Economics in the Laboratory

Vernon L. Smith*

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1 Introduction

Why do economists conduct experiments? To answer that question, it is first necessary briefly to specify the ingredients of an experiment. Every laboratory experiment is defined by an *environment*, specifying the initial endowments, preferences and costs that motivate exchange. This environment is controlled using monetary rewards to induce the desired specific value/cost configuration (Smith, 1991, 6).[1] An experiment also uses an *institution* defining the language (messages) of market communication (bids, offers, acceptances), the rules that govern the exchange of information, and the rules under which messages become binding contracts. This institution is defined by the experimental instructions which describe the messages and procedures of the market, which are most often computer controlled. Finally, there is the observed *behavior* of the participants in the experiments as a function of the environment and institution that constitute the controlled variables.

Using this framework of environment, institution, and behavior, I can think of at least seven prominent reasons in the literature as to why economists conduct experiments. Undoubtedly, there are more (Davis and Holt, 1992, chapter 1 and passim).

1.1 Test a theory, or discriminate between theories

This motivation comes from the economic and game theory literature. We test a theory by comparing its message or its outcome implications with

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[1]Where appropriate, references to work by me and my coauthors will be to the paper numbers in Smith (1991).

the experimental observations. The greater the frequency with which the observations hit these "predictions," in the context of a design in which hits are unlikely to occur by chance, the better the theory.[2] Examples can be found in the auction literature (Smith, 1991, 25-29), where risk averse models of bidding in Dutch and first price sealed bid auctions are favored by the data over risk neutral models, while dominate strategy auctions such as the English, whose outcomes are predicted to be independent of risk attitude, perform well in the laboratory. Of course, theories subjected to sufficiently rigorous tests are nearly always found to need improvement; this leads to the second reason for doing experiments.

1.2 Explore the causes of a theory's failure

When the observations of an experiment fail to conform to the implications of the theory, the first thing to be done is to reexamine the design, and to be sure that the predictive failure is the fault of the theory. Well-articulated theories formally model the environment and the trading rules, and the experimentalist seeks to reproduce these conditions of the theory. In the course of testing when the experimental design continues to seem appropriate and the theory still fails, this tends to encourage an experimental examination designed to discover the cause. Establishing the anatomy of failure is essential to any research program concerned with modifying the theory. Examples are to be found in the bargaining literature (Roth, 1987; Hoffman and Spitzer, 1985; Hoffman *et al.*, 1992; Bolton, 1991) and in common value auctions (Kagel and Levin, 1986; Cox and Smith, 1992). Often theories that initially perform poorly show improvement if subjects are given more experience (Cox and Smith, 1992), or the payoffs are increased (Smith and Walker, 1993), but sometimes these measures fail to yield results that improve the theory's performance (Smith and Walker, 1993).

1.3 Establish empirical regularities as a basis for new theory.

Well-formulated theories in most sciences tend to be preceded by much observation, which in turn stimulates curiosity as to what accounts for the documented regularities. Microeconomic theory tends to build upon simplifying assumptions, and to eschew attempts to model many of the complex trading and contracting institutions that we observe. But in the laboratory,

[2] Selten (1989) offers a measure of predictive success. I use the terms "prediction" and "implication" of a theoretical model interchangeably. Consistency with a "prediction" does not require that the theory be done in advance of an observation.

especially with computerization, institutions with complex trading rules are as easy to study as are simple single unit auctions. This makes it possible to range beyond the confines of current theory to establish empirical regularities which can enable theorists to see in advance what are the difficult problems on which it is worth their while to work. The continuous double auction, used the world over, is a fine example. In this institution buyers announce bid prices, sellers announce offers, or asking prices. Any new bid (offer) must be at a price which is lower (higher) than the standing bid (offer); i.e. the bid-asked spread must narrow. A binding contract occurs when a buyer accepts a seller's ask, or a seller accepts a buyer's bid. Contracts occur in sequence as new bids, asks and acceptances occur. Because of its robust equilibrating properties with small numbers of traders possessing only private information this institution (Smith, 1991, 1, 2, 6) was studied extensively in the laboratory long before the attempts by R. Wilson, D. Friedman and others to model it (see Friedman and Rust, 1992, for references).

1.4 Compare environments

Comparing environments using the same institution permits an investigation of the robustness of that institution. The objective is to stress the theory with extreme environmental conditions under which an institution's established properties may begin to break down. Thus, in common value auctions (where the item has the same value to all bidders after the auction is completed), the Nash Model performs better when there are 3-4 bidders than when there are 6-7 bidders (Kagel and Levin, 1986). Similarly, the Nash equilibrium prediction performs fairly well in the Fouraker and Siegel (1963) bargaining environment, but breaks down in the ultimatum game environment (Hoffman *et al.*, 1992), as discussed below.

1.5 Compare institutions

Using identical environments, but varying the market rules of exchange, has been the means by which the comparative properties of institutions has been established. Examples include the comparison of English, Dutch, first and second price sealed bid auctions, the comparison of uniform and discriminative price multiple unit auctions, and the comparison of posted (retail) pricing with double auction trading (Smith, 1991, 25, 5, 17).

1.6 Evaluate policy proposals

Friedman's (1960) original proposal that the Treasury auction securities in one-price auctions led to their comparison with the discriminative rules (Smith, 1991, 5). Bids to buy in this auction are arranged from highest to lowest; if the offering was $2 billion worth of bills, this amount of the highest bids are accepted at a price given by the highest rejected bid. In the past decade, private industry and government sponsors have funded studies of the incentives for off-floor trading in continuous double auction markets, alternative institutions for auctioning emissions permits, mechanisms for allocating space shuttle resources, and market mechanisms for the allocation of airport slots (Plott, 1987).

1.7 The laboratory as a testing ground for institutional design

A growing use of the laboratory is as a testing ground for examining the performance properties of new forms of exchange. The early experiments studying the one-price sealed bid-offer auction for Treasury securities helped Henry Wallich to motivate the Treasury in the early 1970s to offer some long term bond issues using this procedure (Smith, 1991, pp. 511-512). This led eventually to the use of the procedure in auctioning commercial paper and in setting the dividend rate on variable rate preferred corporate securities. In 1992, Treasury resumed its earlier experiments with the one-price auction because of publicized irregularities in dealer bidding.

A second example is the new Arizona Stock Exchange (AZX). In 1988 we started running our first experiments with the uniform price double auction. In this mechanism, buyers submit bids to buy, and sellers submit offers to sell in real time during the specified market "call" period. All bids, offers, and the tentative market clearing uniform price, are displayed as they are entered, so participants can see the existing state of the market, and alter their own bids or offers accordingly. It turns out that this approach has efficiencies comparable to those of continuous double auction, but with no price discrimination. Subsequently we learned that Steven Wunsch independently developed a similar system, and was seeking SEC authority to operate it as a proprietary stock exchange for institutions. Wunsch Auction Systems opened in New York in 1991. About this time officials of the Arizona Corporation Commission, who had heard of our experimental studies of "electronic exchange," approached us with the idea of starting an Arizona Stock Exchange. We demonstrated the uniform price double auction for them, pointed out its properties, and they were eager to get moving. Our first action was to get them together with Wunsch to explore the possibility of moving his exchange to Arizona. Eventually, Wunsch adopted the new name, AZX, and the new exchange has experienced accelerated growth since its move in March 1992. Had it not been for the experiments we would not have come to understand the comparative properties of the uniform price double auction, and been able to recommend it wholeheartedly as a reasonable direction for a new electronic exchange.

2 What Have Economists Learned from Experiments?

Hoffman's (1991) "Bibliography of Experimental Economics" contains 1500 entries. I can only attempt to report a small selection of some of the findings.

2.1 Institutions Matter

Experimentalists have long known that the continuous double auction rules of trade in securities markets constitutes a mechanism remarkably adept at maximizing the gains from exchange at prices tending to converge to competitive equilibria (Smith, 1991, 1). What we have learned since is that this is just one of many illustrations of the principle that institutions matter. This is because the rules determine the information states and individual incentives in the trading game: institutions matter because incentives and information matter. Consequently, posted offer retail pricing converges more slowly and erratically and is less efficient than continuous double auction (Plott and Smith, 1978). Unlike the latter, sellers receive no continuous bid price information from competing buyers. Also, sellers must quote one price per period for all units making price cuts more costly.

Does this mean that posted offers are inferior to continuous double auction? No. The experiments evaluate only the allocative properties of the two mechanisms, and do not address their different transactions cost properties. With continuous double auction, every trade involves decentralized multilateral negotiation, while pricing is centralized in a posted offer system, and clerks need have no bargaining skills. The latter is cost effective for mass retail distribution, the former has been well-suited to the broker-dealer structure of securities markets.

As early as 1965 (Smith, 1991, 4), an extreme environment was used as a stresstest to explore the limits of the ability of the continuous double auction to generate competitive equilibria. This was the 'swastika' environment in which the demand price is constant up to a maximum quantity, and the supply price (below demand price) is also constant up to a maximum quantity greater than the maximum demand quantity. If you draw these demand and supply curves you see what looks like a swastika emblem. Such markets still performed efficiently, but convergence to the competitive equilibrium was slow and erratic when the excess supply was very small. Van Boening and Wilcox (1992) have recently reported a much more successful stress-test of continuous double auction. They report experiments in which the sellers' only costs are fixed costs that can be avoided by selling zero units, and the demand price is constant up to a fixed capacity. This lumpy environment is structured so that there is no uniform price competitive equilibrium like that to which continuous double auction usually converges; yet efficient allocations exist. The important result is that continuous double auction cannot handle this environment, and research is under way for new or traditional mechanisms that can handle such cases. The issue is of practical importance. airlines, for example, have large flight costs that can only be avoided by not flying.

One of the better-known predictive failures of expected utility theory is the "preference reversal" phenomenon. A subject reports that gamble A is preferred to B, but in responding with her selling price places a higher price on B (say \$10) than on A (\$7) (Lichtenstein and Slovic, 1971). But Chu and Chu (1990) report that such reversals are much reduced on the second iteration of a process in which the experimenter arbitrages the inconsistency, and the reversals disappear on the third iteration establishing that subjects are not satisfied with their own choices when they experience the implications of those choices. More subtle experiments have been reported by Cox and Grether (1992), in which each subject's selling price is elicited in an English Clock auction which is known to have good demand revelation properties. In this auction a clock is set at a low price; all buyers respond with their demands. The clock then ticks up to successively higher prices, and buyers respond by reducing their demand until there is but one unit demanded. After five repetitions, subjects' selling prices were in general consistent with their choices. Consequently, this provides another example of the tendency for rational behavior to emerge in the context of a repetitive market institution. But in this case, the market corrects the inconsistency of behavior found in choice elicitation experiments.

2.2 Unconscious Optimization in Market Interactions

In his early path-breaking critique of the feasibility of rational calculation in human choice, Simon (1955, p. 104) explicitly did not "rule out the possibility that the unconscious is a better decision-maker than the conscious." Unknown to both of us at the time was the fact that the first of hundreds of continuous double auction experiments reported in Smith (1991, 1, Chart 1) would spotlight the crucial importance of not ruling out the rationality of unconscious decision in rule-governed repeat interaction settings. Consider the typical conditions of a continuous double auction experiment. Subjects have private information on their own willingness-to-pay or willingness-to-accept schedules which bound the prices at which each can profitably trade. No subject has information on market supply and demand. After an experiment, upon interrogation they deny that they could have maximized their monetary earnings or that their trading results could be predicted by a theory. Yet despite these conditions, the subjects tend to converge quickly over time to the competitive equilibrium. Thus "the most common responses to the market question were: unorganized. unstable, chaotic, and confused. Students were both surprised and amazed at the conclusion of the experiment when the entrusted student opened a sealed envelope containing the correctly predicted equilibrium price and quantity" (Gillette and DelMas, 1992, p. 5).

That economic agents can achieve efficient outcomes which are not part of their intention was the key principle articulated by Adam Smith, but few outside of the Austrian and Chicago traditions believed it, circa 1956. Certainly I was not primed to believe it, having been raised by a socialist mother, and further handicapped (in this regard) by a Harvard education, but my experimental subjects revealed to me the error in my thinking.

In many experimental markets, poorly informed, error-prone, and uncomprehending human agents interact through the trading rules to produce social algorithms which demonstrably approximate the wealth maximizing outcomes traditionally thought to require complete information and cognitively rational actors[3].

[3]That this description applies to markets in the field has been demonstrated by Forsythe *et al.*(1992), who report the remarkable forecasting accuracy of their presidential stock market, which beats the opinion polls by a wide margin.

2.3 Information: Less Can Be Better

Providing subjects with complete information, far from improving market competition, tends to make it worse. In 1976, I reported continuous double auction results, using the "swastika" environment described above, comparing the effect of private with complete information (Smith, 1991, 6). Under private information, convergence to the equilibrium outcome (in this case, the Nash-competitive outcome) was much more rapid and dependable then under complete and common information[4]. Similar results had been reported earlier by Fouraker and Siegel (1963) for Bertrand and Cournot oligopoly, and more recently by Noussair and Porter (1992) and Brown-Kruse (1992). When people have complete information they can identify more self-interested outcomes than Nash (and competitive) equilibria, and use punishing strategies in an attempt to achieve them, which delays reaching equilibrium.

Of course, it can be said that all of this simply supports the "folk theorem" that repetition aids cooperation. But the folk theorem operates in situations with small numbers and complete information — like the fact that a repeated prisoners' dilemma game tends to converge to cooperation. The argument here is much stronger: competitive tendencies prevail under the private information conditions that pervade markets in the economy.

The principle that private payoff information can yield "better" results has also been established in the Nash bargaining game (Roth, 1987). Nash assumed that the bargainers knew each other's utilities (preferences). Roth and his coworkers implemented this theory with ingenious simplicity: subjects bargained over the division of 100 lottery tickets, each representing a chance to win fixed large or small prizes for each of the two players, with the prizes generally being different for the two players. When the two players know only their own prizes (and each other's percentage of the lottery tickets), the outcome conforms to the Nash bargaining solution. When the bargainers also know each other's prizes the Nash prediction fails; in short, Nash theory is not falsified, it is just not robust with respect to the bargainers knowing both prizes.

The principle that less information can be advantageous also applies under asymmetric payoff information in which Schelling (1957) argued that the less informed bargainer may have an advantage over a completely informed adversary. In fact Siegel and Fouraker (1960) observed this to be the case. The better informed bargainer, knowing that the other player knew only

[4]Kachelmeier and Shehata (1992) report that these results also hold in cross-cultural comparisons of subjects from China, the United States and Canada.

his own payoff, is more forgiving when his opponent makes large demands. This concessionary posture works to the disadvantage of the completely informed player. Camerer, Loewenstein and Weber (1989) call this the "curse of knowledge" and report new evidence in a market setting.

2.4 Common Information is Not Sufficient to Yield Common Expectations or "Knowledge"

It has been argued that game theory requires common knowledge. [5] This arbitrarily limits the value of game theory in organizing experimental data, and directs our attention away from the fact that common knowledge is a condition the process of achieving which we must understand if game theory is to make progress in predicting behavior. This is implicitly recognized by the growing current interest among game theorists in concepts of bounded rationality and of learning. Although I believe these are conceptually the right directions to take, if the exercises are guided by introspective model development, uniformed by observations and testing, they are unlikely to achieve their full predictive potential.

Experimentalists have attempted to implement the condition of "common knowledge" by publicly announcing instructions, payoffs, and other conditions in an experiment. Some examples of this process would be Roth (1987) in Nash bargaining games, Smith, Suchanek and Williams (Smith, 1991, 19) in finite horizon asset trading experiments, and McCabe (1989) in finite horizon fiat money experiments, but there are many others. However, it should be noted that administering common instructions in public literally achieves common information — not common knowledge in the sense of expectations. In other words, there is no assurance that a public announcement will yield common expectations among the players, since each person may still be uncertain about how others will use the information.

[5] Aumann (1987, p. 473) has emphasized in unmistakable terms this requirement of game theory: "It is not enough that each player be fully aware of the rules of the game and the utility functions of the players. Each player must also be aware of this fact ... There is evidence that game theorists had been vaguely cognizant of the need for some such requirement ever since the last fifties or early sixties; but the first to give a clear sharp formulation was the philosopher D. K. Lewis (in 1969). Lewis defined an event as common knowledge among a set of agents if all know it, all know that all know it, and so on ad infinitum. The common knowledge assumption underlies all of game theory and much of economic theory. Whatever be the model under discussion, whether complete or incomplete information, consistent or inconsistent, repeated or one-shot, cooperative or noncooperative, the model itself must be assumed common knowledge; otherwise the model is insufficiently specified, and the analysis incoherent."

In laboratory stock markets each player receives an initial endowment in cash and shares of stock. It is public information that the expected dividend in a given time period will be some fixed number for each of the T periods of the game. With zero interest rate the value of a share of stock in the first time period should be T times the expected dividend. In each time period, the rational expectations hypothesis is that share prices will be equal to the remaining dividends to be paid, and will decline by an amount equal to the expected dividend in each time period.

In fact, first time participants in experiments of this sort — whether they are undergraduates, graduates, business persons, or stock traders — produce bell-shaped price bubbles starting below fundamental value, rising well above and crashing to near fundamental value in the last few periods. Trading volume is high. When subjects return for a second session, the price bubbles are dampened, and volume is reduced. When they return for a third session, trading tends to follow the decline in fundamental value, with very thin volume. These experiments illustrate that participants come to have common expectations by experience, not by being given common information and then reasoning that others will expect prices to be near fundamental value[6].

Unless players have common expectations of behavior in later periods, they cannot reason backwards to the present. This problem, for theories based on backward induction rationality, is illustrated by the wage search experiments of Cox and Oaxaca (1989). In their experiments subjects search a distribution of wages, and must decide in each period whether to accept a certain wage offer; if accepted the subject must forego continued search and the possibility of receiving a better subsequent offer. In this situation, subjects have only to anticipate their own behavior in later periods in order to properly backward induct. Subjects in these experiments behave as if they are solving the backward induction problem properly. Hence, it would appear that when common expectations exist (because the subject "knows" his or her own expectations) then subjects will backward induct. Of course, this does not mean that subjects are conscious of having solved such a

[6]Of relevance here is the "getting to common knowledge" theorem discussed in this journal by Geanakoplos (1992). The theorem is driven by a process in which all agents observe in turn each agent's action. At some finite time, t*, all agents have common knowledge of what each agent will do in the future. The asset experiments confirm the predictions of the theorem. But this does not imply that the subjects in the experiments go through a reasoning process like that which is used to prove the theorem.. In fact, subjects would have great difficulty articulating the means whereby they reached their unwillingness to trade away from fundamental value.

problem, and can tell you about it.

In this journal, Brandenberger (1992) has usefully emphasized that the assumption of common knowledge is sometimes unduly strong; examples are given in which if each of two players are rational and they have mutual knowledge (both know it, but not necessarily that both know that both know it), then a Nash equilibrium follows. These distinctions between various degrees of knowledge are certainly helpful, but if game theory is to have *predictive* value, it is necessary to go further and seek to discover *operationally* how to achieve the required conditions of knowledge. Theories based upon abstract conditions make no predictions. Subjects obtain knowledge of the strategy choices of others, by experience. This is why I see no way for game theory to advance independently of experimental (or other) observations. We have to understand the processes whereby the required conditions of knowledge are satisfied — processes like pregame play, repeated play, cheap talk, or the futures market example discussed in a moment — before the implications of those conditions can become testable hypotheses.

It has been observed that if the failure of rational expectations in finite horizon trading experiments was due to the lack of common expectations about later periods, then introducing futures markets should hasten convergence to rational expectations equilibria by speeding up the process of creating common expectations of later period behavior (Porter and Smith, 1989). Forsythe, Palfrey and Plott (1982) had reported that convergence in two-period horizon experiments was hastened by introducing a futures market on period two. If our interpretation was correct, then a futures market on period 8 in 15-period asset trading experiments would aid in creating common expectation at midhorizon (subjects already expect trading at fundamental value near the end), and price bubbles should be retarded in the presence of such a futures market. Porter and Smith (1989) report experiments supporting this hypothesis. The learning suggested by these studies is that the important role of futures markets may be to foster common expectations among traders concerning a future event. This permits the backward induction calculus to yield the appropriate rational expectations in the current period.

2.5 Dominated Strategies Are for Playing, Not Eliminating

It is commonly argued that dominated strategies should never rationally be played, and thus can be eliminated in game-theoretic analysis. But players in repeated games do sometimes play dominated strategies and there are sound reasons why.

Consider the two person alternating play game tree in Figure 1, which is played repeatedly for a long time with uncertain termination (McCabe, Rassenti and Smith, 1992). If player 1 moves down at x1 then at x2 player 2 can signal a desire to achieve the cooperative outcome (50:50) by moving left, or, by moving right, signal a desire to achieve the subgame noncooperative outcome (40:40). But if player 2 chooses left at x2, player 1 can defect by moving down at x3, forcing player 2 at node x5 to choose between (60:30) and the direct punishment outcomes that result at node x7. Game theory reasons that player 2 should play left at node x5, accepting player 1's defection, but punish on the next round of repeated play by choosing right at node x2 (choosing right at x2 almost without exception ends at the equilibrium (40:40)). Subject player 2's tend not to do this, but instead to play down at x5, and thereby to punish immediately. The reason is clear, the resulting message is unambiguous, with no possibility that player 1's will misunderstand. The strategy works: even when 12 subjects are randomly repaired after each play, there is a strong tendency toward the cooperative outcome by round 15-20. (If the game is altered by interchanging the (50:50) and (60:30) payoff boxes, thereby removing player 2's ability to punish immediately, then cooperation fails to emerge). This is not the game-theoretic route to repeated-play cooperation because the bargainers are assumed to have common expectations (knowledge). But, as we have seen, common expectations is achieved by a process of play, not by deductive analysis. Part of this process may be to punish in ways that will be clearly understood.

Figure 1 A Two-Person Alternating-Play Game
Insert figure

2.6 Efficiency and Underrevelation Are Compatible

It is well-known that a market participant, whether a buyer or seller, can sometimes tilt the conditions of the transaction toward personal gain and away from market efficiency, by not revealing true willingness to trade. Consequently, economists often seem to argue as if market efficiency must rely on complete revelation of preferences.

As an empirical counterexample, consider the version of the uniform price double auction mechanism studied in McCabe, Rassenti and Smith (1992). Remember that in this auction format, subjects submit openly displayed bids during a market call period. In this format, subjects greatly underreveal demand and supply, but they adjust their bids and offers so that the market clearing price and quantity approximates a competitive equilibrium. At this equilibrium they produce many bids and offers tied at the same price. This behavior serves to protect each side of the market against manipulation by the other side. That is, if a buyer attempts to lower the market price by bidding lower, that buyer's bid is replaced by another tied bid without moving the price, and similarly if a seller attempts to raise the price.

In short, efficiency only requires enough revelation to allow the marginal units on both sides of the market to trade. This can occur although there is massive underrevelation of the inframarginal units. In uniform price experiments, one frequently observes that subjects capture 100 percent of the surplus while revealing only 10-15 percent of it in their bids.

2.7 The Endowment Effect

Thaler (1980) has argued that the observed tendency in survey studies for willingness-to-accept to exceed willingness-to-pay by nontrivial amounts is due to an "endowment" (or ownership) effect which arises because of loss aversion; an example is the man who paid $5 per bottle for a case of wine. A few years later he is offered $100 per bottle, and refuses, although he has never paid more than $35 for a bottle of wine. In this case giving up the wine yields a loss which is more highly weighted than the gain from purchasing an equivalent bottle. The existence of an endowment effect has been suggested by numerous hypothetical survey studies; recently, the experimental focus has been to verify its existence with real goods.

It has been argued by Kahneman, Knetsch and Thaler (1990) that the endowment effect does not apply to goods held for resale; only to goods which are consumed. Similarly, it does not apply to the exchange of rights (or tokens) on which value has been induced by cash payments in experiments. In either case, since what is being acquired is intended from the start to be resold, losses and opportunity costs are transparently equivalent. Kahneman, Knetsch and Thaler (1990) report both choice and exchange experiments confirming the results with tokens, but establishing the willingness-toaccept/willingness-to-pay discrepancy for consumer goods (like emblem mugs, pens, and so on). They also reject empirically the important qualification that the discrepancy is due to income effects (see their experiments 6 and 7). Franciosi, Kujal, Michelitsch and Smith (1993) have reported experiments that narrow the reported willingness-toaccept/willingness-to-pay discrepancy by using a more uniform choice task, and by using the uniform price double auction (with its good revelation properties for marginal units) to establish price. While these results reduce the discrepancy, the endowment effect remains statistically (and economically) significant.

Samuelson and Zeckhauser (1988) suggest that the endowment effect may be a manifestation of a broader "status quo bias;" they provide results showing the existence of such a bias even when the problem is not framed in terms of gains and losses. Models of utility-maximizing when decision costs are taken into account postulate a trade-off between the sum of all the various costs of decision making and the value of the decision outcome (Smith and Walker, 1993). Such models predict a bias in favor of one's current status, since any change is cognitively and information costly.

2.8 Fairness: Taste or Expectation?

According to survey studies reported by Kahneman, Knetsch and Thaler (1986), people indicate that it is unfair for firms to raise prices and increase profits in response to certain changes in the environment which are not justified by an increase in costs. Thus, respondents report that it is 'unfair' for firms to raise the price of snow-shovels after a snowstorm, or to raise the price of plywood following a hurricane. In these circumstances, economic theory predicts shortages, an increase in prices toward the new market clearing levels, and, eventually an increase in output. Unfortunately, economic theory does not predict the verbal behavior of agents in this process so that such expressions do not falsify the theory.

Do expressions of unfairness reflect interpersonal utilities that reduce effective demand for the product of offending parties, or do they vent the unpleasant need for expectations to be adjusted? If such results show no more than a lag as aggrieved parties adjust their expectations to the new reality, the standard models will predict the eventual result, as the indignation subsides. But protesting parties may react strategically in their self-interest by withholding demand and punishing price "gougers," or, fearing this, sellers may moderate or forgo their increase in prices. Alternatively, by way of contemporary contract theory, one side or the other may see the reference price and transactions as an implicit contract, not to be lightly tampered with. If an economic agent can extract resources by claiming unfair treatment, then it is consistent with standard theory for the agent to manufacture words to that effect. In such situations, it isn't clear that standard self-interested utility-maximizing models can account fully for the observed market behavior.

Kahneman, Knetsch and Thaler (1986) do not predict the final outcome in these cases; a departure from the reference transaction, initially seen as unfair, may eventually achieve the status of a new reference transaction. This argument is a form of the standard adaptive expectations hypothesis, and has been tested in an experimental market environment (Kachelmeier *et al.*, 1991; Deng *et al.*, 1992). In an initial baseline series of trading periods with a 50 percent profits tax on sellers, the after-tax profit of sellers is identical with the consumer's surplus of buyers, and the division of surplus is "fair." Then the reference baseline is altered by substituting a 20 percent sales tax for the 50 percent profit tax on sellers. The effect of the sales tax is to raise the market clearing price, and substantially increase seller after-tax profit relative to buyer profit in comparison with the reference situation. Across experiments, the subjects are divided into three different treatment groups: (1) marginal cost disclosure, in which buyers are informed of the price implications of the sales tax; (2) no disclosure, in which buyers are given no new information; (3) profit disclosure, in which buyers receive a graph showing for each price what the potential split of total surplus is between buyers and sellers.

Deng *et al.* (1992) choose a particular institutional context in which sellers independently post selling prices at the beginning of each period. Buyers, queued at random, choose to make their purchases one at a time. The Kahneman, Knetsch, Thaler argument implies that in the first period, prices will be highest under marginal cost disclosure, where buyers are informed of the price implications of the sales tax, because the disclosure serves to justify price increases and to reduce any resistance to them. Revealing profits, on the other hand, will lead to the lowest prices in the first period, because the change from the reference (baseline) transactions is greatest, and will lead to substantial resistance. The no-information group should, according to the hypothesis, fall between these extremes.

The results strongly and significantly support the Kahneman, Knetsch and Thaler hypothesis. In period one, the price in the marginal cost disclosure group was very near the new competitive equilibrium, with prices much the lowest in the profit disclosure group. But in successive trading periods, the mean prices in the profit disclosure and no disclosure groups increase, and by period 10 none of the three means are statistically different from each other or the competitive price. These results offer strong confirmation of standard theory, as the sellers in the profit disclosure treatment raise prices over time in response to the excess demand. Furthermore, as sellers raise prices they are not deterred by any significant incidence of demand withholding by buyers.

Fairness questions also arise in the ultimatum game where a sum of money, say $10 is to be allocated between two people. Player 1 moves first offering some amount, X, of the $10 to player 2. If player 2 accepts that amount, then player 1 receives the rest; if player 2 rejects that amount, both players receive zero. Game theory predicts that player 1 will offer the smallest possible amount to player 2; player 2 will accept it as better than nothing; and player 1 will take the lion's share. However, in the experimental context when players are anonymously paired, and play only once, the modal offer by player 2 is $5, with a lower median.

These observations have been interpreted as showing that the players have a taste for fairness (see Bolton, 1991, and his references). In particular player 2 is concerned about being treated fairly by player 1, and the latter must take this into account lest her offer be rejected. But this interpretation has been called into question by the results of the "dictator game" in which player 2 must accept the offer of player 1. Forsythe *et al.* (1988) find significantly lower offers in the dictator game than in the ultimatum game. Hoffman *et al.* (1992) corroborate these results and report dramatically lower offers (two-thirds offer zero) when the dictator game is run double blind: the experimenter does not know the decisions or payoffs of any subject. To put it another way, the dictator results are highly sensitive to the degree of anonymity from other persons. This suggests that the ultimatum game results are due primarily to strategic and expectational considerations, and not just to a taste for fair outcomes. The same considerations apply to the above market experiments.

2.9 Methodology and Experiment

The fact that the planet Mercury exhibited an orbit that violated Newton's theory did not lead Newtonians to conclude that the theory was falsified; rather, they concluded that there must exist a heretofore unknown planet between the sun and Mercury that perturbed its orbit from the predicted path (they even named it Vulcan, and there was no subsequent shortage of claimed sightings) (Roseveare, 1982). *All* tests of a theory require various auxiliary hypotheses that are necessary in order to interpret the observations as a test of the theory. These auxiliary hypotheses go under various names: initial conditions, *ceteris paribus* clauses, background information, and so on. Consequently, all tests of a theory are actually joint tests — that is, a test of the theory conditional on the auxiliary hypotheses. This leads to the Duhem-Quine theses, according to which one can always rescue a theory from an anomalous observation by *ex post hoc* recourse to imaginative and persuasive auxiliary hypotheses. Conversely, every observational victory for a theory can be questioned by a suitable revision of the background knowledge in which the theory is embedded. This thesis denies the possibility of direct falsification of any specific testable implication of a theory (and, in its strong form, denies rational rules of selection).

My view is that some philosophers have exaggerated the significance of the Duhem-Quine problem, while experimentalists may be unaware of its power in influencing their day-to-day activities. Experimental economists are intuitively if not formally aware of the problem; this is why they do so many experiments probing the sources of a theory's failure, or success, as in the ultimatum game and other examples discussed above. If you have a confounding problem with auxiliary hypotheses, then you do new experiments to test them. If the auxiliary hypotheses are not testable, this is preeminently your critic's problem.

A recent exchange among experimentalists in the December 1992 *American Economic Review* is squarely reflective of the Duhem-Quine problem. Harrison (1992) has questioned all falsifying observations in experimental economics as due to a postulated low opportunity cost of deviating from theoretical optimality. This thesis sets the stage for the convenient nihilist belief that all recalcitrant observations must be due to inadequate payoff opportunity cost. (Of course, this argument raises the unanswered question of why there exists validating results with low opportunity cost). But, like most important instances of Duhem-Quine, the proposition can be and has been tested — in this case many times over the last 30-odd years (Smith and Walker, 1993, offer a review).[7] The results have made it plain that money does matter; that factors besides money also matter; that many anomalies do not disappear by escalating payoffs (and foregone profits); and that inadequate attention has been given to modelling the possible relationship between the performance of a theory and the (monetary and nonmonetary) motivation of decision makers.[8]

[7] At the other pole from Harrison stand some psychologists who downplay the evidence that monetary payoffs can have a significant affect on outcomes. To wit: "We agree with Smith and Walker (1993) that monetary incentives could improve performance under certain conditions by eliminating careless errors" (Tversky and Kahneman, 1992, p. 316). The reader will not find any statement like this in the cited reference to agree with. The "errors" we discuss are not careless; they are deviations from optimality attributed to decision costs. If subjects care less about getting it right when there are zero or low rewards, and decision is costly, this is because it is in their interest to care less. We canvass 31 studies in which increasing rewards relative to baseline either reduces the deviations of the data around the theory's prediction, or moves the ventral tendency of the data closer to this prediction.

[8] Of course, one can always offer the incredible argument that any recalcitrant case would go away if you just made payoff opportunity cost large enough. But this argument simply shows the limitations of a theory that postulates motivated agents, but is devoid of all detail as to that motivation. "Auxiliary" hypotheses in experimental economics that have to do with key issues involving the state of the agent like motivation and experience

But other Duhem-Quine issues regularly arise. Both when the results are favorable and when they are unfavorable to a theory, experimental economists have asked if the observations were affected by increased subject experience. Thus, Alger (1986) reports oligopoly results in which early convergence to Nash behavior does not persist when much longer experiments are run. But Alger (1986) used simulated buyers, and it has been shown that mean prices are uniformly lower in oligopoly competition when real buyers are used (Brown-Kruse, 1991). These and a host of similar Duhem-Quine issues are subject to empirical examination and are part of the day-to-day operating life of experimentalists.

The "replication" problem is also related to Duhem-Quine. It is often claimed that there is inadequate replication in economics. The common complaint is that because replications are inadequately "original," editors are reluctant to publish them, and researchers are not well-motivated to conduct them. Experimental economists should perform replications, and often do so, as part of the process of reporting new experiments, so that the results can be compared with replications of previous studies. Of course, few such replications are completely pure: seldom does a researcher attempt to replicate exactly all the instructions, procedures, subject type, and other conditions used in a previous study. I would argue that such attempts at pure replication are in order only when the *results* of a previous study fail to replicate, and it is desirable to investigate why. If I do an experiment similar to yours as a baseline control for comparison with a related experiment I intend to perform, I am testing the robustness of your original results using my instructions, my subjects and a different experimenter. In effect, I am varying some of the more routine auxiliary hypotheses, and asking if the results are nonetheless indistinguishable. As a practical matter they most often are. When they are, then my experiment provides *more* support for the original theory than if the *same* (your) experiment was simply repeated. Franklin (1990, p. 107–8) makes this point by noting that if you want to know the correct time, it is more informative to compare your watch with another's than for either of you to look at your own watch twice. Intuitively, experimentalists and editors apply this principle in rejecting routine "pure replication" as not sufficiently original.

Experimentalists and other economists often use the rhetoric of "falsifying" theories, but it is clear from the totality of our professional conduct that falsification is just a means to a different end: the modification of theory in

(learning), must ultimately be incorporated into the theory, not banished to the realm of auxiliary hypotheses for the experimentalists to worry about.

the light of evidence. To pursue this end, we need to know not only the conditions under which extant theory is falsified, but also the conditions under which it is verified. It is naive to suppose that any experiment will deliver the death blow to some theory. Theory always swims in the rough water of anomaly. You don't abandon a theory because of a (or many) falsifying observation(s). When Newton published the *Principia*, it was well-known that he could not even account for the orbit of the moon. Einstein's famous paper "On the Electrodynamics of Moving Bodies" (*Annalen der Physik*, 17, 1905) was "refuted" within a year by Kaufman (in the same journal) whose β-ray experiments showed that the deviations from the predictions of the theory were considerably beyond the limits of error that could be attributed to his equipment. Einstein agreed, but rationalized: "Only after a diverse body of observations becomes available will it be possible to decide with confidence whether systematic deviations are due to a *not yet recognized* source of errors or to the circumstance that the foundations of the theory of relativity do not correspond to the facts" (Einstein, 1907, p. 283, italics are mine). As it turned out, Kaufman's apparatus was later found to be faulty.

If you look at what experimental economists do, not what they say, you get the right picture of science learning. When a theory works well, they push imaginatively to find deliberately destructive experiments that will uncover its edges of validity, setting the stage for better theory and a better understanding of the phenomena. When a theory works poorly, they reexamine instructions for lack of clarity, increase the experience level of subjects, try increased payoffs, and explore sources of "error" in an attempt to find the limits of the falsifying conditions; again, this is for the purpose of better understanding the anatomy of a theory's failure, or the procedures for testing it, and thereby laying the basis for improving the theory. Ultimately, the procedures under which a theory is tested should be part of the theory. [9] But this step requires theorists' models to reflect a close understanding of the circumstances that produced the observations.

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[9] This is recognized by Bicchieri (1988), Brandenberger (1992), Geanokoplos (1992) and others when they model common knowledge as part of the theory of backward induction games. It is common for "background assumption" eventually to be made part of the theory.

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