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INFORMATION CASCADES: REPLICATION AND AN EXTENSION TO MAJORITY RULE AND CONFORMITY REWARDING INSTITUTIONS

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Abstract

In a randomly determined order, each agent was given an independent, private signal about which of two states was selected by a random draw. After receiving the private signal each agent made a publicly announced decision about the state. Thus, at the time of personal decision each agent had a private signal and also knew the decisions of all preceding agents. The experiments focused on three different types

of organization. (1) Agents were rewarded according to whether their announced decision was right or wrong. This "individualistic institution" is the one studied by Anderson and Holt (AER, 1997). Their discovery of information cascades is replicated. (2) Agents were rewarded according to whether a majority of announced decisions were right or wrong. Under this "majority rule institution" the instance of information cascades is sharply reduced. (3) Agents are rewarded more according to whether their personal announced decision was the same as the majority decision than they were rewarded if their decision was correct. This "conformity rewarding institution" is motivated by proceedings in which there is incentive to produce reports that conform to the reports of others. Substantial information cascades are observed.

Information Cascades: Replication and an Extension to Majority Rule and Conformity Rewarding Institutions

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1 Introduction

This paper contributes to a discussion about the ability of decision processes to aggregate information that is distributed across different agents. The literature reflects an attempt to understand how different institutions and different incentives influence information production and use. The quality of information production and use can be viewed from two different perspectives. First, is the point of view of an individual who is making a decision and living with the consequences. The second is the view of an outsider

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who is making inferences about the underlying state based on the pattern of individual decisions and the other observable properties of the system. The analysis uses both perspectives.

In all environments studied here each agent was given an independent, private signal about which of two states had been chosen by a random draw. After receiving the private signal each agent was called upon according to a randomly determined sequence to announce a decision about the state. That is, the individual's decision was publicly announced before a decision was made by the succeeding individual. The decision of an individual was not necessarily a report of the individual's private information, but instead was an announcement that would have an influence on the individual's payoff. Thus, at the time of personal decision each agent had a private signal and also knew the decisions of all preceding agents. The agent was aware of the rules that governed the relationships among announced decisions and individual payoffs.

The experiments focused on three different types of institutions consisting of different rules and organization. (1) Agents were rewarded according to whether their announced decision was right or wrong. This organization is the "individualistic institution" studied by Anderson and Holt (1997).

(2) Agents were rewarded according to whether a majority of announced decisions were right or wrong under the "majority rule institution." (3) Agents are rewarded more according to whether their personal announced decision was the same as the majority decision than they were rewarded for a correct decision under the "conformity rewarding institution."

The paper poses three fundamental questions. First, do the results of Anderson and Holt (1997) replicate? The second question is related to the organization of the decision process, the rules that are in place governing individual rewards and incentives. Do the rules make a difference? Third, can the influence of the organization be detected in models of individual decisions? While a complete model of the individual agent decision is not developed, several incomplete models are employed to facilitate an answer to this question.

First, the Anderson and Holt observation that information cascades will occur in particular environments is strongly upheld by the experiments we report[2]. When the individual's payoff is determined by his/her own announced decisions then individuals tend to treat their private signal as irrel-

[2]The Anderson and Holt results have also been replicated by Wilinger and Ziegelmeyer (1997).

evant and follow the trend of their predecessors, if a clear pattern is present. In this sense the results reported here are consistent with a long history that has many roots in psychology[3]. Second, we find that relative to the individualistic institution studied by Anderson and Holt, the predominance of information cascades sharply decreases with the change in institution to a majority rule process. The data reported here are consistent with the data from experiments of majority rule jury decisions studied by McKelvey and Palfrey (1998). Furthermore, the tendency to cascade increases when the conformity rewarding institution is implemented. Finally, following Grether (1980), we begin to explore the quantitative effects of changes in institution on the nature of individual decisions. While the model we explore is clearly incomplete, it provides a framework within which individual decisions are understandable.

The paper is divided into seven sections plus an appendix. Section 2 discusses the institutions. Section 3 is the experimental design. Section 4 is an outline of measures of information production. This is the information that participants in the process and an outside observer of the process might infer

[3]A good introduction to the way psychologists have studied this problem is contained in Aronson, et. al. (1997).

from behavior. Section 5 are measures that reflect on how individuals use information. While we have no complete theory of individual behavior, this section develops a model that facilitates interpretations. Section 6 summarizes models of individual announcements. Section 7 summarizes the results, and Section 8 concludes.

2 Institutions: The Rules and Procedures

The study of rules and procedures initiates an investigation of the relationships among incentives, the technology of communication and the information producing properties of decision making systems. In all of the systems explored here the technology of communication is the same. It is sequential in the sense that the individuals make their announced decisions in a randomly determined order and at the time of the decision they have private information in addition to the public announcements of all who went before them. They also know that all decision makers operate under the same conditions. Thus, by changing the rules while maintaining the communications technology, we are able to gain insights about the relationship between information derived from the behavior of others, incentives and private information.

2.1 The Individualistic Institution

The first set of rules which we call the "individualistic institution," are those studied by Anderson and Holt. When individuals make decisions they have their own private information plus the information contained in the decisions of those who made decisions in the past. Furthermore, aside from information (externality) issues, the effects of an individual's decisions are confined to the individual who makes the decision. Examples include models of job search, financial markets, fads, and herd behavior (see Bikhchandani, et al. (1998) for an overview of applications). The basic question is whether all of the relevant information available was contained in the decisions with economic consequences or were people mislead in a cascading manner.

2.2 The Majority Rule Institution

The second set of rules is the collective decision rule of majority rule. The frequency with which majority rule is used to make important decisions makes it a natural candidate for study. In this case the effects of an individual's announced decision are not confined to the individual. The individual announced decisions become votes which tie the consequences of individuals together in the sense that all individuals must abide by the same decision

and that is the decision of a majority. Individuals are given the latitude of how they vote in the context of this group decision but they cannot make independent payoff relevant decisions apart from the vote. The study of majority rule has theoretical interest. In particular it is non manipulable so there is a presumption that the "best information" will be produced.

2.3 Conformity Rewarding Institution

The third rule is a rule in which there are special incentives to conform to the decision of a majority. These are "conformity rewarding" incentives. In this environment individuals have an incentive to be right but they have a bigger incentive to not deviate from the decisions of others.

Pressures to conform to group behaviors have been widely discussed for many decades. For example, the early literature on cascades was viewed as a study of conformity resulting from the nature of groups and social interaction (Asch, 1958). In addition, groups are viewed as "punishing" deviates thereby providing private incentives for individuals to conform to the patterns of behavior of others in the group (Schachter, 1951). Indeed, political processes and perhaps even managements are sometimes viewed has generating distrust or lack of confidence in those whose opinions and voting patterns are different

from those of the majority. In this context the use of grand jury procedures is of special interest because of the possibility of charges of perjury that can result from testimony that differs from the testimony of others. In all such cases the truth may never be known but instead is assumed to be captured by the announcements of a majority. Thus, personal rewards and punishments are closely tied to consistency with the decisions and recorded opinions of others, independent of whether such decisions and opinions are closely tied to the truth.

3 Experimental Design

Four experiments were conducted in the Laboratory for Experimental Economics and Political Science at Caltech. Each experiment had 10 Caltech undergraduates as subjects. The experiments consisted of 28-55 periods and lasted for about one and a half hours. The procedures described below were adapted from those used by Anderson and Holt (1997). Some changes reflect employment of computers. The nature of incentives were changed to save money. The four experiments are summarized in Table 1.

Experiment 1 most closely resembles the experiments of Anderson and

Holt (1997). In experiment 1, the urn that was to be used each period was randomly predetermined. Urn A contained two RED balls and one WHITE ball, and urn B contained two WHITE balls and one RED ball. Each period, the contents of the chosen urn were emptied into an unmarked container. Subjects were then approached in a random order by the experimenter and would make one private draw, with replacement. After seeing the draw, the subject was asked to record the color of the draw and his decision on a record sheet. The experimenter then announced the decision, and all the subjects would record this decision on their record sheets. The process was repeated until all subjects had made decisions, at which time the actual urn used was announced. Subjects were asked to record their earnings: \$2 if their decision was correct, and \$0 otherwise. Experiment 1 consisted of 28 periods.

In experiment 2, the procedure was the same, except that subjects interacted with computer terminals rather than the experimenter. A subject is "approached" by the computer and given a draw by an announcement of "Your draw is WHITE" or "Your draw is RED." After seeing the draw, subjects were then asked to enter their decision into a box on the screen. All the subjects would then see this decision on their screens. As before, subjects were asked to record their draws, their own decisions, and the deci-

sions of others on a record sheet. This process was repeated until all subjects had made decisions, at which time the actual urn used would appear on the subjects' screens. In periods 1-10 and 26-36, the "individualistic" periods, subjects would also see their payoff on the screen, $2 for a correct decision, and -$2 otherwise. In periods 11-25, the "majority" periods, subjects would see the "group decision" as well as their payoff on the screen. The group decision was determined by majority rule, with ties broken randomly. Subjects were paid $2 for a correct group decision, and -$2 for an incorrect decision, regardless of their own decision.

Experiment 3 differed from experiment 2 in that periods 1-10 and 26-38 were "majority" periods, and periods 11-25 were "individualistic" periods, and in that subjects were paid $1 for a correct decision or correct group decision, and -$1 otherwise.

In experiment 4, we introduce the "conformity rewarding" institution. In these rounds, the payoff to a subject is determined by his whether her private decision is correct, and also if her private decision matches the group decision, where once again, the group decision is determined by majority rule. Subjects are paid $0.25 for a correct private decision and -$0.25 for an incorrect decision, and they are paid $0.75 for a private decision that matches

the group decision and -$0.75 for a private decision that does not match the group decision.

4 Three Measures of System Performance

The literature seems to assume that cascades indicate poor information production and use within the system, which leads to poor system performance. However, this assumption is not entirely correct. Cascade behavior can result in better decisions because it does involve aspects of information aggregation. Thus in order to assess such possibilities, we explore two related measures of systemic performance in addition to the traditional measure of cascades : the efficiency of systemic decisions and the quality of information production.

4.1 Traditional Information Cascades

Our initial interest in studying information production was the study of the phenomena of cascades. The consensus in the literature is that a cascade is defined by a sequence of individuals whose decisions do not depend on their private information (see Smith and Sorenson, 1997 or Bikchandani et al., 1998). Following Anderson and Holt, we add the additional stipulation (that

is usually implicit in the definition) that a cascade is defined by an established pattern of decisions together with the presence of subsequent decisions that are consistent with this pattern, but inconsistent with the private draws.

4.2 Efficiency of Systemic Decisions

Systemic efficiency is the degree to which actual systemic decisions coincide with the decisions that would result if all underlying information available to the system (in the form of private signals) was made publicly available at the time of decisions.

The subjects' actual decisions are compared with the fully informed decision, the decision that they would have made (assuming that they are rational, expected payoff maximizers) if they had known the information in the system, the entire sequence of true signals. Clearly, for the individualistic and conformity rewarding institutions, the systemic decision is the vector of the individuals' announcements. However, for the majority rule institution the individual announcements are, in effect, votes that determine the unique systemic decision. The quality of systemic decision is measured each period as the proportion of the systemic decisions that match the fully informed decision.

Let a_{ij} be individual i's announcement in period j. The systemic decision, sd_j, is a function of the vector of the individual's announcements, where the function depends on the institution:

$$sd_j = G(a_{1j}, ...a_{10j})$$

Under the individualistic and conformity rewarding institutions,

$$sd_j = G(a_{1j}, ...a_{10j}) = (a_{1j}, ...a_{10j})$$

and under the majority rule institution,

$$sd_j = G(a_{1j}, ...a_{10j}) = \begin{cases} (A, A, ...A) \text{ if } \sum_{i=1}^{10} 1\{a_{ij} = A\} > 5 \\ (B, B, ...B) \text{ if } \sum_{i=1}^{10} 1\{a_{ij} = A\} < 5 \\ (\frac{1}{2}A + \frac{1}{2}B, \frac{1}{2}A + \frac{1}{2}B, ...\frac{1}{2}A + \frac{1}{2}B) \text{ else} \end{cases}$$

where $1\{\bullet\}$ is the indicator function. Then we can define the efficiency of systemic decisions in period j as:

$$(\textit{efficiency of } sd)_j = \frac{\sum_{i=1}^{10} 1\{sd_{ij} = fd_j\}}{10}$$

where sd_{ij} is individual i's systemic decision in period j and fd_j is the fully informed decision of period j.

4.3 Quality of Information Production

Another measure of system performance is the amount of the underlying information of the system that is exposed to an outside observer. Consider an observer who is outside of the decision process and from only the announcements of the subjects must make inferences about the true state of the world. A variety of such measures exists depending upon the behavior of the individuals assumed by the outside observer's inference process. The measure used here assumes that the individual's announcement reflects the state of the world that he thinks is most likely. The outside observer's posterior probabilities of the true state are compared with those of an observer who can observe all the private signals. The quality of information production is measured using the absolute difference between the posterior probabilities of an outside observer who observes only the entire sequence of announcements and the posterior probabilities of an outside observer who observes the entire sequence of private signals:

$$(quality\ of\ ip)_j = 1 - |\Pr(A|a_{1j}, ...a_{10j}) - \Pr(A|d_{1j}, ...d_{10j})|$$

where $a_{1j}, ...a_{10j}$ is the sequence of announcements in period j and $d_{1j}, ...d_{10j}$ is the sequence of private draws in period j. As the absolute difference

decreases, the quality of information production increases. Therefore, the best quality of information production has a quality of one, and the worst has a quality of zero.

5 A measure of individual use of information

While the focus of the study is on institutions and the effects of the institutions, as opposed to individual behavior, one way to capture that effect is in terms of the individual. Thus, even though we might not have a good understanding of exactly why individuals behave as they do, certain models will help us detect when they are behaving differently and how their behavior differs under different institutions.

Before announcing an urn, a subject has two sources of information: her private draw, and the announcements of those who preceded her. The General Decision-Weight model is constructed on the premise that a subject's announcement is based on these two sources. Given a pattern of announcements, the model allocates weight that a subject places on her public information (the preceding announcements) relative to the weight that she places on her private information in making her announcement.

Let A be the event that urn A is the true urn, and B be the event that urn B is the true urn. The relative odds in favor of A can be expressed as: $\frac{P(A)}{1-P(A)} = \frac{P(A)}{P(B)}$.

Clearly, the odds depend on the information available. Let $x_{it} = (a_{it}, d_{it})$ be the information that individual i has at position t. Let a_{it} denote the announcements that individual i has heard at position t, and let d_{it} denote the private draw of individual i at position t. For a Bayesian individual i who makes his decision at position t:

$$\frac{P(A|x_{it})}{P(B|x_{it})} = \frac{P(x_{it}|A)P(A)/P(x_{it})}{P(x_{it}|B)P(B)/P(x_{it})} = \frac{P(x_{it}|A)P(A)}{P(x_{it}|B)P(B)}$$

If a_{it} and d_{it} are independent (conditional on a given urn), then the individual's subjective posterior odds in favor of urn A are given as:

$$\frac{P(A|x_{it})}{P(B|x_{it})} = \frac{P(x_{it}|A)P(A)}{P(x_{it}|B)P(B)} = \frac{P(a_{it}|A)}{P(a_{it}|B)}\frac{P(d_{it}|A)}{P(d_{it}|B)}\frac{P(A)}{P(B)}$$

Now taking logs, we find

$$\ln\left[\frac{P(A|x_{it})}{P(B|x_{it})}\right] = \ln\frac{P(a_{it}|A)}{P(a_{it}|B)} + \ln\frac{P(d_{it}|A)}{P(d_{it}|B)} + \ln\frac{P(A)}{P(B)}$$

which can be generalized to:

$$Y_{it} = \alpha + \beta\ln\left[\frac{P(a_{it}|A)}{P(a_{it}|B)}\right] + \gamma\ln\left[\frac{P(d_{it}|A)}{P(d_{it}|B)}\right] + \delta\ln\left[\frac{P(A)}{P(B)}\right] + u_{it}$$

where $Y_{it} = \ln\left[\frac{P(A|x_{it})}{P(B|x_{it})}\right]$; α, β, γ, and δ are unknown scalars; and u_{it} is a random disturbance.

We do not observe the subjective log odds Y_{it}. If we assume that the individual chooses the urn believed to be most likely, we observe the discrete variable Y_{it}^*, which equals one if Y_{it} is positive ("A" is announced), and zero otherwise. The parameters of this binary response model may be estimated by maximum likelihood under distributional assumptions on u_{it}, given that the matrix of independent variables is of full rank. However, because the prior odds are fixed throughout the experiment, δ is not identified. Note that $\ln\left[\frac{P(A)}{P(B)}\right] = 0$; therefore, this term drops out and the intercept can be identified separately. We can rewrite the model as:

$$Y_{it} = \alpha + \beta \ln\left[\frac{P(a_{it}|A)}{P(a_{it}|B)}\right] + \gamma \ln\left[\frac{P(d_{it}|A)}{P(d_{it}|B)}\right] + u_{it} \qquad (1)$$

For the "private information" variable, the variable associated with the coefficient γ, we assume that subjects are Bayesian. That is, if $d_{it} = R$, then $\ln\left[\frac{P(d_{it}|A)}{P(d_{it}|B)}\right] = \ln\left[\frac{\frac{2}{3}}{\frac{1}{3}}\right] = \ln 2$ and if $d_{it} = W$, then $\ln\left[\frac{P(d_{it}|A)}{P(d_{it}|B)}\right] = \ln\left[\frac{\frac{1}{3}}{\frac{2}{3}}\right] = -\ln 2$.

The "public information" variable is calculated using the following formula: if n_{it} is the number of "urn A" announcements and m_{it} is the number of "urn B" announcements that individual i has heard when he is called upon

to make his report his decision at position t, then $\ln\left[\frac{P(a_{it}|A)}{P(a_{it}|B)}\right] = \ln\left[\frac{2^{n_{it}}}{2^{m_{it}}}\right] = (n_{it} - m_{it})\ln 2$.

Grether (1980) used this model to study Bayesian updating in a similar experimental setting. Following Grether (1980), we estimate a logit model under the assumption that the disturbances u_{it} are identically and independently distributed logistic with mean zero. Without further assumptions on this distribution, the parameters α, β, γ are identified only up to an unknown scale. However, identification up to an unknown scale is sufficient for our analysis.

We define the Equal Decision-weight model as a special case of this model with $\alpha = 0, \beta = \gamma = \delta$ and $u_{it} = 0$ for all i, t. If the individual weighs public information more than private information, then $\frac{\beta}{\gamma} > 1$; and if the individual weighs private information more than public information, then $\frac{\beta}{\gamma} < 1$.

6 Models of Individual Announcements

Even though the environment is not particularly complex we were unable to solve and apply a complete model from game theory. For example, we attempted to model and solve this as an extensive form game without success.

We also attempted to solve the Quantal Response model (McKelvey and Palfrey, 1995), but were unsuccessful. We are left with only simple and partial models with which to understand the behavior that is taking place.

Four models follow naturally from the literature. The first two we call "rules of thumb" because they are non-Bayesian and non-strategic. A third model is that of a naive Bayesian. While we do not have a strategic model, we can provide as a fourth "model" some observations about elements of strategic behavior.

These models serve two functions. The first is to capture important elements of individual behavior. The second is the relate behavior to institutional context so that the influence of institutions can be detailed. Table 2 summarizes the predictions for all the models. The third column gives predictions for β and γ, the weights placed on public and private information available, respectively. Columns four through seven rank the predicted prevalence of cascades and both components of quality.

6.1 Private information Revealer

According to the first rule of thumb, everyone behaves as a pure "signal revealer." That is, everyone's announcement perfectly matches his private

draw. The individual ignores the public information available in making his decision.

At an individual level, we would expect to see that individuals are placing little weight on the public information available, because their decision is based purely on the private information. In terms of the general decision weight model, if subjects are acting as private information revealers, we would expect to find that β is not significantly different from zero, as seen in Table 2. At an aggregate level, there would be no cascades. Quality of information production would be high for all institutions. Efficiency of systemic decisions would be low for the individualistic and conformity rewarding institutions and high for the majority rule institution. Moreover, the institutional context would have no influence.

6.2 Public information Revealer

The second rule of thumb is a rule in which the announcement of a subject other than the first person perfectly matches the public information available at the time. The individual, therefore, disregards her private information in making her decision. At an individual level, we would expect to see little weight being put on private information; that is, we would expect to find that

γ is not significantly different from zero. At the aggregate level, we would expect to see cascade behavior every round. The additional measures of systemic performance would be low if individuals acted as public information revealers. As was the case with the other rule of thumb, the institutional context should have no impact on behavior.

6.3 Naive Bayesians

Consider a model of behavior in which the subjects are "naive Bayesians" in the sense that the subjects take into account both private and public information in making their announcements, but this is not common knowledge. This seems to be the primary model used in the literature. An individual believes that the announcements that he has heard perfectly match the private draws of his predecessors. That is, the individual believes that his predecessors have chosen according to their private information alone, without regard to the announcements they have heard. However, his own decision is based solely on his posterior subjective probabilities that are updated every period using Bayes' Law, taking into account both private and public information. These individuals act according to the Equal Decision-Weight model: they place equal weight on public and private information. If the subjects act as

naive Bayesians, then the hypothesis that $\beta = \gamma$ can not be rejected.

At the aggregate level, we would expect to see cascades: as soon as there is an imbalance of public announcements, a cascade will start. For all the institutions, quality of information production would be lower than the quality that would result if subjects were private information revealers, but higher than the quality that would result if they were public information revealers. The efficiency of systemic decisions would be higher than the qualities that result from the public information revealers. Furthermore, under the individualistic and conformity rewarding institutions, the efficiency of systemic decisions would be higher than that of the private information revealers.

Notice that this model has a clear consequence. As with the rules of thumb, individual announcements will not change with the institution. According to the model, individuals believe that other individuals have accurately reported their observations but in making a personal report the individual announces her belief about the most likely state with all the information integrated. Thus the individual is naive about the behavior of others and in developing the consequences of her announcement.

6.4 Strategic Players

The fourth "model" is a collection of properties. Consider subjects who are strategic: they respond to their incentives, they take into account both public and private information before making their announcements, there is a non-zero probability that they may make errors and they believe that other subjects behave the same way.

In the individualistic institution, subjects place more weight on private than on public information for two reasons. First, there is some probability that previous announcements reflect some error. Second, because other subjects are acting strategically as well, the announcements do not perfectly reveal private signals. In fact, they realize that once a cascade has started, subsequent announcements which follow the cascade reveal no new information. For strategic players in the individualistic institution, the hypothesis that $\frac{\beta}{\gamma} < 1$ can not be rejected. Cascade behavior would be apparent, but less prevalent than if the subjects were naive Bayesians. Efficiency of systemic decisions and quality of information production would be higher than the measures that would result if players were Naive Bayesians.

The majority rule mechanism, as mentioned above, is an incentive compatible mechanism. In the context of a majority rule decision making system,

given a belief that others are doing the same, it is in the subjects' best interest to announce the state of the world reflected by their private information alone[4]. Therefore, strategic players should act as private information revealers in the majority rule case.

Given the belief that others are behaving the same, a strategic player in the conformity rewarding institution should consider the majority winner of the announcements that precede him. This should then be his announcement. Strategic players in the conformity rewarding institution should therefore act as public information revealers.

7 Results

7.1 Data Examples

Consider some examples of periods from the actual experiments. The columns represent the order in which individuals saw their draws and made their announcements. The first row is the private draw of the individual. It was either a Red ball (which suggests urn A) or a White ball (which suggests urn

[4]For a theoretical proof of existence of this equilibrium under a majority rule institution with sequential voting, see Dekel and Piccione (1997) or Fey (1998).

B). The private draws are recoded as A or B, accordingly, to facilitate the analysis. The second row gives the announcements of the individuals. The relative odds of urn A given the private draw are given in row three. Row four gives the relative odds of urn A given the announcements heard up to that point, assuming that all previous announcements perfectly reveal the private signal.

In experiment 1, period 10, in which the individualistic institution was in effect, each subject's announcement perfectly revealed his signal except the subject who made the eighth announcement. His announcement reflects cascades behavior: his announcement is inconsistent with his private draw, but consistent with the majority of the preceding announcements. Note that period 10 is only a partial cascade because of the subject who made the fourth announcement. Even though she has heard a predominance of "B" announcements, she chooses to follow her private information.

Both measures of system performance are high in this period. In this period, the fully informed decision is "B". Therefore, the efficiency of systemic decisions, the proportion of decisions that match the fully informed decision is 0.8. Furthermore, the measure of the quality of information production is 0.96.

Subjects do not act as either private nor public information revealers in this period. The behavior seen here is consistent with both the naive Bayesian and the strategic player models.

Individualistic Institution, Experiment 1, Period 10

	1	2	3	4	5	6	7	8	9	10	actual	cascade?
draw	a	b	b	a	b	b	b	a	b	b		
announcement	A	B	B	A	B	B	B	B	B	B	B	partial
$\frac{\Pr(A\|d_t)}{\Pr(B\|d_t)}$	2	$\frac{1}{2}$	$\frac{1}{2}$	2	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	2	$\frac{1}{2}$	$\frac{1}{2}$		
$\frac{\Pr(A\|a_t)}{\Pr(B\|a_t)}$	1	2	1	$\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$		

a_t = announcements that have been made by position t, d_t = private draw at position t

In experiment 3, period 30 in which the majority rule institution is in place, we see no cascades. Every subject's announcement perfectly matches her private draw. In this case, both components of quality attain the maximum possible value. The efficiency of systemic decisions is 1.0, and the measure of quality of information production is 1.0.

Behavior this period is consistent with both the private information revealer and strategic player models of behavior.

Majority Rule Institution, Experiment 3, Period 30

	1	2	3	4	5	6	7	8	9	10	actual	cascade?
draw	a	a	a	a	a	b	a	a	a	b		
announcement	A	A	A	A	A	B	A	A	A	B	A	no
$\frac{\Pr(A\|d_t)}{\Pr(B\|d_t)}$	2	2	2	2	2	$\frac{1}{2}$	2	2	2	$\frac{1}{2}$		
$\frac{\Pr(A\|a_t)}{\Pr(B\|a_t)}$	1	2	4	8	16	32	16	32	64	128		

a_t = announcements that have been made by position t, d_t = private draw at position t

In experiment 4, period 10, in which the conformity rewarding institution is in place, we see dramatic cascade behavior. All but three of the announcements are inconsistent with the private draw. Both components of information quality are low. The efficiency of systemic decisions is 0.3. The measure of the quality of information production is 0.06. Lastly, the observed behavior is consistent with the public information revealer and strategic player models of behavior.

Conformity Rewarding Institution, Experiment 4, Period 10

	1	2	3	4	5	6	7	8	9	10	actual	cascade?
draw	a	b	b	b	a	b	b	b	a	b		
announcement	A	A	A	A	A	A	A	A	A	A	B	yes
$\frac{\Pr(A\|d_t)}{\Pr(B\|d_t)}$	2	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	2	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	2	$\frac{1}{2}$		
$\frac{\Pr(A\|a_t)}{\Pr(B\|a_t)}$	1	2	4	8	16	32	64	128	256	512		

a_t = announcements that have been made by position t, d_t = private draw at position t

7.2 Statements of Results

The cascade phenomenon described by Anderson and Holt is replicated in these experiments. A prevalence of cascade behavior is observed in the periods in which the individualistic institution is in place. As summarized by the following result, the phenomenon is observed even though different subject pools, instructions, and procedures are in place.

Result 1 The Anderson and Holt results are replicated for the individualistic institution. Furthermore, their results are robust to changes in payoffs and experimental settings.

Support In 77.5% of individualistic institution rounds, we observe cascade behavior; that is we see reports that are inconsistent with the private

draw, but are consistent with a pattern established by the predecessors.[5]

Of course it is important to make sure that a fundamental bias is not the explanation for the observation of cascades. Estimation of the General Decision-Weight Model can reveal the occurrence of a bias toward one urn or the other. Table 3 presents the results of estimation of the General Decision-Weight Model (Equation 1). We do not find any bias toward one urn or the other.

Result 2 The cascade phenomena is not due to an urn bias.

Support We find that, in equation 1, $H_0 : \alpha = 0$ cannot be rejected at any reasonable significance level (See Table 4).

The next result establishes that behavior responds to institutions. In particular, using the measure of individual behavior, we rule out the simple models of behavior: the private information revealer and public information

[5]Note that in reporting the proportion of cascades, Anderson and Holt begin by eliminating rounds in which there is not "an imbalance of previous inferred signals." However, in reporting our results, we include all rounds, not just rounds in which an "imbalance" occurs.

revealer rules of thumb, and the Equal Decision-Weight Model. This result acquires additional significance in light of the fact that the instructions could be interpreted as having an institutional-neutrality bias.[6]

Result 3 Individuals do not behave as private information revealers nor as public information revealers. Furthermore, we can reject the Equal Decision-Weight Model as a statistical representation of the data for the individualistic and majority rule institutions

Support Tables 5-7 present the p-levels for the following hypotheses, respectively: individuals are private information revealers ($H_0 : \beta = 0$), individuals are public information revealers ($H_0 : \gamma = 0$), and individuals act according to the Equal Decision-Weight Model ($H_0 : \beta = \gamma$).

We reject the private information revealer rule of thumb: the hypothesis $\beta = 0$ can be rejected at the 1% significance level for the individualistic and majority rule institutions, and can be rejected at the 5% significance level for the conformity rewarding institution (Table 5). Next we test the hypothesis that the individuals are public information revealers. Because the first mover every period has no public

[6]Constant across institutions were the instructions that subjects should try to guess the "urn that he or she thinks is more likely to have been used" (see Appendix).

information, and therefore, cannot be a public information revealer, we test $H_0 : \gamma = 0$ where γ is the estimate of the coefficient on private information for positions 2-10 only. We can reject the null at all reasonable levels of significance (Table 6). Lastly, we find that we can reject the hypothesis $H_0 : \beta = \gamma$ at all reasonable levels of significance for the individualistic and majority rule institutions, and therefore, we can reject the Equal Decision-Weight Model (Table 7).

We have shown that we can rule out some rules which predict that the institution does not matter. Now we turn our attention to the differences in behavior and information production that can be attributed to the change in institution. Table 8 summarizes Results 4-6.

Result 4 Institutions change the information production of the system and the use of information by the individual. In particular, behavior changes in the ways suggested by a theory of strategic agents:

1. Cascades observed can be ordered from least to most frequent depending on the institution that is in place: majority rule, individualistic, conformity rewarding

2. Individual expressions (decisions and votes) reflect private infor-

mation the most (in descending order): majority rule, individualistic, conformity rewarding.

3. The weight placed on publicly available information relative to the weight placed on privately available information increases as we change the institution from majority rule to the individual decision setting to the conformity rewarding rule.

Support For each of the above results, we find that:

1. 39% of majority rule rounds, 77.5% of individualistic institution rounds, and 96.7% of conformity rewarding rounds result in cascades or partial cascades.

2. 92% of announcements in majority rule rounds, 85% of announcements in individualistic institution rounds, and 64.7% of announcements in conformity rewarding rounds are signal-revealing.

3. Under majority rule, subjects place more than seven times as much weight on private information than on public information: $\frac{\beta}{\gamma} = 0.13$. Subjects place more than twice as much weight on private than on public information under the individualistic institution: $\frac{\beta}{\gamma} = 0.37$. Only under the conformity rewarding institution do

subjects place more weight on public than on private information: $\frac{\beta}{\gamma} = 1.24$

We now explore the additional measures of system performance. To measure the efficiency of systemic decisions, we calculate the proportion of decisions that coincide with the fully informed decision, the decision that an omniscient agent would make if he knew the entire sequence of signals. Periods in which the posteriors used in calculating the fully informed decision equal 0.5 were left out.

Result 5 We can rank the institutions in the order of highest to lowest efficiency of systemic decision: majority rule, individualistic, and conformity rewarding.

Support The means of the proportions of systemic decisions that match that of the omniscient agent for the individualistic majority rule, and conformity rewarding institutions, respectively, are 0.82, 0.94 and 0.74 (Table 8). In fact, with only two exceptions, the efficiency of systemic decision equals one under the majority rule institution. Under the individualistic institution, we see an increase in the number of proportions that fall below 0.5. Under the conformity rewarding institution, we

see that all the proportions lie at one extreme or the other: all observations are either greater than or equal to 0.8 or less than or equal to 0.1.

Consider the quality of information production. Figures 1-3 compare the posterior probabilities of urn A given the aggregate announcements with the posterior probabilities of urn A given the aggregate signals.

Result 6 The overall quality of public information is biased (ascending order): majority rule, individualistic, and conformity rewarding.

Support The average quality of information production is 0.98 under the majority rule institution (Table 8). This is not surprising given that 92% of the announcements are signal revealing. The average absolute difference between the posterior probabilities given the private signals and the posterior probabilities given the announcements under the individualistic institution is more than twice as large as under the majority rule institution, and is reflected by a quality of information production of 0.85. Lastly, under the conformity rewarding institution, the average absolute difference is twice that of the individualistic institution: 0.30, and therefore, the quality of information production is 0.70.

Figures 1-3 offers further support for this result. The posterior probabilities given the private signals is along the x-axis and the posterior probabilities given the announcements is along the y-axis. For a given round, if these probabilities are identical, then the data point associated with that period will lie on the 45 degree line. Under the majority rule institution, all but a few points lie directly on the 45 degree line. This occurs less frequently under the individualistic rare, and it is rare to see points on the 45 degree line under the conformity rewarding institution. We see that under the conformity rewarding institution, there are large discrepancies between the series of probabilities. While in the individualistic institution, we see large discrepancies in 9% of the periods, in the conformity rewarding institution, we find 20% of the periods have posteriors that differ by more than 0.5 points.

8 Conclusion

While keeping the technologies of communication constant, we examine the effects on information aggregation and production under three different institutions: the individualistic institution, which is that studied by Anderson

and Holt (1997), the majority rule institution, and the conformity-rewarding institution. The results of Anderson and Holt replicate (Result 1). In our experiments we observe the phenomena they report. The experiments reported here reflect a different subject pool, different procedures, computerized processes, different payoffs, and many other things. It follows that the Anderson and Holt discovery is robust to changes in these classes of variables.

In addition, we find marked changes in individual behavior and information production due to the change in institution. Individual decisions change as institutions change and the changes are understandable in terms of theory. In particular, majority rule is more "truth" revealing than either of the other institutions. Conformity rewarding procedures do produce conformity, but at the expense of data revealing choices (Result 4). The loss due to misjudgments about the state are highest under conformity rewarding institutions.

In terms of information production, an outside observer learns the most from observing a majority rule process and the least from a conformity rewarding process (Results 5 and 6). This supports the predicted inverse relationship between quality of information production and prevalence of cascades.

In examining individual behavior, the differences in behavior due to the institution follow the direction expected. The weight that individuals place on public information, relative to private information, in making decisions is highest under the conformity rewarding institution; indeed, this is the only institution under which public information is weighed more than private information. At the other extreme, under the majority rule institution, the least weight is put on the public information relative to the private information (Result 4).

Result 3 rules out simple rule of thumb models of behavior in which strategic behavior has no part. The results reported here suggest that individuals act strategically, and that individuals believe that others act strategically. Clearly, there is much work to be done in developing a model of how individuals use the public information, together with their private information, and their beliefs about the behavior of others to come to their decisions.

The pattern of results suggest two important messages. The first message is that patterns of conformity widely observed in social behavior can result from a deeper motivation than simply a "desire to conform." Decisions of others contain information that is important for incorporation with "own decisions." Notice that even though cascades exist, they are not overwhelm-

ingly inefficient. Indeed, "going along with the group" is not all bad. It reflects an element of wisdom. For example, under the individualistic institution the system efficiency would be 71.6% if all individuals made decisions according to their private information alone. If they were naive Bayesians the system efficiency would have been 83.1%. The actual efficiency was 81.7%. Thus, the naive Bayesian behavior, which produces substantial cascades also produces a substantial improvement in decisions from a social point of view. Interestingly enough, the fact that actual systemic efficiency falls short of that of naive Bayesians suggests that individuals do not pay enough attention to others.

The second message is that care must be taken in the design of collective decision process. The rules of the institution make a difference and that difference is understandable in terms of rational and strategic positions in which the rules place individuals.

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9 Appendices

9.1 Instructions

The following is the instructions from experiment 4. The instructions from experiments 1-3 are similar and can be obtained from

the authors.

This is an experiment in the economics of decision making. Various agencies have provided funds for the experiment. Your earnings will be paid to you privately, in cash, at the end of the experiment.

In this experiment you will be asked to predict from which randomly chosen urn a ball was drawn. It is equally likely that urn A or urn B will be drawn. Urn A contains 2 red balls, and 1 white ball. Urn B contains 1 red ball and 2 white balls.

To help you determine which urn has been selected, each person will be allowed to see one ball, chosen at random, from the urn. The result of this draw will be your private information and should not be shared with the other participants. After each draw, we will return the ball to the container before making the next private draw. Each person will have one private draw, with the ball being replaced after each draw. This is done on the computer. When it is your turn to see your draw, the upper right hand corner of your window will read. "Your draw is WHITE" if the ball the computer has randomly drawn for you is white, and "Your draw is RED" if the ball the computer has randomly drawn for you is red. The order in which you see your draw is randomly determined every period.

After each person has seen his or her draw, each subject will be asked to input the letter of the urn (A or B) that he or she thinks is more likely to have been used. The person who was chosen to see his draw first will input his letter in the box labeled "Input here." Everyone will then be able to see his choice in the last line of their windows. The second person will then see her draw, and will be asked to input the letter of the urn the she thinks is more likely, and everyone will be able to see her choice in the last line of their windows. This process will be repeated until all remaining people have made decisions. Finally we will inform everyone of the urn that was actually used.

Your earnings are determined as follows: if your decision matches the urn that was actually used then you earn \$0.25. Otherwise you lose \$0.25. In addition, if your decision matches the majority of the group's decisions, then you earn an additional \$0.75. Otherwise you lose an additional \$0.75. For example, if 7 people announce "urn A" and 3 people announce "urn B," then the group decision is "urn A." If you announce "urn B," and if the actual urn used is urn A, then you will earn -\$0.25+0.75 = -\$1.00. If you announce "urn A," and if the actual urn used is urn A, then you will earn \$0.25+0.75 = \$1.00. If you announce "urn B," and if the actual urn used is urn B, then

you will earn \$0.25-0.75 = -0.50. If you announce "urn A," and the actual urn used is urn B, then you will earn -\$0.25+0.75 = 0.50. In the case of a tie, the group decision will be randomly chosen: it is equally likely that the group decision will be A or B.

The experiment will consist of many periods. The results for each period should be recorded on a separate row on the decision sheet in front of you. The period numbers are listed on the left side of each row. Next to the period number is a blank that should be used to record the draw (RED or WHITE) when it appears in your window. Write R (for Red) or W (for White) in column (0) at the time the draw is made. The columns numbered (1) through (10) should be used to record the decisions of others as they appear on your screen. When you are asked to input the letter of an urn, you will be able to see the decisions, if any, that have been made previously by other participants. Write your decision in the column, (1) through (10), that corresponds to the order in which you have been approached, and circle your decision to distinguish it from others' decisions. When all participants have made their choices, the group decision will appear on your screen. Record this letter in column (11). Then the letter of the urn that was actually used will appear on your screen. Record this letter in column (12). Record you

payoff in column (13)

In addition, at the end of each round, everybody's choices will be recorded in the large area at the center of the window along with the actual urn used, your payoff for the round, and your cumulative payoff. Note that your choice will be capitalized. Always check to make sure that your information and payoffs on your decision sheet match those on your screen.

Before we begin the actual experiment, we will go through a demonstration period. We will demonstrate the process in which the actual urn is chosen, and the process by which the draws are made. Note that, in the actual experiment, the computer will choose the actual urn, as well as make the draws for each individual.

At this time, we will flip a coin. If the result if the coin flip is heads, then urn A will be used, and if the result of the coin flip is tails, then urn B will be used. We will now draw a ball for the first person to see. If this were not a demonstration period, then this person would record the color of the ball (R or W) in column (0), make a decision, and enter it in column (1), and circle it. Then everyone else would record this decision in column (1), but would not circle this decision since it is not your own.

Next, we will now draw a ball for the next person to see. If this were not

a demonstration period, this person would record the color of this ball (L or D) in column (0), make a decision (A or B), enter it in the appropriate column, and circle it. Then everyone else would record this decision in the appropriate column.

Are there any questions before we begin? Please do not talk with anyone during the experiment. We will insist that everyone remain silent until the end of the last period. If we observe you communicating with anyone during else during the experiment we will ask you to leave without completing the experiment.

It is very important that you do not open other windows or leave the page in front of you while the experiment is running.

Before we begin the actual periods, we will go through a practice period, for which you will not be paid.

After round 15, the following was read to the subjects:

That concludes the first part of the experiment. For the second part, the procedure is the same, but your payoff will be determined as follows: if your own decision matches the letter of the urn used, you will earn $1, otherwise, you will lose $1. For this part of the experiment, leave column (11) blank. At the end of each round, record the letter of the urn that was actually used

in column (12). If your decision matches this urn, then record $1 in column (13). Otherwise, record -$1.

9.2 Tables and Figures

Table 1: Experimental Design

Exp	Periods in which institution is in effect			Payoffs	Computer
	individualistic	majority	conformity		
1	1-28			$2, 0	No
2	1-10, 26-36	11-25		$2, -2	Yes
3	11-25	1-10, 26-38		$1, -1	Yes
4	16-30, 46-55		1-15, 31-45	$.75, -.75 / $.25, -.25	Yes

Table 2: Predictions of the Models of Behavior

Model	Institution	$\frac{\beta}{\gamma}$	Cascades	Eff of system	Qual of ip
			Rankings		
Private info	individualistic	$\beta = 0$	6	5	1
	majority rule	$\beta = 0$	6	1	1
	conf rewarding	$\beta = 0$	6	5	1
Public info	all	$\gamma = 0$	1	6	6
Naive Bayesian	all	$\frac{\beta}{\gamma} = 1$	3	4	4
Strategic	individualistic	$\frac{\beta}{\gamma} < 1$	4	3	3
	majority rule	$\frac{\beta}{\gamma} << 1$	5	2	2
	conf rewarding	$\frac{\beta}{\gamma} > 1$	2	5	5

Table 3: Logit Regression Estimates. Standard errors are in parentheses

		n	α	β	γ	Log-likelihood
individualistic	overall	890	0.062	1.142	3.046	-219.4749
			(.124)	(.088)	(.225)	
	exp1	280	0.011	0.904	3.382	-62.4918
			(.235)	(.131)	(.420)	
	exp2	210	-0.225	1.273	2.790	-54.8688
			(.251)	(.194)	(.452)	
	exp3	150	0.564	1.708	4.266	-24.603
			(.387)	(.358)	(.858)	
	exp4	250	0.155	1.149	2.794	-68.503
			(.220)	(.167)	(.385)	
majority rule	overall	380	-0.001	0.523	3.89	-88.1445
			(.212)	(.109)	(.342)	
	exp2	150	-0.112	0.624	3.139	-47.1357
			(.277)	(.161)	(.450)	
	exp3	230	0.250	0.457	4.793	-35.8739
			(.368)	(.162)	(.583)	
conformity rewarding	overall	300	-0.026	4.063	3.293	-26.1855
			(.359)	(.839)	(.742)	

Table 4: Test of urn bias

		p-level for $H_0 : \alpha = 0$
individualistic	overall	0.6187
	exp1	0.9614
	exp2	0.3705
	exp3	0.1449
	exp4	0.479

Table 5: Test of Private Information Revealer Rule of Thumb

		p-level for $H_0 : \beta = 0$
individualistic	overall	0.000
	exp1	0.000
	exp2	0.000
	exp3	0.000
	exp4	0.000
majority rule	overall	0.000
	exp2	0.000
	exp3	0.000
conformity rewarding	overall	0.011

Table 6: Test of Public Information Revealer Rule of Thumb

		p-level for $H_0 : \gamma = 0$
individualistic	overall	0.0000
	exp1	0.0000
	exp2	0.0000
	exp3	0.0000
	exp4	0.0000
majority rule	overall	0.0000
	exp2	0.0000
	exp3	0.0000
conformity rewarding	overall	0.0000

Table 7: Test of Equal-Decision Weight Model

		p-level for $H_0 : \beta = \gamma$
individualistic	overall	0.0000
	exp1	0.0000
	exp2	0.0000
	exp3	0.0000
	exp4	0.0000
majority rule	overall	0.0000
	exp2	0.0000
	exp3	0.0000
conformity rewarding	overall	0.1999

Table 8: Experimental Results: Occurence of information cascades and Measures of system performance

Institution	$\frac{\beta}{\gamma}$	Cascades	Eff of system	Qual of ip
		% occurence	Means	
individualistic	$\frac{\beta}{\gamma} = 0.3749$	77.5%	0.817	0.85
majority rule	$\frac{\beta}{\gamma} = 0.1344$	39%	0.943	0.98
conf rewarding	$\frac{\beta}{\gamma} = 1.2338$	96.7%	0.75	0.70

Figure 1: Comparison of Posterior Probabilities
Individualistic Institution

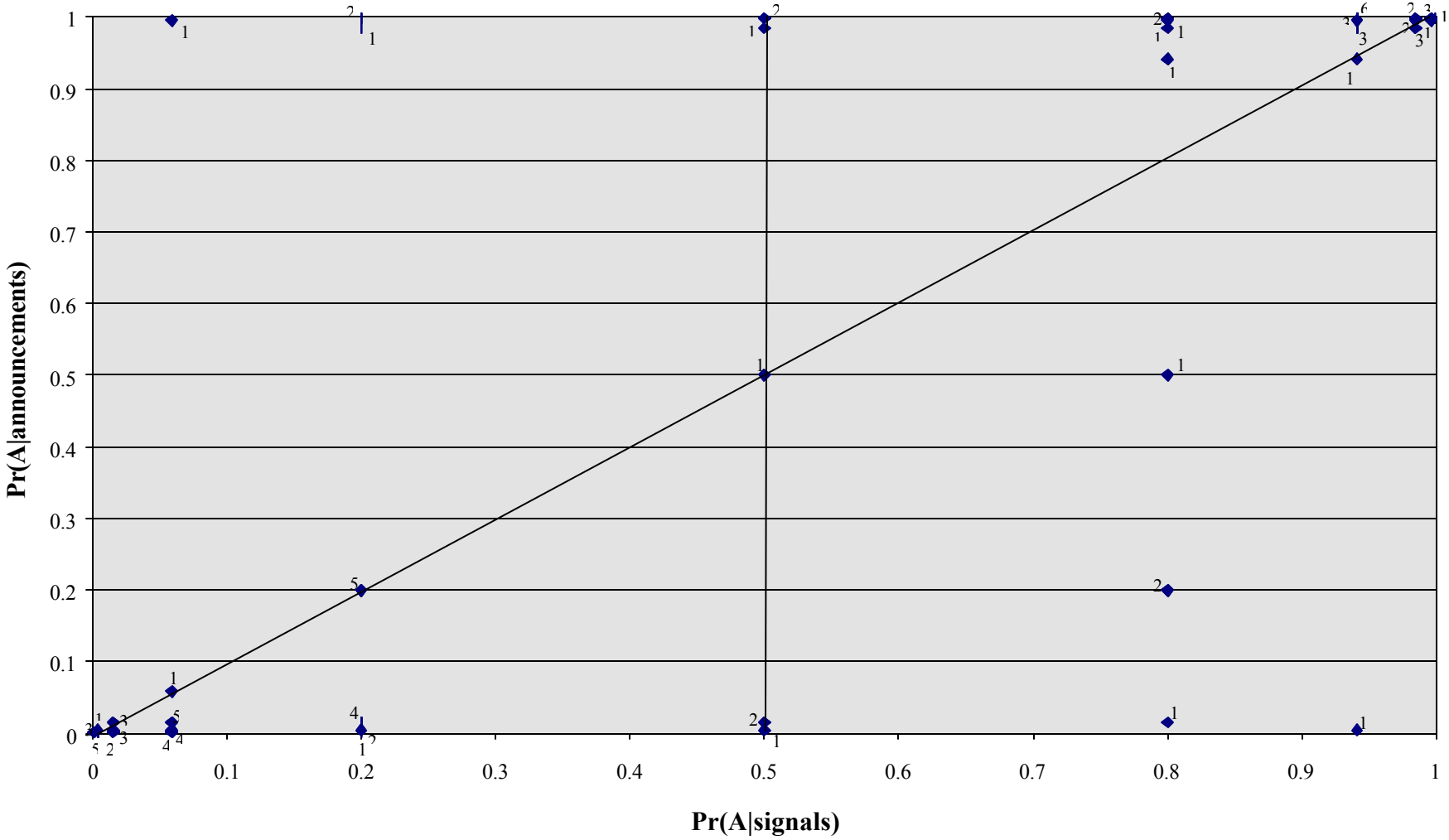

Figure 2: Comparison of Posterior Probabilities
Majority Rule Institution

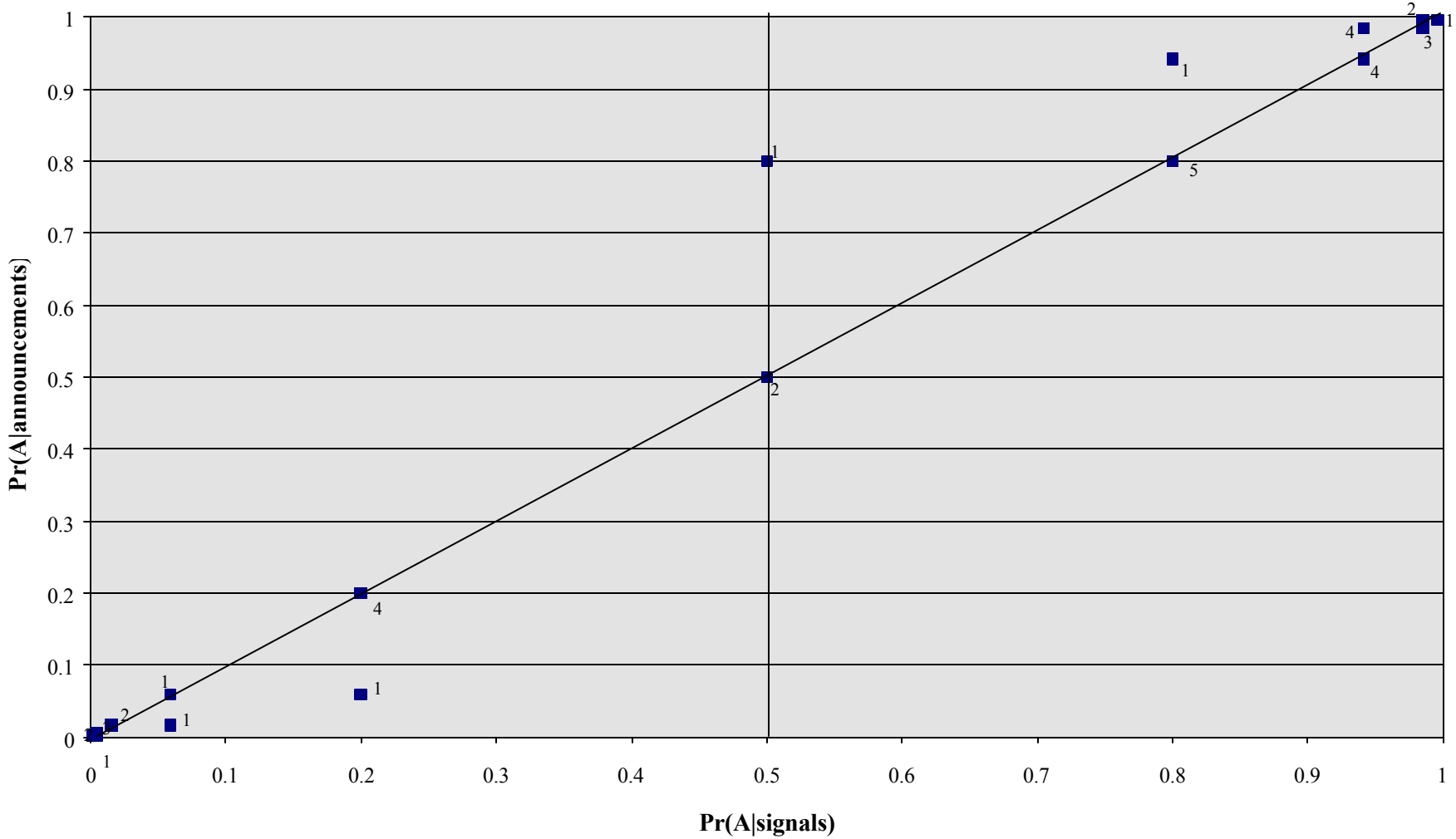

Figure 3: Comparison of Posterior Probabilities
Conformity Rewarding Institution