean Air Act Amendments (CAAA) created a system of tradeable emissions permits for the reduction of SO_2. The participants in this new system are large electricity generation facilities in the U.S.. By initiating such a system, proponents argue that reductions in emissions can be achieved at the least cost to society as a whole. The idea is to introduce market based solutions to what had traditionally been relegated to systems of command-and-control. This is the first test on such a scale of this type of incentive-based regulatory system. Its success or failure will have a profound influence on the adaptation of such systems in the future.

The trading system that has been mandated by the U.S. Environmental Protection Agency (USEPA) has three separate opportunities for permit transactions (see Federal Register 1991a and 1991b). The first mechanism is a formal auction process using a revenue-neutral auction mechanism. This system allows firms to submit both bids to buy and offers to sell permits. The bids are arrayed from highest price to lowest to form a demand curve for permits while the offers are arrayed from lowest price to highest to form a supply curve. In standard fashion, all those whose bids and offers are to the left of the intersection of these supply and demand curves trade. Those to the right are shut out of that particular trading opportunity. The auction is discriminative price- and revenue-neutral so that each purchaser of a permit pays exactly what he or she bids, and the auctioneer (in this case USEPA) does not receive any of the auction's proceeds. In the mechanism specified, the highest bidder purchases the permit from the agent making the lowest offer, and pays exactly what he or she bids. Therefore, the lowest ofter receives the amount paid by the highest

bidder and so on up and down the respective schedules[1]. This formal market is to occur once a year and will be the arena in which the permits withheld at the annual allocation are traded[2].

The second trading opportunity is an informal process. In this case, agents are allowed to negotiate individual deals for permits at any time. Such transactions have occurred already with the Tennessee Valley Authority as principle purchaser of permits (Charilier, 1992).

The final opportunity for permit transactions is direct purchase of permits from USEPA. In this situation, agents contact USEPA to purchase permits at some posted price. The price is designed to be significantly higher than the price established in the other trading markets. Agents will see this as an option of last resort that is used very infrequently.

Permits have a life of one year but can be banked. That is, once a permit is used to cover SO_2 emissions at a plant, it cannot be used again. However, permits need not be used in the year they are issued. Permits can be held or "banked" until such time in the future that the firm wishes to use or sell them. This introduces an intertemporal aspect to this emission right system.

While there has been much theoretical work in the past describing, and analyzing a system of marketable permits (see Montgomery 1972 and Dales 1968), very little literature has addressed the hybrid system that is currently in place. Instead this new program is being analyzed within the controlled laboratory environment of experimental economics.

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[1] As might be expected this type of incentive structure is not incentive capatable, and may create opportunity for profitable strategic bidding and offering. The reader is referred to Cason, 1992 for a full theoretical development of this auction's strategic characteristics.

[2] The units withheld from the allocation enter as permits with a 0 offer price. Their revenue is distributed equal on the bases of the number of units actually withheld

In an initial study before the legislation was finalized, the discriminative price revenue-neutral auction mechanism was tested. That work focused on the size of mandatory contribution to this market, and the effects of using a discriminative price versus a more well understood uniform price. The results of that work (Franciosi et al., forthcoming) added to our understanding of some of the fundamentals of this novel system.

This paper reports the results of two experimental economic investigation into the workings of the mandated pollution permit market. One study focuses on the formal revenue-neutral auction. While other contains both this formal auction and the opportunity for informal trades. As is explained in greater detail below, the informal market takes the form of a double auction. Each study allows for banking of permits.

The results show that one mechanism alone can be effective in realizing the gains from permit trade. Yet, by adding the second trading opportunity, the results begin to diverge from our equilibrium forecasts, and gains from trade fall substantially. Further, effective use of banking may be hindered by this complication.

It is important to note at this time that the comparison of these results is qualitative only. While both studies used the same experimental parameters, they used different procedures, so a rigorous statistical procedure is not possible. A study already underway will attempt to replicate these results using a standard procedure and parameter set. In this way we will be able to investigate formally the results reported in the present paper.

The remainder of the paper is organized in three sections. Section II briefly describes the experimental design and procedures used in these experiments. The next section will turn to the results. Well focus on the issues of permit price fluctuation and system efficiency. The final section draws some tentative conclusions and outlines future analysis in this area to help understand the dynamics at work within this complicated institution.

II. Experimental Designs

These experiments were conducted in two different locations using two different procedures. The University of Colorado's Laboratory for Economics and Psychology (LEAP) undertook experiments that focused on the revenue-neutral auction. The University of Arizona's Economic Science Laboratory (ESL) created an environment that contained the informal market and a simplified revenue-neutral auction. In the remainder of this section I focus on a short description of the procedures used by the specific experiments at each location. One important feature that will be discussed is the training procedure used at both locations, as these may have some influence on the results. For a detailed discussion on the exact procedures used see Franciosi et al. 1992 and Brown-Kruse and Cronshaw 1992.

Revenue-Neutral Auction Only

In these experiments subjects acted as the managers of revenue-maximizing-rate-of-return regulated firms. That is, at the beginning of each round each firm was given a fixed revenue and its profit depended on its cost reduction behavior. Also at the beginning of each round, firms were given an allocation of emission permits. The allocation in these series of experiments was the same for all firms (6 permits to start) with the allocation being cut in half in round 5 to simulate the change that occurs in the late 1990's in the USEPA's regulation. Subjects knew in advance the length of the experiment and each period's allocation.

For these experiments firms would produce, as a matter of course, some emissions that had to be cleaned up. Firms could chose to use permits to cover the emissions produced or pay to clean them up. There were five firm types which varied in the amount of emissions and cost to clean them up. This gave incentive for firms with low emissions to sell permits to high emission firms. Table 1 contains the parameter set used in these experiments, including the value of permits to firms and their initial allocation.

Once the initial allocation of money and permits was made, subjects made decisions about

use of permits. This involved deciding how many permits to buy or sell, and have many to use or bank. At the end of the round new balances were calculated and added to the subject's total. At the end of the experiments, subjects were paid in cash.

For this series of experiments subjects first participated in a "banking only" experiment. In this case, the initial allocation of money and permits was made, and the only choice subjects faced was how many permits to bank or use; there was no trading between subjects. The purpose was to introduce the subject to the somewhat complex concept of banking without including the further complexity of the auction. All subjects participating in this training session were paid as usual, but only those who made over a specified amount of the optimal profit were invited back for the full session.

The experienced subjects who were brought back faced the same experiment as their trainer expect it now featured both banking and the revenue-neutral auction. Then when the initial allocation of permits is made, some were withheld (see Table 1 for initial allocation and withholding quantity). Subject were then asked to entered their bids and offers for the auctions into the computer. Subjects first entered their bids for permits and then were asked to enter their offers to sell. In this way, subjects could operate on both sides of the market and operate as true traders in permits.

Once all bids and offers had been entered, the computer ranked them as described above, and notified subjects as to the number of permits they bought and sold and of their net profit. Subject were given time to study this information before they had to decide on the number of permits to use or bank. Once all subjects had made and entered their banking decisions, a new allocation was made, and the auction was opened up. At the end of the experiment all permits had to be used or fell to a zero value. Subjects again were paid in cash at the conclusion.

Table 1

Experimental Parameters

	Firm No.				
Unit No.	1,6	2,7	3,8	4,9	5.10
1	3.80	15.20	7.60	19.00	22.00
2	3.40	13.60	6.80	17.00	20.40
3	3.00	12.00	6.00	15.00	18.00
4	2.60	10.40	5.20	13.00	15.60
5	2.20	8.80	4.40	11.00	13.20
6	1.80	7.20	3.60	9.00	10.80
7	1.40	5.60	2.80	7.00	8.40
8	1.00	4.00	2.00	5.00	6.00
9	.60	2.40	1.20	3.00	3.60
10	.20	.80	.40	1.00	1.20
Allotment (forced)					
Prd 1-4	6(2)	6(2)	6(2)	6(2)	6(2)
Prd 5-12	3(1)	3(1)	3(1)	3(1)	3(1)

Two Permit Markets

As noted, the procedure used at the ESL varied from that used at LEAP. This set of experiments utilized software designed by ESL for the Department of Energy for their continuing research effort in the area of marketable emissions permits. Subject were told that the permits could be redeemed for cash. That is, instead of acting as firm managers, these subjects were simply utility-maximizing individuals. As in the other experiments, permits were allocated at the beginning of each round. Subjects knew the allocation for the entire experiment, and the redemption value for permits.

Training sessions for this series of experiments were also conducted independently of the sessions reported here. In these sessions, subjects went step by step through the computerized, on-screen instructions. At the conclusion of the instructions, subjects were

allowed to participate in three rounds of the experiment to see how the procedures worked first hand. After these practice rounds had been completed a written examination about the procedures in the experiment was given to the subjects. Those subjects who scored greater than 60% were asked to be in the regular sessions. All subjects participating in this training session were paid a flat fee for their time.

The sessions using these experienced subjects again began with the computerized instructions. After subjects had reviewed the instructions the sessions started with an allocation of permits. Again some permits were withheld for mandatory participation in the auction. Once the allocation was made, an informal trading opportunity was opened. In these sessions this informal market was a double auction. This institution was chosen for its well-known properties of conversion to the competitive equilibrium. This market was open for 3 minutes, allowing all subjects to buy and sell permits as they liked.

At the close of the market, subjects were asked by the computer if they would like to voluntarily contribute more units to the auction that was coming up. In this set of experiments, there was no opportunity for subjects to put a reservation price on contributed units as in the LEAP experiments. After all voluntary contributions were registered by the computer the auction was opened. Here subjects were asked to indicate to the computer their bids to buy permits. Once all bids had been entered, the computer ranked bids from highest to lowest, and distributed them to those with winning bids. It also reduced their balance by the amount of their bid. Because the auction was still revenue-neutral, the proceeds were distributed on a per unit basis to all those who had units forced into, or voluntarily contributed to, the auction. As noted, this was a more simpler procedure than either the one used in LEAP or mandated by the USEPA rules. However, it was agreed that the complexity of the experiment necessitated this compromise.

After the results of the auction were posted, subject were asked to consult their individual redemption values to consider how many units they wished to redeem for cash and how

many they wished to bank for the future; balances are adjusted accordingly. At the end of the experiment subjects are again paid in cash.

Thus we have results from one set of experiments that utilize only the revenue-neutral auction, and one that combines this mechanism with an opportunity to trade within a double market institution. By including this new mechanism we have introduced the opportunity to arbitrage across markets. However, as will become obvious this new feature may create problems for the efficient operation of this system of marketable permits.

III. Results

As noted in the introduction, the focus of this paper is on the prices of the traded permits and the overall efficiency of the system There are of course other important points that should be considered such as the optimal banking pattern, the number of permits used (or redeemed) each period, and the bid and offer pattern. These topics can and will be addressed in later papers and are discussed in some detail in both the Franciosi, and Brown-Kruse and Cronshaw papers.

Figures 1-3 are representative of the results of the auction-only experiments. The lowest trading price is the last accepted bid in the revenue-neutral auction, and the mean trading price is the average price bid on, and paid for, permits. The adapted CE price is a measure of the expected competitive equilibrium given the banking pattern within the given experiment. That is, instead of comparing these price measures with a competitive equilibrium based on optimal banking patterns ($71), the adaptive CE is based on the previous banking patterns observed in the particular experiment and is a dynamic measure across the life of the experiment. It was hypothesized that subjects made price decisions based not on some expectation of optimal banking established in period one, but on their current behavior and that of the other subjects.

As can be observed from the figures, prices seem to converge to the adaptive CE price. Further, as the experiment progresses, the bids tighten. The variation across winning bids becomes very small; the mean and the lowest trading prices converge. The falling CE price is the result of the excessive number of permits banked (thereby making subsequent purchases less important). Even if we ignore this CE price, we can see that the price of traded permits does not move too far from the original expected price of $71. The system seems to operate effectively and efficiently.

Another important observation is that there is no price fluctuation when the allocation of permits is cut in half at the start of period 5. This would indicate that banking is serving its purpose by helping to stabilize the prices in this market. This is consistent across all the sessions. Thus, prices in under this revenue-neutral auction seem stable across time and tend to converge to the adaptive CE price.

However, when we examine the results from the experiments with both the auction and the market we see a completely different story. Figures 4-6 show much of the same data as the previous figure. Again we can see the mean trading price, and in this case, the highest reject bid (the one right below the lowest accepted bid). Further, the solid connected points represent the contract prices established in the double auctions. The dashed line at $7.10 represents the experiment's equilibrium permit price with banking, while the solid line is the equilibrium price with each round[3].

As can be observed, prices are unstable relative to with the earlier results. We no longer see the convergence of the mean bid price and the lowest rejected bid. In fact there is quite a pronounced divergence. Also there is a definite effect when the allocation is reduced in period 5. Here, at least in the figures 4 and 5, we see a sharp increase in both the prices in the auction and in the market. It is possible that this pattern could be a "bubble and

[3] The prices in the two experimental designs are stated in different units, but are comparable.

crash" phenomenon that has been reported in other experimental asset markets (Smith et al. 1988).

Further there is a significant divergence in the prices between the auction and the market. This would mean that it would be possible to buy a permit under one institution and sell in another at a profit. This is especially pronounced in figure 6. Even though the market price seems to converge early to the banking equilibrium, it is well above the auction prices. It seems that the arbitrage is not working. By adding the second trading opportunity, the system seems to inherit a number of non-optimal characteristics.

This is reenforced when we examine the efficiencies within the experiments. Here we define efficiency as a percentage of the optimal profit realized across the entire experiment. As would be expected, the average efficiency in the auction-only experiments was quite high, at just over 80% across all the experimental sessions. This compares with efficiencies ranging from 7.5% to 47% in the auction and market experiments. Somehow, the introduction of this new market drastically affects the operation of the system in a negative way.

IV. Conclusions

It would seem that the introduction of a new trading institution dramatically effects the outcome in this permit market. Prices become wildly unstable, not only across time, but across markets in a period; we have no indication of an optimal social price for permits. Realizations of gains from trade are lost as banking becomes very erratic. In effect a system that operates near its expected optimum in the one-market case seems to fly apart when we introduce this double auction.

What is it about the introduction of this second trading opportunity that so adversely affects these results? The answer is not easy or obvious. It is important, before

postulating to extensively too remember that these two sets of experiments used two different procedures -- not only to run the experiments but to create the experienced subject pool used. It will be important to study this in a more systematic approach by using one procedure both for data collection and training.

Also, it will be important to use a parameter set that is designed for this type of study. If we look at other results from the two-market experiments using a different data set, we see much higher efficiencies, similar to those seen in the one-market sessions. Of course these experiments still yielded prices that were similar to those in figures 4-6. But the radical and consistent fall in efficiencies seen with the introduction of the double auction may be caused by some quirk in the parameters.

Experiments are being designed to look at these issues. They will employ the software used in the two market experiments. A completely new parameter set also will be created. Further subjects not form either location will be used to control the unlikely event there is some kind of subject pool effect. The experiments will be run both with and without the double auction. Also the training procedure will be varied systematically in order to control for training effects.

It is important that we understand what is going on in this market. With one experiment giving a thumbs up and another a thumbs down to this incentive-based system, we are sending radically different signals to the policy makers who are closely watching. If we can create a system that controls emissions while reducing government "involvement," we may see widespread acceptance and use of incentive-based regulation. If we create a system that blows up (and we cannot explain why), this grand experiment may be for naught and we will continue with command-and-control.

Experimental economics offers a testing bed for this type of policy, but only if we can show its consistency, reliability and usefulness in identifying, explaining and mitigating

problems such as those we have found here. We must carefully examine anomalies like those seen in this paper and methodically work to explain them. By doing so we will demonstrate the power of experimental economic methods as a policy analysis tool.

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FIGURE 1

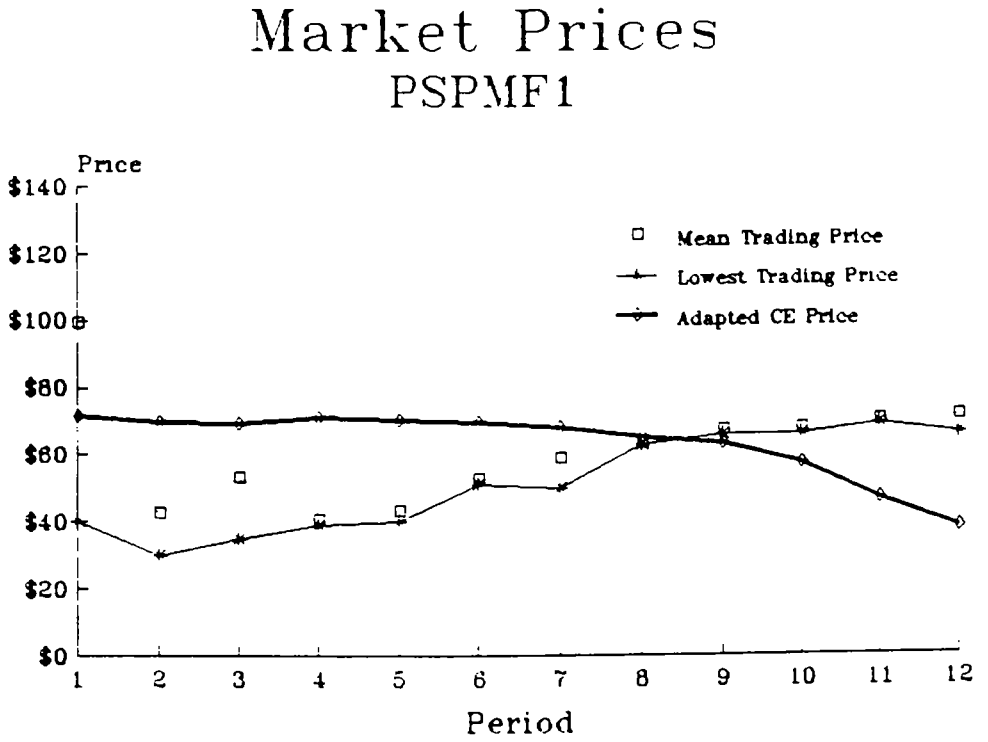
Market Prices
PSPMF1
Price
$140
$120
$100
$80
$60
$40
$20
$0
1
2
3
4
5
6
7
8
9
10
11
12
Period
Mean Trading Price
Lowest Trading Price
Adapted CE Price

FIGURE 2

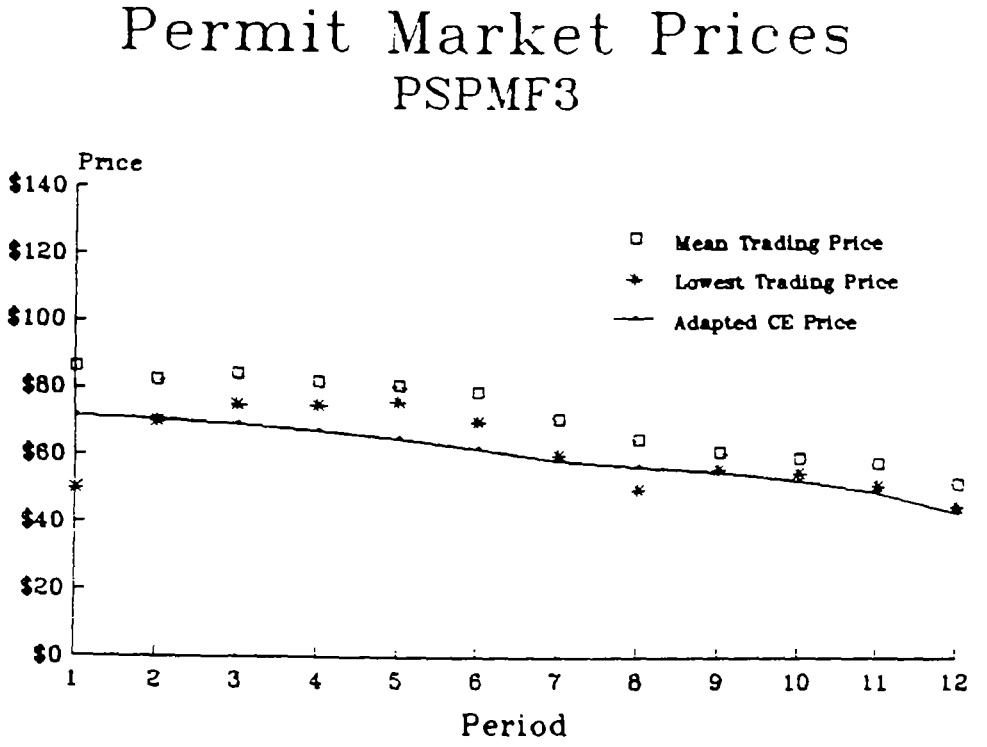
Permit Market Prices
PSPMF3
Price
$140
$120
$100
$80
$60
$40
$20
$0
1
2
3
4
5
6
7
8
9
10
11
12
Period
Mean Trading Price
Lowest Trading Price
Adapted CE Price

FIGURE 3

Permit Market Prices
PSPMF6

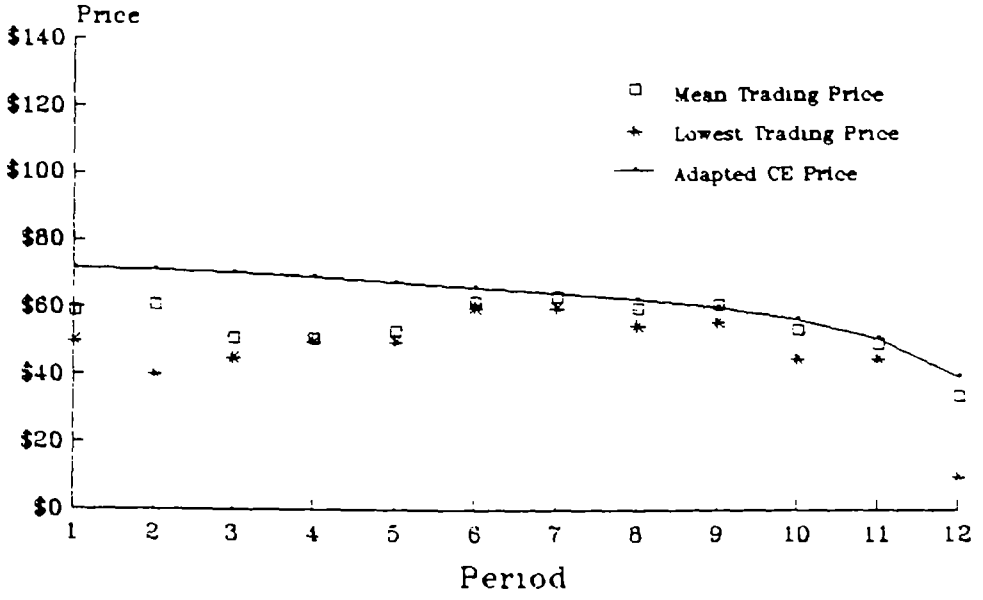

FIGURE 4

MARKET AND AUCTION PRICES

R10_12DC

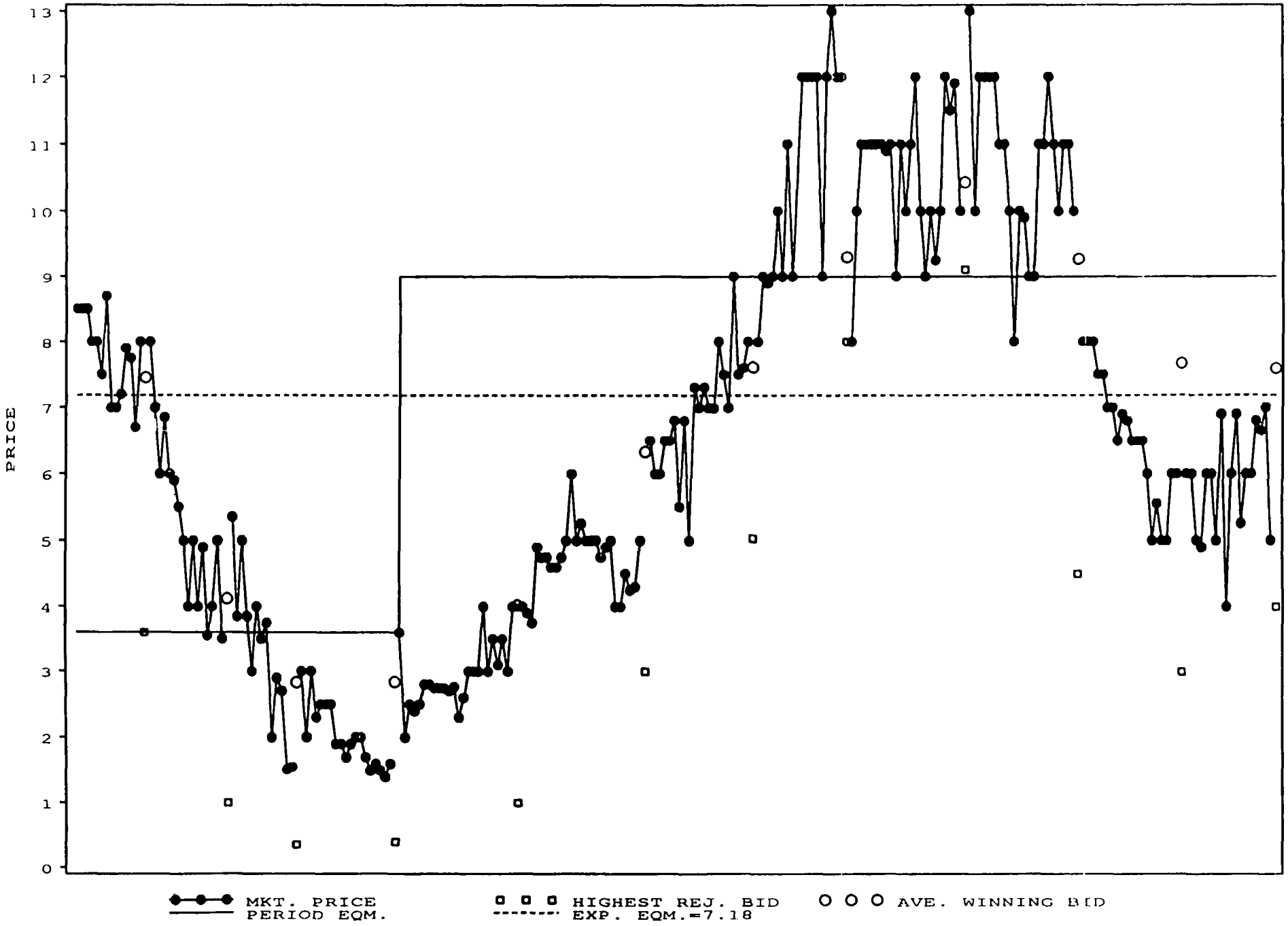

FIGURE 5

MARKET AND AUCTION PRICES

R11_12DC

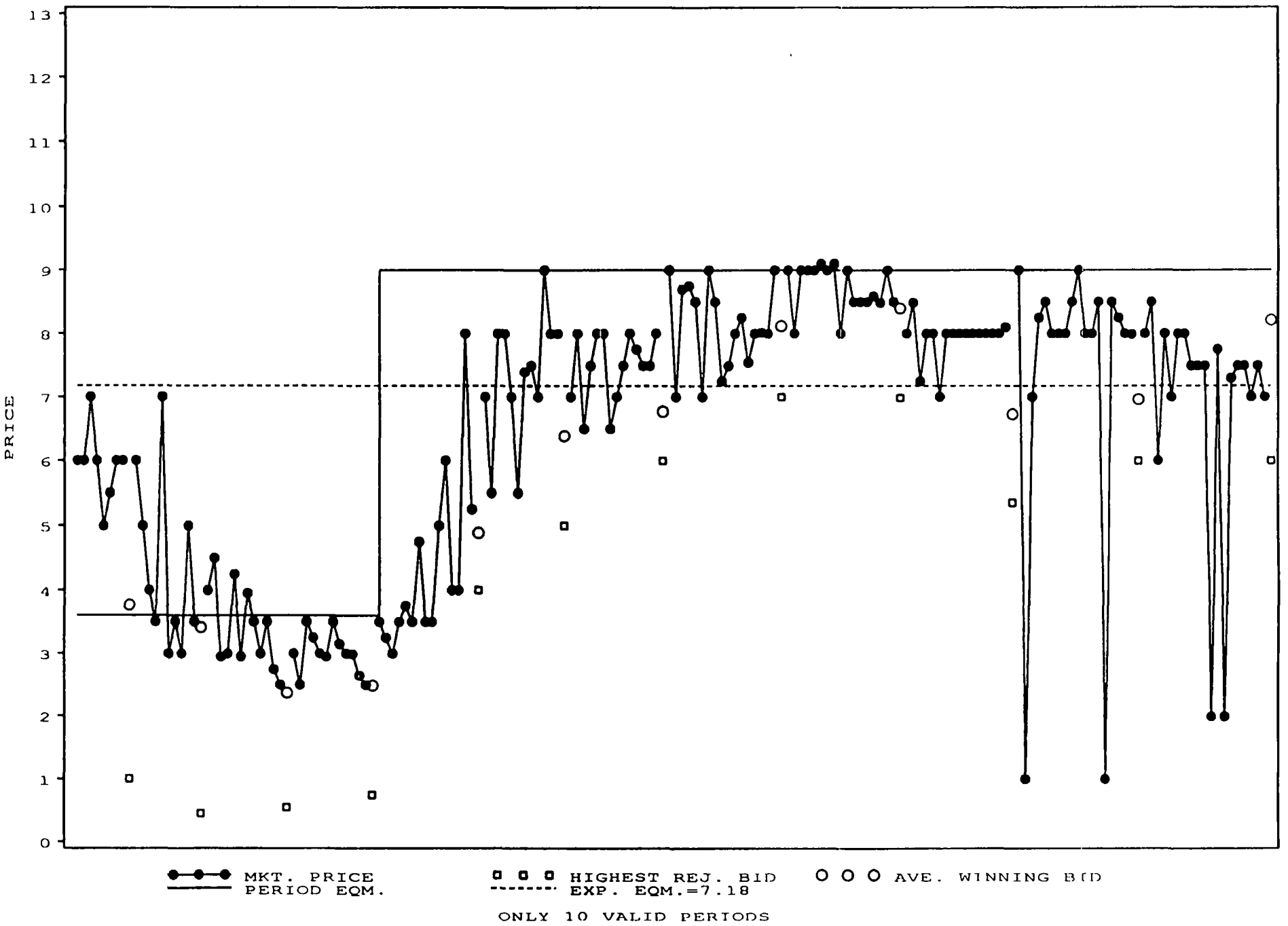

FIGURE 6

MARKET AND AUCTION PRICES

R12_10DC