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Incentive Regulation: A Case Study in the Use of Laboratory Experimental Analysis in Economics

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Edited by

Shane Moriarity
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1986

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Incentive Regulation: A Case Study in the Use of Laboratory Experimental Analysis in Economics

INTRODUCTION

For many years economic theorists have argued the potential shortcomings of rate of return regulation (RORR), particularly with regard to its application to public utilities. The failings of RORR became more than a matter of academic speculation during the 1970s and 1980s. Successive waves of shocks (capital costs, fuel costs, environmental protection, nuclear power cost overruns, and so on) seemed to leave the process lurching from one crisis to another with vocal dissatisfaction on the part of *all* participants: firms, consumers, regulators, shareholders and bondholders.

In such an environment, it should be no surprise that there is great interest in alternatives to RORR. In particular, it has been noted that RORR is premised upon an information environment in which regulators are presumed to have an incredibly rich knowledge of both *economic* costs and demand schedules. In fact, the environment is information sparse and regulators are typically forced to react to information on *accounting* costs transmitted to them by the regulated firms. Regulators' knowledge of demand consists of historical (and perhaps irrelevant) observations and of imperfect statistical projections about future consumer behavior. Thus, the search for alternatives to RORR has, among other things, looked for regulatory processes that do not require such strong information requirements for achievement of optimal outcomes. Reducing the information requirements suggests a decentralization of decision-making. Yet if there is a valid economic rationale for regulation (such as the existence of an uncontestable natural monopoly), then decentralizing the process may leave

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profit maximizing firms with the incentive and the discretion to choose inefficient outcomes. Therefore, an even narrower class of alternatives to RORR will be considered here: decentralized regulatory processes (mechanisms) which make the economically efficient prices and quantities the result of profit maximizing decisions by the regulated firm. We shall refer to this class of processes as "incentive regulation."

While several such processes have been developed by economists there has not been, to understate the point, a flood of state regulatory commissions jumping on the incentive regulation bandwagon. This is not only unsurprising, it is quite rational for any single regulatory agency. For all of its shortcomings, RORR holds a unique position as the extant regulatory process of virtually every municipal and state utility regulatory agency in the country. As the regulatory process *in situ*, economic and political agents at all levels have substantial amounts of economic, financial, political, and human capital in place which is predicated upon the existence of RORR. With so much at stake, one would expect regulators to move very cautiously before scrapping RORR and instituting an alternative regulatory process which has existed only on the pages of an academic journal.

While the institutional inertia described above is explicable, it leads to a "Catch-22" for proposals to replace RORR. No regulator will seriously consider an alternative to RORR without some documentation of its performance properties; but this conservatism means that alternative processes do not get tried. This creates a bias in favor of the incumbent regulatory institution, whose status may be due more to historical accident than to inherent superiority.

What we intend for this paper is to present a case study to make two points. First, the technique of laboratory experimental economic analysis can provide useful information about the performance features of alternative regulatory institutions and thus help to break the inertia which favors RORR by default. Second, the fear on the part of "practical-minded" participants in the regulatory arena that what "works" in economic theory may not "work" in practice is not unfounded. Specifically, we report on research which is part of a larger inquiry into regulatory and deregulatory alternatives to RORR conducted for the Arizona Corporation Commission. As a case study, we will present and compare theoretical and experimental analyses of proposed incentive regulatory mechanisms. We will compare the behavior of flesh and blood humans to the theoretically optimal behavior predicted by the theory. And, we will show how the divergence of the two led to fruitful new directions for research.

THE EVOLUTION OF THEORIES OF INCENTIVE REGULATION

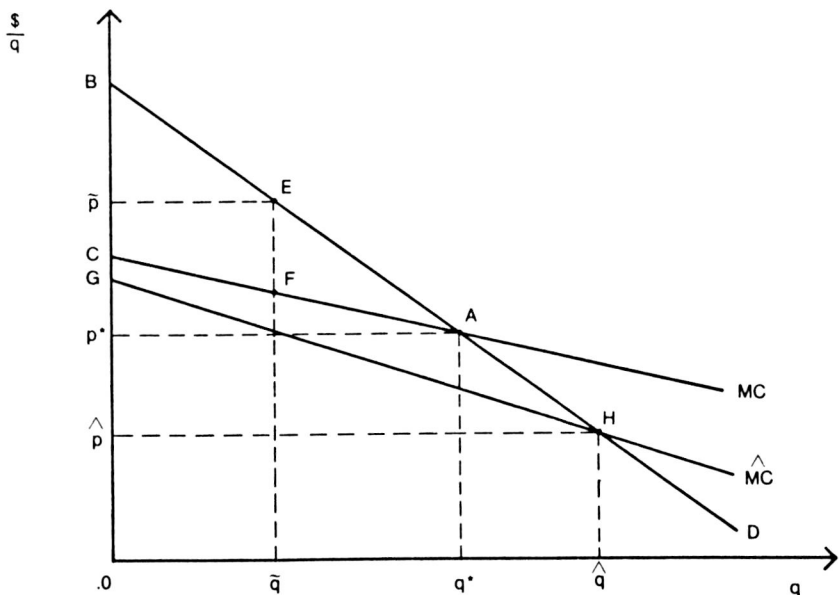
The first incentive mechanism that we will discuss is the Loeb-Magat (LM) mechanism. The approach of Loeb-Magat [1979] was to extend the concept of a dominant-strategy revelation mechanism [Groves and Loeb, 1975] to the context of a regulatory authority facing a monopoly firm. Under the LM mechanism the firm chooses its own price and the regulatory agency pays the utility a subsidy equal to the Marshallian consumer surplus at the

chosen price. Both the regulator and the firm are assumed to know the demand curve for the firm's product. In addition the firm, but not the regulator, is assumed to know the firm's marginal cost curve.

The properties of the LM mechanism can be developed with Figure 1 as follows. D is the demand curve for the firm's output and MC is its marginal cost curve. These "curves" are linear in the figure, but linearity is not essential to the argument. MC is decreasing in the figure, as for a decreasing-average-cost natural monopoly, but that is also not essential to the properties of the LM mechanism. Suppose the firm chooses the efficient price, p^* , where the demand and marginal cost curves intersect. The firm will collect revenue from selling quantity q^* at price p^* equal to p^*q^* . In Figure 1, p^*q^* revenue is the rectangular area $0q^*Ap^*$. The subsidy equal to the entire consumer surplus for quantity q^* is the area under the demand curve out to q^* , excluding the revenue rectangle. It is the area p^*AB . The firm's total variable cost of producing quantity q^* is the area under its marginal cost curve out to q^* , which in the figure is area $0q^*AC$. Thus the firm's profit is area CAB minus its fixed cost of production. If the firm chooses some other price, such as \tilde{p} , its revenue will be $0\tilde{q}E\tilde{p}$; its subsidy will be $\tilde{p}EB$; and its variable cost will be $0\tilde{q}FC$. Thus by choosing a price \tilde{p} , above p^* , the firm's profits would be decreased by an amount equal to area FAE .

The preceding discussion makes clear why the LM mechanism provides an incentive for the regulated firm to choose the efficient price defined by

FIGURE 1
The L-M Mechanism



the intersection of its demand and marginal cost curves. In addition to its incentive for allocative efficiency, the LM mechanism also provides an incentive for cost efficiency, as can be seen by the following. Suppose that by the elimination of waste, or through innovation, the firm is able to reduce its costs. A reduction in fixed cost will not affect either the size of the subsidy or the profit-maximizing price; hence it will increase the firm's profits by the full amount of the cost reduction. Alternatively, a reduction in marginal cost from, say, MC to \hat{MC} in Figure 1 will decrease the profit-maximizing price from p^* to \hat{p} and increase profits by an amount equal to area $GHAC$. In either case, under the LM mechanism the firm continues to reap a benefit from cost reduction indefinitely; whereas under RORR the firm's rewards for cost reduction are typically rescinded at the next rate proceeding. Therefore, the LM mechanism provides a stronger incentive for cost efficiency than does RORR.

Some may object to the preceding version of the LM mechanism because the subsidy to the firm is equal in size to all the gains from exchange. Loeb and Magat suggested two possible extensions of their mechanism to reduce the size of the subsidy: (a) a lump sum tax; and (b) auctioning the franchise. A lump sum tax in an amount that did not exceed the firm's maximum after-subsidy profits (area CAB in Figure 1 minus fixed cost) would not cause the profit-maximizing price to deviate from the price, p^* . Alternatively, maximum after-subsidy profits would be the value of an exclusive franchise. Auctioning the franchise would make it possible for the regulatory authority to recapture part of the profits and thus reduce the next subsidy payment. In addition, we have described a "modified Loeb-Magat" (MLM) mechanism, which reduces the subsidy and the informational requirements for the regulator, but still requires the regulator to know part of the firm's demand curve [Block, et al., 1985].

Both the size of the subsidy and the informational requirements for running a mechanism can be further reduced if the mechanism introduced by Finsinger-Vogelsang [1981] is used instead of the MLM mechanism as a replacement for RORR. The subsidy formula for the Finsinger-Vogelsang (FV) mechanism involves an adjustment process based on observed market prices and quantities, as follows. Let p_r be the extant market price when the FV mechanism is applied to the firm. Beginning with period 0 under the FV mechanism, the firm can choose its price for each time period. The chosen price at time period t is p_t , $t = 0, 1, 2, \dots$. This price can vary from one period to another but must be constant within a time period. The firm must supply the entire quantity, q_t , that is demanded at its chosen price in each time period. Beginning with extant price and quantity, (p_r, q_r) , if the firm chooses price p_0 in period 0 then its subsidy is

$$S_0 = q_r [p_r - p_0] \quad (1)$$

Note that if $p_0 = p_r$ then the subsidy is zero. If $p_0 > p_r$ then the "subsidy" is negative; that is, the firm is taxed if it raises its price. If $p_0 < p_r$ then the firm receives a positive subsidy. One such subsidy for period 0 is represented by area A in Figure 2. The subsidy in time period 1 is

$$S_1 = S_0 + q_0 [p_0 - p_1] \quad (2)$$

If $p_1 < p_0$ then $S_1 > S_0$. If $p_1 < p_0 < p_r$ then $S_1 > S_0 > 0$. One such subsidy for period 1 is given by area A plus area B in Figure 2. If $p_2 < p_1 < p_0 < p_r$ then the subsidy for period 2 is given by area A plus area B plus area C in the figure. The subsidy formula for any time $t = 0, 1, 2, \dots$ can be written as

$$S_t = S_{t-1} + q_{t-1} [p_{t-1} - p_t] \tag{3}$$

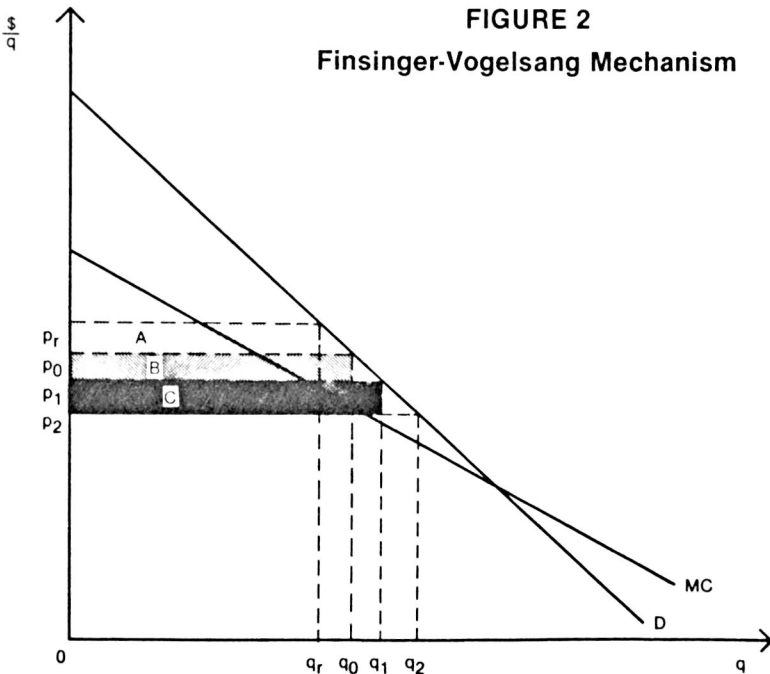
using the convention that $S_{-1} \equiv 0$, $q_{-1} \equiv q_r$, and $p_{-1} \equiv p_r$.

An alternative way of writing subsidy formula (3) is

$$S_t = \sum_{\tau=0}^t q_{\tau-1} [p_{\tau-1} - p_{\tau}] \tag{3'}$$

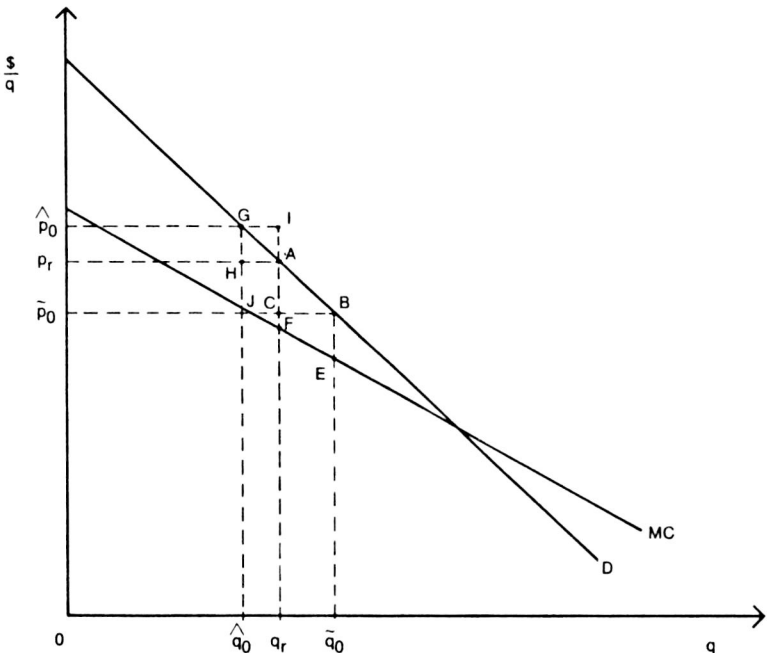
$$= q_r [p_r - p_0] + q_0 [p_0 - p_1] + q_1 [p_1 - p_2] + \dots + q_{t-1} [p_{t-1} - p_t]$$

Statement (3') makes clear an important property of the FV mechanism: if the firm ever raises its price ($p_{\tau} > p_{\tau-1}$, for some τ) it is penalized in the current and in all later periods by a negative term in the subsidy formula ($q_{\tau-1} [p_{\tau-1} - p_{\tau}] < 0$). Figure 2 makes clear another important property of the FV mechanism: for any given reduction in price (say, from p_r to p_2), the subsidy paid under the FV mechanism will be less than the subsidy paid under the LM mechanism (because the former excludes the "stairstep" areas).



Further insight into the incentive properties of the FV mechanism can be gained from Figure 3. Let p_r and q_r be the extant price and quantity when the FV mechanism is applied to the firm. The firm is then free to choose p_0 . Consider a time 0 price that is less than p_r (say \tilde{p}_0) and an alternative time 0 price that is greater than p_r (say \hat{p}_0). What are the implications for profits in time 0 of these alternative time 0 prices? Sales revenue from selling quantity q_r at price p_r is given by area $0 q_r A p_r$ in Figure 3. Sales revenue from selling quantity \tilde{q}_0 at price \tilde{p}_0 is given by area $0 \tilde{q}_0 B \tilde{p}_0$ in Figure 3. These two areas both contain the area $0 q_r C \tilde{p}_0$; hence the change in sales revenue from reducing the price in time period 0 from p_r to \tilde{p}_0 is given by area $q_r \tilde{q}_0 B C$ less area $\tilde{p}_0 C A p_r$. But the subsidy is given by area $\tilde{p}_0 C A p_r$. Thus the change in sales revenue plus subsidy from reducing the price from p_r to \tilde{p}_0 is the positive amount given by area $q_r \tilde{q}_0 B C$. The increase in quantity from q_r to \tilde{q}_0 , which is required to supply the increase in quantity demanded following the price decrease, increases cost by an amount given by area $q_r \tilde{q}_0 E F$. Since this area is smaller than area $q_r \tilde{q}_0 B C$, decreasing the price from p_r to \tilde{p}_0 in period 0 would increase profits *in period 0*.

FIGURE 3
Incentive Properties of the FV Mechanism



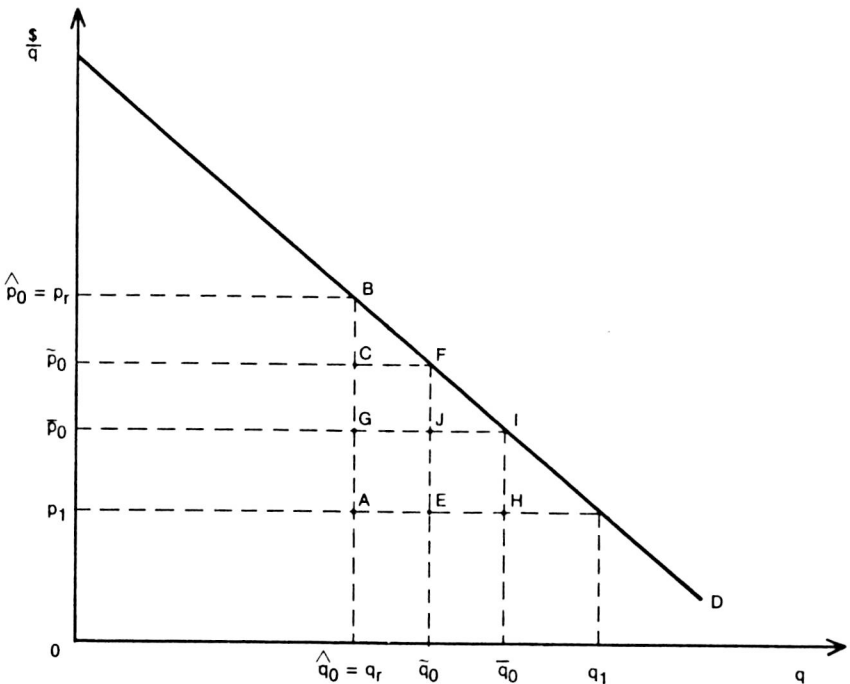
Next, consider the time 0 profit implications of increasing the price from p_r to \hat{p}_0 in time period 0. Sales revenue from selling quantity \hat{q}_0 at price \hat{p}_0 is given by area $0 \hat{q}_0 G \hat{p}_0$ in Figure 3. Since sales revenue of selling quantity q_r at price p_r is given by area $0 q_r A p_r$, the change in sales revenue from increasing the price from p_r to \hat{p}_0 is given by area $p_r H G \hat{p}_0$ less area $\hat{q}_0 q_r A H$. But the subsidy given by statement (1) for the price increase is the negative amount given by minus one times area $p_r A I \hat{p}_0$. Thus the change in sales revenue plus subsidy in period 0 from increasing the price from p_r to \hat{p}_0 is the negative amount given by minus one times (area $H A I G$ plus area $\hat{q}_0 q_r A H$), which is minus one times area $\hat{q}_0 q_r I G$. The reduction in quantity from q_r to \hat{q}_0 will decrease costs by an amount given by area $\hat{q}_0 q_r F J$. Therefore, increasing price from p_r to \hat{p}_0 would decrease profits in time period 0 by an amount given by area $J F I G$. Furthermore, similar reasoning would show that any price increase (from p_r to any higher price) would reduce time 0 profits. Therefore, since we have shown that some price decreases (for example, from p_r to \tilde{p}_0) would increase time 0 profits, we conclude that the FV mechanism would cause the firm to decrease price in time 0 if its objective were to maximize time 0 profits.

Next, suppose that the firm's objective is to choose p_0 and p_1 so as to maximize the present (time period 0) discounted value of profits for periods 0 and 1. Then in choosing p_0 , the firm would need to be concerned with the effect of that choice on profits in period 1 in addition to its effect on profits in period 0. Figure 4 yields some insight into this question. This figure includes three alternative possible prices for period 0, \hat{p}_0 , \tilde{p}_0 , and \bar{p}_0 . Let us take p_1 as given and consider the implications for the period 1 subsidy of the alternative period 0 prices. However, first note that p_1 is taken to be less than all of the alternative period 0 prices. The reason for this is essentially the same reasoning we used to show that time 0 profits can be increased by choosing $p_0 < p_r$ would imply that time 1 profits can be increased by choosing $p_1 < p_0$.

Now consider the effect on the period 1 subsidy, S_1 , of choosing p_0 to be alternatively \hat{p}_0 , \tilde{p}_0 , or \bar{p}_0 . If $p_0 = \hat{p}_0$ then statements (1) and (2) tell us that $S_1 = S_1(p_r, \hat{p}_0, p_1)$ is given by area $p_1 A B \hat{p}_0$ in Figure 4. Alternatively, if $p_0 = \tilde{p}_0$ then statements (1) and (2) imply that $S_1 = S_1(p_r, \tilde{p}_0, p_1)$ is given by area $\tilde{p}_0 C B p_r$ plus area $p_1 E F \tilde{p}_0$. Thus choosing \tilde{p}_0 rather than \hat{p}_0 increases S_1 by an amount given by area $A E F C$. Since by previous reasoning we know that choosing \tilde{p}_0 rather than \hat{p}_0 also increases period 0 profits, we are assured that the price sequence p_r, \tilde{p}_0, p_1 dominates the sequence $p_r,$

\hat{p}_0, p_1 . Next suppose $p_0 = \bar{p}_0$. In that case, statements (1) and (2) imply that $S_1 = S_1(p_r, \bar{p}_0, p_1)$ is the amount given by area $\bar{p}_0 G B p_r$ plus area $p_1 H I \bar{p}_0$. Therefore, the relative sizes of $S_1(p_r, \bar{p}_0, p_1)$ and $S_1(p_r, \bar{p}_0, p_1)$ are determined by the relative sizes of areas $GJFC$ and $EHIJ$ in Figure 4. Therefore, in choosing p_0 as part of a sequence of profit-maximizing prices, p_0, p_1, p_2, \dots , the firm would need to take account of the effect of its choice of p_0 on S_1 , and therefore on profits in all periods subsequent to period 0, as well as the effect on period 0 profits. Because of this linkage across time periods, we cannot use a graphical approach to derive all of the properties of a profit-maximizing price sequence under the FV mechanism. These properties are derived by more advanced methods in an appendix to Block, et al. [1985]. It is there demonstrated that, for a firm regulated by FV, a sequence of prices that maximizes the present discounted value of profits is: (a) decreasing over time ($p_{t+1} < p_t$ for all t); and (b) convergent to the efficient price determined by the intersection of the demand and marginal cost curves.

FIGURE 4
Intertemporal Linkage of the FV Price



In summary, the FV mechanism appears to have three desirable properties:

1. It does not require the regulator to know the firm's cost or demand curves;
2. It requires a smaller subsidy than the LM mechanism;
3. The profit-maximizing path of prices for an FV-regulated firm is monotonically decreasing, converging towards the fully efficient price-output combination determined by the intersection of the demand and marginal cost curves.

EXPERIMENTAL TESTS OF THE TWO INCENTIVE MECHANISMS

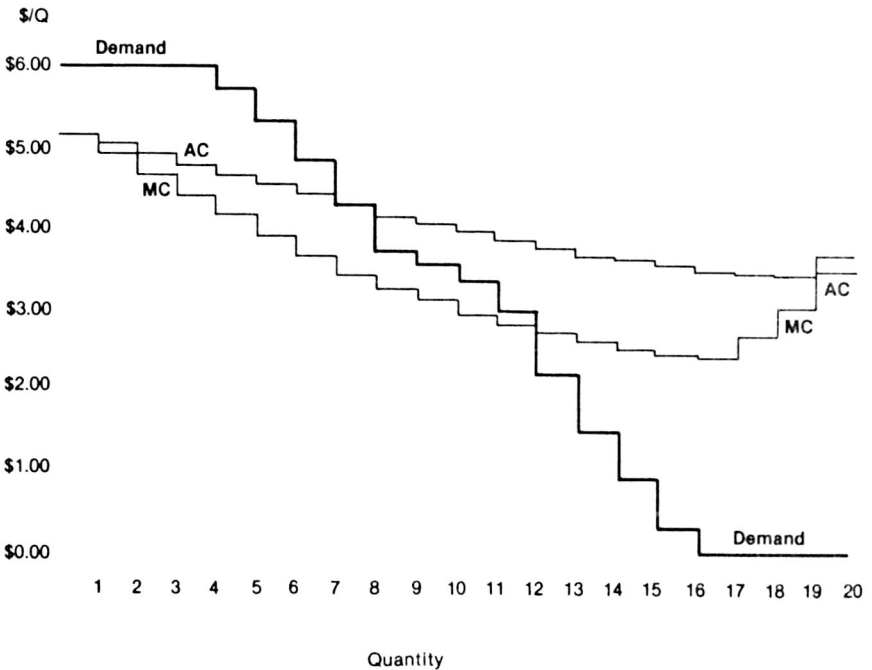
The previous section traced the theoretical evolution of the FV mechanism and discussed its desirable properties. What we intend to demonstrate here is that laboratory experimental economic analysis can provide useful policy-oriented information that is distinct from the contributions of economic theory. Specifically, we will report on a series of laboratory experimental processes designed to test the operation of the FV mechanism in light of the theoretical prediction that it will achieve efficient market outcomes. Because the FV mechanism can be viewed as a low-information-requirement, iterative approximation to the LM mechanism, a useful benchmark for this investigation is the behavior of the LM process in our laboratory environment.

In a previous study, Harrison and McKee [1985] have demonstrated in a laboratory setting that the LM mechanism behaves substantially as predicted. Our first task was to check to see if the earlier LM results would be replicated in our own environment. First, the economic environment of all of our incentive mechanism experiments is displayed in Figure 5. Notice that the induced demand and cost conditions create a classic "natural monopoly" market. The efficient (marginal cost pricing) outcome is for quantity to equal twelve units. In a competitive market, twelve units would be a profit maximizing quantity for the seller for any price in the range [\$2.80, \$2.94]. The standard monopoly market predictions are for $P_M = \$5.70$ and $Q_M = 5$ units. "Average cost" pricing (which captures the spirit of RORR) would yield $P_A = \$4.28$, $Q_A = 8$. In the experiments reported below, the regulated firm will, because of the subsidy functions, have equal incentives to choose *any* price which supports the competitive 12 units of output. Therefore, we will use an expanded notion of a "competitive" price, namely the range of prices which will cause buyers to purchase the efficient 12 units of output. This range, to be denoted CE^* on the charts, is [\$2.21, \$2.97].

All of these experiments were conducted as "posted offer" markets (see Ketcham, Smith, and Williams [1984]) which exhibit many of the features of a retail market for a non-storable commodity (such as electricity). Whereas each market had one seller (the regulated monopolist), the buyer behavior was "simulated" according to the parameters of the demand curve

to capture the concept of a very large number of buyers, no one of which believes that he can influence the seller's price. A more technical discussion of the experimental procedures and a copy of the instructions are contained in the appendix to this paper.

FIGURE 5



Using these economic cost and demand conditions, we conducted four experiments using the LM process. The results of these experiments are displayed in Figure 6. As can be seen, the LM process works well, just as had been found previously by Harrison and McKee. On average it took our participants only 8 periods to converge to the efficient outcome (where convergence is defined as a 5-period repetition). In only one case in one period did the outcome stray from the efficient quantity once convergence had occurred.

Of course, this laboratory version of LM exhibits the two practical implementation limitations noted in the LM theory. The regulator must know the demand curve; and, at the efficient output level, subsidies from the "government" will be large, at least 38 percent of total revenue in this particular design. The FV mechanism on the other hand, is an attempt to approximate the LM process without the regulator having to know the demand curve. Whether the firm must itself know the demand curve is ambiguous in the FV exposition, so we chose to test the mechanism both ways.

FIGURE 6
LM Mechanism

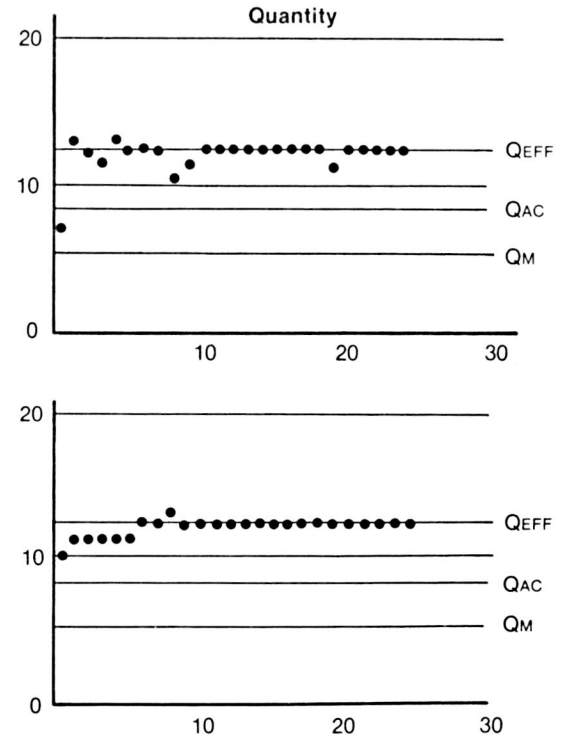
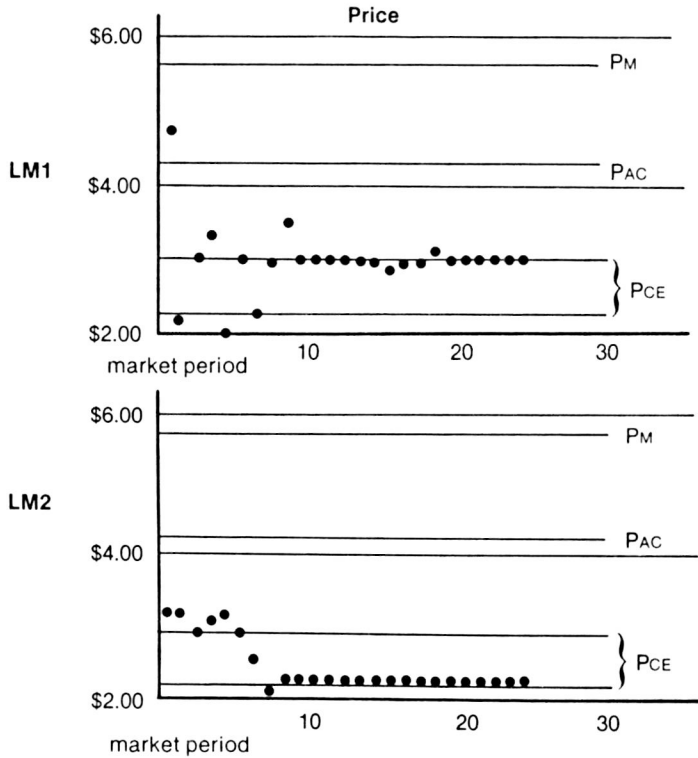
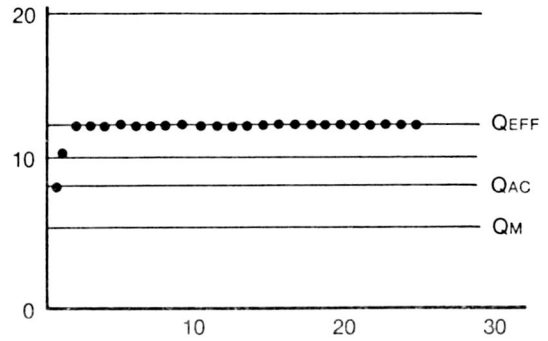
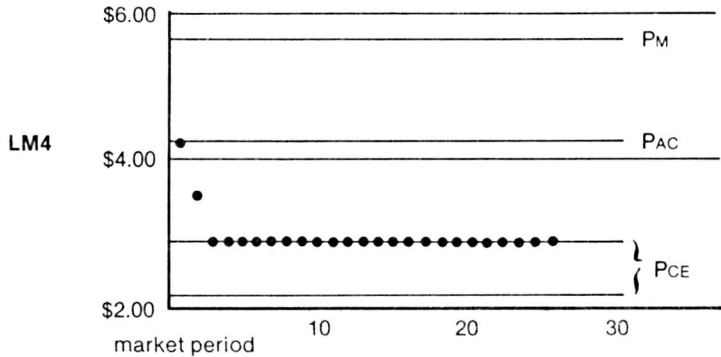
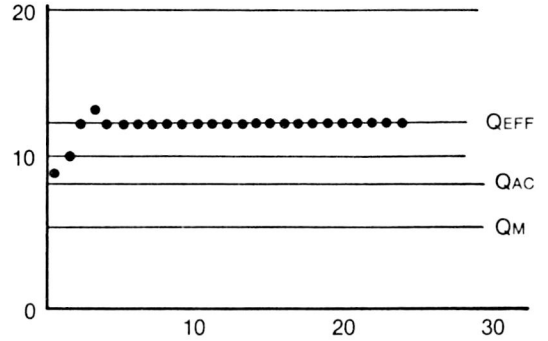
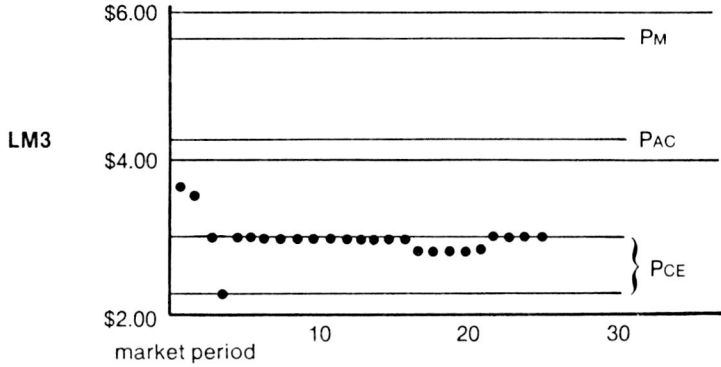


FIGURE 6 (continued)
LM Mechanism



The results of our FV series are a perfect example of how laboratory experimental tests of proposed regulatory institutions can be invaluable in public policy analysis. The theory states that this mechanism's optimal path will converge to the efficient outcome (in this case, an output of 12 units). But what happens if the firm errs, and gets off the optimal path? As Seagraves [1984] has noted, there is the possibility of such "cycles" adversely affecting the firm's profits. In fact, subject bankruptcy was a robust occurrence in our tests of the FV mechanism. Consider Figure 7. In experiment FV-1, the market behavior was virtually identical to that in the LM experiments. However, in FV-2, the seller raised his price to \$4.80 and then dropped it too quickly, becoming bankrupt. At this point, we cancelled his debts and went over with him step-by-step the path to his bankruptcy. Then, we told him that we would not cancel his debts again, but that we would be happy at any point to explain in advance the consequences of any decision he might want to make. Nevertheless, this seller again went bankrupt with a "Seagraves-cycle" in periods 10-11.

For the next experiment, FV-3, we announced, in advance, that periods 1-3 were "trials," not actual payment periods. The participant was free to start afresh in period 4. This seller also would have been bankrupt by period 3. We explained his losses step-by-step, and started the experiment "for real" in period 4. This seller avoided bankruptcy in the rest of the experiment but *did not converge* to efficient outcomes.

Finally, in FV-4 we examined the most limited information case in which *neither* the firm *nor* the regulator knows the demand curve in advance. Demand is revealed only by the sequential behavior of buyers. This market, FV-4, did not converge to efficient outcomes before the seller went bankrupt in period 17.

Thus, even though the FV mechanism has theoretically desirable optimal convergence properties, it is a mechanism which is permanently "unforgiving" of errors. In our laboratory markets, this feature proved to be important, with three of four sellers going bankrupt because of errors off the theoretically optimal path.

THE RESULTS AS A CASE STUDY

As might be expected, the undesirable behavioral properties evidenced by the laboratory FV mechanism weighed heavily in our decision to recommend against further consideration of the FV process as a practical alternative regulatory process. (However, as discussed below, it did *not* end our consideration of other incentive regulatory mechanisms.) What we wish to explore here is how the research program we have described illustrates the contributions of laboratory experimental techniques to questions of the design of public policy.

Before the FV experiments were begun we had completed the derivation of a well-defined theory of the operation of the institution. Smith [1982] (using a term suggested by Kaplan) classifies as nomothetic those experiments which are designed to establish expected regularities of human behavior and which are based upon well-defined hypotheses.¹ An oft-heard question is "if you have proven the theory (i.e. if its internal logic is correct) what is there

FIGURE 7
FV Mechanism

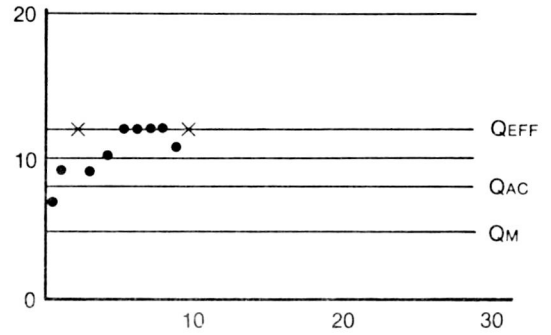
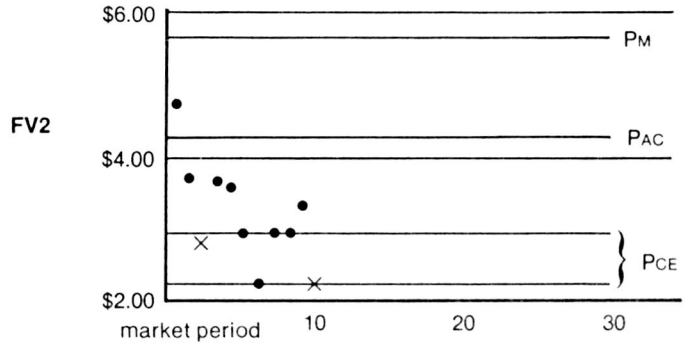
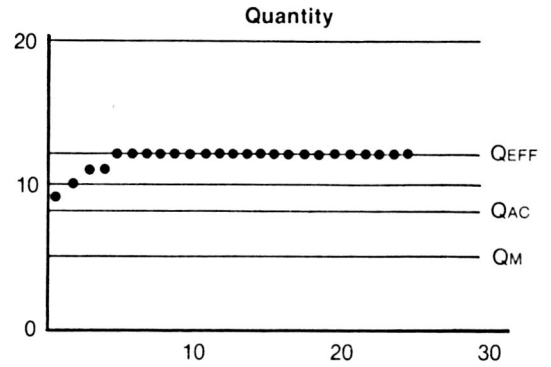
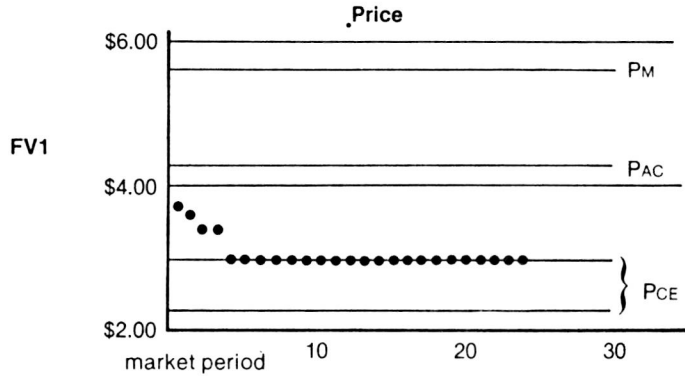
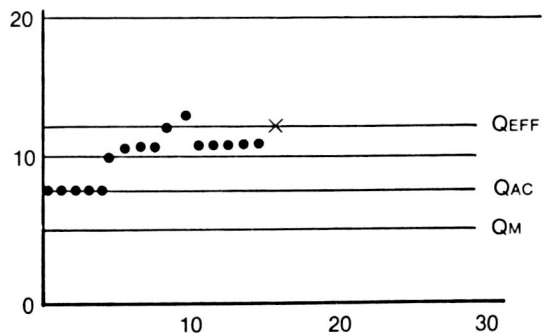
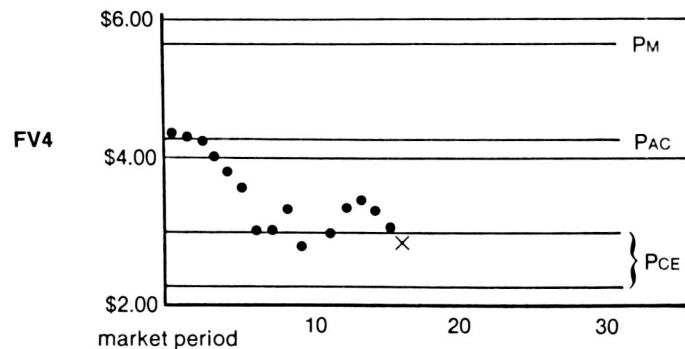
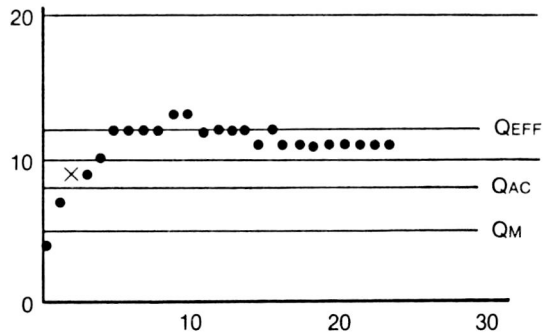
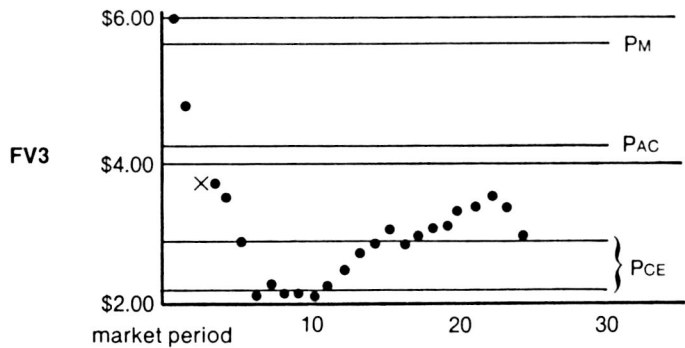


FIGURE 7 (continued)
FV Mechanism



X indicates seller bankruptcy

to test?" Or, put another way, there is a tendency to reject the usefulness of laboratory experimental tests of any logically consistent theory because either: a) the results are consistent with (do not falsify) the theory, so that the result was "obvious and expected;" or b) the results are not consistent with (do falsify) the theory, which means there must be something wrong with the experiment (that is to say, the experiment did not correctly capture all of the assumptions, because the assumptions logically imply the "correct" results).

The arguments stated above are invalid because they fail to distinguish between the different levels of economic theories. At one level is the core theory (or theorem or proposition) which is "proven" by its internal logical consistency. At another level is the *operationalized* theory which is purported to have interesting predictive power in an actual economic environment. The argument that the core theory (theorem, proposition) is useful in a predictive context draws upon a constellation of meta-assumptions which connect the core theory to the operationalization. Isaac [1983] has argued that for the typical economic theories which appear in applied contexts, such as regulatory policy, there are at least three crucial requirements of operationalization which could lead a logically correct theory to be a poor predictor of the behavior of economic agents. First, the theory may fail to specify some important feature of the economic environment (such as the nature of the trading institution, the information position of the participants, and so on). Secondly, the operationalization of a core theory requires assumptions to be made about unobservable characteristics of economic agents. Examples of such (implicit or explicit) assumptions about individual economic agents are: that they are or are not perfect optimizers, that they are or are not risk neutral, and so on. Also, the prediction of the core theory may depend upon assumptions about group interaction. These assumptions are usually referred to as the equilibrium or solution concepts of the theory: e.g. Nash equilibrium, perfect equilibrium, etc. The operationalization of the theory requires an answer to the question, "to what group of real economic agents is the theory expected to apply?" This is not a trivial question given that such individual characteristics as optimizing skills and risk attitudes, and such group attributes as tendencies to act in non-cooperative Nash fashion, are inherently unobservable. Finally, operationalizing the theory requires specifying the theory's predictions, and this may generate ambiguities that are not apparent in the core theory.

In the framework described above, it is easy to see that a logically correct core theory can generate interesting operationalizations which are falsifiable. Therefore, tests of such operationalized theories are informative whether the results are falsifying or non-falsifying. If the results of a test of an operationalized theory are consistent with the theory, then confidence in the predictive usefulness of the core theory is increased and further theoretical and empirical work can address questions about how robust the positive results will be. (Smith [1982] refers to this process as searching for the boundaries of falsification.) If the results of the tests are falsifying, then the burden of proof shifts against the policy usefulness of the core theory. Further work can include new theoretical work at the core level and/or tests of different operationalizations of the same core theory.

The incentive regulation research program provides a good example of the methodological process just described. The FV theory is somewhat vague as to precisely how much information the regulated monopolists have about their own demand; so we chose two different operationalizations. In one case the sellers began the experiment with a complete demand schedule, in the other, only a single point was revealed at the start. The FV theory is one of intertemporally optimizing economic agents. We had to ask for what category of economic agents should the FV process reasonably be expected to behave in the manner predicted? Our interpretation was that the core theory contained no implication that it should be applied to one group of people as opposed to another, so long as all were reasonably intelligent, literate adults. We decided to draw from a subject pool of University of Arizona students who were upperclass undergraduate or graduate students in business or computer science and thus were not merely literate, English-speaking adults but were also persons with the type of advanced training one would expect to find among utility executives.

Thus operationalized, the laboratory FV mechanism failed to achieve the predicted outcomes. The apparent reason for this failure is twofold: i) the difficulty for economic agents of calculating the optimal price path; and ii) the incentives against getting back on the optimal path once a mistake has been made. We do *not* claim that our results *prove* that similar problems would necessarily occur if a field version of FV were operationalized with utility managers. What we do argue is that we have shown that the problem of non-optimal behavior off the optimal path is more than a theoretical curiosity. Three of our four monopolists were caught in the profit-destroying cycles. These results greatly lowered our confidence in the FV process.

As mentioned, useful policy inquiry can continue after negative experimental results. In the incentive regulation program, we moved to the construction of a new regulatory mechanism which (we hoped) would avoid the undesirable behavioral properties which we had seen in the FV process. The theoretical development and laboratory testing of the resulting "Arizona" mechanism are described in greater detail in Block, et al. [1985].

SUMMARY

Results from a laboratory experimental series designed to test a proposed alternative process for utility regulation have been presented as a case study of the usefulness of experimental inquiry. Laboratory experiments are not the only form of testing. They are complementary to field empirical techniques in analyses of alternative regulatory institutions. The clear advantages of laboratory economic experiments include knowledge and control over the economic environment, well defined predictions in that environment, replicability, and low direct and opportunity costs of creating and comparing different allocative institutions. (See Cox, Isaac, and Smith [1983] for a more detailed discussion of these advantages in the context of exploring the properties of alternative procedures for auctioning oil leases.)

Likewise, there are limitations to the applicability of laboratory tests. Experimentation would not be particularly well suited for estimating population parameters, and, as we have stressed, falsifying and non-falsifying

results in the laboratory do not prove that identical results would occur in the field. Nevertheless, in our research on alternative regulatory processes, laboratory experiments were invaluable in shaping our recommendations against the adoption of a specific regulatory mechanism.

NOTE

¹The usefulness of laboratory economic experiments is not confined to the category of nomothetic experiments in which a well developed formal theory exists before the experiments are conducted. A second category of experiments is that which Smith [1982] has described as "heuristic", in which the experiments begin with informal conjectures about the operation of one or more allocative institutions. Some public policy-related examples of heuristic experiments are detailed in Isaac [1983].

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APPENDIX

Experimental Procedures and Sample Instructions

Most retail markets in developed economies are organized under what has been called the "posted offer" institution. As we define it for our single seller markets, in this institution the seller posts in each market period a single take-it-or-leave-it price. Unlike other versions of the posted offer market, however, the quantity actually traded at that price is determined by the *customers*—the firm has no right to refuse service to a buyer willing to pay the posted price.

The seller has a record sheet which assigns to each of the possible units of production a marginal cost, representing the additional cost to him of selling that unit. These MC values are displayed in Figure 5.

Each period begins with the seller recording on his record sheet the price he wishes to post for that period. Then the experimenters calculate how many units a population of competitive buyers would purchase at the seller's announced price. This insures that demand is defined by the demand curve displayed in Figure 5. After this quantity purchased is announced, the experimenters calculate the seller's trading profits (retail sales revenues less total production costs) and the bonus payment according to the appropriate incentive mechanism being studied.

All sellers in these experiments were "experienced" in the sense that each had previously participated in other, unrelated experiments at the University of Arizona.

INSTRUCTIONS

General

This is an experiment in the economics of market decision making. Various research support agencies have provided funds for the conduct of this research. The instructions are simple, and if you follow them carefully and make good decisions you might earn a considerable amount of money which will be paid to you in cash at the end of the experiment.

In this experiment, we are going to create a market in which you will be the only seller in a sequence of market days or trading periods. In this market, you will be the seller of a commodity to buyers in the market. During each market period, you are free to offer for sale units of the commodity. Assume that you produce only for immediate sale—that is, this good cannot be stored. There are no inventories. You will be free to announce to the buyers whatever price you wish to charge. The details of how to do this will be explained below. However, in any one trading period you may announce only *one* price. All the units you sell will be sold at this price. (Of course, you are free to change your price from one period to the next, if you wish.) Furthermore, the amount that you sell will be determined by how many units the buyers are willing to purchase at your announced price. That is, you cannot refuse to sell to anyone who wishes to buy at your announced price. We turn now to a discussion of how the buyers decide how many units to purchase.

The Purchasing Decisions of Buyers

In this experiment, we will make the purchasing decisions of the buyers. In doing this, we will use a purchasing rule designed to simulate the behavior of a market of many buyers, all of whom make purchasing decisions following a very simple rule: Buyers value the commodity you are selling. Buyers purchase *all* the units of the commodity which are profitable to them at the price you (the seller) have announced.

At this point, we are going to tell you exactly how much the buyers value the commodity. On the sheet labeled "Buyers Purchasing Rule," we have listed exactly how much this group of buyers would value each *additional* unit they purchase from you. This same information is shown as a graph at the bottom of the page.

Suppose that you posted a price of 4.28. Notice that the buyers value is greater than or equal to 4.28 for units 1-8, but less than 4.28 for units 9 and above. Therefore, in this example, these buyers would purchase 8 units from you. That is, at an

announced price of 4.28 you will sell 8 units. How many units will you sell at a price of 6.10? How about a price of .30?

Where do you get the units of this commodity to sell to the buyers? That is a good question, and it will be answered in the next section.

SPECIFIC PROFIT INFORMATION FOR THE SELLER

Recall that during each market period you are free to offer for sale units of the commodity at a specified price. You must announce only one price for all units during a market period, but you may change your announced price from one period to the next. You have received TWO sheets in addition to these instructions. One of them is labeled "Summary of Seller's Costs of Production." On this sheet, the dollar amounts listed in Column (2) are your total costs of producing the number of units listed in Column (1). The dollar amounts in Column (3) give you another way of looking at the same information: in Column (3) you see the *additional* cost to you of producing the last *additional* unit of the commodity. Notice, for example, that the total cost of producing 15 units is equal to the total cost of producing 14 units plus the additional cost of producing the 15th unit ($54.10 = 51.60 + 2.50$).

Each trading period will open when you record on line 1 of your "Seller's Record Sheet" the price at which you wish to offer units for sale. You will turn your record sheet in to the experimenter who, using the "buying rule" described above, will return it to you after recording on line 2 how many units the buyers have purchased. Your profits from the trading period are calculated in two parts: "trading" profits and "bonus" profits. Each of these two types of profits are computed as follows:

A. Trading Profits If during any trading period you make any sales, you will receive as profits the difference between your *total sales revenue* and your total production costs for the number of units you sold. Your total sales revenue (line 3 on your record sheet) is simply your announced price times the number of units the buyers purchase from you (that is, line 1 times line 2). Your total costs of production are found in Column (2) of the "Seller's Costs of Production" sheet, and are entered on line 4 of your record sheet. Your trading profits for any one period are then simply calculated as line 3 minus line 4. As an example, notice the column marked "example period" on your record sheet. Suppose you were to post a price of 4.28. The buyer's purchasing rule described above states for this test run that buyers would purchase 8 units at 4.28. From your cost sheet, you will find that your total cost of producing 8 units is 34.20. Thus, your total trading profits are $8 \times 4.28 = 34.24$ minus 34.20 or .04.

B. Bonus Profits. In each trading period, you will receive a "bonus" which depends upon three numbers: 1) your announced price in the previous period, call this price P_{t-1} ; 2) the number of units the buyers purchased from you in the previous period, call this quantity Q_{t-1} ; 3) your announced price in the current period, call this P_t .

In period 1, your bonus payment will be $8 \cdot (\$4.28 - P_1)$, where P_1 is your announced price in period one. For the second and every subsequent period, your bonus payment in that period will be the same as in the previous period *plus* the amount $Q_{t-1} \times (P_{t-1} - P_t)$. That is, your bonus will be increased in each period by the previous period's purchases times the amount by which you have reduced your announced price since the previous period. Notice that if you lower your price, your bonus will be the same or larger. If you raise your price, your bonus will be the same or smaller. We will calculate your bonus for you, but the step-by-step calculations will be shown on your record sheet.

CLOSING COMMENTS

Notice that for any trading period your total profits *may* be positive even if your trading profits are negative provided that you have *sufficiently* large positive bonus profits. (Likewise, your total profits *may* be positive even if your bonus profits are not positive, provided that you have *sufficiently* large positive trading profits. Finally, before we begin the actual trading, we will start you off with an initial capital endowment of 5.00.

Are there any questions?

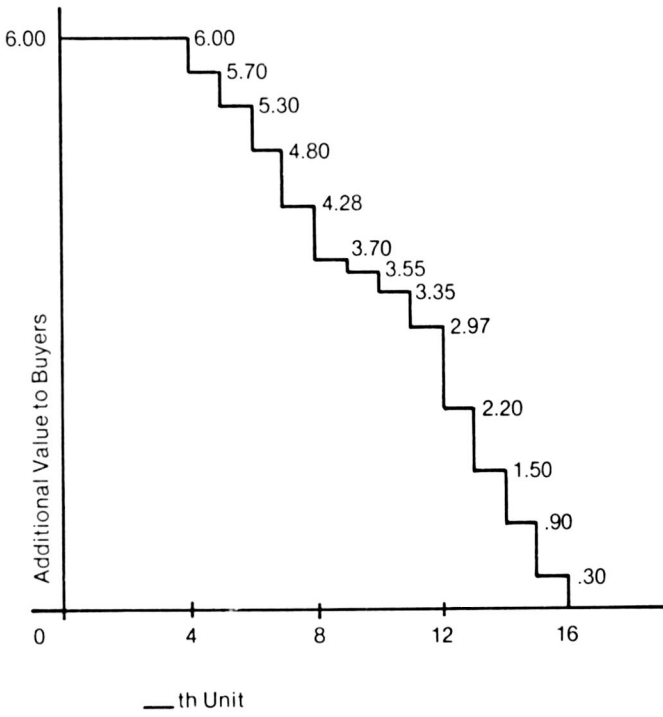
SUMMARY OF SELLER'S COSTS OF PRODUCTION

| (1) UNIT # _____ | (2) TOTAL COST of producing _____ units | (3) ADDITIONAL COST of producing unit |
|---------------------|---|---|
| 1 | \$ 5.15 | \$ 5.15 |
| 2 | 10.05 | 4.90 |
| 3 | 14.70 | 4.65 |
| 4 | 19.10 | 4.40 |
| 5 | 23.25 | 4.15 |
| 6 | 27.15 | 3.90 |
| 7 | 30.80 | 3.65 |
| 8 | 34.20 | 3.40 |
| 9 | 37.45 | 3.25 |
| 10 | 40.55 | 3.10 |
| 11 | 43.50 | 2.95 |
| 12 | 46.30 | 2.80 |
| 13 | 49.00 | 2.70 |
| 14 | 51.60 | 2.60 |
| 15 | 54.10 | 2.50 |
| 16 | 56.55 | 2.45 |
| 17 | 58.95 | 2.40 |
| 18 | 61.60 | 2.65 |
| 19 | 64.60 | 3.00 |
| 20 | 68.25 | 3.65 |
| 21 | 72.50 | 4.25 |

BUYERS' PURCHASING RULE

| Unit # _____ | Additional Value to Buyers of the _____ Unit |
|--------------|--|
| 1 | \$ 6.00 |
| 2 | 6.00 |
| 3 | 6.00 |
| 4 | 6.00 |
| 5 | 5.70 |
| 6 | 5.30 |
| 7 | 4.80 |
| 8 | 4.28 |
| 9 | 3.70 |
| 10 | 3.55 |
| 11 | 3.35 |
| 12 | 2.97 |
| 13 | 2.20 |
| 14 | 1.50 |
| 15 | .90 |
| 16 | .30 |
| 17 | 0 |
| 18 | 0 |
| 19 | 0 |
| 20 | 0 |
| 21 | 0 |

BUYERS' PURCHASING RULE (continued)



| | PERIOD | Example | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
|-------------------------------|---|---------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Trading Profits | 1) Price posted | | | | | | | | | | | | | | | | | | | |
| | 2) # of units sold | | | | | | | | | | | | | | | | | | | |
| | 3) Total sales revenue (1 × 2) | | | | | | | | | | | | | | | | | | | |
| | 4) Total cost of units sold | | | | | | | | | | | | | | | | | | | |
| | 5) Trading profits (3 - 4) | | | | | | | | | | | | | | | | | | | |
| Bonus Profits | 6) Last period's bonus | | | | | | | | | | | | | | | | | | | |
| | 7) Previous period's bonus | | | | | | | | | | | | | | | | | | | |
| | 8) This period's price (line 1) | | | | | | | | | | | | | | | | | | | |
| | 9) $P_t - p_{t-1}$ (line 7 - line 8) | | | | | | | | | | | | | | | | | | | |
| | 10) # of units sold in previous period | | | | | | | | | | | | | | | | | | | |
| | 11) Increase in bonus (9 × 10) | | | | | | | | | | | | | | | | | | | |
| | 12) This period's bonus (6 + 11) | | | | | | | | | | | | | | | | | | | |
| 13) Total Profits (5 + 12) | | | | | | | | | | | | | | | | | | | | |