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STRATEGIC UNCERTAINTY, EQUILIBRIUM SELECTION, AND COORDINATION FAILURE IN AVERAGE OPINION GAMES*

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Deductive equilibrium analysis often fails to provide a unique equilibrium solution in many situations of strategic interdependence. Consequently, a theory of equilibrium selection would be a useful complement to the theory of equilibrium points. A salient equilibrium selection principle would allow decision makers to implement a mutual best response outcome. This paper uses the experimental method to examine the salience of payoff-dominance, security, and historical precedents in related average opinion games. The systematic and, hence, predictable behavior observed in the experiments suggests that it should be possible to construct an accurate theory of equilibrium selection.

Deductive equilibrium methods are powerful tools for analyzing economies that exhibit strategic interdependence. Typically, equilibrium analysis does not explain the process by which decision makers acquire equilibrium beliefs. The presumption is that actual economies have achieved a steady state. In economies with stable and unique equilibrium points, the influence of inconsistent beliefs would disappear over time, see Lucas [1987]. The power of the equilibrium method derives from its ability to abstract from the complicated dynamic process that induces equilibrium and to abstract from the historical accident that initiated the process. Unfortunately, deductive equilibrium analysis often fails to determine a unique equilibrium solution in many economies and, hence, often fails to prescribe or predict rational behavior.

In economies with multiple equilibria, the rational decision maker formulating beliefs using deductive equilibrium concepts is uncertain which equilibrium strategy other decision makers will use, and in general, this uncertainty will influence the rational decision maker's behavior. Strategic uncertainty arises even in situations where objectives, feasible strategies, and institutions are

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completely specified and are common knowledge.[1] The deductive equilibrium method is incomplete. A satisfactory theory of interdependent decisions not only must identify the outcomes that are equilibria when expected, but also must explain the process by which decision makers acquire equilibrium beliefs. Consequently, a theory of equilibrium selection would be a useful complement to the theory of equilibrium points.

An interesting conjecture is that decision makers may focus on some selection principle to identify a specific equilibrium point in situations involving multiple equilibria; see Schelling [1980]. This salient principle would allow the decision makers to implement an equilibrium. The salience of an equilibrium selection principle is essentially an empirical question.

This paper uses the experimental method to examine the salience of payoff-dominance, security, and historical precedents in related average opinion games. The average opinion games studied exhibit multiple equilibria, which in the baseline experiments were Pareto ranked. Hence, deductive equilibrium analysis of these average opinion games is indeterminate. Yet the observed behavior in the experiments was systematic. The distribution of initial actions in a treatment varied systematically with considerations of payoff-dominance and security. Given an initial median, the median in the remaining periods of a treatment was perfectly predictable. The systematic and, hence, predictable behavior observed in the experiments illustrates the importance of equilibrium selection theory.

I. Average Opinion Games

Cooper and John [1988] demonstrate that a large number of superficially dissimilar market and nonmarket models with strategic complementarities and demand spillovers have a similar strategic form representation.[2] Rather than developing an extensive form market game and then converting it into the strategic form for our

1. Sugden [1989, p. 88] provides a lucid critique of the view that a rational decision maker can deduce a unique "rational" strategy from the information contained in a complete information description of a game. Strategic uncertainty should not be confused with uncertainty arising from incomplete information about other aspects of a decision maker's environment. Keynes's [1936, p. 156] discussion of the average opinion problem in newspaper beauty contests and in stock markets is a venerable example of strategic uncertainty.

2. Milgrom and Roberts [1990] demonstrate that extant models of macroeconomic coordination failure, bank runs, technology adoption and diffusion, R&D competition, and manufacturing with nonconvexities exhibit strategic complementarities.

analysis, we work directly with the strategic form. To focus the analysis, consider the following average opinion game.

Let $x_1, \ldots, x_n$ denote the actions taken by n decision makers, where n is odd, and let M be the median of these actions. The period game Γ is defined by the following payoff function and action space for each of n decision makers indexed by i:

$$\pi(x_i,M) = aM - b[M - x_i]^2 + c, \qquad a > 0, b > 0, \tag{1}$$

where $x_i \in \{1,2, \ldots, X\}$. A decision maker's payoff is decreasing in the distance between the decision maker's choice x_i, and the median M, and is increasing in the median M. Assume that the decision makers have complete information about the payoff functions and feasible actions, and know that the payoff function and feasible actions are common knowledge.

If the decision makers could explicitly coordinate their actions, the—real or imagined—planner's decision problem would be trivial. Efficiency requires that each decision maker choose the largest feasible action X, that is, the unique efficient outcome is $(X, \ldots, X)$. Moreover, a negotiated "pregame" agreement to choose $(X, \ldots, X)$ would be self-enforcing.

However, when the decision makers cannot engage in pregame negotiation, they face a nontrivial coordination problem: an average opinion problem. In game Γ, decision maker i's best response is to set x_i equal to i's forecast of the median action. The principle of mutually expected rationality implies that, when forecasting the median, decision maker i expects decision maker j to set x_j equal to j's forecast of the median action. Hence, decision maker i's best response becomes set x_i equal to i's forecast of the median of the forecasts of the median. Again, the principle of mutually expected rationality applies, and decision maker i confronts an infinite regress of forecasts of the median of the forecasts of the median of the forecasts of the . . . .[3]

Suppose that the decision makers attempt to use the Nash equilibrium concept to inform their strategic behavior in the tacit average opinion game Γ. Formally, an n-tuple of feasible actions $(x_1^*, \ldots, x_n^*)$ constitutes a Nash equilibrium point, if

$$\pi(x_i, M^*) \leq \pi(x_i^*, M^*) \tag{2}$$

for all $x_i \in \{1,2, \ldots, X\}$ and for all i. Since a decision maker's

3. Frydman and Phelps [1983, introduction] provide a related discussion of the average opinion problem in Rational Expectations Equilibria.

unique best response to M is to choose x_i equal to M, by symmetry it follows that any n-tuple $(x, \ldots, x)$ with $x \in \{1,2, \ldots, X\}$ is a Nash equilibrium point.

All feasible actions can be rationalized as part of some Nash equilibrium. The Nash equilibrium concept neither prescribes nor predicts the outcome of this tacit coordination game. The deductive equilibrium analysis is indeterminate. A conventional response to this indeterminacy is to argue that some Nash equilibria are not self-enforcing. However, all of the pure strategy equilibria are strict, that is, each decision maker has a unique best response to M. Hence, the usual refinements do not reduce the set of equilibrium points; see Van Damme [1987, p. 20]. Moreover, the indeterminacy of the equilibrium analysis and the resulting strategic uncertainty undermines the presumption that the outcome of Γ will satisfy the mutual best response condition (2).

II. Equilibrium Selection Principles

An equilibrium selection principle identifies a subset of equilibrium points according to some distinctive characteristic of the game's description or of the decision makers' experiences. Deductive selection principles select equilibrium points based on the game's description. Inductive selection principles select equilibrium points based on the decision makers' experiences.

An interesting conjecture is that decision makers may focus on some selection principle to identify a specific equilibrium point in situations involving multiple equilibria. Hence, the outcome of situations involving strategic uncertainty may, nevertheless, satisfy the mutual best response condition (2). A salient principle selects an equilibrium point based on its conspicuous uniqueness in some respect. The salience of an equilibrium selection principle is essentially an empirical question.

A. Deductive Selection Principles

When multiple equilibrium points can be Pareto ranked, it is possible to use the concepts of efficiency to select a subset of equilibrium points: examples include Luce and Raiffa's [1957, p. 106] concept of joint-admissibility, Basar and Olsder's [1982, p. 72] concept of admissibility, and Harsanyi and Selten's [1988, p. 81] concept of payoff-dominance. An equilibrium point is said to be payoff-dominant if it is not strictly Pareto dominated by any other equilibrium point.[4] Considerations of efficiency may induce decision makers to focus on and, hence, select a payoff-dominant equilibrium point if it is unique; see Schelling [1980, p. 291].

When equilibria can be Pareto ranked, it is important to distinguish between disequilibrium outcomes—outcomes that do not satisfy the mutual best response condition—and coordination failure—an inefficient equilibrium outcome.[5] When a unique payoff-dominant equilibrium point is salient, this not only allows decision makers to coordinate on an equilibrium point, but also insures that they will not coordinate on an inefficient one. Hence, payoff-dominance solves both the disequilibrium and coordination failure problems. For example, in game Γ, payoff-dominance selects $(X, \ldots, X)$, which implies not only that $x_i = M$ for all i, but also that $M = X$.

However, payoff-dominance may not be salient in many strategic situations because it does not take account of out-of-equilibrium payoffs. Several selection principles based on the "riskiness" of an equilibrium point have been identified and formalized: examples include Von Neumann and Morgenstern's [1972] concept of maximin and Harsanyi and Selten's [1988] concept of risk-dominance. A secure action is an action whose smallest payoff is at least as large as the smallest payoff to any other feasible action. Security selects equilibrium points implemented by secure actions. Security, in contrast to payoff-dominance, may select very inefficient equilibrium points in non-zero-sum games.[6]

Consider a specific representation of game Γ, which illustrates security and is used in the experiments reported below. Payoff Table Γ sets parameter X equal to 7, parameter a equal to 0.1, parameter b equal to 0.05, and parameter c equal to 0.6 in equation (1). The cells along the diagonal give the payoffs corresponding to

4. Luce and Raiffa's [1957] concept makes comparisons with feasible but disequilibrium outcomes. Basar and Olsder's [1982] concept does not require that all decision makers be strictly better off. In our experiments the payoff-dominant equilibrium is also the best feasible outcome.

5. The recent literature on macroeconomic coordination games (see Bryant [1983] and Cooper and John [1988] for examples and references) emphasizes the possibility of coordination failure; while the older literature emphasizes disequilibrium.

6. Security, like payoff-dominance, has the practical advantage that it only requires ordinal preferences that are increasing in the score of the observable game. Hence, it is consistent with the hypothesis that, all else equal, people prefer outcomes with higher money payoffs. The experimentalist confronts a more ambitious task when attempting to induce Von Neumann and Morgenstern preferences over the score of an observable game, which is required for mixed strategy equilibria and risk-dominance.

PAYOFF TABLE Γ

		Median value of X chosen						
		7	6	5	4	3	2	1
Your	7	1.30	1.15	0.90	0.55	0.10	−0.45	−1.10
choice	6	1.25	1.20	1.05	0.80	0.45	0.00	−0.55
of	5	1.10	1.15	1.10	0.95	0.70	0.35	−0.10
X	4	0.85	1.00	1.05	1.00	0.85	0.60	0.25
	3	0.50	0.75	0.90	0.95	0.90	0.75	0.50
	2	0.05	0.40	0.65	0.80	0.85	0.80	0.65
	1	−0.50	−0.05	0.30	0.55	0.70	0.75	0.70

the seven strict equilibrium points. Hence, payoffs range from 1.30 in the payoff-dominant equilibrium (7, . . . , 7), to 0.70 in the least efficient equilibrium (1, . . . , 1). The secure equilibrium is (3, . . . , 3), which pays 0.90 in equilibrium and insures a payoff of at least 0.50. In game Γ both payoff-dominance and security select a unique equilibrium point, and hence, both are potentially salient.

In game Γ there is a tension between efficiency and security. This tension may undermine the salience of both selection principles unless it is common knowledge which selection principle takes priority in average opinion games, which seems unlikely. A plausible conjecture is that payoff-dominance is more likely to be salient if it does not conflict with security and, conversely, that security is more likely to be salient if it does not conflict with payoff-dominance.

Consider a game that has the same equilibrium actions and payoffs as Γ, but that has a zero payoff to all disequilibrium outcomes. The period game Ω is defined by Payoff Table Ω. In game Ω, unlike game Γ, all actions are equally secure because they all insure a payoff of zero.[7] Hence, security cannot be a salient equilibrium selection principle for game Ω, but payoff-dominance uniquely selects (7, . . . , 7) and, hence, is potentially salient.

Alternatively, consider the game obtained by setting parameter a equal to zero and parameter c equal to 0.7 in equation (1). Specifically, the period game Φ is defined by the Payoff Table Φ. Game Φ has the same set of equilibrium points as game Γ, but the

7. There exists a mixed strategy that insures an expected payoff greater than zero.

PAYOFF TABLE Ω

		Median value of X chosen						
		7	6	5	4	3	2	1
Your	7	1.30	0	0	0	0	0	0
choice	6	0	1.20	0	0	0	0	0
of	5	0	0	1.10	0	0	0	0
X	4	0	0	0	1.00	0	0	0
	3	0	0	0	0	0.90	0	0
	2	0	0	0	0	0	0.80	0
	1	0	0	0	0	0	0	0.70

payoffs associated with the equilibrium points are no longer increasing in the median. In game Φ, unlike game Γ, all strict equilibria are included in the set of payoff-dominant equilibria. Hence, payoff-dominance cannot be a salient equilibrium selection principle. Security selects (4, . . . , 4), which insures a payoff of 0.25. Hence, security is a potentially salient equilibrium selection principle for game Φ.

Our discussion of deductive selection principles has focused on the simple principles of efficiency and security that are directly applicable to the average opinion games Γ, Ω, and Φ. Our experimental research attempts to determine how people *actually* use the strategic details of their environment to solve equilibrium selection problems.

B. Inductive Selection Principles

If decision makers fail to coordinate on an equilibrium, repeated interaction may allow decision makers to learn to coordi-

PAYOFF TABLE Φ

		Median value of X chosen						
		7	6	5	4	3	2	1
Your	7	0.70	0.65	0.50	0.25	−0.10	−0.55	−1.10
choice	6	0.65	0.70	0.65	0.50	0.25	−0.10	−0.55
of	5	0.50	0.65	0.70	0.65	0.50	0.25	−0.10
X	4	0.25	0.50	0.65	0.70	0.65	0.50	0.25
	3	−0.10	0.25	0.50	0.65	0.70	0.65	0.50
	2	−0.55	−0.10	0.25	0.50	0.65	0.70	0.65
	1	−1.10	−0.55	−0.10	0.25	0.50	0.65	0.70

nate. Consider a finitely repeated game $G(T)$, which involves the n decision makers playing one of the average opinion games, either Γ, Ω, or Φ, for T periods. Having t periods of experience in $G(T)$ provides a decision maker with observed facts, in addition to the description of the game, that can be used to reason about the equilibrium selection problem in the continuation game $G(T - t)$. This experience may influence the outcome of the continuation game $G(T - t)$ by focusing expectations on a specific equilibrium point.

In the continuation game $G(T - t)$ decision makers can use precedent to solve their coordination problem. Selecting an equilibrium based on precedent requires decision makers to focus on some salient analogy to a past instance of the present equilibrium selection problem and to expect others to focus on the same analogy. Hence, precedent requires decision makers to have some shared experience.

There are too many ways to use precedent to enumerate them all. However, a plausible conjecture in average opinion games is that the historical median provides a salient precedent for the present equilibrium selection problem. However, the plausibility of the conjecture depends on how similar the past and present equilibrium selection problems are. It is useful to distinguish between two forms of precedent, which we denote as strong precedent and weak precedent for clarity.[8]

A historical outcome of the period game G may provide a strong precedent for $G(T - t)$ when it is observed by all the decision makers. Suppose that decision makers observe $\{M_1, M_2, \ldots, M_t\}$, then decision makers can use the strong precedent established by a historical median or some statistic of historical medians to inform their strategic behavior in the continuation game $G(T - t)$.

A historical outcome of a related average opinion game $G^r(\tau)$, some pregame, may provide a weak precedent for $G(T)$ when it is observed by all the decision makers. (For example, let $G^r(\tau)$ equal $\Omega(\tau)$, and let $G(T)$ equal $\Gamma(T)$.) Suppose that decision makers observe $\{M^r_1, M^r_2, \ldots, M^r_\tau\}$, then decision makers can use the weak precedent established by a historical median or some statistic of

8. Lewis [1969] contrasts precedent, which is based on shared experience, and convention, which is based on common knowledge of how members of a population solve the present equilibrium selection problem and common knowledge that all relevant decision makers belong to that population. We assume that the equilibrium selection problem in an abstract game is sufficiently novel that subjects cannot use conventions in the experiments reported below.

historical medians in a related average opinion game to inform their strategic behavior in the present game $G(T)$. This paper reports evidence on the salience of strong and weak precedent in repeated average opinion games.

It is possible, even likely, that decision makers will focus on different inductive or deductive selection principles. Hence, the decision makers must form complex beliefs about the average opinion of the salience of alternative selection principles. If attempting to reason about the equilibrium selection problem is too complex, some decision makers may adopt simple trial and error learning rules. Many learning rules coevolve to an equilibrium point in average opinion games; see Crawford [1991] for an "evolutionary" interpretation of our results.

III. Experimental Design

A laboratory environment capturing the essential aspects of the equilibrium selection problem in a many-person decentralized economy must include two features. First, the environment must not assume away the problem by allowing an arbiter—or any other individual—to make common knowledge pregame assignments.[9] Second, the environment must allow repeated interaction among the decision makers so that they have a chance to learn to coordinate. The repeated average opinion games described above are well suited for an experimental study of equilibrium selection.

The games were described to the subjects using payoff tables Γ, Ω, and Φ discussed above, where the payoffs denote dollars. Treatment Gamma denotes repeated play of Γ, Treatment Omega denotes repeated play of Ω, and Treatment Phi denotes repeated play of Φ. All initial treatments last ten periods. Nine subjects participated in each of the twelve experiments reported in the text.

In treatment Gammadm subjects participated simultaneously in two games: one set n equal to nine, and the other set n equal to twenty-seven. See Appendix A for a discussion of the dual market design and experimental results.

The instructions were read aloud to insure that the description of the game was common information. Appendix C contains the instructions used in Treatment Gamma. No preplay negotiation

9. See Van Huyck, Gillette, and Battalio [forthcoming] for experiments on the ability of an arbiter to select equilibrium points and for references to the "cheap talk" literature.

TABLE I
EXPERIMENTAL DESIGN MATRIX

Experiment		Treatment			
Nm.	Date	Gamma Table Γ	Omega Table Ω	Phi Table Φ	Gamma Table Γ
1	3/1/88	1*,2, . . . , 10	11*, . . . , 18	—	19*,20
2	3/1/88	1*,2, . . . , 10	11*, . . . , 18	—	19*,20
3	3/1/88	1*,2, . . . , 10	11*, . . . , 18	—	19*,20
4	3/3/88°	1*,2, . . . , 10	11*, . . . , 15	—	—
5	3/3/88°	1*,2, . . . , 10	11*, . . . , 15	—	—
6	3/3/88°	1*,2, . . . , 10	11*, . . . , 15	—	—
7	3/31/88	—	1*,2, . . . , 10	—	11*, . . . , 15
8	3/31/88	—	1*,2, . . . , 10	—	11*, . . . , 15
9	3/31/88	—	1*,2, . . . , 10	—	11*, . . . , 15
10	3/30/88	—	—	1*,2, . . . , 10	11*, . . . , 15
11	3/30/88	—	—	1*,2, . . . , 10	11*, . . . , 15
12	4/5/88	—	—	1*,2, . . . , 10	11*, . . . , 15

Notes. Nm. = number. *denotes a period in which subjects made predictions. ° = dual market treatment.

was allowed. After each repetition of the period game, the median action was publicly announced, and the subjects calculated their earnings for that period. The only common historical data available to the subjects were the reported medians.

After ten periods of a treatment, the subjects were switched into a continuation treatment. Instructions for continuation treatments were given to the subjects after earlier treatments had been completed. Table I outlines the design of the twelve experiments reported in this paper.

At the beginning of each treatment, the subjects predicted the distribution of actions in that period.[10] For each prediction a subject was paid \$0.50 less \$0.02 times the sum of the absolute value of the difference between the actual and predicted actions. At the end of the experiment, the subjects were told the actual distribution of actions and were paid for their predictions.

The subjects were sophomore and junior economics students attending Texas A&M University. A total of 108 students participated in the twelve experiments. After reading the instructions, but before the experiment began, the students filled out a questionnaire to determine that they understood how to read the payoff

10. In two earlier pilot experiments predictions were not made in any period. The substantive results were the same as those reported here.

TABLE II
DISTRIBUTION OF CHOICES IN PERIOD 1

	Treatment									
	Gamma		Gammadm		Combined (baseline)		Omega		Phi	
Action	Nm.	(Pr.)	Nm.	(Pr.)	Nm.	(Pr.)	Nm.	(Pr.)	Nm.	(Pr.)
7	5	(18)	3	(11)	8	(15)	14	(52)	2	(7.5)
6	3	(11)	1	(4)	4	(7)	1	(4)	3	(11)
5	8	(30)	7	(26)	15	(28)	9	(33)	9	(33)
4	8	(30)	11	(41)	19	(35)	3	(11)	11	(41)
3	3	(11)	5	(18)	8	(15)	0	(0)	2	(7.5)
2	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
1	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Total	27	(100)	27	(100)	54	(100)	27	(100)	27	(100)

Notes. Nm. = number of subjects. Pr. = percent of subjects.

table for the treatment—that is, how to map actions into money payoffs—and how to calculate the median of nine numbers. All of the subjects read the payoff table correctly. In a few experiments a subject failed to calculate the median correctly. On those occasions the instructions were read again.

The experiments take less than two hours to conduct. Consequently, the subjects could earn significantly more than the minimum wage. For example, in experiments 1–3 if all subjects choose 7 in each period, each subject would earn $27.

IV. EXPERIMENTAL RESULTS: THE SALIENCE OF PAYOFF-DOMINANCE AND SECURITY

This section reports the period 1 results for the twelve experiments. The data in period 1 are particularly interesting because the subjects can only use deductive selection principles to inform their behavior. Hence, the period 1 data provide a direct test of the salience of payoff-dominance and security. Recall that in

11. The text groups the choice data from treatments Gamma and Gammadm. Nonparametric tests failed to reject the hypothesis that the sample distribution of choices was drawn from the same population distribution. The chi-square statistic was 1.7 with a probability value of 0.19.

12. Since the secure mixed strategy assigns a probability of 48 percent to actions 1, 2, and 3, the fact that these actions are never observed is inconsistent with the hypothesis that subjects were using the secure mixed strategy.

period game Γ payoff-dominance selects (7, . . . , 7), and security selects (3, . . . , 3); in period game Ω payoff-dominance selects (7, . . . , 7), and security does not apply; and in period game Φ payoff-dominance does not apply and security selects (4, . . . , 4).

Neither payoff-dominance nor security is salient in period game Γ. In the baseline treatments—Gamma and Gammadm, action 7 was chosen by only 15 percent (8 out of 54) of the subjects and action 3 was also chosen by 15 percent of the subjects; see Table II.[11] However, subjects' behavior was not diffuse. Rather than play either the payoff-dominant or the secure action, 70 percent (38 out of 54) of the subjects chose an action between 7 and 3. In the six baseline experiments, the median action was 4 in three experiments and 5 in three experiments.

Payoff-dominance predicts the modal response to period game Ω. In Treatment Omega, action 7 was chosen by 52 percent (14 out of 27) of the subjects; see Table II. Actions 4, 5, and 6 were chosen by the remaining subjects.[12] In the three Omega treatments the median action was 7 in two experiments and 5 in one experiment. Using nonparametric procedures, the difference between the distribution of actions in Treatment Omega and the distribution of actions in the baseline treatment is statistically significant at the 1 percent level. This contrast between period games Γ and Ω is consistent with the conjecture that eliminating considerations of security in Γ increases the salience of payoff-dominance.

Security predicts the modal response to period game Φ. The secure action 4 was chosen by 41 percent (11 out of 27) of the subjects. Hence, there is some support for the proposition that eliminating considerations of payoff-dominance in Γ increases the salience of security.

However, seven times as many subjects played above the secure action 4 as played below it. This is curious given that, unlike Γ and Ω, Payoff Table Φ has the same values in the upper left corner of the table as in the lower right corner. Hence, subjects must be responding to description-specific details of the payoff table. (We placed the payoff-dominant equilibrium in the upper left corner of Γ and Ω for this reason; that is, we believed that we were biasing the experiments in favor of payoff-dominance.) The median action was a 4 in one experiment and a 5 in two experiments beginning with Treatment Phi.

Subjects' predictions of individual behavior were dispersed. Ninty-one percent (49 out of 54) of the subjects predicted a heterogeneous response to the Payoff Table Γ. Similar results obtain for treatments Omega and Phi. Only 18 percent (5 out of 27) of the subjects predicted that everyone would chose the payoff-dominant action, 7, in response to Payoff Table Ω. Only 4 percent (1 out of 27) of the subjects predicted that everyone would chose the secure action 4 in response to Payoff Table Φ. Hence, 85 percent (46 out of 54) of the subjects predicted a heterogeneous response to payoff tables Ω and Φ.

The subjects' dispersed predictions suggest that they expect some of the other subjects to respond to the payoff table differently than they did. The data are inconsistent with any theory of equilibrium selection that assumes that, because a decision maker will derive his prior probability distribution over other decision makers' pure strategies strictly from the parameters of the game, all decision makers will have the same prior probability distribution. Instead, most subjects predict that some participants will be more optimistic or pessimistic than themselves.

The subjects' predictions and actions are consistent.[13] Those who made optimistic predictions chose large values, and those who made pessimistic predictions chose small values. The inefficient disequilibrium outcomes observed in period 1 appears to result from the heterogeneous response of subjects to the description of the game and from the subjects' expectation of a heterogeneous response to the description of the game.

V. Experimental Results: The Salience of Strong Precedents

Repeated interaction may allow subjects to learn to coordinate. At the end of each period, the median was reported to the subjects. Hence, the experimental design allowed subjects to use their shared experience in past period games, the historical median, to inform their behavior in the current period game, which provides evidence on the salience of strong precedents.

The strong precedent of the initial median is salient in these average opinion games. Table III reports the median for periods 1 through 10 in treatments Gamma, Gammadm, Omega, and Phi. While the period 1 median differed across experiments and treat-

13. The number of subjects that gave a best response to the median of their predictions was as follows: 21 out of 27 subjects in Treatment Gamma, 13 out of 27 subjects in Treatment Gammadm, 22 out of 27 subjects in Treatment Omega, and 22 out of 27 in Treatment Phi.

TABLE III
MEDIAN CHOICE FOR THE FIRST TEN PERIODS OF ALL EXPERIMENTS

	Period									
Treatment	1	2	3	4	5	6	7	8	9	10
Gamma										
Exp. 1	4	4	4	4	4	4	4*	4	4*	4*
Exp. 2	5	5	5	5	5	5	5	5	5	5
Exp. 3	5	5	5	5	5	5	5	5	5	5*
Gammadm										
Exp. 4	4	4	4	4	4	4*	4*	4*	4*	4*
Exp. 5	4	4	4	4*	4*	4*	4*	4*	4*	4*
Exp. 6	5	5	5	5	5	5	5	5*	5*	5*
Omega										
Exp. 7	7	7	7	7*	7*	7*	7*	7*	7*	7*
Exp. 8	5	5	5	5	5*	5*	5*	5*	5*	5*
Exp. 9	7	7	7*	7*	7*	7*	7*	7*	7*	7*
Phi										
Exp. 10	4	4	4	4	4*	4*	4*	4*	4*	4*
Exp. 11	5	5	5	5*	5*	5*	5*	5*	5*	5*
Exp. 12	5	5	5	5*	5*	5*	5*	5*	5*	5*

Notes. Exp. = experiment. * = indicates a mutual best response outcome.

ments, the median in subsequent periods was always equal to the period 1 median. This stability was observed whether the initial outcome was efficient or inefficient and whether the treatment was Gamma, Gammadm, Omega, or Phi. In eleven out of twelve experiments, the period 10 outcome satisfied the mutual best response condition (2). The equilibrium selected always generated a median equal to the period 1 median. Hence, in these treatments subjects select an equilibrium that is determined by the historical accident of the initial median.[14]

Examination of individual behavior in treatments Omega, Phi, and Gammadm confirms the salience of the initial median. The number of subjects selecting a period 2 action equal to the period 1 median was 18 out of 27 in Treatment Omega, 17 out of 27 in treatment Phi, 18 out of 27 in Treatment Gammadm, and 8 out of

14. The dynamics of these average opinion games are remarkably different from the tacit coordination game studied in Van Huyck, Battalio, and Beil [1990], which used larger teams and a minimum rule—rather than a median rule—to aggregate choices. Under a minimum rule, the initial outcome plays no role in selecting the equilibrium. Instead, the process always converges to the most inefficient equilibrium point.

27 in Treatment Gamma. The data on individual behavior in Treatment Gamma reveal systematic adaptive behavior.

A subject's payoff is decreasing in x_i when he (she) played above the median, and those subjects that played above the median show a strong tendency to reduce their action. The observed mean reduction in x_i is increasing in the difference between a subject's period 1 action and the period 1 median, but the mean reduction is significantly smaller than this difference. Conversely, a subject's payoff is increasing in x_i when he (she) played below the median, and those subjects that played below the median show a tendency to increase their action. The observed mean increase in x_i is increasing in the difference between the subject's period 1 action and the period 1 median, but the mean increase is significantly smaller than this difference. Consequently, these average opinion games quickly converge to an outcome that satisfies the mutual best response property of a Nash equilibrium.

The speed of convergence to equilibrium appears to differ across treatments. Treatments Omega and Phi all converge within five periods, while only one of six baseline treatments converges within five periods. In the baseline treatments, subjects appear to "explore" the consequences of choosing an action one above or below last period's median. Inspection of Payoff Table Γ reveals that choosing an action one above or below the median cost only five cents. However, the "exploring" behavior observed in the baseline treatments would be very costly in Treatment Omega—any error results in zero earnings—and pointless in Treatment Phi—all strict equilibrium points are contained in the set of payoff-dominant equilibrium points.

In the baseline treatments subjects *never* coordinated on the payoff-dominant equilibrium. Payoff-dominance was not a salient selection principle. Hence, these treatments provide striking examples in which strategic uncertainty leads to coordination failure. The observed coordination failure results from subjects' heterogeneous response to strategic uncertainty, the adaptive behavior subjects exhibit in disequilibrium, the median rule, and the salience of the historical median.[15]

The strong precedent of the initial median M_1 was salient to

15. Van Huyck, Battalio, and Beil [1990] and Cooper, DeJong, Forsythe, and Ross [1990] also report experimental games exhibiting coordination failure. In both Van Huyck et al. and Cooper et al., the secure but inefficient equilibrium obtains. (Cooper et al. results also depend on the presence of a strictly dominated "cooperative" strategy.) These results contrast with the coordination failure of the text, which does not depend on subjects adopting a secure action.

enough subjects that the historical accident of the initial median M_1 selected the equilibrium in all of the average opinion treatments. Even though equilibrium analysis of $G(9)$ is indeterminate, the median in periods 2 through 10 is perfectly predictable given the initial median M_1 in these average opinion games.

VI. Experimental Results: The Salience of Weak Precedents

This section reports the results of the continuation treatments in the twelve experiments, which test the salience of the weak precedent established by a historical equilibrium in a related game. The subjects received new instructions and a new payoff table in period 11. Hence, the subjects were seeing Payoff Table Γ or Ω for the first time.

We discuss the influence of weak precedents on gamma continuation treatments first. In experiments 10, 11, and 12, the equilibria obtained in pretreatment Phi produced a median M_{10}^{r} of either 4 or 5, while the period 11 median in continuation Treatment Gamma was either 6 or 7; see Table IV. Only 5 out of 27 subjects chose an action in period 11 equal to the period 10 median. The other 22 subjects chose an action greater than the period 10 median.

The weak precedent of the historical median in a related game was not salient in the Phi-Gamma experiments. While not salient, the historical median does appear to anchor subjects' behavior in the continuation treatment; that is, they appear to use it as a lower bound on the median from which improvements can safely be sought. Also, the presentation of a new table in and of itself may help them coordinate their attempt to move to a better equilibrium.

The three experiments using the sequence Omega-Gamma are more difficult to interpret, because in experiments 7 and 9 the payoff-dominant equilibrium obtained in treatment Omega. Hence, experiments 7 and 9 cannot distinguish between the salience of the payoff-dominant equilibrium point and the salience of the weak precedent of M_{10}^{r}. However, an inefficient equilibrium, $M_{10}^{r} = 5$, obtained in experiment 8; see Table IV. In period 11 of the Gamma treatment of experiment 8, only two out of nine subjects chose an action equal to 5. The other seven subjects chose an action greater than 5. As in the Phi-Gamma experiments, the historical median was not salient. Instead, most subjects used it to anchor their beliefs and coordinate on the payoff-dominant equilibrium.

A comparison between the distribution of actions in period 1

TABLE IV
MEDIAN CHOICE FOR THE CONTINUATION TREATMENTS OF ALL EXPERIMENTS

		Period									
	M^r_{10}	11	12	13	14	15	16	17	18	19	20
	M^{Gamma}	Omega								Gamma	
Exp. 1	4*	7	7*	7*	7*	7*	7*	7*	7*	7	7*
Exp. 2	5	7	7*	7*	7*	7*	7*	7*	7*	7	7*
Exp. 3	5*	5	5	5*	5*	5*	5*	5*	5*	5*	5*
	M^{Gammadm}	Omega									
Exp. 4	4*	7	7*	7*	7*	7*	—	—	—	—	—
Exp. 5	4*	7	7*	7*	7*	7*	—	—	—	—	—
Exp. 6	5*	5	5*	5*	5*	5*	—	—	—	—	—
	M^{Omega}	Gamma									
Exp. 7	7*	7*	7*	7*	7*	7*	—	—	—	—	—
Exp. 8	5*	7	7	7	7*	7*	—	—	—	—	—
Exp. 9	7*	7*	7*	7*	7*	7*	—	—	—	—	—
	M^{Phi}	Gamma									
Exp. 10	4*	6	6	6	6	6	—	—	—	—	—
Exp. 11	5*	7	7*	7*	7*	7*	—	—	—	—	—
Exp. 12	5*	7	7*	7*	7*	7*	—	—	—	—	—

Notes. M^r_{10} = period 10 median in related game r. Exp. = experiment. * = indicates a mutual best response outcome. — = not applicable.

and period 11 for Treatment Gamma reveals the dramatic influence experience has on subject behavior; compare Tables II and V.[16] Only 15 percent of the inexperienced subjects chose the payoff-dominant action 7 in period 1, while 74 percent of the experienced subjects chose the payoff-dominant action 7 when first exposed to Payoff Table Γ.[17] Chi-square tests reject the hypothesis that the distribution of actions for gamma in period 1 and period 11 are the same at the 1 percent level of statistical significance. Paradoxically, experienced subjects, who could use weak precedents, focus on the

16. Prediction accuracy in period 11 is similar to the prediction accuracy in period 1. An analysis of prediction accuracy can be found in our June 1988 working paper.

17. The distribution of actions in Gamma is only marginally influenced by the pretreatment of Omega rather than Phi. Chi-square tests fail to reject the hypothesis that the sample distributions were drawn from the same population.

TABLE V
DISTRIBUTION OF INDIVIDUAL CHOICES IN PERIOD 11

	Treatment							
	Omega (following baseline)		Gamma (following Omega)		Gamma (following Phi)		Gamma (combined)	
Action	Nm.	(Pr.)	Nm.	(Pr.)	Nm.	(Pr.)	Nm.	(Pr.)
7	32	(59)	23	(85)	17	(63)	40	(74)
6	2	(4)	2	(7.5)	4	(15)	6	(11)
5	14	(26)	2	(7.5)	3	(11)	5	(9)
4	6	(11)	0	(0)	3	(11)	3	(6)
3	0	(0)	0	(0)	0	(0)	0	(0)
2	0	(0)	0	(0)	0	(0)	0	(0)
1	0	(0)	0	(0)	0	(0)	0	(0)
Total	54	(100)	27	(100)	27	(100)	54	(100)

Notes. Nm. = number of subjects. Pr. = percent of subjects.

payoff-dominant equilibrium much more strongly than do inexperienced subjects, who could not.

In experiments 1, 2, and 3, we used an A-B-A design, specifically Gamma-Omega-Gamma, to determine whether behavior was reversible. As Table IV reveals, the median in period 18 equals the median in period 10 in only one of the three experiments. Given the extreme path dependence observed in the experiments, we abandoned the A-B-A designs for the remaining experiments in the project.

Experienced subjects when first exposed to Payoff Table Ω, following Payoff Table Γ, do not focus on the equilibrium closest to the historical equilibrium of the "pregame" in four out of six experiments; see Table IV. Only 18 out of 54 subjects chose a period 11 action equal to the period 11 median. Thirty-five subjects chose an action greater than the period 10 median. Most subjects ignored the weak precedent of a historical equilibrium in a related game and focused on the payoff-dominant equilibrium instead. A Chi-square test fails to reject the hypothesis that the distribution of actions for Treatment Omega in periods 1 and 11 are drawn from the same population distribution; compare Table II and V.

The outcome of the continuation treatment in period 11, like the initial treatment, is extremely stable in these average opinion games. Table IV reports the median for periods 11 through the end of the experiment. While the outcome of the continuation treatment in period 11 differed across experiments and treatments, the median in subsequent periods was always equal to the period 11 median.

In eleven out of twelve experiments, the period 15 outcome satisfied the mutual best response condition (2). The equilibrium selected always generated a median equal to the period 11 median. In the continuation treatment, convergence to a mutual best response outcome is extremely rapid, occurring in one or two periods. In nine out of twelve experiments the period 12 outcome satisfied the mutual best response condition (2). Like the initial treatment the historical accident of M_{11} determines which equilibrium point obtains in the continuation treatment. The median in periods 12 through 15 is perfectly predictable given M_{11} in these average opinion games.

VII. Summary

In the baseline average opinion game, which has a unique payoff-dominant equilibrium and a unique secure equilibrium, neither payoff-dominance nor security was a salient equilibrium selection principle. Instead, the modal response was between the payoff-dominant and the secure action. Repeated interaction produced simple dynamics that converged to the inefficient equilibrium selected by the historical accident of the initial median. The baseline experiments provide a striking example of how strategic uncertainty can lead to coordination failure.

Treatment Omega reduced the strategic uncertainty confronting subjects by eliminating considerations of security. Payoff-dominance accurately predicts the modal response to period game Ω. Treatment Phi reduced the strategic uncertainty confronting subjects by eliminating considerations of payoff-dominance. Security accurately predicts the modal response to period game Φ. As with the baseline treatment, the historical accident of the initial median selected the equilibrium outcome implemented in all three Omega treatments and all three Phi treatments.

Continuation treatments found little evidence for the salience of weak precedents. Instead, experience in related games increased the salience of payoff-dominance. However, like the initial treatment, the historical accident of the period 11 median determines which equilibrium point obtains in the continuation treatment. Hence, all treatments provide evidence that the initial median in a treatment provides a salient precedent.

Deductive equilibrium analysis of these average opinion games is indeterminate. Yet the observed behavior in the experiments was systematic. The distribution of initial actions in a treatment varied systematically with considerations of payoff-dominance and security. Given an initial median, the median in the remaining periods of a treatment was perfectly predictable. The systematic and, hence, predictable behavior observed in the experiments suggests that it should be possible to construct an accurate equilibrium selection theory.

Appendix A: Dual Market Order Statistic Games

In baseline experiments 4, 5, and 6, subjects participated simultaneously in two games: one set n equal to nine, and the other set n equal to twenty-seven. In both games the column was chosen by the fifth-order statistic. The dual market technique allows us to study whether an individual subject behaves differently in games that differ only according to the number of decision makers and, hence, only in the level of strategic uncertainty. This difference in behavior is independent of subject heterogeneity and experience; see Battalio, Kogut, and Meyer [1990]. The hypothesis tested was that subjects would chose a more secure action in the game with 27 subjects.

On average, subjects did chose a more secure action in the large game. In period 1, the mean difference between the choice in the small game less the choice in the large game was 0.22. This difference is consistent with the expected effect, but it is not statistically significant. In the large game the fifth-order statistic was a four in every period of both the Gamma and Omega treatments.

However, the mean difference between the predicted median for the small game less the predicted median for the large game was 1.83, which was significantly different from zero at the 1 percent level. Subjects predicted that other subjects would chose a more secure action in the large game. As reported in the text and unlike Treatment Gamma, most subjects did not chose an action equal to the median of their predictions. Apparently, the dual market technique influenced subject behavior—specifically, the relationship between predictions and actions.

APPENDIX B: SUBJECT CHOICES BY EXPERIMENT

	Period														
Subject	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Exp. 1	Treatment Gamma										Treatment Omega				
1	5	5	4	4	4	4	4	4	4	4	4	7	7	7	7
2	4	4	7	4	4	4	4	4	4	4	7	7	7	7	7
3	3	5	6	5	4	4	4	4	4	4	7	7	7	7	7
4	4	4	4	4	4	4	4	4	4	4	7	7	7	7	7
5	3	1	5	5	2	6	4	3	4	4	6	7	7	7	7
6	5	5	4	4	4	4	4	4	4	4	7	7	7	7	7
7	5	5	4	5	4	4	4	4	4	4	7	7	7	7	7
8	5	4	4	4	4	4	4	4	4	4	4	7	7	7	7
9	3	4	3	4	4	4	4	4	4	4	7	7	7	7	7
Exp. 2	Treatment Gamma										Treatment Omega				
1	5	6	4	5	5	5	5	5	5	5	7	7	7	7	7
2	6	7	5	6	6	5	5	5	5	6	7	7	7	7	7
3	5	3	5	5	5	5	5	5	5	5	7	7	7	7	7
4	6	5	5	6	5	5	5	5	5	5	7	7	7	7	7
5	5	6	6	6	6	6	6	5	5	5	7	7	7	7	7
6	7	5	5	5	5	5	5	5	5	5	7	7	7	7	7
7	4	4	4	4	4	4	4	4	4	5	5	7	7	7	7
8	4	4	5	6	5	5	5	5	5	5	5	7	7	7	7
9	6	6	6	5	6	6	6	5	5	5	5	7	7	7	7
Exp. 3	Treatment Gamma										Treatment Omega				
1	4	3	5	4	4	4	4	4	5	5	5	5	5	5	5
2	5	6	5	5	5	5	5	5	6	5	5	7	5	5	5
3	7	6	6	6	7	7	6	5	6	5	6	5	5	5	5
4	7	5	5	5	5	5	5	5	5	5	5	5	5	5	5
5	4	4	5	5	5	5	5	5	5	5	7	5	5	5	5
6	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5
7	7	7	7	5	5	5	5	6	5	5	7	7	5	5	5
8	4	2	5	5	5	5	5	5	5	5	5	5	5	5	5
9	7	5	5	5	5	5	5	5	6	5	7	7	5	5	5
Exp. 4	Treatment Gammadm										Treatment Omega				
1	6	5	5	4	4	4	4	4	4	4	4	7	7	7	7
2	4	4	4	4	4	4	4	4	4	4	7	7	7	7	7
3	7	4	4	4	4	4	4	4	4	4	7	7	7	7	7
4	4	4	5	5	5	4	4	4	4	4	7	7	7	7	7
5	4	4	4	4	4	4	4	4	4	4	7	7	7	7	7
6	5	4	4	4	4	4	4	4	4	4	7	7	7	7	7
7	3	3	4	4	4	4	4	4	4	4	7	7	7	7	7
8	5	4	4	4	4	4	4	4	4	4	4	7	7	7	7
9	3	4	3	4	4	4	4	4	4	4	7	7	7	7	7

APPENDIX B: (CONTINUED)

Subject	Period 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Exp. 5	Treatment Gammadm										Treatment Omega				
1	4	4	4	4	4	4	4	4	4	4	7	7	7	7	7
2	4	5	5	4	4	4	4	4	4	4	7	7	7	7	7
3	4	4	4	4	4	4	4	4	4	4	7	7	7	7	7
4	3	5	6	4	4	4	4	4	4	4	7	7	7	7	7
4	3	5	6	4	4	4	4	4	4	4	7	7	7	7	7
5	5	4	4	4	4	4	4	4	4	4	7	7	7	7	7
6	3	4	4	4	4	4	4	4	4	4	7	7	7	7	7
7	5	4	4	4	4	4	4	4	4	4	5	7	7	7	7
8	4	4	4	4	4	4	4	4	4	4	4	7	7	7	7
9	4	4	4	4	4	4	4	4	4	4	7	7	7	7	7
Exp. 6	Treatment Gammadm										Treatment Omega				
1	3	4	6	6	7	5	6	5	5	5	5	5	5	5	5
2	5	4	5	4	5	5	5	5	5	5	7	5	5	5	5
3	4	5	5	4	5	5	5	5	5	5	5	5	5	5	5
4	7	6	5	5	5	5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
6	5	4	4	4	5	4	4	5	5	5	7	5	5	5	5
7	7	5	5	5	5	5	5	5	5	5	5	5	5	5	5
8	4	5	5	5	5	5	5	5	5	5	4	5	5	5	5
9	4	4	4	4	5	5	5	5	5	5	7	5	5	5	5
Exp. 7	Treatment Omega										Treatment Gamma				
1	5	7	7	7	7	7	7	7	7	7	7	7	7	7	7
2	4	6	7	7	7	7	7	7	7	7	7	7	7	7	7
3	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
4	6	7	6	7	7	7	7	7	7	7	7	7	7	7	7
5	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
8	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
9	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Exp. 8	Treatment Omega										Treatment Gamma				
1	5	5	5	5	5	5	5	5	5	5	7	7	7	7	7
2	7	7	5	5	5	5	5	5	5	5	7	7	7	7	7
3	5	4	4	5	5	5	5	5	5	5	6	7	7	7	7
4	7	4	5	5	5	5	5	5	5	5	5	7	7	7	7
5	5	3	6	5	5	5	5	5	5	5	7	7	7	7	7
6	4	6	5	5	5	5	5	5	5	5	7	7	7	7	7
7	5	3	3	5	5	5	5	5	5	5	7	7	7	7	7
8	4	5	5	5	5	5	5	5	5	5	5	5	5	7	7
9	5	5	5	5	5	5	5	5	5	5	6	7	7	7	7

APPENDIX B: (CONTINUED)

Subject	Period 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Exp. 9	Treatment Omega										Treatment Gamma				
1	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
2	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
3	5	7	7	7	7	7	7	7	7	7	7	7	7	7	7
4	7	6	7	7	7	7	7	7	7	7	7	7	7	7	7
5	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
7	5	4	7	7	7	7	7	7	7	7	7	7	7	7	7
8	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
9	5	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Exp. 10	Treatment Phi										Treatment Gamma				
1	4	4	4	4	4	4	4	4	4	4	7	7	7	7	7
2	4	4	4	4	4	4	4	4	4	4	7	7	7	7	7
3	4	4	4	4	4	4	4	4	4	4	6	6	6	6	6
4	5	3	4	4	4	4	5	4	5	4	5	5	6	6	6
5	6	3	4	5	4	4	4	4	4	4	4	6	6	6	6
6	4	5	5	4	4	4	4	4	4	4	7	6	6	6	6
7	4	4	4	4	4	4	4	4	4	4	4	5	6	6	6
8	4	4	4	4	4	4	4	4	4	4	4	6	7	6	6
9	4	4	4	4	4	4	4	4	4	4	7	6	7	6	6
Exp. 11	Treatment Phi										Treatment Gamma				
1	4	5	5	5	5	5	5	5	5	5	6	7	7	7	7
2	4	3	4	5	5	5	5	5	5	5	7	7	7	7	7
3	5	4	4	5	5	5	5	5	5	5	7	7	7	7	7
4	5	4	5	5	5	5	5	5	5	5	5	7	7	7	7
5	5	5	5	5	5	5	5	5	5	5	7	7	7	7	7
6	5	4	5	5	5	5	5	5	5	5	7	7	7	7	7
7	5	5	5	5	5	5	5	5	5	5	7	7	7	7	7
8	5	5	5	5	5	5	5	5	5	5	7	7	7	7	7
9	5	5	5	5	5	5	5	5	5	5	7	7	7	7	7
Exp. 12	Treatment Phi										Treatment Gamma				
1	7	5	5	5	5	5	5	5	5	5	7	7	7	7	7
2	3	4	5	5	5	5	5	5	5	5	7	7	7	7	7
3	3	4	5	5	5	5	5	5	5	5	6	7	7	7	7
4	4	4	4	5	5	5	5	5	5	5	5	7	7	7	7
5	5	5	5	5	5	5	5	5	5	5	7	7	7	7	7
6	4	5	5	5	5	5	5	5	5	5	7	7	7	7	7
7	6	5	5	5	5	5	5	5	5	5	6	7	7	7	7
8	7	5	5	5	5	5	5	5	5	5	7	7	7	7	7
9	6	5	5	5	5	5	5	5	5	5	7	7	7	7	7

Appendix C Instructions

This is an experiment in the economics of market decision making. The instructions are simple. If you follow them closely and make appropriate decisions, you may make an appreciable amount of money. These earnings will be paid to you, in cash, at the end of the experiment.

In this experiment you will participate in a market of nine people. There will be a number of market periods. In each period every participant will pick a value of X. The values of X you may choose are 1, 2, 3, 4, 5, 6, 7. The value you pick for X and the median value of X chosen will determine the payoff you receive for that period.

(The median choice is determined as follows. The choices made by the nine participants will be ordered from smallest to largest in numerical order. The median choice is the fifth from the bottom or the fifth from the top of the ordered choices. For example, to find the median of the nine numbers 33, 30, 30, 27, 34, 32, 34, 29, 32, arrange the numbers in ascending order—27, 29, 30, 30, 32, 32, 33, 34, 34—find the fifth choice counting either from the first number forward or the last number back of the ordered choices and that is the median value. In this example the median choice is 32.)

You are provided with a table that tells you the potential payoffs you may receive. Please look at the table now. The earnings in each period may be found by looking across from the value you choose on the left-hand side of the table and down from the median value chosen from the top of the table. For example, if you choose a 4 and the median value chosen is a 3, you earn 85 cents that period.

At the beginning of every period, each participant will write on a reporting sheet their participant number and the value of X they have chosen and hand it in to the experimenter. The median value of X chosen will be announced, and each participant will then figure out their earnings for that period.

If you will now look at your record sheet, you will see the following entries: BALANCE, YOUR CHOICE OF X, MEDIAN VALUE OF X CHOSEN, and YOUR EARNINGS. In the first period your BALANCE is \$2. In the second period your BALANCE is the value of your earnings in the first period plus the \$2 beginning balance. In the third period your BALANCE is the value of your BALANCE in the second period plus the value of your earnings in the second period. Please keep accurate records throughout the experiment.

To be sure that everyone understands the instructions, please fill out the sheet labeled questions and turn it in to the experimenter. *DO NOT PUT YOUR NAME OR PARTICIPANT NUMBER ON THE QUESTION SHEET.* If there are any mistakes on the question sheet, the experimenter will go over the instructions again.

IF YOU HAVE ANY QUESTIONS, PLEASE ASK THEM AT THIS TIME.

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