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UNCERTAINTY AND SHOPPING BEHAVIOR: AN EXPERIMENTAL ANALYSIS

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ABSTRACT

This paper reports experimental tests of three search equilibrium models. These models which differ only in the search strategies available to the buyers have qualitatively different predictions, that is, equilibria: price distributions, single price equilibria at the competitive price and at the monopoly price and two price equilibria. The experimental outcomes generally were consistent with the models' predictions. This suggests that debate on the utility of this class of models should shift to the realism of the models' assumptions rather than focus on their ability to characterize market outcomes. Also, since the basic models have been validated, the project of analyzing experimentally the results of relaxing some of their assumptions seems worthwhile.

UNCERTAINTY AND SHOPPING BEHAVIOR: AN EXPERIMENTAL ANALYSIS†

David M. Grether,* Alan Schwartz,** and Louis L. Wilde***

INTRODUCTION

Much intellectual effort has gone into constructing equilibrium search models—models that exhibit nontrivial wage or price dispersion when one or both sides of the market respond optimally to the presence of costly information. These models not only are illuminating positively but have potential normative significance, because a great deal of regulation, at both Federal and State levels, is devoted to curing the harms of "imperfect information." Search equilibrium models, however, seldom are used in policy analysis for two related reasons. First, the models' results are extremely sensitive to their assumptions about the technology of information acquisition and dissemination; these assumptions tend to be highly stylized, detailed and often unrealistic (Schwartz and Wilde 1982a). Second, the predictive power of the models has not been directly tested. Given the nature of the assumptions on which these models rest, moreover, it simply is not clear how one would go about "testing" them using available, real-world data. Consequently, models that are a potentially useful source of guidance in the resolution of important public policy questions have played almost no role in shaping the actual resolutions that decisionmakers have reached.

Laboratory experiments are partially responsive to these two difficulties. In fact, the predictive properties of existing search equilibrium models are especially suited for experimental testing because of the models' simplified, stylized structure. However, one does not, strictly speaking, test theories. Theories are sets of mathematical statements, assumptions and propositions whose correctness is not an empirical question. Performing a meaningful experiment requires the design and operation of an economic institution intended to capture the essential structure of some particular economic model. In designing laboratory institutions one quickly discovers that these institutions are richer and more complicated than the abstract economic theories from which they are derived.

Nevertheless, laboratory environments are simpler than naturally occurring markets. If the predictions of the theories are not met in the experimental markets this raises a presumption that those theories will not be adequate for the study of the natural markets. On the other hand models which predict well in laboratory environments do not necessarily have full external validity but they have passed a nontrivial test (Smith 1982; Wilde 1980). This paper reports experimental tests of

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three well known equilibrium search models, Salop and Stiglitz (1977), Wilde and Schwartz (1979), and a variation of the well known monopoly model (e.g., Diamond 1971; Butters 1977).

These models make very different assumptions about the technology by which consumers acquire information, and yield quite different predictions about the nature of the equilibrium price dispersion. Part I of the paper briefly describes the models we test. Part II sets out the experimental design. Part III reports the results. It should be stressed that models of this technical complexity have seldom been tested in the laboratory, yet the results of our experiments generally were consistent with the models' predictions, though some experiments did not yield the "correct" outcome. That the results supported the models was by no means preordained. An initial question was whether a correct laboratory institution could be designed. More importantly, all of the models tested rely on Nash Equilibria; whether that equilibrium concept would prove appropriate was not at all obvious a priori. However, given the outcome of the experiments, it is clear that debate on the utility of search equilibrium models should focus more on the realism of the models' assumptions than on the models' ability to characterize market outcomes given those assumptions. They also suggest that using experimental techniques to improve understanding of how environments characterized by imperfect information behave seems promising. Part IV makes concluding remarks and indicates directions for future research.

I. THE MODELS

The three equilibrium search models we analyze make similar assumptions regarding firms. Each firm uses an identical technology that is described by a fixed cost, F, and a constant marginal cost, k. To approximate U-shaped average cost curves, firms are assumed to produce up to a capacity constraint "s"; beyond this level of output, costs become infinite. Firms produce units of an identical homogeneous product and maximize expected profits.

Consumers demand one unit of the product or none. Each consumer in the market will pay up to some exogenously given limit price, L, to obtain the product. The models differ according to the shopping strategies pursued by the consumers.

(i) Salop-Stiglitz: Consumers have the opportunity to purchase, at some cost, a list of all prices being charged. Thus for a fee they may buy at the lowest price. A consumer who does not buy the list shops one firm at random, for free. In equilibrium, the buyers are assumed to know the complete distribution of prices before they decide whether to purchase the price list. Finally, the buyers are divided into two groups according to the cost of purchasing the information; a proportion a face cost c_1 and $(1-a)$ must pay cost c_2, where $0 \leq c_1 \leq c_2$.

(ii) Wilde-Schwartz: Buyers are divided into two groups: a proportion a are "shoppers" and $(1-a)$ are "nonshoppers." The shoppers randomly sample some *fixed* number of firms, n, where $n \geq 2$, and buy at the lowest price their samples reveal, if it is less than L. Nonshoppers sample one firm at random. Sample sizes are exogenously given.

(iii) The Monopoly Model: Buyers may purchase a sample of prices of size n, where $n \geq 2$, at some cost, c. All buyers are identical, and know the equilibrium distribution of prices when they decide whether to buy the sample.

Equilibrium in each of these models is given by a number of firms (determined by a free entry, zero expected profits condition) and a distribution of prices (one for each firm) such that each firm maximizes its expected profits taking the other firms' prices as given, assuming consumers behave so as to minimize the net expected cost of purchasing one unit of the product. The resultant equilibria are easiest to describe when the total number of consumers is taken to be arbitrarily large. The following results are stated without proof.

(i) Salop-Stiglitz:

(a) A degenerate distribution at p^* (the competitive price) is an equilibrium if and only if

$$0 = c_1 \leq c_2 \tag{1}$$

and

$$1 - a \leq F/s(L-k). \tag{2}$$

(b) A degenerate distribution at L is an equilibrium if and only if

$$(L-k) - (F/s) < c_1. \tag{3}$$

(c) A two-price distribution with $P_L = p^*$ and $P_H = L$ is an equilibrium if and only if

$$0 \leq c_1 < (L-k) - [F/s(1-a)] \leq c_2. \tag{4}$$

(d) Otherwise no equilibrium exists.

Under the assumption that the number of consumers is arbitrarily large these cases are exhaustive and mutually exclusive.

(ii) Wilde-Schwartz:

(a) A degenerate distribution at p^* is an equilibrium if and only if

$$1 - a \leq F/s(L-k). \tag{5}$$

(b) A nondegenerate distribution with a mass point at p^* and $P_H = L$ is an equilibrium if and only if

$$1 - [na/(1-a+na)] < F/s(L-k) < 1 - a. \tag{6}$$

(c) A nondegenerate distribution with $P_L > p^*$ and $P_H = L$ is an equilibrium if and only if

$$F/s(L-k) \leq 1 - [na/(1-a+na)]. \tag{7}$$

These cases are exhaustive and mutually exclusive.

(iii) The Monopoly Model:
A degenerate distribution at L is always the unique equilibrium.

The Salop-Stiglitz model yields no equilibrium, a single-price equilibrium or a two-price equilibrium. The single-price equilibrium is at the competitive price if a sufficiently high proportion of buyers have zero information acquisition costs. It is at the monopoly price if $L - p^* < c_1$, so that it never pays anyone to become informed. A two-price equilibrium occurs when it pays one group to become informed (those with costs c_1) but not the other (those with costs c_2). The Wilde-Schwartz model yields competitive equilibria when a sufficiently high proportion of buyers shop, regardless of their sample size. Otherwise a nondegenerate equilibrium occurs with a maximum price equal to the monopoly price. Finally, the monopoly model yields, not surprisingly, a monopoly outcome.

Our experiments were designed to test certain predictions of these models. In the Salop-Stiglitz model we focus on case (c), the two- price equilibrium with $p_L = p^*$ and $p_H = L$. In the Wilde-Schwartz model we consider cases (a) and (c); the competitive equilibrium and an equilibrium with price dispersion but no mass points. The monopoly model, of course, has only one outcome of interest. As these were the first experimental tests of this class of models, we chose to focus on cases in which the models make qualitatively different predictions and to emphasize replication rather than exploring the parameter space. Since experiments of this type are costly, both in time and money, we limited ourselves in this initial set to those outcomes which would best "test" the relevant models. It would clearly be of interest, for example, to compare cases (a) and (b) of the Salop-Stiglitz model to case (a) of Wilde-Schwartz and the monopoly model, respectively, but we do not do so in this paper.

In our analysis of the results of experimental markets designed to represent the three models described above, the Nash equilibria for each are obvious null hypotheses. But, one needs also to consider other sensible hypotheses. In the Wilde-Schwartz model, even when the number of shoppers is large, each shopper is aware only of the prices charged by a sample of firms with sample sizes possibly as small as two. In this case it is problematic whether competitive equilibrium can ever be achieved or, more generally, whether the number of shoppers affects market outcomes at all. We summarize these hypotheses as:

H1: In the Wilde-Schwartz market the distribution of transaction prices is independent of the proportion of shoppers.

This can be strengthened to

H2: In the Wilde-Schwartz market all firms will charge the monopoly price independent of the proportion of shoppers.

The Salop-Stiglitz market and the monopoly market are the same as the Wilde-Schwartz market except for the information acquisition technology; the fundamentals structure of the demand and supply sides of the markets are the same. One might therefore expect that:

H3: If the cost and demand parameters are the same, then the distribution of prices and transactions is independent of the use of Wilde-Schwartz, Salop-Stiglitz, or the monopoly information acquisition technology.

II. EXPERIMENTAL PROCEDURES

The experiments were conducted on the campus of the California Institute of Technology using Caltech undergraduates as subjects.[1] The subjects were recruited for "economics experiments"; they were told that they would be paid in cash at the end of each experiment but were not told the nature of the experiments.

The experimental sessions were similarly organized. Subjects were divided into two groups—buyers and sellers—and given sets of instructions.[2] These were read aloud to *all* subjects at the beginning of each session. Participants were given their own parameters for the market but were not told the values of the parameters for other participants. After the instructions were read, numerical examples of the experimental tasks were presented.

Sellers were told that they could earn money by selling units of a commodity to the buyers. They could buy these units from the experimenters at preset prices and keep the difference between these prices and the prices at which the units traded in the experiment (plus a $.10 commission per sale which was paid to ensure that marginal units traded). The cost schedules for the sellers included a fixed cost per period (called a participation fee) and a constant marginal cost for each unit ordered up to a fixed limit (capacity). Sellers did not have to participate in any period and could, thus, avoid paying the fixed cost. Sellers that did not participate could not buy or sell units or be active in the experiment in any way. The right, and nature, of nonparticipation implemented the free entry and exit conditions of the models. Sellers were prohibited from selling units below the competitive price, to limit the possible losses sellers could incur. In an experiment of this type, subjects typically (and correctly) believe that they will not lose personal wealth if at the end of the experiment they have an overall loss. Therefore, in designing the experiment care has to be taken to make sellers take seriously the possibility of losses. For these experiments, this was done by giving each seller a lump sum at the beginning of the experiment, to which all profits and losses were added. The sum varied from $10 to $15 depending on the cost parameters. The price floor ensured that the experimenters did not face the credibility problem that actual reductions in personal wealth would have caused.

1. Results based on the performance of Caltech students may be thought to lack external validity because the students are not typical subjects. In these experiments, however, the major decisions were made by "firms," who, as will be seen, had to perform difficult tasks of inventory management and price setting. Firms in real markets can perform these tasks, and Caltech students proved able to learn them quickly in the laboratory.

2. Typical sets of instructions are attached as Appendix A.

The loss problem was an issue in these experiments because the models all calculate expected profits assuming full "rain checks" in case of excess demand and no holding costs in case of excess supply. Thus the sellers had to keep inventories. At the end of each experiment, all stocks in inventory were lost; that is, the experimenters would not redeem them for cash. On the other hand, if a seller had unfilled orders, the seller had to buy the requisite units from the experimenters at the same price as it would have cost to "produce" them during the experiment. This includes paying the fixed cost for each multiple of their per period capacity or fraction thereof needed. Sellers therefore faced a possibility of incurring losses because excess supply imposed costs—they paid for units but could not sell them—and excess demand imposed costs—they had to incur fixed costs to sell the last units, but these costs could have been avoided by wiser ordering in earlier periods, when the fixed costs for those periods had already been sunk.

Sellers were seated facing one blackboard—"the sellers' blackboard"; buyers were seated facing another—"the buyers' blackboard." The sellers could not see the buyers' blackboard but the buyers could see both blackboards. At the beginning of each market round, the sellers would decide whether to participate and, if participating, what price to set for that period. The experimenters collected the prices from the participating sellers and posted them on the sellers' blackboard (though the identities of the sellers were not given), and also posted them on the buyers' blackboard. The buyers then placed their orders, which were summarized on the sellers' blackboard so that during the experiment all subjects could see the complete history of the prices charged and the volumes traded at each price. Each participating seller was told the number of units he or she had sold in the just concluded round. The seller then had to decide how many new units to order, to record prior transactions, and to update inventory records. When all sellers were finished with these tasks, another market period was begun. The subjects were never told when the experiment would end; the experimenters "arbitrarily" announced terminations at the end of a particular round. This was done to avoid last period strategic behavior.

Since sellers were allowed to accumulate positive or negative inventories, the "end-game" issue was particularly important in these experiments. However, to the extent possible, we used the same set of subjects for all experimental sessions. The length of treatments varied from four periods to fourteen (in some sessions more than one treatment was used), and subjects quickly learned to manage their inventories in such a way that no systematic termination effects were observed (e.g., "dumping" excess inventories at low prices late in a treatment). The decision to terminate a treatment was taken either when a clearly discernible pattern of prices was observed, or when a variable time limit was exhausted.

Buyers were told that they could buy units of the artificial product from the sellers and resell them to the experimenters, who would pay a fixed price per unit. Buyers were not allowed to purchase units priced above this price. This of course was the limit price, L, which in the experiments was termed the redemption value. The buyers could keep any difference between the prices they paid the sellers and the redemption value, plus a ten cent commission per sale. Buyers were classified in two groups—shoppers and nonshoppers. For all the experiments, nonshoppers were required to "visit" a preassigned seller and purchase a single unit, if the price equaled or was less than L. Shoppers sampled from a set of sellers, buying at the lowest price the sampled revealed provided, again, that this price did not exceed the redemption value. The nature of the sample of firms and the decision whether to shop were the main control variables for this set of experiments.

As indicated above, the buyers were seated facing a blackboard that the sellers could not see. When the experimenters had picked up the seller prices at the start of a period, they posted the prices on the buyers' blackboard, with or without seller identification numbers depending upon the model being tested. At the beginning of an experiment, buyers were given transaction record sheets to record their purchases.[3] These sheets also had written on them identification numbers of the sellers from which they could buy units. For some of the experiments, these preassigned numbers were concealed. In these experiments, the models required buyers to decide between dealing with a single seller chosen at random or paying a fee and then engaging in some form of shopping behavior. Buyers often kept complete price histories on all sellers during an experiment, and would use this information in deciding whether to go to the preassigned seller or to pay the fee and "shop," if in any round they knew who the sellers were. This behavior violated the randomness assumption of the models, and was defeated by requiring buyers to decide whether to shop or not before they knew the sellers with whom they would be shopping. After the buyers had made their purchases, these were recorded by the experimenters, the sellers were privately informed as to their sales and the volume data was posted on the sellers' blackboard.

For the experiments testing the Wilde-Schwartz model, the buyers were essentially passive. The shoppers were given previously determined samples of sellers and purchased one unit from the lowest priced seller if that price was one at which they could buy.[4] The procedures for testing the Salop-Stiglitz model were different. After the sellers had submitted their prices, the complete price distribution was posted on a blackboard that only the buyers could see. Then each buyer had to decide whether to shop or not. To be a shopper, a buyer had to pay a fee (either $.10 or $.30 per unit), which entitled the buyer to purchase one unit from the lowest priced seller in the market. This was the equivalent of the model's assumption that consumers knew the price distribution but not the identity of the firms charging the prices, and then decided whether to incur search costs to learn that identity. In each round that tested Salop-Stiglitz, nine units traded with the smaller fee and sixteen units with the larger one.[5] Experiments using the monopoly model had a similar buyer technology. In these experiments, the buyers could either buy from a single seller or for a fee obtain a sample of size two and purchase from the lower priced seller.

III. THE EXPERIMENTAL DESIGN AND RESULTS

We ran twelve experiments. Some of these involved only one treatment (a choice of market type and set of parameters) while others involved two. We also discovered the need for certain design features in the course of running the experiments (e.g., a price floor at the competitive price).

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3. Copies of the sellers' and buyers' record sheets are attached as Appendix B.

4. In all of the experiments, the shoppers had a sample size of at least two, and somethimes the sample was the market. This created the possibility that two or more firms in a given buyer's sample charged the same price. We used a random numbers scheme for the buyers to follow in order to resolve ties. The scheme is describved in the buyer instruction sheets.

5. Twenty-five units traded in each round of every experiment. Because the models permitted buyers to purchase one unit or none, there thus were twenty-five buyers per round. Given the relative simplicity and essential similarity of the tasks that the buyers had to perform, we had five subjects playing the buyer role in each experiment, with each subject responsible for making five purchases.

This section will discuss the experiments in the order we ran them. Part IV summarizes the results[6] and suggests future modifications of interest. The experimental design and primary features of each experiment are summarized in Table 1. In all experiments there were twenty-five units demanded per period and each firm had a capacity of five units.

Experiments 1 through 5 each tested the Wilde-Schwartz specification with shoppers sampling prices of three firms and nonshoppers observing only one price. In experiment 1 for the first twelve periods there were five shoppers, twenty nonshoppers and eight sellers. As predicted by the model, we observe price dispersion. In period 13 the number of shoppers was increased to twenty, leaving five nonshoppers, and the number of firms was cut from eight to five. In this case the model predicts a competitive equilibrium and, given the parameters, five firms operating at capacity (thus just satisfying total demand). Reducing the number of firms from eight to five was done to save money as otherwise we would have had to give a greater lump sum payment to sellers to offset the operating losses caused by excess capacity. With fewer firms it could have been more difficult to obtain a competitive equilibrium but this did not appear to be the case. Experiment 2 repeats the treatments of experiment 1 introducing a price floor at the competitive equilibrium price. All subsequent experiments had price floors at the competitive price.

The goal of experiments 1 and 2 was to examine the effects of shifts in the number of shoppers. The results are dramatic. In both experiments there is price dispersion in the early periods, and when the proportion of shoppers is increased, prices drop quickly to the competitive equilibrium (or even below it in experiment 1). Experiment 3 repeats experiment 2 with a slightly changed parameter set and experiment 4 reverses the order of the treatment starting with twenty shoppers (periods 1 through 7) and then decreasing the number of shoppers to five. The predictions of the Wilde-Schwartz model are easily borne out—the reader can see this dramatically in figures 1 to 4. H1, that the proportion of shoppers does not affect the price distribution, loses by Savage's inter ocular trauma test.

Experiment 5 repeated the Wilde-Schwartz market using a third parameter set and less extreme mixes of shoppers and nonshoppers. In the first nine periods, with nine shoppers and sixteen nonshoppers, we observed the predicted price dispersion; in the last six periods (twenty shoppers and five nonshoppers), the market converged to the equilibrium price.

Experiment 6 was the first test of the Salop-Stiglitz model. The parameters were chosen such that a two-price equilibrium with five firms charging the limit price ($L = 1.00$) and three firms charging the competitive price ($p^* = .64$) are predicted. The distribution actually did converge to a two-price equilibrium at p^* and L, but the distribution of firms was not 5/3 and there were too few shoppers. The experimental procedure, however, permitted buyers to violate the random shopping condition of the model. Nonshoppers were supposed to sample one firm at random. These firms were predetermined, randomly, and displayed on the buyers' record forms. Buyers thus learned the identity of the randomly selected firm before deciding whether to buy the information revealing which firms charged what prices. As a result, they kept records of the price-histories of the sellers, so they could tell whether the randomly selected seller they would sample if they did not purchase

6. The results of all the experiments are set out in detail in graphs in Appendix C.

TABLE 1: Experimental Design

Cost and Demand Parameter	Experiment Number	Model Tested	Treatment
1. Fixed cost = \$1.00; marginal cost = \$.30 limit price = \$ .70; capacity = 5 units competitive equilibrium = \$.50	1	Wilde-Schwartz	a. 5 shoppers and 8 firms, sample size 3; b. 20 shoppers and 5 firms, sample size 3.
	2	Wilde-Schwartz	Same as Experiment 1 with price floor at competitive equilibrium.
2. Fixed cost = \$1.00; marginal cost = \$.40 limit price = \$ .80; capacity = 5 units competitive equilibrium = \$.60	3	Wilde-Schwartz	Same as Experiment 2.
	4	Wilde-Schwartz	Same as Experiment 2 with order of treatment reversed.
3. Fixed cost = \$1.20; marginal cost = \$.40 limit price = \$1.00; capacity = 5 units competitive equilibrium = \$.64	5	Wilde-Schwartz	a. 9 shoppers and 8 firms, sample size 3; b. 20 shoppers and 5 firms, sample size 3.
	6	Salop-Stiglitz	c_1 = \$.10 (9 units); c_2 = \$.30 (16 units).
	7	Salop-Stiglitz/ Wilde-Schwartz	a. Same as Experiment 6; b. same as Experiment 5, treatment (a).
	8	Monopoly	c = .10, sample size 2.
	9	Monopoly	Same as Experiment 8.
	10	Monopoly/ Wilde-Schwartz	a. Same as Experiment 8; b. Wilde-Schwartz with sample size 2.
4. Fixed cost = \$.90; marginal cost = \$.35 limit price = \$.80; capacity = 5 units competitive equilibrium \$.53	11	Wilde-Schwartz	20 shoppers, sample size 2, all periods. a. 5 firms; b. 8 firms.
	12	Wilde-Schwartz/ Monopoly	a. Same as treatment (b), Experiment 11; b. monopoly model.

information was likely to price high or low. This influenced the amount of shopping that took place, and consequently the equilibrium distribution of firms. But even with less shopping than predicted the price distribution developed into a two-price distribution as predicted and at the predicted prices. H3, that the information acquisition technology does not matter, is clearly inconsistent with these data.

In the first five periods of experiment 7, we replicated the Salop-Stiglitz two-price equilibrium when buyers could not see which randomly selected seller they would sample if they chose not to purchase information listing the lowest priced sellers. In this case, we observed both the correct number of buyers purchasing information and the predicted two price equilibrium. We continued to observe a 4/4 split on the sellers, but this result is a function of the $.10 commission on sales, and does not contradict the model's predictions.

To understand this last point one must keep in mind that experimenters typically use five to ten cent commissions in order to induce subjects to make marginal transactions. With five firms each selling two units at the monopoly price and three firms operating at capacity (five units) at the competitive price, revenue exactly covers production costs. The commission makes it more attractive (by thirty cents per round) to be a low priced firm. Switching one firm from the monopoly to the competitive price nearly equates earnings of high and low price firms.

In periods 6-16 of experiment 8, we replicated the Wilde-Schwartz market of experiment 5(a), i.e., with 64 percent of buyers nonshoppers. The predicted price dispersion was again observed.

Experiment 8 was our first test of the monopoly model. It did not yield the indicated monopoly outcome, and we do not know why. Experiment 9 was an exact repeat of experiment 8. It did approximate the monopoly outcome.

The first eight periods of experiment 10 replicate the monopoly equilibrium of experiment 9. The remaining ten periods tested the Wilde-Schwartz model under parameters that predicted a competitive equilibrium when shoppers observed two instead of three firms. The predictions of the monopoly model were obtained, but the anticipated competitive equilibrium outcome of the Wilde-Schwartz model did not occur. The apparent reason for the latter result was the small number of sellers. In this model, when all firms charge the competitive price, a firm that deviates will charge L because it will sell only to nonshoppers. If such a deviant could not earn positive profits at L, a competitive equilibrium is then expected. The parameters for experiment 10 precluded a single deviant seller from earning a positive profit at L, and so predicted a competitive equilibrium. In the experiment, the sellers that deviated from p^* in early rounds quickly learned to charge L or a price close to L, and the firm charging L did not earn positive profits. The experimental parameters, however, permitted the second highest priced seller to break even or earn positive profits, and the third highest priced seller could do quite well. The sellers apparently perceived this possibility, for they seemed to game against each other to charge the second and third highest prices. For example, while the prices charged in each later period were roughly similar to the prices in the immediately preceding period, the rank of the sellers varied considerably, with the seller that was highest in one period usually being lowest in the next period (to recover losses). The formal model precludes a game of this sort because the probability that a particular seller can play it successfully when an arbitrarily large number of sellers exist is vanishingly small. Accordingly, we decided to repeat this experiment with eight sellers.

The first ten periods of experiment 11 were similar to periods 9-18 in experiment 10; the Wilde-Schwartz model was run with twenty shoppers, each seeing two firms, but with only five sellers. The market failed to converge to the competitive price. However, when the number of potential sellers was increased to eight, the market rapidly approached the predicted competitive outcome (periods 11-19). This suggests that the model is inapplicable to the "tight" oligopoly case, but otherwise can characterize outcomes when a wide range of sellers is in the market.[7]

The final experiment replicated the Wilde-Schwartz competitive outcome of experiment 11 (where the sample size is 2) but there were eight potential sellers (periods 1 through 6). It also replicated the monopoly outcome of experiment 9 using different parameters. Both models worked as predicted (except, once again, not enough sellers dropped out) as can be seen dramatically in figure 12. The change in information technology shifts the price distribution from the competitive equilibrium to the monopoly price.

IV. SUMMARY AND CONCLUDING REMARKS

The predictions of all three models can be summarized in terms of prices being at the competitive equilibrium, at the monopoly price, or intermediate. The Wilde-Schwartz model predicts either the competitive price (if there are sufficiently many shoppers) or a continuous distribution of prices. Pooling data from experiments 1 through 5 and 7, we find that when the model predicts price dispersion, 3.6 percent of the transactions took place at the competitive price and 14.4 percent at the monopoly price, while in those cases in which the prediction is the competitive price, 80.2 percent of the transactions actually took place at the competitive price (less than 1 percent were at the monopoly price). In fact 94.2 percent of the transactions were at or within five cents of the competitive price.

The versions of the Salop-Stiglitz model used in our experiments predict that equilibrium transactions will take place only at the competitive and monopoly prices, and in experiment 6 and 7 just 10.8 percent of the transactions were at intermediate prices. If one considers the last four periods of each treatment, the rate of intermediate prices drops to 1.5 percent.

With the monopoly model (excluding experiment 8) 32 percent of the transactions took place at the monopoly price and another 17.1 percent were within five cents of it. Restricting attention to the last four periods of each treatment we find 87.0 percent of all transactions at or within five cents of the monopoly price (61.7 percent exactly at that price). Including experiment 8 lower these figures to 66.5 percent and 47.5 percent respectively.

The data summarized above are displayed in Table 2. Under hypothesis H1 we would expect the distribution of transaction prices across these categories to be the same regardless of the number of shoppers. This produces a chi-square statistic of 1490.9 (2 degrees of freedom) which is significant by any conventional standard. Similar tests comparing the other informational regimes also soundly reject the hypothesis that the underlying distributions are the same.

7. In these experiments, three sellers should have dropped out, but this occurred in only one period. We suspect that fewer sellers dropped out than the model predicts because the existence of a commission precludes a true zero price equilibrium; that is, the commission enables sellers to earn positive returns at the competitive price and thus creates an incentive for them to stay in the market. This incentive is absent in the world of the model.

TABLE 2: Summary of Transaction Prices

Treatment	Full Treatment Number of Transactions at: Competitive Price	Monopoly Price	Intermediate Prices	Last Four Periods Number of Transactions at: Competitive Price	Monopoly Price	Intermediate Prices
Wilde-Schwartz (5 shoppers) Experiments 1, 2, 3, 4, 5, 7	58	234	1334	32	86	481
Wilde Schwartz (20 shoppers) Experiments 1, 2, 3, 4, 5	580	6	137	405	6	87
Salop-Stiglitz Experiments 6, 7	341	82	51	146	51	3
Monopoly Experiments 8, 9, 10, 12	235	265	600	34	190	176
Monopoly Experiments 9, 10,12	120	240	390	2	185	113

Treatment	Full Treatment Number of Transactions 5 cents or Less from the: Competitive Price	Monopoly Price	Last Four Periods Number of Transactions 5 cents or Less from the: Competitive Price	Monopoly Price
Wilde-Schwartz (5 shoppers)	205	439	88	158
Wilde-Schwartz (20 shoppers)	681	6	485	6
Salop-Stiglitz	348	86	146	51
Monopoly (including exp. 8)	247	403	37	266
Monopoly (excluding exp. 8)	122	368	2	261

Overall, our experiments yielded outcomes largely consistent with the predictions of the models. This does not mean that the outcomes were predetermined. In some experiments the predicted outcomes were not observed. For example, in the first monopoly model, experiment 8, we observed price dispersion for the full 14 periods of that treatment. Yet in experiment 9 we observed essentially the monopoly outcome under exactly the same parameters. Similarly, we observed a deviation from the predicted competitive outcome of the Wilde-Schwartz model in experiment 10, an outcome which experiment 11 indicated was due to the small number of sellers used in experiment 10. Thus, while the incentives facing the participants never changed, the institutions we constructed in the laboratory did not always yield outcomes consistent with the predictions of the models. In some cases these deviations yielded insights into situations where use of the Nash Equilibrium concept may not be appropriate (i.e., when there is a small number of sellers and shoppers observe only a few prices), and in other cases they simply indicated that some variation in outcomes is possible even in situations where the Nash Equilibrium generally predicts well. The distinction between these two kinds of lessons is important, though, because the former suggests ways to modify both the theory and the experimental institution in future work.

The existing models are in many respects not meant accurately to reflect real-world markets. For example, no such institution as that studied by Salop-Stiglitz actually exists, and the consumers in the Wilde-Schwartz model have exogenous sample sizes. The assumptions of these models reflect compromises between realism and analytical tractability. Nevertheless, they have the virtue of yielding specific predictions. Thus, a sensible research program should start by testing them, as we have done, because there is no point in analyzing more complicated laboratory environments, especially ones for which we have no theoretical results, unless the simple models predict well. The consistency between the widely different predictions of the models we tested and the experimental outcomes suggests that our experimental procedures design will be useful in analyzing the effects of relaxing various of the models' assumptions. For example, the role of the rational expectations assumption has recently come into question (Schwartz and Wilde, 1982a), but the technical difficulties associated with relaxing this assumption are formidable. These difficulties can be avoided with laboratory experiments—modifying the rational expectations assumption is convenient in our experimental framework. Having validated the basic models, one can place some confidence in the robustness of results that the variations yield.

The experiments described here thus suggest at least three avenues for future research: first, as indicated, to modify the rational expectations assumption and see what equilibria are observed; second, to test models such as (Schwartz and Wilde, 1983) and (Chan and Leland, 1982) that permit firms to vary product quality and that endow consumers with preferences over qualities; third, to test in the laboratory institutions that more closely resemble institutions that do or could exist in natural markets, such as those that permit consumers to purchase price data communicated via video or teletext systems. These three sets of experiments would be interesting positively and may have considerable normative significance. Moreover they can provide directions for future theoretical work.

APPENDIX A

INSTRUCTIONS TO BUYERS

This is an experiment in market behavior. The buyer's role in this experiment is largely passive; nevertheless, your earnings will depend on how accurately you do your job. You will be paid in cash at the end of the experiment.

As a buyer you may purchase units of a good from sellers, and then resell the units to the experimenters. You may keep any profits you make from these transactions, plus a commission of $0.10 per unit.

The market will operate in a sequence of rounds or trading periods. During each period you may buy no more than ___ units. The experimenters will redeem the units you buy for ___ each. Therefore, to avoid buying units at a loss you are not to purchase units priced over ___.

The market will proceed as follows. Sellers will set their prices and these prices will be posted on a blackboard. Your purchase decision will be made by comparing the lowest price in a set of prices with ___. Notice that your BUYER SHEET contains spaces for ___ units each round. For each unit, the seller numbers you have been randomly assigned appear in the third column. The offered prices corresponding to these seller numbers comprise the set of prices you are allowed to compare in reaching your purchase decision for a given unit. If the lowest price in the set is less than or equal to ___, you may order one unit from the low-priced seller. In the event of ties, you must order from the uppermost seller among those tied in the set (the sequences of seller numbers in the sets have been randomized.) Remember, if the lowest price in a set exceeds ___ then you may not make a purchase.

In any given round, a seller may choose not to participate. If this occurs, you are to consult the tables below for the seller number to substitute for that of the nonparticipant, wherever it appears on your buyer sheet for that round. Thus, if in some round you find that seller 4 has declared himself a nonparticipant, you look down the table and see, for example, the notation 4 → 7; this directs you to replace seller 4 with seller 7.

Place your orders by filling out one of the ORDER SLIPS provided, and be sure to record your earnings and transactions on the BUYER SHEETS.

INSTRUCTIONS TO SELLERS

This is an experiment in market behavior. The decisions you make during the course of the experiment will determine the amount of money you will earn. You will be paid in cash at the end of the experiment.

As a seller, you may purchase units of a good from the experimenter and sell them to buyers. You will receive a commission of $0.10 for each unit you sell. Each of you will be given an initial credit of $15.00. Any profits or losses you make from your transactions will be added to the $15.00 to determine your overall earnings for the experiment.

The market will operate in a sequence of rounds or trading periods. In each period you may participate or not. If you do not participate, then you cannot earn anything for that period. Only the participants can buy or sell units or make offers. Nonparticipants are not allowed to play any role in the experiment. Each period that you do participate you will be charged a fee, or FIXED COST of _____, whether you sell any units or not. You may purchase any number of units you wish in any round, up to a limit of _____, at a COST PER UNIT of _____. If you choose not to participate, you do not pay the participation fee for that round.

Each period will be conducted as follows. The experimenter will announce the beginning and the end of the period. At the beginning of the period you must decide whether or not to participate. If you choose not to participate, simply write "no" on the offer slip. Next, if participating, you must choose the price you will offer for the units you hope to sell that period. Once you have decided on a price, you may not change it that period, but you may alter it between periods. Put your seller number and the current period number, along with the price you will offer, on one of the OFFER SLIPS provided. The slips will be collected by the experimenters and the prices will be displayed to the buyers; the buyers will then place their orders according to the following scheme.

The buyers are divided into two classes, shoppers and nonshoppers. Each nonshopper observes one price, chosen at random, from the current period's set of prices, and purchases one unit at that price if and only if it is less than some maximum value. A shopper is allowed to compare more than one offered price (although not necessarily all of the prices), and buy at the lowest price found, again provided that it is less than some maximum value. For this experiment the nonshoppers may buy up to _____ units and the shoppers may buy up to _____ units per round. Note that buyers must purchase a unit if they see a price less than or equal to their maximum value. When the buyers have placed their orders, the experimenters will collect them, match them to the correct sellers, and communicate the orders to you. The list of prices and the number of units sold at each price will be posted on the blackboard after each period.

After you receive the buyers' orders, you may wish to purchase some units from the experimenters. If at the end of a period you find that you have some unsold units, they may be carried over and sold during a later period. From an examination of your assigned unit costs, you will find that your average unit cost is _____, assuming that you order the maximum number of units you are permitted. Thus, you may NOT offer units for sale at a price less than _____. You should update your profit and inventory records on your SELLER TRANSACTION RECORD at the end of each period.

When a number of periods have been completed, the experimenter will announce that the experiment has ended. If at this time your final NET STOCK is negative, that is, you have sold more units than you have purchased from the experimenters, you will have to purchase an offsetting number of units to fill your outstanding sales. You may purchase the necessary units at the same cost per unit of ____. However, you must pay a penalty of ____ for every ____ units (or fraction thereof) that you buy. As an example, let us say that at the end of the experiment you find your NET STOCK to be -13; so that you have 13 more sales than orders (from the experimenter). First, figure out the penalty. Suppose your limit on orders per round (column [5]) is five; then each five units or fraction thereof costs you one penalty charge. (So the 13 units cost you three charges, one for the first five units, one for the second five, and one for the remaining three.) In addition, each unit you must order requires payment of the COST PER UNIT. Therefore, for the 13 unit NET STOCK deficit, you would be charged (3 · PENALTY CHARGE) + (13 · COST PER UNIT). Notice that because you have already recorded the sales of these units on your TRANSACTION RECORD, you have already been credited with the revenue from the sales. If you have unsold units at the end of the experiment, (a positive NET STOCK), the units cannot be sold, carried over, or resold to the experimenter. Note that because of the penalty charge it is cheaper to order units during periods in which you participate than to wait and order them at the end of the experiment. On the other hand because unsold final inventories cannot be sold to the experimenter (i.e., they have a value of zero) you do not want to order too many units during the experiment.

APPENDIX B

SELLER TRANSACTION RECORD

SELLER #

	REVENUES			COSTS				PROFIT	INVENTORY		
PER	PRICE [1]	UNITS SOLD [2]	REVENUE [2]×(.10+[1])	FIXED COST [4]	UNITS ORDERED [5]	COST PER UNIT [6]	TOTAL COST [4]+[5]·[6]	PROFIT	CUMULATIVE SALES	CUMULATIVE ORDERS	NET STOCK

BUYER TRANSACTION RECORD

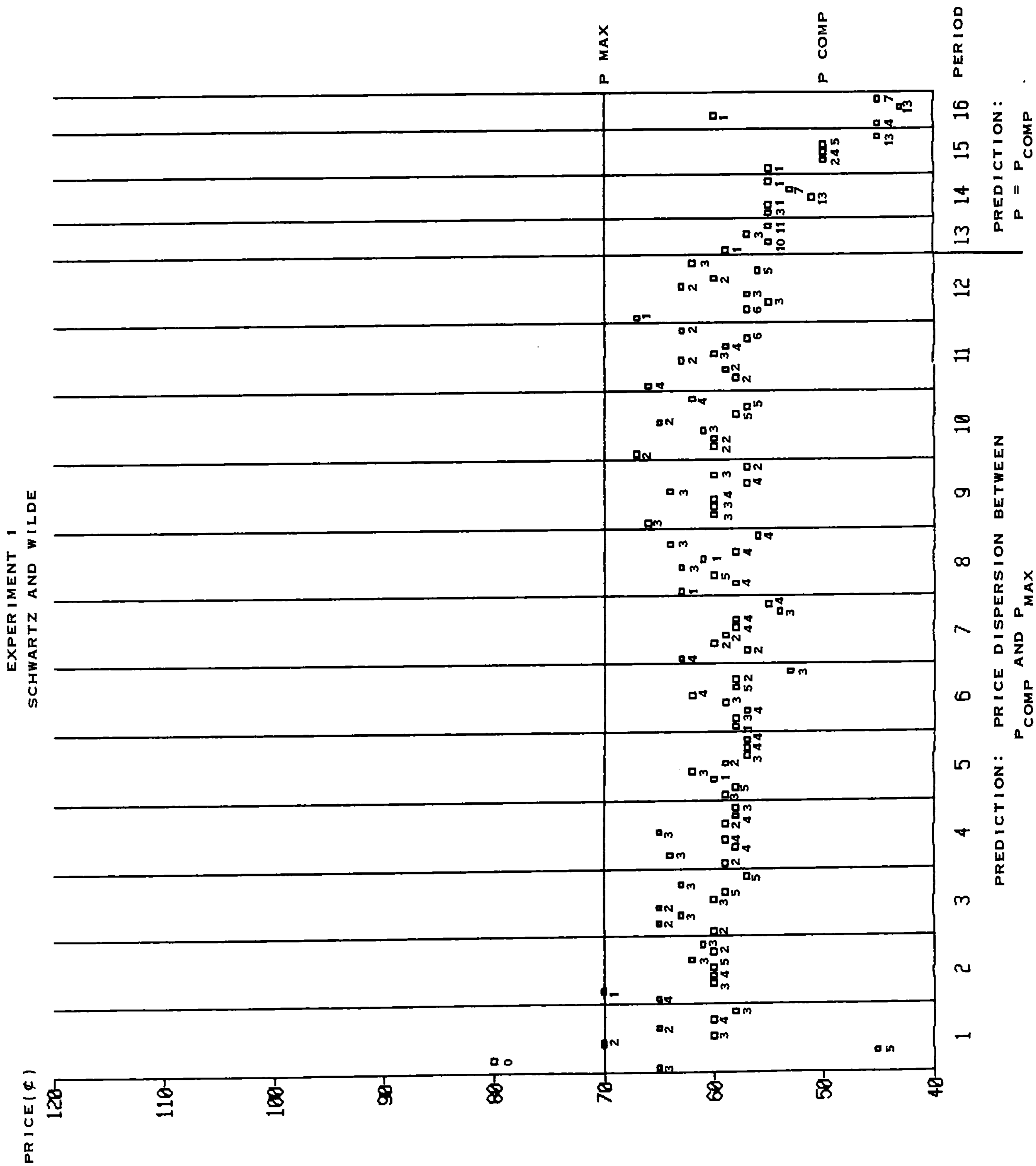
(1) UNIT #	(2) RDMPTN VALUE	(3) SELLER #	(4) SELLER PRICE	(5) SAMPLE SIZE	(6) SAMPLE COST	(7) UNIT PRICE	(8) COMSN	(9) UNIT PROFIT (2)+(8)-(6)-(7)
1								
2								
3								
4								
5								

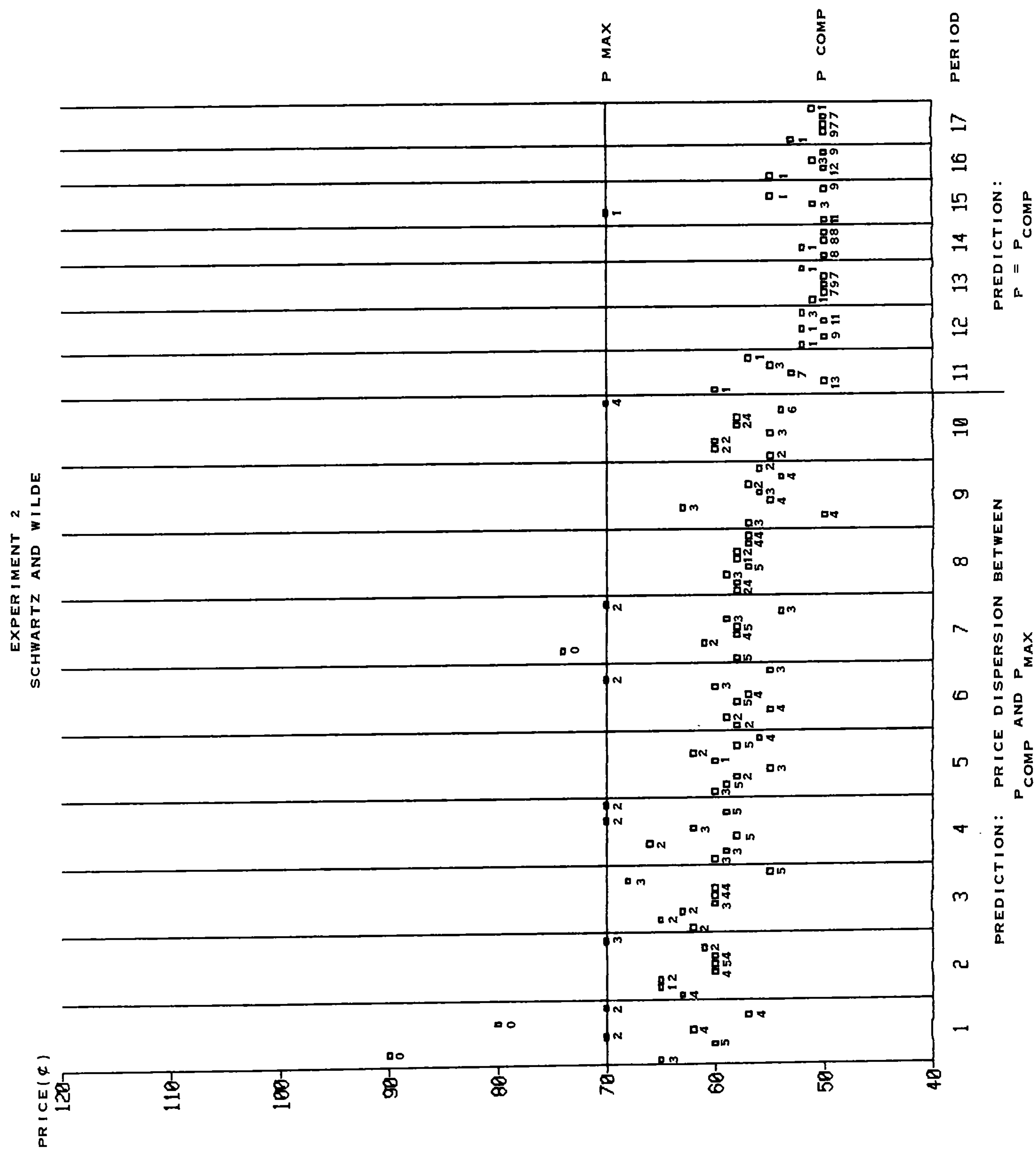
BUYER ____ ROUND ____ TOTAL PROFIT THIS ROUND ____

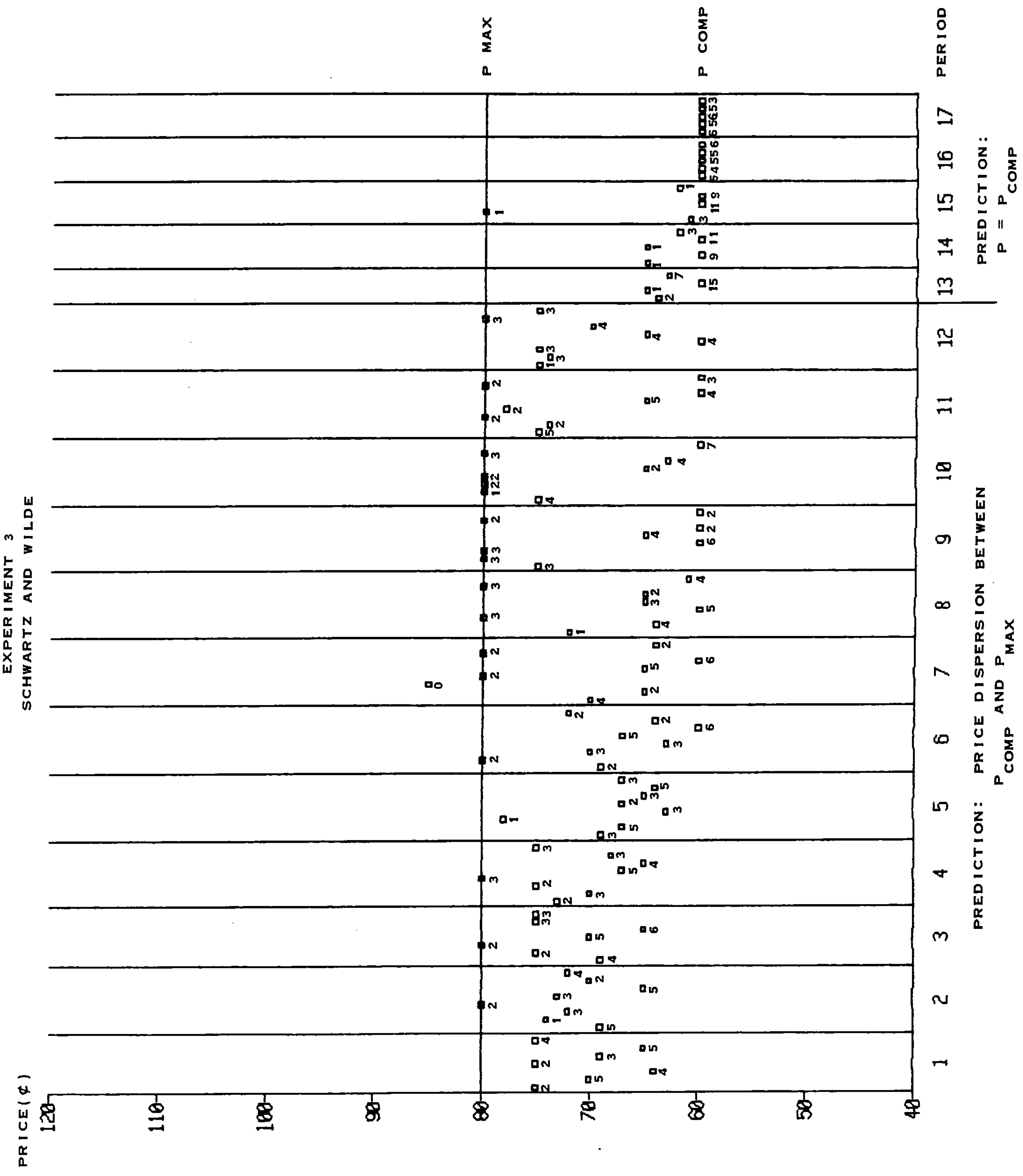
(1) UNIT #	(2) RDMPTN VALUE	(3) SELLER #	(4) SELLER PRICE	(5) SAMPLE SIZE	(6) SAMPLE COST	(7) UNIT PRICE	(8) COMSN	(9) UNIT PROFIT (2)+(8)-(6)-(7)
1								
2								
3								
4								
5								

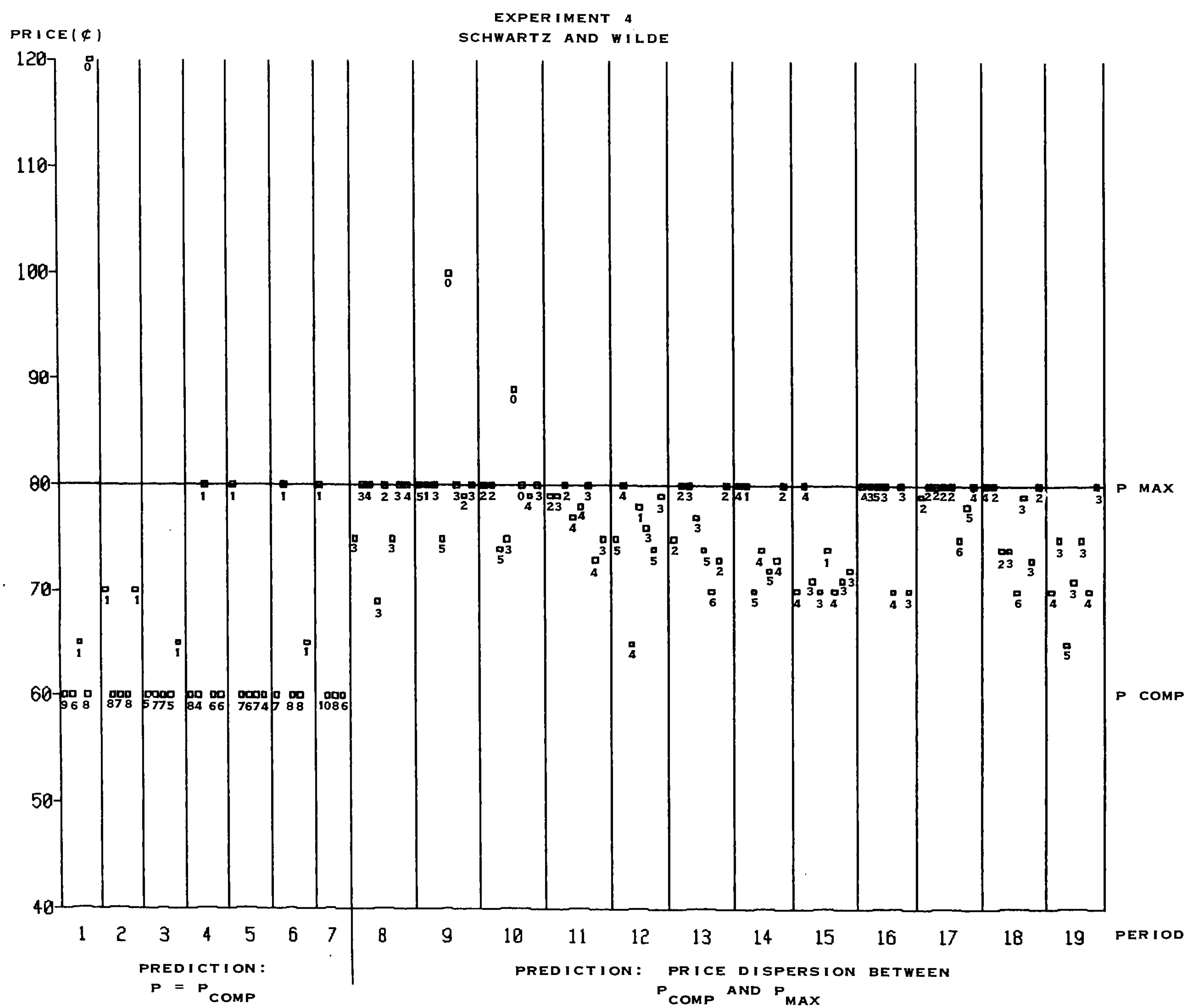
BUYER ____ ROUND ____ TOTAL PROFIT THIS ROUND ____

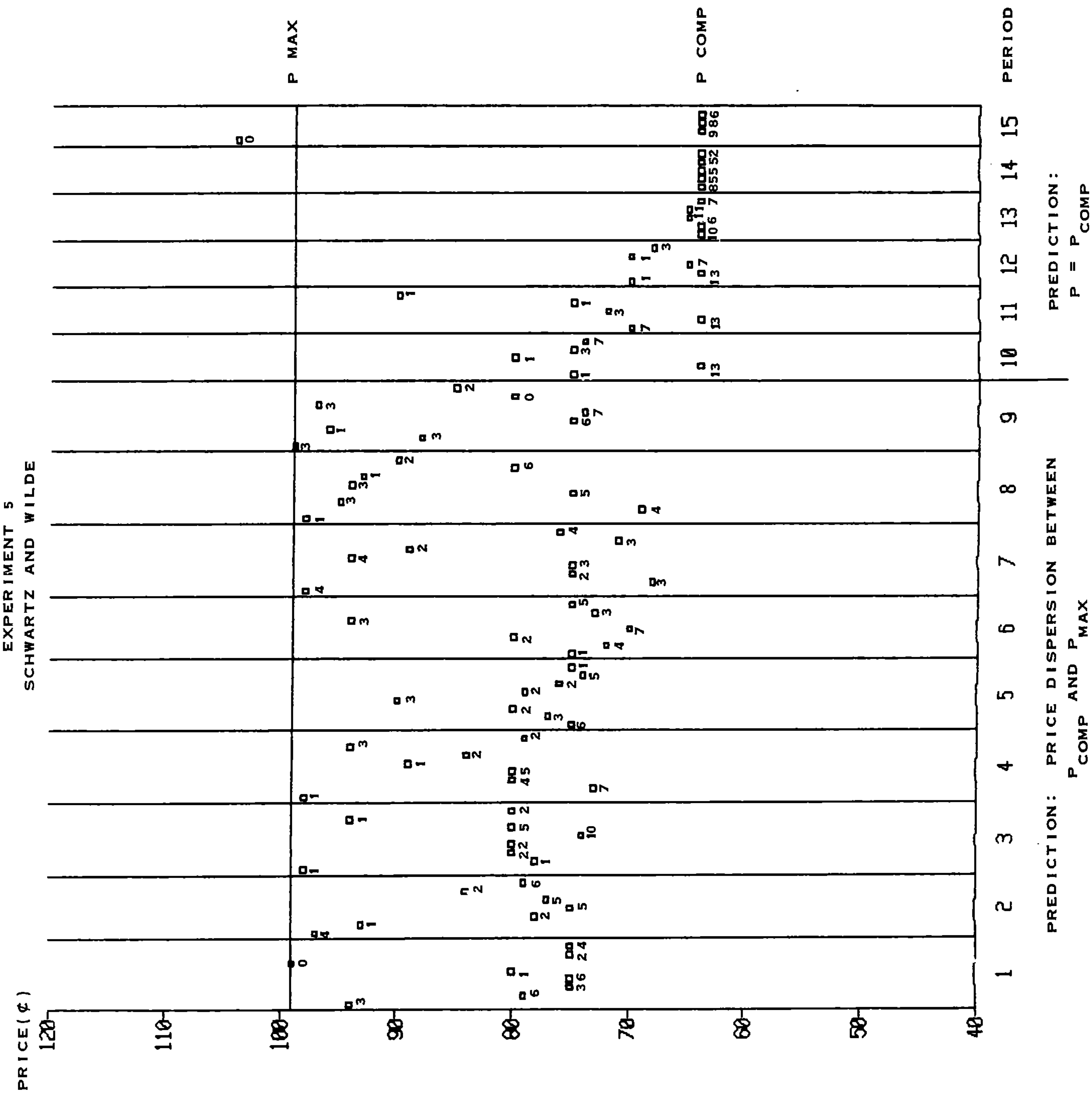
APPENDIX C

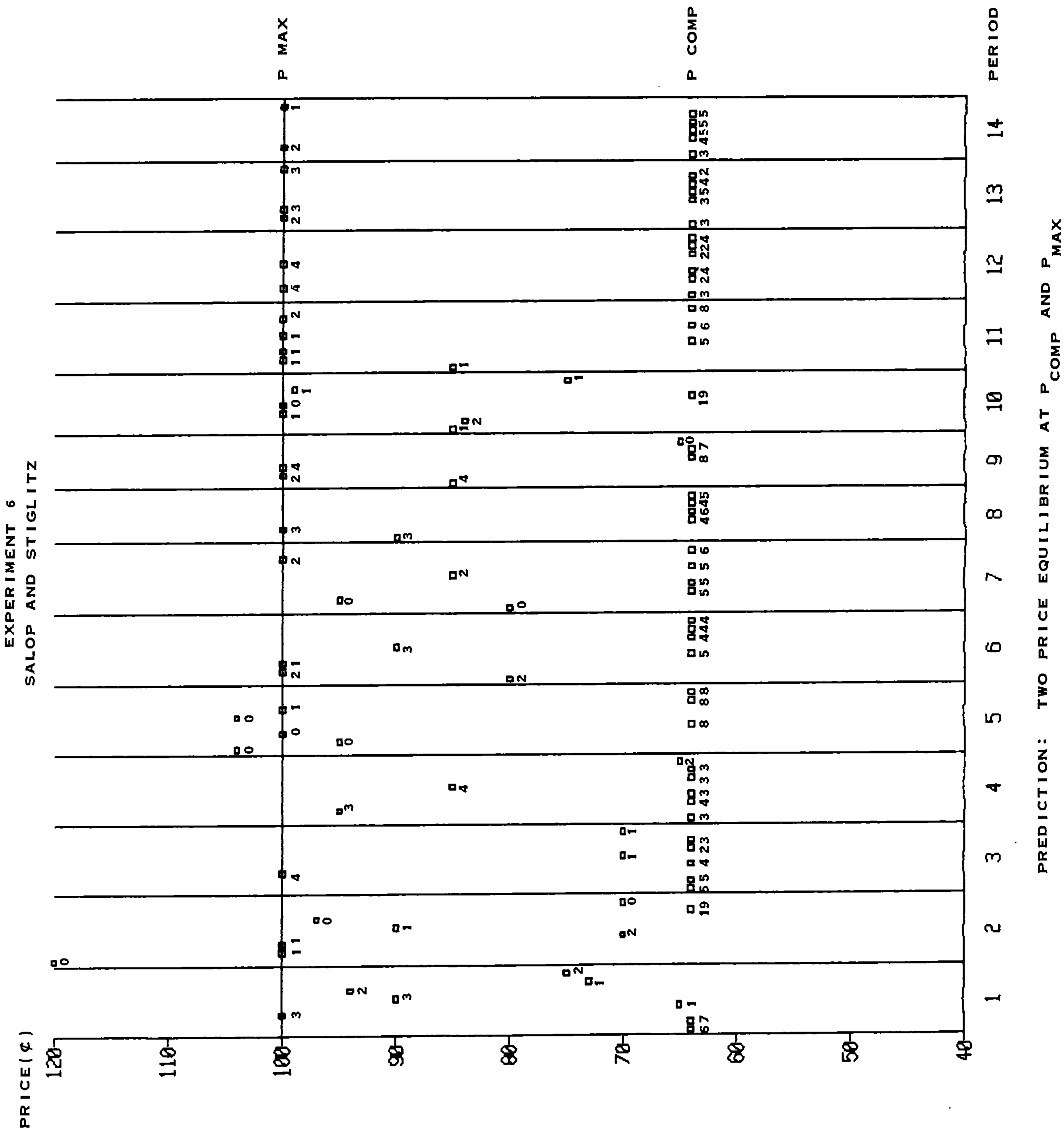

EXPERIMENT 1
SCHWARTZ AND WILDE
PRICE(¢)
120
110
100
90
80
70
60
50
40
P MAX
P COMP
PERIOD
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
PREDICTION: PRICE DISPERSION BETWEEN P COMP AND P MAX
PREDICTION: P = P COMP

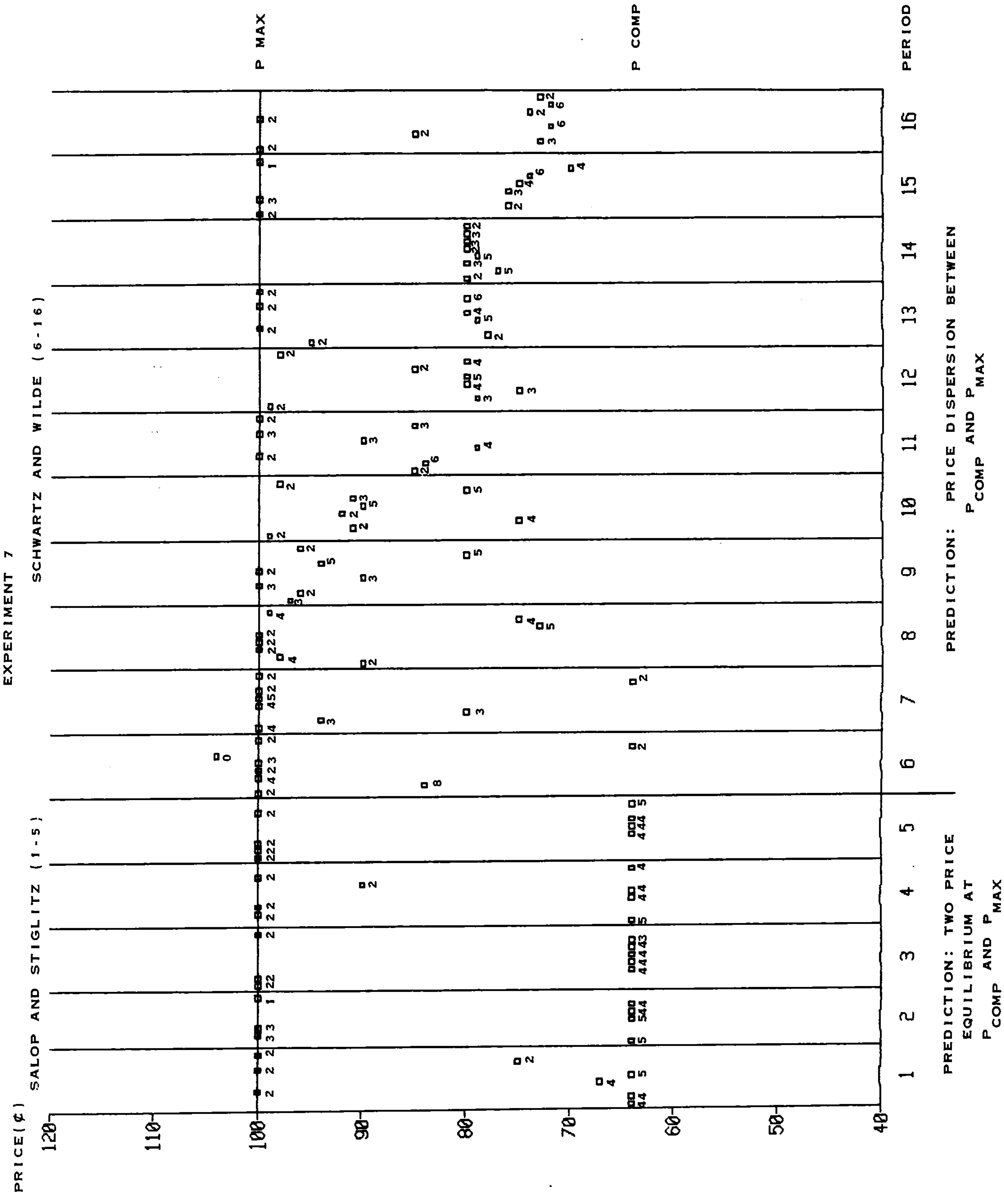

EXPERIMENT 2
SCHWARTZ AND WILDE
PRICE(¢)
120
110
100
90
80
70
60
50
40
P MAX
P COMP
PERIOD
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
PREDICTION: PRICE DISPERSION BETWEEN
P COMP AND P MAX
PREDICTION:
P = P COMP


EXPERIMENT 3
SCHWARTZ AND WILDE
PRICE(¢)
120
110
100
90
80
70
60
50
40
P MAX
P COMP
PERIOD
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
PREDICTION: PRICE DISPERSION BETWEEN P_{COMP} AND P_{MAX}
PREDICTION: $P = P_{COMP}$

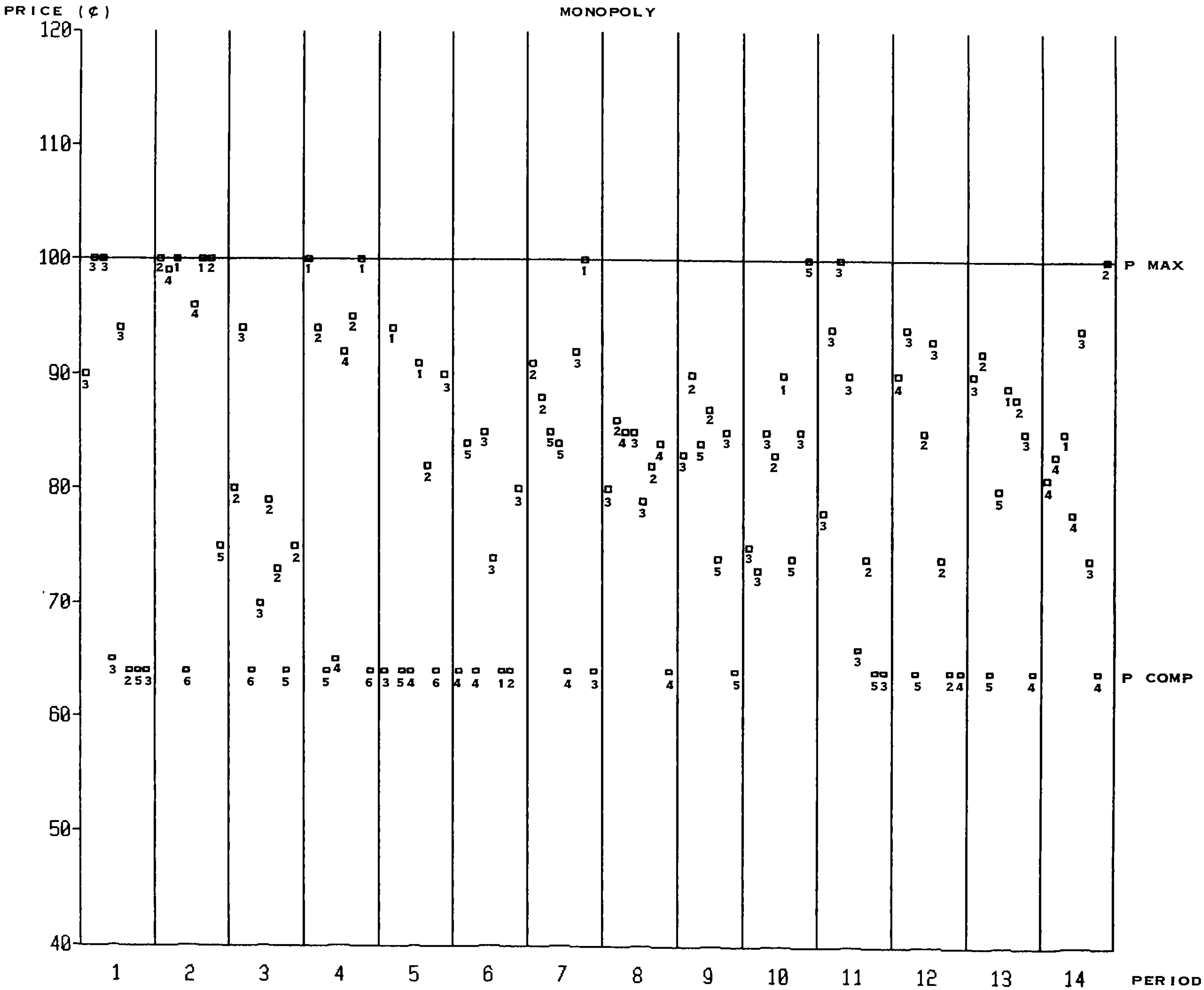

EXPERIMENT 4
SCHWARTZ AND WILDE
PRICE(¢)
120
110
100
90
80
70
60
50
40
P MAX
P COMP
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
PERIOD
PREDICTION: P = P_COMP
PREDICTION: PRICE DISPERSION BETWEEN P_COMP AND P_MAX


EXPERIMENT 5
SCHWARTZ AND WILDE
PRICE(¢)
P MAX
P COMP
PERIOD
PREDICTION: PRICE DISPERSION BETWEEN P COMP AND P MAX
PREDICTION: P = P COMP

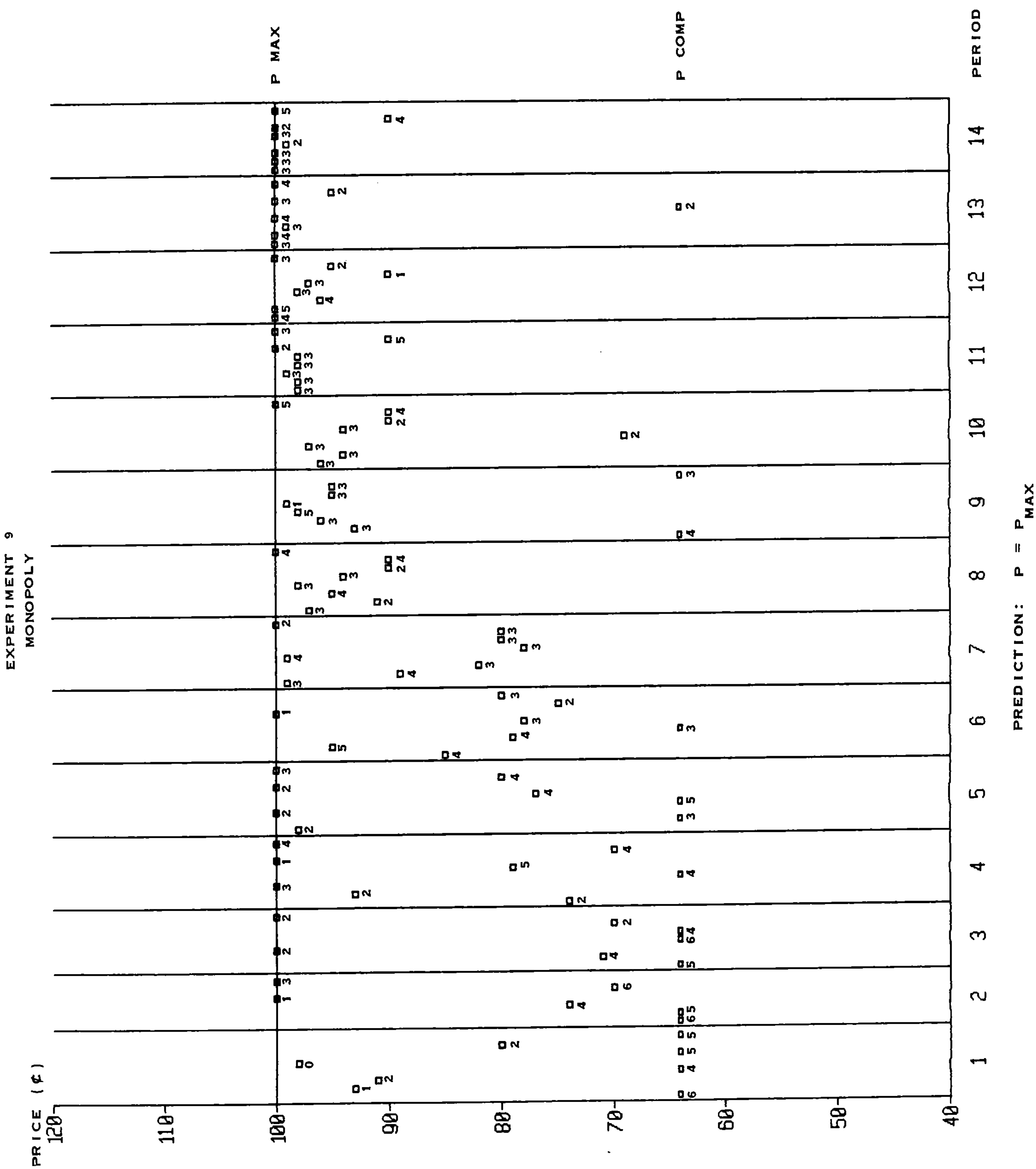

EXPERIMENT 6
SALOP AND STIGLITZ
PRICE(¢)
120
110
100
90
80
70
60
50
40
P MAX
P COMP
PERIOD
1
2
3
4
5
6
7
8
9
10
11
12
13
14
PREDICTION: TWO PRICE EQUILIBRIUM AT P_{COMP} AND P_{MAX}

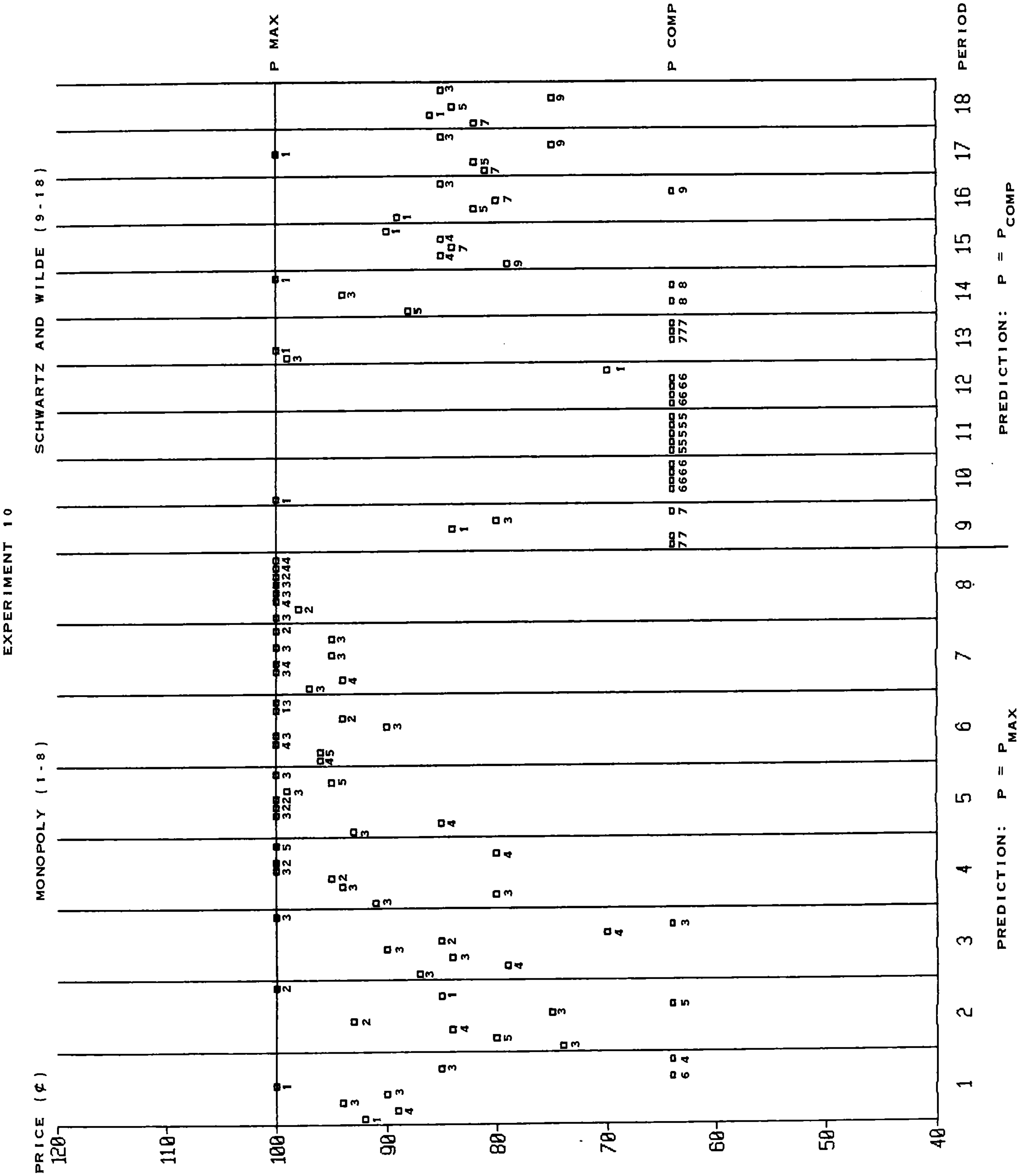

EXPERIMENT 7
SALOP AND STIGLITZ (1-5)
SCHWARTZ AND WILDE (6-16)
PRICE(¢)
120
110
100
90
80
70
60
50
40
P MAX
P COMP
PERIOD
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
PREDICTION: TWO PRICE EQUILIBRIUM AT P_{COMP} AND P_{MAX}
PREDICTION: PRICE DISPERSION BETWEEN P_{COMP} AND P_{MAX}

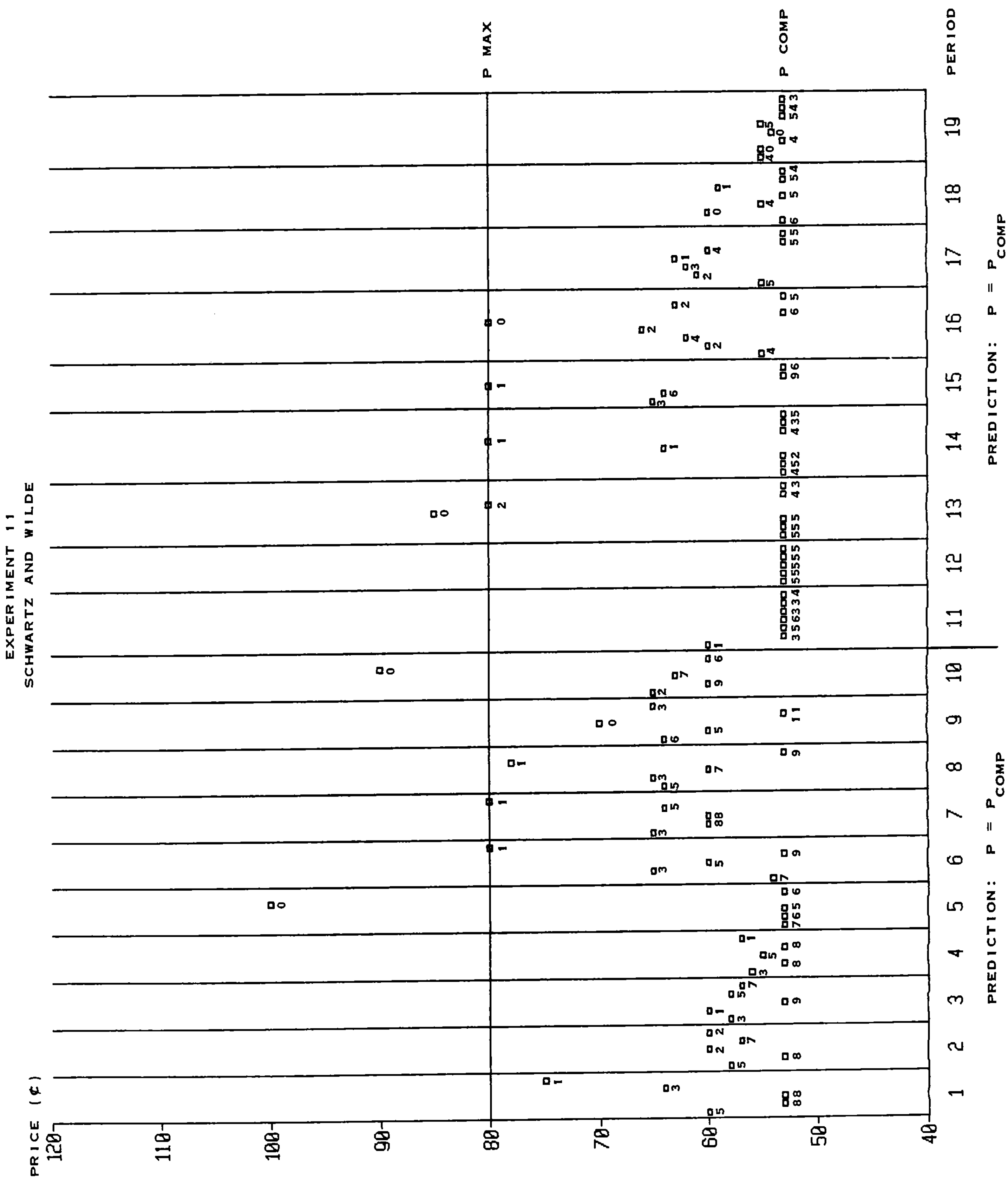
EXPERIMENT 8
MONOPOLY

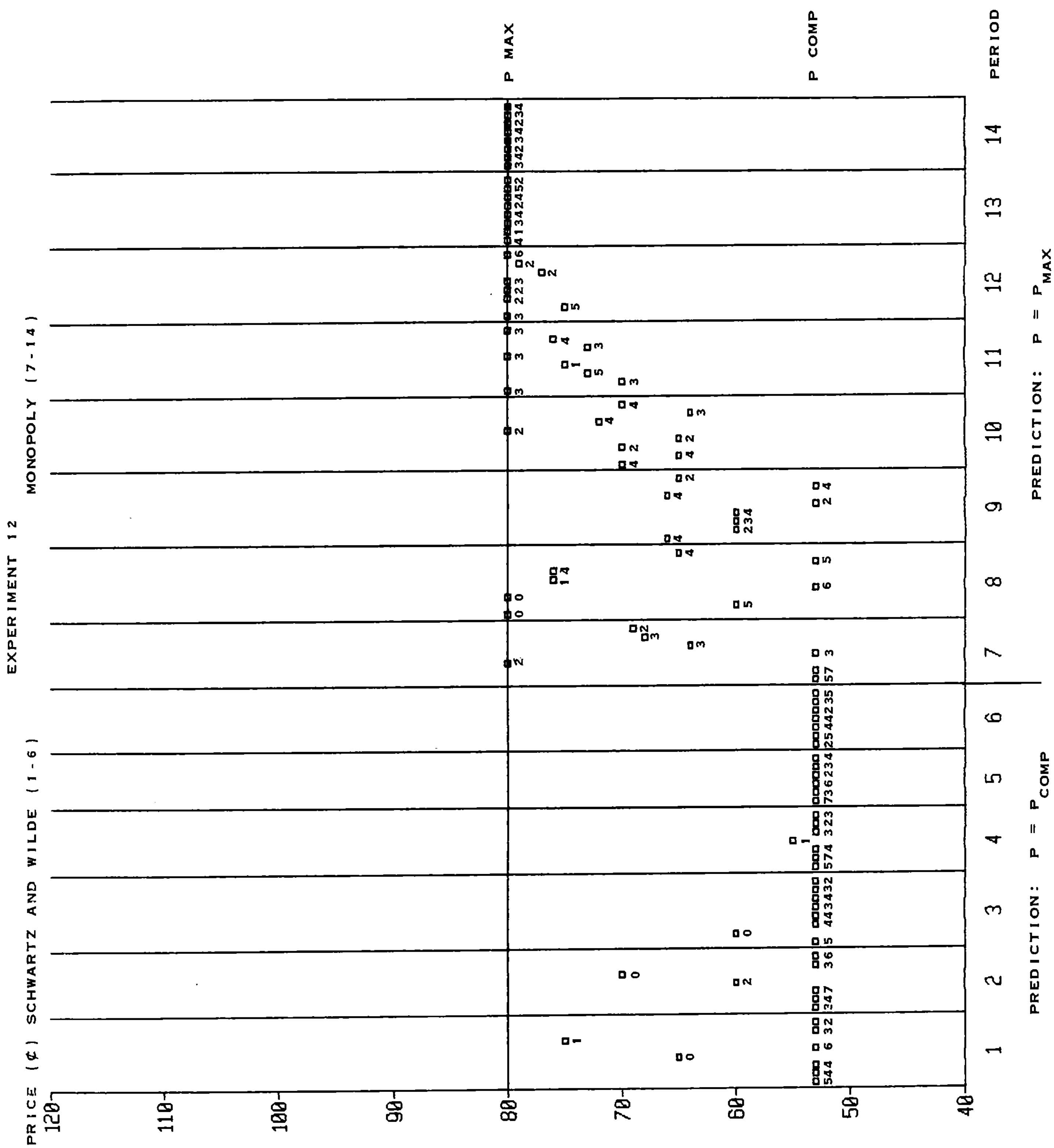


PREDICTION: $P = P_{MAX}$


EXPERIMENT 9
MONOPOLY
PRICE (¢)
P MAX
P COMP
PERIOD
PREDICTION: P = P MAX
120
110
100
90
80
70
60
50
40
1
2
3
4
5
6
7
8
9
10
11
12
13
14


EXPERIMENT 10
MONOPOLY (1-8)
SCHWARTZ AND WILDE (9-18)
PRICE (¢)
P MAX
P COMP
PERIOD
PREDICTION: P = P_{MAX}
PREDICTION: P = P_{COMP}
120
110
100
90
80
70
60
50
40
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18


EXPERIMENT 11
SCHWARTZ AND WILDE
PRICE (¢)
P MAX
P COMP
PERIOD
PREDICTION: P = P_{COMP}
PREDICTION: P = P_{COMP}
120
110
100
90
80
70
60
50
40
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19


EXPERIMENT 12
SCHWARTZ AND WILDE (1-6)
MONOPOLY (7-14)
PRICE (¢)
120
110
100
90
80
70
60
50
40
PERIOD
1
2
3
4
5
6
7
8
9
10
11
12
13
14
P MAX
P COMP
PREDICTION: P = P_{COMP}
PREDICTION: P = P_{MAX}

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