RULES, PROCEDURES AND INFORMATION AGGREGATION IN SPATIAL COMMITTEES: EXPERIMENTS AND MODELS

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Abstract:

Committees are employed to aggregate committee member preferences and select a single decision for the entire group. Whether in congress or the local school board, committee member preferences are in general heterogeneous and individual members often possess uncertainty over the mapping of decisions to outcomes; i.e. committee members are uncertain of their own preferences. Often in such cases of uncertainty, the committee relies on information provided by self-interested experts. Using an experimental design we test the hypothesis that committee procedures similar to Robert's Rules of Order transmit information from self-interested experts to a committee comprised of members with uncertain and heterogeneous preferences. This committee design is found to aggregate information despite self-interested experts who possess incentives to manipulate the committee decision; however, expert recommendations are not fully revealing. Furthermore, committee procedures that facilitate the development of expert reputations improve information aggregation in the context of Robert's Rules of Order.

I. INTRODUCTION

Through competition among insiders it is well established that market relevant information known to insiders can become revealed to outsiders in properly designed financial markets through self interested attempts to maximize profits (Plott and Sunder 1982, 1988; Glosten and Milgrom 1984; Forsythe and Lundholm 1990). However, in the context of committee decisions made via majority rule, few studies exist that examine precise procedures and rules that promote information aggregation from informed outsiders to individual committee members.[1] Through an experimental design we analyze whether specific committee procedures lead to committee decisions that reflect information held by non-voting, privately informed experts who possess incentives to distort the truth. This research is relevant to a large number of political problems, from Congressional committees to the local school board, where committees rely on the opinions of outside experts to provide the committee members with relevant information. The two main hypotheses studied in this article are: (1) do procedures similar to Robert's Rules of Order lead to information aggregation in a multimember committee and (2) within the framework of Robert's Rules of Order do specific committee procedures or rules that lead to greater information aggregation?

The committee process studied here is that in which an otherwise uninformed committee chooses informed, self-interested experts to serve as advisors to the committee. The experts are given the opportunity to provide policy recommendations, but experts are not allowed to vote with the committee. As expert preferences differ from committee members, we ask the question do committee procedures common to most political settings lead to the transmission of

[1] One exception is Ottaviani and Sørensen (2001) who consider the order of information revelation when committee members possess private, asymmetric information.

information from experts to committee members even when experts have incentives to distort the truth in order to influence the committee decision?

In the context of a one dimensional policy space, theoretical results show biased experts do not fully reveal their private information (Crawford and Sobel 1982; Gilligan and Krehbiel 1989; Austen Smith 1993; Krishna and Morgan 2001). Sobel (1985) analyzes the effect of expert credibility on information aggregation and finds experts feign friendliness in order to develop a good reputation. Building on the credibility literature Morris (2001) develops a model with a single expert and decision maker and finds that no information may be conveyed when experts have preferences over their reputation. Analyzing information aggregation under a different set of assumptions Ottaviani and Sørensen (2001) show that when committee members possess private information herding may result in poor public outcomes.

Contrary to results over a single dimension, Battaglini (2002) finds the existence of a fully revealing equilibrium with multiple experts in a multidimensional space. However, Ambrus and Takahashi (2006) show that when the policy space is restricted, Battaglini's fully revealing equilibrium may not exist. Ambrus and Takahashi (2006) and Levy and Razin (2005) find that no information is revealed as the biases between experts and the decision maker goes to infinity. Finally, Londregan and Snyder (1994) challenge theoretical evidence of information aggregation on the grounds that committees tend to be comprised of ideologically extreme individuals.

While related to the previous work on information aggregation, the experimental results reported herein are not a direct test of the above theoretical models. Our experimental design differs from the above theoretical models along several dimensions. In discussing the ideological composition of U.S. congressional committees Krehbiel (1991) concludes, "…their composition is heterogeneous almost without exception." Furthermore, theoretical research is often silent on the precise committee rules and procedures. Accounting for these two items, we consider information aggregation in a multimember committee, where individual members have heterogeneous preferences, and the committee follows procedures similar to Robert's Rules of Order. Additionally, we account for the Londregan and Snyder (1994) critique as we consider a committee with multiple members who possess extreme preferences relative to both experts and other committee members.

Through laboratory experiments we analyze information aggregation in committees when non-voting experts possess private information relevant to committee member preferences. Committee members possess no private information but observe expert recommendations and have information about the preferences of experts relative to their own preferences. Committee members know something about expert preferences so the recommendations of experts and any bias in those recommendations become part of the information aggregation process.

The next sections present the distribution of committee and expert preferences, and how information asymmetries between committee members and experts affect preferences. The experimental design and procedures are then discussed, followed by models of committee decisions and behavior. Finally, the committee decisions are analyzed to determine: (1) if information aggregation occurs when the committee operates under procedures similar to Robert's Rules of Order and (2) precise rules that lead to greater information aggregation in the context of Robert's Rules of Order.

II. OVERVIEW

The committee problem is to choose a point in a two dimensional space using a simplified version of Robert's Rules of Order. Much is known about the behavior of such committees when committee members have well formed preferences. When committee members possess no uncertainty over their preferences and there exists a median voter in all dimensions, then the committee decision is the ideal point of the median voter (Plott 1967; Fiorina and Plott 1978). The focus of this article is on the less studied question of committee behavior when committee members possess uncertainty over their preferences, such as when preferences depend on the realization of random state variables. In order to understand the nature of preferences it is best to first consider a case in which committee members possess no uncertainty in their preferences over the outcome space as is illustrated in the group labeled A in Figure 1. That is committee members publicly observe the outcome of a randomly drawn state variable. The ideal points of committee members are illustrated by black dots and the ideal points of experts are represented by the open circles; experts do not possess voting rights.

By construction, if committee members possess full information, then the distribution of preferences in A of Figure 1 results in a unique equilibrium committee decision; equal to the ideal point of the median voter. Furthermore, under full information, the relative preferences of committee members are always the same. However, when committee members possess uncertainty over their preferences the committee members could possess ideal points consistent with the locations represented by B in the figure. Thus, when a committee member's preferences over outcomes are dependent upon a randomly drawn state of nature, then uncertainty over this random state becomes uncertainty over preferences. The preferences of the experts relative to the committee members are always in the same proximity as shown in Figure 1. The state is known by experts and thus experts always know their own preferences. We define dyadic competition as the configuration of ideal points found in Figure 1. That is dyadic competition occurs when experts' ideal points are symmetrically distributed about a voter who is the median in all directions. As will become clear, dyadic competition has some desirable properties and is a part of our committee design.

III. EXPERIMENTAL ENVIRONMENT

A. Preferences and Relationship to States

Each period five committee members make a decision via majority rule under procedures similar to Robert's Rules of Order. The committee decision is a point in the x-y coordinate plane and determines the period payoff for all committee members and experts. Committee member and expert preferences are state dependent. Thus, at time *t* preferences and payoffs for any two points vary depending upon the realization of two random state variables, (S_{xt},S_{yt}). A realization of s_{xt} shifts all individual ideal points along the x-axis by the amount s_{xt}, while a realization of s_{yt} implies that individual ideal points are shifted along the y-axis by the amount s_{yt}. Figure 2 plots the ideal points of the committee members and experts after a realization of $(s_{xt}=0,s_{yt}=0)$; where circles represent the ideal points of committee members and the diamonds represent the ideal points of experts. Committee ideal points are dependent upon the state and thus vary with different realizations of (S_{xt},S_{yt}). Figure 3 plots the ideal points of committee members and experts following the realization of state (30,30).

Given Euclidean preferences observation of (s_{xt},s_{yt}) alters not only individual ideal points, but preferences over the entire policy space. When committee members observe (s_{xt},s_{yt}), then a unique equilibrium exists as the distribution of ideal points upholds the equilibrium conditions developed by Plott (1967).[2] Thus, under perfect private information there exists a point (x_{ct},y_{ct}) which is the unique Nash equilibrium committee outcome and is equal to the ideal point of the median committee member (Fiorina and Plott 1978).

Relative to the fully informed equilibrium, (x_{ct},y_{ct}), expert preferences are symmetrically distributed. Given experts possess Euclidean preferences and the symmetry of their ideal points about (x_{ct},y_{ct}), there is no point, $(x_t,y_t) \in \Re^2$ that both experts prefer to (x_{ct},y_{ct}). Thus, in a non-repeated game with expert preferences distributed according to Figure 2, dyadic competition implies that among experts there are no incentives to collusion.

B. Information

Committee decisions different information environments are analyzed to determine if experts provide relevant information to heterogeneous committee members. In these experiments the "testimony" of experts is limited to a recommendation for committee choice; that is a single point in the x-y coordinate plane. Experts are perfectly informed regarding the realization of the random state variable, but do not possess voting rights. Committee members possess voting rights, but their information over the realized state is dependent upon the information environment. As preferences depend upon the state, the information committee members and experts have regarding the state is crucial to well-formed preferences over the outcome space. Four different information environments are used to analyze information aggregation and test the two main hypotheses.

In the first information environment, full information, (s_{xt},s_{yt}) are publicly revealed to all committee members prior to the start of a period. In the full information environment, no

[2] There exists a median in all directions Plott (1967).

uncertainty exists over the state values and experts do not provide recommendations. Experiments conducted under the full information environment provide the upper bound to information aggregation.

The second information environment, distribution limited information (DLI), represents a scenario in which committee members observe only the distributions, f_x and f_y, which generate the two random variables. As information regarding the realizations of the two random variables is prohibited the DLI environment does not contain experts. The DLI environment replicates an information environment where members know the distributions of state relevant variables but receive no outside information regarding the realizations of $(s_{xt,}s_{yt})$. The DLI environment provides an estimate of the lower bound of information aggregation that can occur during the committee process.[3]

In order to test our main hypotheses two information environments, feedback and no feedback, are created to analyze information aggregation under Robert's Rules of Order. In both the feedback and no feedback environments two perfectly informed, biased experts provide policy recommendations to the committee. In the third information environment, feedback, the realized state variables $(s_{xt,}s_{yt})$ are publicly revealed following each committee decision, (x_t,y_t). However, in the fourth information environment, no feedback, the realized state values $(s_{xt,}s_{yt})$ for period *t* are not revealed until after the conclusion of the experiment. Thus, the ability of committee members to assess the accuracy of expert recommendations depends on the experimental environment.

[3] The DLE provides only an estimate of the lower bound. It is possible that expert recommendations may confuse committee members to a large enough degree that an environment that solicits expert recommendations may result in less information aggregation.

The feedback and no feedback experiments are used to model committee procedures that either facilitate or restrict the development of an expert's credibility or reputation. Specifically, the feedback environment represents a procedure that requires the committee to repeatedly solicit information from the same set of experts. In the no feedback environment committee members possesses little or no information over the accuracy of an expert's previous recommendation. Thus, the no feedback environment is similar to a committee procedure that stipulates new experts be consulted for each new policy decision.

IV. EXPERIMENTAL DESIGN

A. The Committee Rule and Procedures

In each period the committee is required to pass a policy, (x_t,y_t), which determines all payoffs for that period. Except for procedures specific to the information environment the committee procedures are the same under all experimental conditions. Each period started with an initial status quo of (200,150). Upon recognition by the committee chair, who was the experimenter, a committee member or expert proposed an amendment to the existing status quo. Each amendment must receive verbal support from a committee member, other than the proposer, in order for the proposal to proceed to the committee floor for a vote. If a majority of the committee agreed to adopt an amendment, then that amendment became the new status quo. If a majority of committee members voted against the current amendment, then the status quo remained unchanged. Thus, passing a proposal simply changed the current status quo and did not end the period. Committee members were free to make as many proposals as they wish during a period. When recognized by the committee chair, committee members were free to address the committee and experts with a statement about the preferences over the current proposal.[4]

At any time during the proposal process a committee member could make a motion to end debate at which time the entire committee immediately voted whether to accept or reject the current status quo. If a majority of committee members voted to accept the current status quo, then the period immediately ended and payoffs for that period were determined by the current status quo. If a majority of committee members voted against accepting the current status quo, then the proposal process continued from the point of interruption.[5]

In addition to committee members, the experiments conducted under the feedback and no feedback environments contain two experts. In each period, experts possessed perfect private information of (s_{xt},s_{yt}): where s_{xt} and s_{xt} are independently drawn from the uniform distribution, [0, 50]. Prior to the first proposal expert *j* was required to make an initial recommendation, (x_{jt},y_{jt}), to the committee. Experts and committee members were told that the point (x_{jt},y_{jt}) represents *j*'s most preferred committee decision. The initial recommendation process consisted of two actions. First, experts privately committed to a recommendation by writing (x_{jt},y_{jt}) on a piece of paper. Second, experts publicly declared the point (x_{jt},y_{jt}) aloud to the entire committee. In addition to initial recommendations, experts were required to provide additional guidance during the amendment process. Before any amendment goes to the floor for a vote, experts were required to publicly state in what direction they would like to see the current proposal moved.[6]

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[4] That is committee members where able to say whether they approved or disapproved of the current proposal. Additionally, committee members were free to state in what spatial direction they would prefer to see the current proposal moved.

[5] There were no rules that blocked the committee from rejecting specific status quo during the motion to end debate and later passing the same status quo as the final committee decision.

[6] The language the experts may use during this communication is restricted; experts must use language such as "up and to the left" or "left and down".

B. Experimental Conditions

Each experimental condition consists of at least one experiment containing multiple periods. In each period a five member committee was instructed to select a single point (x_t,y_t) in the X,Y coordinate plane by majority rule which would determine all participant payoffs. Committee members possess different ideal points and preferences over the outcome space. Therefore, the decision point which resulted in the highest payoff to one committee member did not result in the highest payoff to another member. Committee members did not have *a priori* information regarding the ideal points of the other committee members. However, committee members did know the spatial direction (up, down, left, right) of their preferences relative to the preferences of other committee members. In the experimental conditions containing experts, conditional upon observing (s_{xt},s_{yt}) committee members could infer the location of the experts' ideal points. Thus, committee members are able to infer if one expert is lying as committee members know the state independent difference in committee member ideal points.[7] Committee members did not possess information regarding the ideal points of the experts relative to other committee members. Below we outline the four experimental conditions labeled Series 1, Series 2, Series 3 and Series 4 which correspond to one of the four information environments studied.

Series 1. Full Information

Prior to the start of each period *t*, committee members were publicly told the realized state values (s_{xt},s_{yt}). The committee proceeded with proposals, deliberation, voting and ultimate choice from among the X-Y coordinate plane. Since the state was known, *a priori* payoffs were computed and recorded following each period.

[7] It is important to note that committee members were only able to infer whether or not one expert was lying and could not tell if both experts were lying. Additionally, experts were not able to distinguish through the recommendations which expert was lying.

Series 2 Distribution Limited Information

Prior to the start of each period *t*, committee members were publicly told the distributions, f_x and f_y, of the two random variables; where f_x~u[0,50] and f_y~u[0,50].[8] Other than the difference in the revelation of information and that payoffs were not computed until the completion of the final period the Series II condition is identical to that of the Series I condition.

Series 3. Experts with Feedback

Before the first proposal in any period, the realized state values, (s_{xt},s_{yt}), were privately revealed to both experts. Each expert was required to write a recommendation on paper and then publicly state this recommendation as the point the expert most preferred the committee adopt as (x_t,y_t). Following initial expert recommendations, the proposal process began. Upon recognition by the committee chair a committee member or expert was free to propose an amendment to the existing status quo.[9] After an amendment was seconded by a committee member but prior to a vote, each expert was required to publicly state in which direction they would like to see the current proposal changed; "up and to the left" etc. Following a final committee decision (x_t,y_t), the state values (s_{xt},s_{yt}) were publicly revealed to all committee members. After state revelation experts and committee members computed their individual payoff for that period.

Series 4 Experts without Feedback

[8] The distribution of the random variables f_x and f_y was kept constant across all periods and information environments.

[9] Of the 42 proposals provided by experts across both the Series III and IV conditions 19 of them passed and no proposal initiated by an expert was enacted as the final committee decision.

The experimental condition for Series 4 is identical to that of Series 3 except that in this condition committee members were not revealed (s_{xt},s_{yt}) following the conclusion of period *t*. Committee members were revealed the value of (s_{xt},s_{yt}) for all *t* following the conclusion of the final period; at which time individuals computed their payoffs for each individual period. Thus, unlike Series 3 the Series 4 condition prohibited committee members from evaluating the truthfulness of expert recommendations.

C. Experiments

A total of 16 experiments were conducted. The experiment dates, information environment, and total number of periods are listed in Table 1. While the realized state values varied across periods within any one experiment, the values of (s_{xt},s_{yt}) for period t were kept identical across experiments. The list of realized state values, (s_{xt},s_{yt}), is found in Table 2. There were 7 total periods under each of the Series 1 and 2 conditions while the Series 3 and 4 experiments contained 62 and 72 periods. The number of periods for the Series 1 and 2 conditions is smaller as prior research by Fiorina and Plott (1978) and strong theoretical results suggest additional periods will not lead to a change in results.

The Series 1 and 2 experiments contained 5 subjects with one additional individual being employed as a scribe. The Series 3 and 4 experiments contained 7 subjects and one additional scribe. Our subject pool is comprised primarily of Caltech undergraduates with a few Caltech and UCLA graduate students and one non-affiliated adult. Recruiting was primarily done through email via a list which was obtained through registration by interested individuals. Some additional recruiting took place in undergraduate economics and political science classes taught on Caltech's campus.

D. Experimental Procedures

At the beginning of each session, the experimenter randomly assigned participants to specific committee or expert positions. Each participant was provided with the following materials: a printed copy of the instructions, ruler, calculator, two pencils, several pieces of scratch paper, and a hand written note informing the participant of their state dependent ideal point. Additionally, participants were given pieces of paper containing a printed x-y coordinate plane. Located on each committee member's x-y coordinate plane was a shaded 50x50 box where the center of the box represented the committee member's ideal point given a realized state of (25,25). Committee members were told that regardless of the state, their highest payoff was always located within the shaded box. Finally, each committee member was given a transparency which contained a point representing the committee member's ideal point and a series of curves representing the committee member's indifference curves. In the Series 3 and 4 experiments the transparency also contained the ideal points of the two experts relative to the ideal point of the committee member.[10] Following sincere expert recommendations the committee members could use the transparency to locate their precise ideal point.

After all participants were seated the experimenter read the instructions aloud to the entire group and answered questions raised during the course of this process. At the conclusion of the instructions the experimenter reiterated that all subjects would be paid in cash following the conclusion of the experiment. During the instruction period the experimenter was often asked the number of periods in the experiment. The experimenter always declined to answer this

[10] Thus, given committee members knew the state, then committee members could calculate the ideal points of the two experts.

question and informed the group that the number of periods was randomly predetermined and the group would be notified when the experiment was over after the conclusion of the final period.

After the instructions were read and any questions had been answered, participants were told the first period would be considered a practice round, for which they would be paid, and the relevant state information would be revealed to all participants following the first period. Upon the conclusion of the first round, the experimenter would verify that each participant understood the instructions and could properly calculate their payoff from the first period.

Subjects calculated their own payoffs using the indifference curves on the transparencies provided. After revelation of the state values, committee members could determine their payoffs by overlaying the transparency on the 200x150 x-y coordinate plane. Using the indifference curves printed on the transparency committee members calculated their payoffs through a legend that gave a specific number of Konars for each indifference curve. For decisions landing between two indifference curves subjects were instructed to approximate the difference between the two curves. Each subject was provided with a conversion factor which translated Konars into dollars; where conversion factors varied among committee members. At the conclusion of the experiment, subjects totaled their payoffs from each period, as well as the practice round, and were paid in cash. Experiments averaged about two hours and subject payoffs ranged between $18 and $45 dollars with most subjects receiving between $25 and $35 dollars.

V. MODELS

Dependent upon the dimensionality, outcome space, number of experts, and size of the expert biases, the research literature produces a variety of predictions about the theoretical existence of a fully revealing equilibrium. Studying a different question we analyze information aggregation under a specific set of procedural rules. We use experiments to test information aggregation in a multi-dimensional space with multiple experts as: (1) we are interesting in assessing whether specific committee procedures result in information aggregation, and (2) theory is relatively silent on how results may change in a majority rule setting with committee members possessing heterogeneous preferences. The first two models listed below are theoretical predictions of the final committee decision (x_t,y_t). While both models are based on the same concept of equilibrium they are listed separately because of the information held by committee members.

Fully Informed Equilibrium (FIE). The equilibrium conditions (Plott, 1967) imply the existence of a unique equilibrium under full information, (x_{ct},y_{ct}), such that there does not exist a point $(\tilde{x},\tilde{y})$ and a majority of committee members, M, such that $U_M(\tilde{x},\tilde{y}) > U_M(x_{ct},y_{ct})$. If committee members possess full knowledge over the states, then the fully information model predicts $(x_t,y_t)=(x_{ct},y_{ct})$.[11]

Distribution Limited Information Equilibrium (DLE). Committee member knowledge is limited to the distributions, f_x and f_y, that generate the random variables. Let $E(\cdot)$ represent the expected of the quantity in the parentheses, where $E(f_x)$ and $E(f_y)$ represent the expected values of the random variables under distributions f_x and f_y.. Given the state realization (0,0) let (x_m,y_m) be the ideal point of the median voter. The DLE states that if information is limited to f_x and f_y, then the committee will behave as expected utility maximizers and will implement the decision $(x_t,y_t)=(x_m+E(f_x), y_m+E(f_y))$.

[11] Prior research supports this model prediction. Fiorina and Plott (1978) find that if (s_{xt},s_{yt}) is fully revealed, then $(x_t,y_t)=(x_{ct},y_{ct})$.

Theorem. Given committee members are risk neutral and possess beliefs over (s_{xt},s_{yt}) consistent with f_x and f_y, the DLE is a Nash equilibrium.

Proof: As the distribution of committee member preferences uphold the equilibrium conditions given in Plott (1967) and the median committee member is the median in all directions, it is sufficient to show for the median committee member: $U(E(f_x),E(f_y)) > U(x_t,y_t)$ $\forall (x_t,y_t) \neq (E(f_x),E(f_y))$. Let (x^*_{mt}, y^*_{mt}) represent the median member's ideal point and recall that committee preferences are Euclidean implying $U(x^*_{mt}, y^*_{mt}) \succ U(x^*_{mt} + \varepsilon_x, y^*_{mt} + \varepsilon_y)$ $\forall \varepsilon_x, \varepsilon_y \succ 0$.

Let s_{xt} and s_{yt} be the realizations for the two independently and uniformly distributed random variables then:

$$E(s_{xt} - x_t) \succ E(s_{xt} - E(f_x)) \ \ \forall x_t \neq E(f_x)$$

let g(z)=$\sqrt{z}$ where $\frac{\partial g(z)}{\partial z} \succ 0$ and $\frac{\partial^2 g(z)}{\partial^2 z} \prec 0$, then it follows that

$$E(\sqrt{(s_{xt} - x_t)^2 + {y_t}^2}) \succ E(\sqrt{(s_{xt} - E(f_x))^2 + {y_t}^2}) \ \forall x_t \neq E(f_x)$$

Similarly it is the case that:

$$E(s_{yt} - y_t) \succ E(s_{yt} - E(f_y)) \ \ \forall y_t \neq f_x$$

$$E(\sqrt{(x_t)^2 + (s_{yt} - y_t)^2}) \succ E(\sqrt{(x_t)^2 + (s_{yt} - E(f_y))^2}) \ \forall y_t \neq E(f_y)$$

As f_x and f_y are independently distributed then $\forall x_t \neq E(f_x), y_t \neq E(f_y)$

$$E(\sqrt{(s_{xt} - x_t)^2 + (s_{yt} - y_t)^2}) \succ E(\sqrt{(s_{xt} - E(f_x))^2 + (s_{yt} - E(f_y))^2})$$

As committee members are assumed to behave as utility maximizers and preferences are Euclidean it follows that $E(U(E(f_x), E(f_y))) \succ E(U(x_t, y_t)) \ \forall x_t \neq f_x$ and $y_t \neq f_x$.

Sincere revelation by experts. Let expert *j* give the recommendation (x_{jt},y_{jt}). Sincere revelation occurs if $U(x_{jt}, y_{jt}) \succ U(\tilde{x}_{jt}, \tilde{y}_{jt}) \ \forall(\tilde{x}_{jt}, \tilde{y}_{jt}) \in \Re^2$, $j = 1,2$. Thus, sincere revelation occurs if and only if both experts truthfully reveal their ideal points.

Uninformative Recommendations by experts. Let $x_{et} = x_{jt} + x_{kt}$ and $y_{et} = y_{jt} + y_{kt}$, thus x_{et} and y_{et} represent the sum of the individual recommendations.

Theorem: Given experts beliefs that the final committee decision along either dimension is monotonically increasing in the sum of their recommendations along that dimension, $g_x(x_{et}) = x_t > \tilde{x}_t = g_x(\tilde{x}_{et})$ and $g_x(y_{et}) = y_t > \tilde{y}_t = g_x(\tilde{y}_{et})$, then there exists no pure-strategy Nash equilibrium where expert recommendations are informative.

The above theorem predicts that if the committee decision is monotonically increasing in expert recommendations along both dimensions, then expert recommendations will diverge to $\pm\infty$.

Proof: Let the pair of points x_{kt}, x_{jt} represent expert recommendations along the x-axis with an expected outcome $g_x(x_{et}) > \hat{x}_{kt}$; where $\hat{x}_{kt}$ is the ideal point of *k* along the x-axis. Given expert beliefs that the committee decision is monotonic in x_{et} it is a best response for *k* to propose $x'_{kt} < x_{kt}$. Anticipating *k*'s response, *j* will exaggerate her claim such that $x'_{jt} > x_{jt}$. Anticipating that *j* will exaggerate their preference, *k*'s best response is to recommend $x''_{kt} < x'_{kt} < x_{kt}$; this process continues ad infinitum.

Consistent Recommendations Model. If expert recommendations are inconsistent with *a priori* information, then due to either purposeful action or uncertainty over preferences the committee decision punishes one or both senders. Recall that committee members possess *a priori* information regarding the state independent distance between the ideal points of the experts. If the distance between recommendations does not match committee member expectations, then the committee knows at least one of the expert recommendations is not sincere. Let expert recommendations be such that if $\sqrt{(x_{jt} - x_{kt})^2 + (y_{jt} - y_{kt})^2} \succ M$, then the consistent recommendations model predicts a decision point (x_t,y_t) such that:

$$E(U_j((x_t, y_t) \mid d((x_{jt}, y_{jt}), (x_{kt}, y_{kt})) \succ M)) \prec E(U_j((\tilde{x}_t, \tilde{y}_t) \mid d((\tilde{x}_{jt}, \tilde{y}_{jt}), (\tilde{x}_{kt}, \tilde{y}_{kt})) \prec M))$$

VI. RESULTS

The first two results report that the committee decision reflects the information individual committee members possess. The third and fourth results analyze information aggregation under a set of specific committee procedures. The final four results focus on the behavior and incentives of experts.

Result 1. Under perfect private information committee decisions are near the fully informed equilibrium.

Support. Prior to the start of the proposal process in the Series 1 experiment, committee members were given perfect information regarding the realization of the two state variables. Series 1 committee decisions, (x_t,y_t), are plotted in Figure 4 and normalized to the fully informed equilibrium, (x_{ct},y_{ct}). The committee decisions under perfect information are nearly identical to the fully informed equilibrium. The average distance between committee decision and fully informed equilibrium was 1.1 units with a standard deviation of .5 units.[12] These results are

[12] We speculate that a portion of this difference is due to the random variables being distributed continuously distributed along the interval [0,50]. Committee members appeared to ignore the information after the decimal point and always made proposals in whole numbers.

consistent with findings by Fiorina and Plott (1978) and we conclude that under perfect information the committee decisions are near the fully informed equilibrium.

Result 2. If the distributions, $f(S_x)$ and $f(S_y)$, are the committee's only source of information, then the committee decisions are consistent with that predicted by the DLE model of committee decisions.

Support. Figure 5 plots the seven committee decisions made under the Series 2 experimental condition where committee decisions, (x_t,y_t), are normalized to the no information equilibrium, $(x_m+E(f_x), y_m+E(f_y))$. Only two points are visible in Figure 5 as the committee implemented only two distinct decision points over the seven periods.[13] When committee members possess knowledge only over the distributions of the random variables the average Euclidean distance between the committee decision, (x_t,y_t), and the no information equilibrium, $(x_m+E(f_x), y_m+E(f_y))$, was 1.3 units with a standard deviation of .5 units. Thus, under an information environment where committee members only possess knowledge over $f(S_x)$ and $f(S_y)$, the committee decision is consistent with behavior that maximizes expected utility.

Result 3. Under dyadic competition and procedures similar to Robert's Rules of Order, the committee process aggregates information from biased, non-voting experts.

Support. In order to determine that the committee process leads to purposeful and meaningful information aggregation we analyze three separate questions: (1) are committee decisions under the Series 3 and 4 environments significantly different than decisions under the no information environment, (2) does the FIE provide a better prediction of the committee decision relative to

[13] The differences along the x and y axes between the predicted equilibrium and the committee decision was (0,1) for five observations and (2,0) for two observations

the DLE and (3) is the average committee decision under the Series 3 and 4 environments significantly closer to the FIE relative to the DLE? The decisions under the Series 3 and 4 experiments are normalized to the DLE and plotted in Figures 6.A and 6.B. Clear patterns emerge in these figures as the vertical lines tend to represent periods with the same state realizations. The existence of state dependent patterns suggests that the deviations between the DLE and the committee decisions under the Series 3 and 4 information conditions are not entirely random.

A comparison of how well the two outcome models predict the committee results under the Series 3 and 4 conditions are located in Table 3.A. If committee members have beliefs that the expert recommendations are uninformative, i.e. recommendations provide no additional information over $f(S_x)$ and $f(S_y)$, then by Result (2) the Series 3 and 4 committee decisions will approximate the distribution limited equilibrium (DLE). A *t*-test that the average distance between the committee decision and the DLE in the Series 3 and 4 is equal to the distance between the Series 2 outcomes and the DLE is rejected at the 99% significance level (t=14, t=14); thus on average the committee decision is significantly different than the point predicted by the DLE.

Turning our attention to the full information equilibrium, we investigate whether expert recommendations fully reveal (s_{xt},s_{yt}). Figures 7.A and 7.B plot the committee decision normalized to the FIE. Contrary to results in the distribution limited information case, no evidence of strong patterns emerge as the distribution of committee decisions appears to be randomly distributed about the FIE. However, expert recommendations are not fully revealing as the average Euclidean distance between the FIE and the committee decision is greater under the Series 3 and Series 4 conditions relative to the Series 1 condition (t=8,t=11).

While neither the DLE nor FIE models perfectly predict the committee decision in the Series 3 and 4 conditions, we analyze whether the FIE outperforms the DLE in predicting the committee decision. The percentage of observations in which the FIE is closer to the committee decision relative to the DLE is listed in Table 3.B and the results are clear. Across the Series 3 and 4 conditions the FIE provides a closer approximation of the committee decision in 82% and 64% of observations. Binomial tests, over the Series 3 and 4 conditions, reject at the 99% significance level the hypothesis that in 50% of observations the DLE is closer to the committee decision relative to the FIE. Additionally, a 95% confidence interval for the likelihood that the committee decision is closer to the FIE relative to the DLE is [.71, .91] under the Series 3 condition and [.52, .75] under the Series 4 condition. Thus, both the Series 3 and 4 conditions predict the FIE is a better estimate of the committee decision relative to the DLE

While a binary analysis is useful to evaluate which information model better predicts the committee outcome, this analysis results in a substantial amount of lost information. It is possible that while the FIE is closer to the committee decision for a greater number of observations, the average distance between the FIE and the committee decision is greater than that between the committee decision and the DLE. Analyzing the experimental results the average distance between the committee decision under the Series 3 and 4 environments is significantly closer to the FIE relative to the DLE (t=-7.0 for Series 3, t =-3.6 for Series 4). In the Series 3 and 4 conditions the average distance between the committee decision and the FIE is approximately 10 and 7 units less than that between the committee decision and the DLE (significant at the 95% confidence level).

In conclusion, experimental results support the claim that information aggregation occurs in the Series 3 and 4 conditions. This conclusion is based on experimental results that find: (1)

the committee decision implements a point significantly different than that predicted by the DLE, (2) the FIE is a better predictor of the committee decision relative to the no information model, and (3) the committee process results in a decision that is consistently closer to the FIE relative to the DLE.

Result 4: Relative to the no feedback environment, the Euclidean distance between the FIE and the committee decision is less under the feedback environment.

Support: Recall the feedback information environment (Series 3 experiments) stipulates a procedure in which following the conclusion of the period the true state values are revealed prior to the start of the next period. The no feedback environment (Series 4 experiments) denotes a procedure in which the true period state values are not revealed to the committee members until the conclusion of the final period. In an analysis that designates the feedback environment, Series 3, as the treatment and the no feedback environment, Series 4, as the control we estimate the average treatment effect on the distance between the FIE and the committee decision. When performing an exact match on the realized state values for periods 1-10, we find that the average treatment effect is -2.47 with a standard error of .96 (z=-2.58) which indicates that the feedback condition produces committee decisions significantly closer to the FIE.[14] Furthermore, in the feedback experiments the 95% confidence interval for the average distance between the FIE and the committee decision is [5.65, 8.08]. The corresponding 95% confidence interval for the average distance between the FIE and the committee decision is [8.12, 10.88]. Thus, the average distance between the committee decision and the FIE is significantly less under the feedback environment.

[14] Recall that realized states values varied within an experiment, but the same state values were used in each experiment. Extending the analysis to the 11th period gives stronger results ATE=-2.82 with a standard error of .97. We refrain from using the 11th period as there is only one outcome in the Series 3 condition.

Result 5. There is no tendency for experts to sincerely reveal their ideal points.

Support. Figures 8.A and 8.B show expert recommendations normalized to their state dependent ideal points for the Series 3 and 4 experimental conditions.[15] Expert A's recommendations are denoted by a diamond while B's recommendations are denoted by a triangle. The graphical evidence shows that expert A's recommendations tend to lie in the second quadrant while B's lie in the fourth quadrant. Given A's (B's) ideal point relative to the full information equilibrium lies in the second (fourth) quadrant, A’s (B’s) recommendations tend to be located in the second (fourth) quadrant in an attempt to influence the committee decision. Across both the Series 3 and 4 conditions the average Euclidean distance between an expert’s recommendation and the expert’s ideal point is 9.4 units with a standard error of .6. Thus, the average Euclidean distance between an expert’s recommendation and their true ideal points is statistically significant at the 99% confidence level. In the Series 3 condition in only 11 out of 124 (8.8%) recommendations do experts initial recommendations come within 1 unit of their ideal point. In the Series 4 experiments in just 1 out of 144 (0.7%) recommendations was an expert's recommendation within 1 unit of their ideal point. Thus, regardless of the feedback condition we do not observe a tendency among experts to consistently reveal their true ideal points.

Result 6. There is no tendency for experts to provide recommendations so extreme that the configuration of recommendations is uninformative.

Support. While the recommendations in Figures 8.A and 8.B indicate experts are not truthfully revealing their ideal points, about 65% of recommendations in both the Series 3 and 4

[15] Three outliers were eliminated from the Series 4 graph in an effort to make the graph reader friendly.

experiments are located within 10 units of the expert's true ideal point. Thus, while not truthfully revealing their ideal points, experts tend to provide recommendations relatively near their ideal points regardless of the feedback environment. If experts submitted recommendations of points in opposite corners of the state space, than the distance between these recommendations would be 70.7 units. An analysis of the data reveals not one period in which both experts provide recommendations consistent with the corners of the state space.

While not completely uninformative, experts may choose to submit recommendations that are uninformative along a single dimension. In the case of uninformative recommendations along a single dimension the distance between the recommendations along that dimension will be 50 units. While recommendations always contain some level of information along both axes in the Series 3 condition, in 2 of 72 observations under the Series 4 condition expert recommendations are uninformative over the y-axis. Across the Series 3 and 4 conditions recommendations provide information relating to the realizations of both state variables in 98% of observations; thus there is a strong tendency for expert recommendations to be informative.

Result 7. The distance between expert recommendations is less under the feedback information environment.

Support. Designating the feedback condition, Series 3, as the treatment and the no feedback condition, Series 4, as the control, we estimate the average treatment effect on the distance between expert recommendations. When performing an exact match on the realized state values for periods 1-10, the average treatment effect is

-4.48 with a standard error of -2.14 (*t*=-2.08). Thus, the distance between recommendations is less under the feedback information environment relative to the no feedback environment.

Result 8. The expected payoffs to both experts are lower when the Euclidean distance between recommendations is greater than 21 units.

Support. Let *M* be the Euclidean distance between expert recommendations. Given dyadic preferences there exists only a single point, the FIE, which results in the same payoff to both experts. Thus, for any outcome other than the FIE one expert receives a higher payoff relative to the other expert. Analyzing expert period payoffs by the highest and lowest payoffs, under the Series 3 condition the average payoffs for both the highest and lowest paid experts are significantly lower in periods where $M>21$ ($t=1.96$ and $t=2.93$). Similarly, in the Series 4 condition the average payoffs for both the highest and lowest paid experts was significantly lower in periods where $M>21$ ($t=1.96$ and $t=2.1$). Thus, we conclude that experts have incentives to provide recommendations where the distance between the recommendations is not too great. Further study is required to determine if this incentive follows from organized committee behavior which punishes experts for untruthful recommendations or the committee randomly selecting a point within constraints provided by the two recommendations.

SUMMERY OF CONCLUSIONS

Experimental results show that when operating under Robert's Rules of Order the committee decision reflects the information possessed by voting committee members. When committee members are fully informed about their preferences the deliberation process results in a committee decision that converges to the fully informed equilibrium (Result 1). When committee members possess only a probability distribution over their preferences the committee decision converges to the unique equilibrium that exists when committee members act as expected utility maximizers (Result 2).

If a committee relies on information from biased experts with dyadic preferences then procedures that resemble Robert's Rules of Order transfer information from experts to an otherwise uninformed committee (Result 3). That is, information is transmitted from privately informed, self-interested experts to committee members despite expert incentives and opportunity to manipulate the outcome. When procedures allow committee members to assess the sincerity of an expert's past reputations, information aggregation under Robert's Rules of Order is significantly higher (Result 4). When the committee assesses the sincerity of an expert's past recommendation, the committee decision reflects more information because expert recommendations under the feedback environment contain more information (Result 7). We infer from these results that procedures which develop expert reputations leads to greater information aggregation.

Expert recommendations do not reveal the experts' true preferences (Result 5), but nevertheless committee members are able to extract information from the experts' recommendations. While experts are willing to manipulate the committee and try to do so, we hypothesize that dyadic competition reduces the reward to such actions resulting in the transmission of information to committee members (Result 8).

The process of information aggregation naturally stimulates many questions. How does information get to the committee members and what is the role of the procedures and institutions in promoting the phenomenon? While experts do not fully reveal their private information, expert recommendations do transmit partial knowledge as recommendations are not uninformative (Result 6). We hypothesize that unrealistic exaggerations of expert preferences will be recognized by the committee members and indeed, when the recommendations become too divergent the experts themselves suffer (Result 8).

The process of information aggregation would seem to be related to the structure of expert preferences. Indeed the process was designed with the anticipation that information aggregation would be fostered, with hints taken from existing committee designs. First, the use of only two experts with preferences known to be different from those of the committee members facilitates "triangulation" by committee members on the true nature of what the experts know. The fact that experts are in a zero-sum, or dyadic competition relationship with respect to the fully informed equilibrium is similar to that used in court proceedings where the interests of litigants present diametrically opposed information to the court. Furthermore, use of only two experts with dyadic preferences relative to the fully informed equilibrium restricts the formation of coalitions and coordinated efforts to manipulate the committee. Experts were prevented from posturing based on the recommendation of the other's recommendation as experts committed to their recommendation without knowing the recommendation of the other expert. The experts do not vote and are thus limited in using the process itself as a tool for manipulation. Experts can comment on proposals by committee members giving a chance for committee members to test for consistency and get additional information about where the experts informed preferences might reside and thereby allowing committee members to deduce information about their own preferences.

Can we design better processes? A committee design employing dyadic preferences is a special case and its elements can be seen in other processes. Our results seem to only touch on the deep and challenging task of designing deliberation processes that better merge conflict over outcome with the process of information gathering and aggregation. We demonstrate that information aggregation in committees is possible under procedures similar to Robert's Rules of Order in the presence of conflict and willingness to manipulate. We suggest that the ability of committees to operate in such environments is closely related to the procedures they employ. As we explore naturally occurring processes from this perspective we hope to gain insights about how to design even better procedures.

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Figure 1

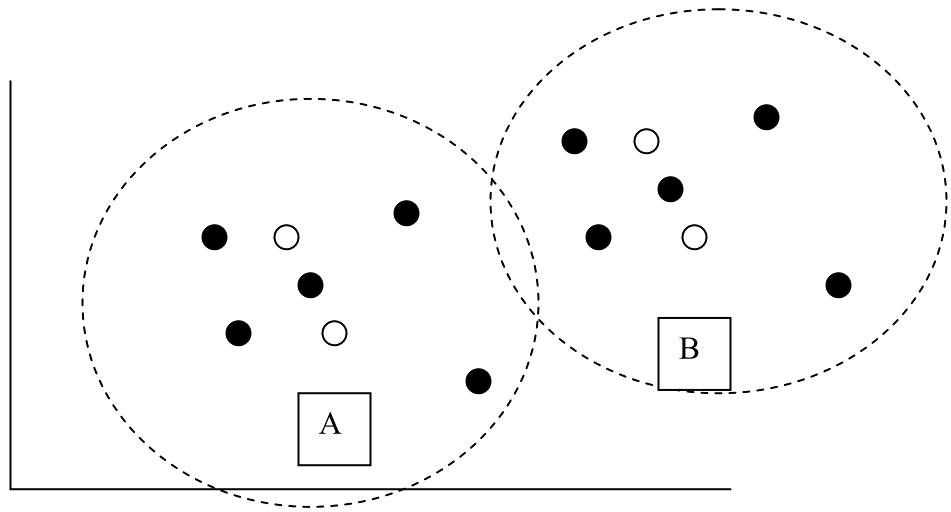


Figure 1

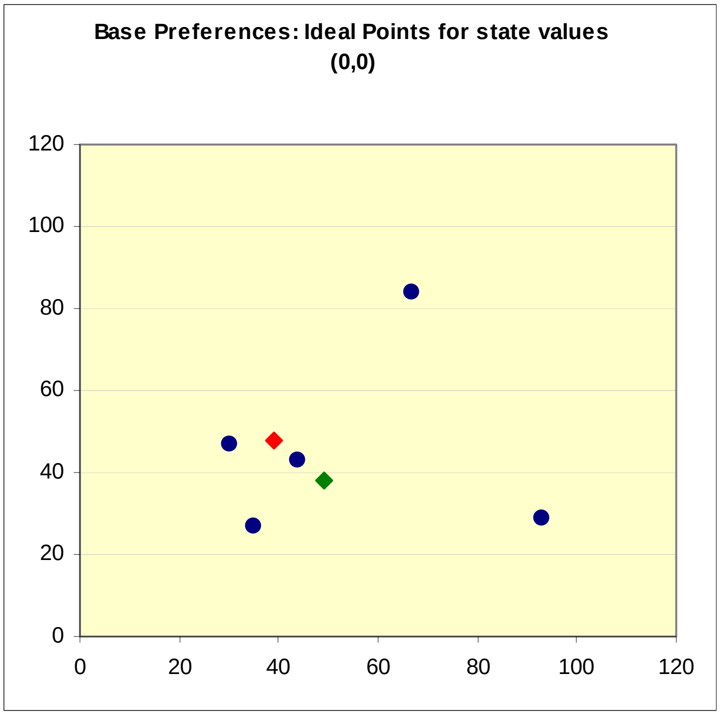


Figure 2

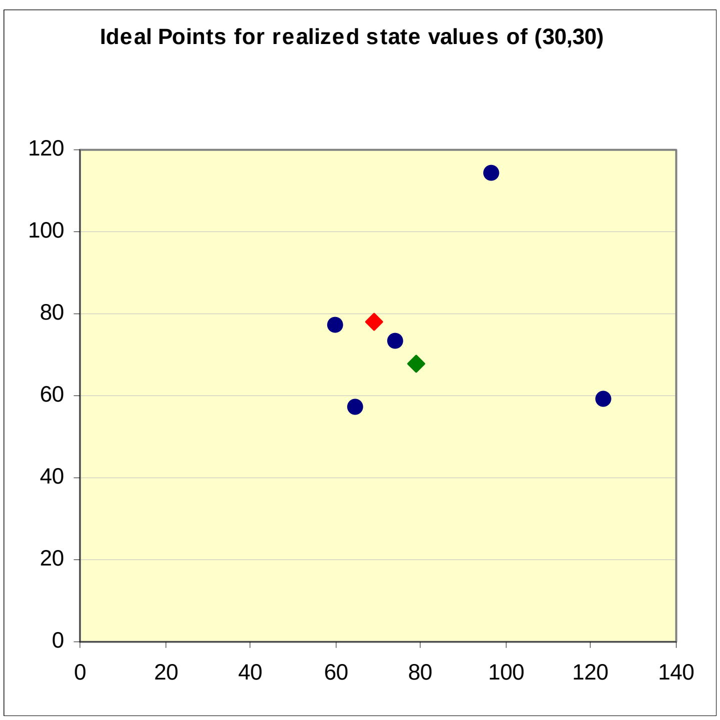


Table 1: List of experiments

List of Experiments	Information	Number of Periods
Series I		
20060507(a)	Perfect Information	7
Series II		
20060607(b)	No Information	7
Series III		
20060114	Feedback	5
20060301(a)	Feedback	8
20060301(b)	Feedback	10
20060305	Feedback	11
20060308	Feedback	9
20060430	Feedback	9
20060502	Feedback	10
Series IV		
20060125	No Feedback	10
20060128	No Feedback	9
20060129	No Feedback	11
20060304(a)	No Feedback	12
20060304(b)	No Feedback	12
20060512	No Feedback	9
20060513	No Feedback	9

Table 2

Period	s_{xt}	s_{yt}
1	25.1	46.5
2	35.5	18
3	18.6	41.1
4	16.7	6
5	9.8	6.8
6	22.6	25.9
7	1.7	31.1
8	12.6	5.3
9	33.4	21.2
10	26.2	25.3
11	2.6	19.1
12	45.9	7.2

Figure 4

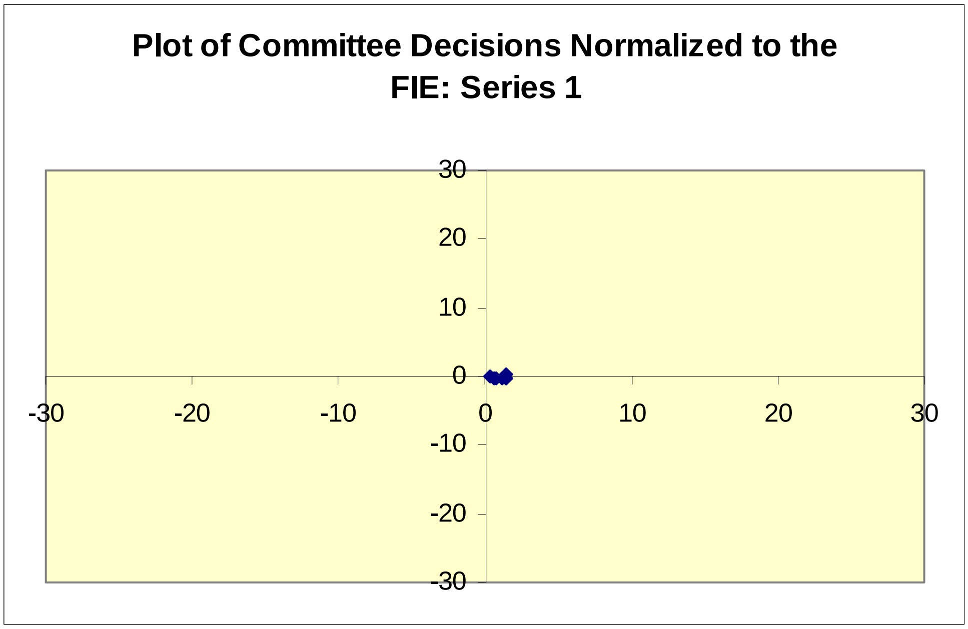
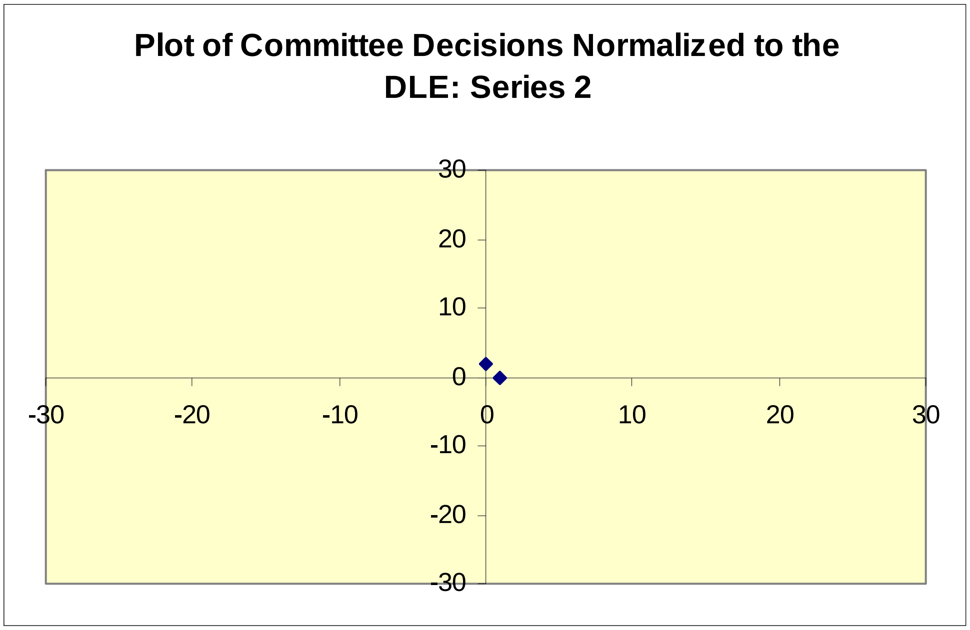

Plot of Committee Decisions Normalized to the FIE: Series 1
30
20
10
0
-10
-20
-30
-30
-20
-10
0
10
20
30

Figure 5:



Plot of Committee Decisions Normalized to the DLE: Series 2
30
20
10
0
-10
-20
-30
-30
-20
-10
0
10
20
30

Table 3.A: Average Distance between Committee Decision and Model Prediction

	Full Information		No Information	
Series 1	17.9	(2.8) [a]	1.3	(3.5) [a]
Series 2	1.1	(.2) [a]	16.4	(.2) [a]
Series 3	6.9	(.6) [a]	14.6	(.9) [a]
Series 4	9.5	(.7) [a]	13.4	(.8) [a]

a - This is the standard error which is computed as $\frac{s}{\sqrt{n}}$ where s is the sample standard deviation and n=62 for Series 3 and n=72 for Series 4.

Table 3.B: Decision by Decision Comparison of Models

	Full Information versus No Information[a]
Series 3	82%
Series 4	64%

a - This column contains the percent of observations in which the Euclidean distance between the committee decision and the point predicted by the full information model was less than the Euclidean distance between the committee decision and the point predicted by the no information model.

Figure 6.A:

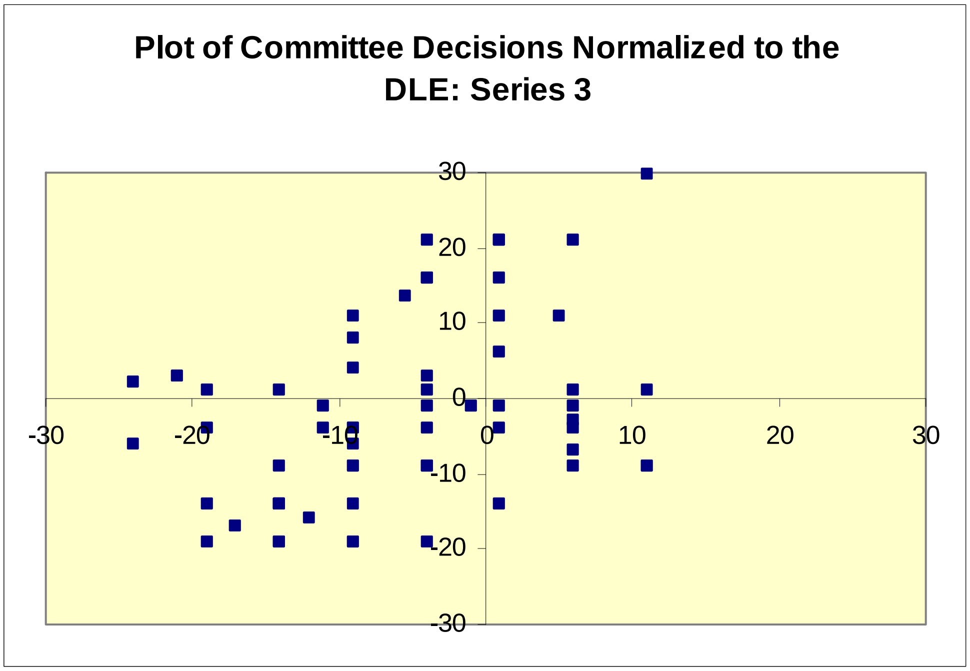


Figure 6.B

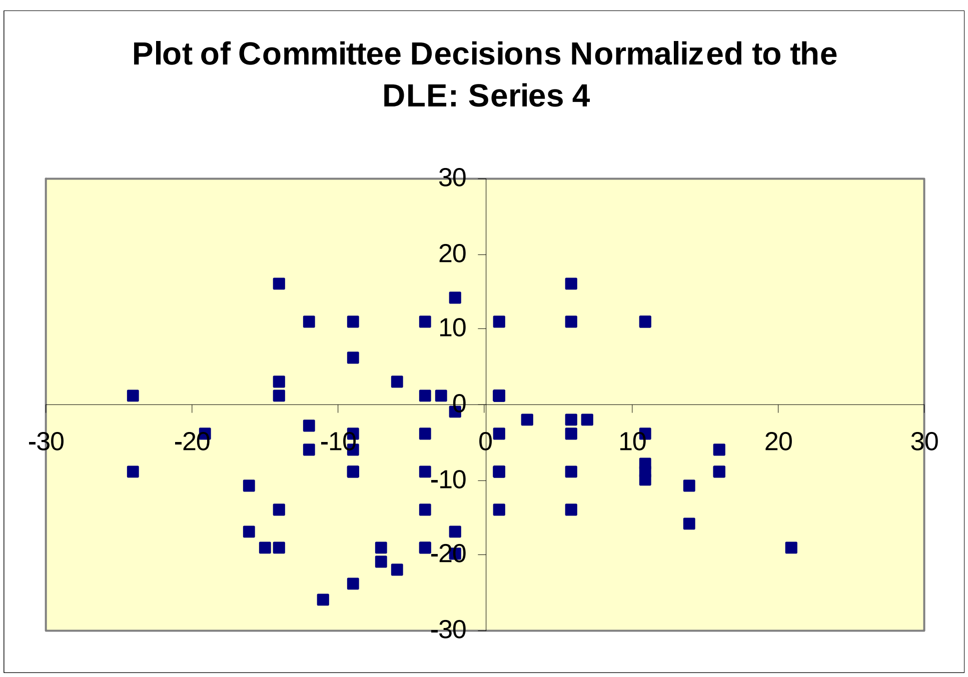


Figure 7.A

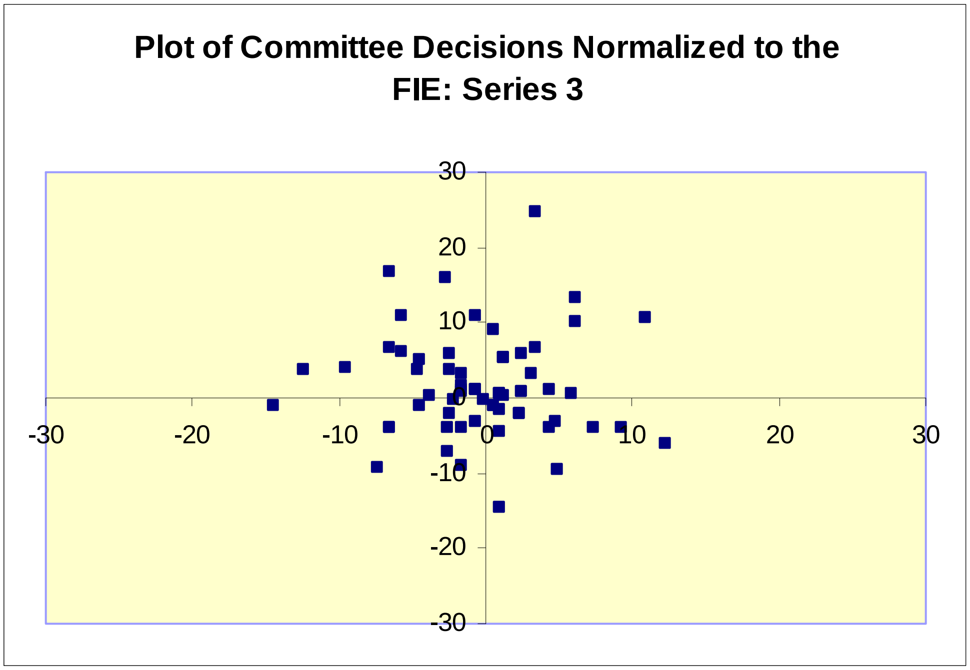


Figure 7.B

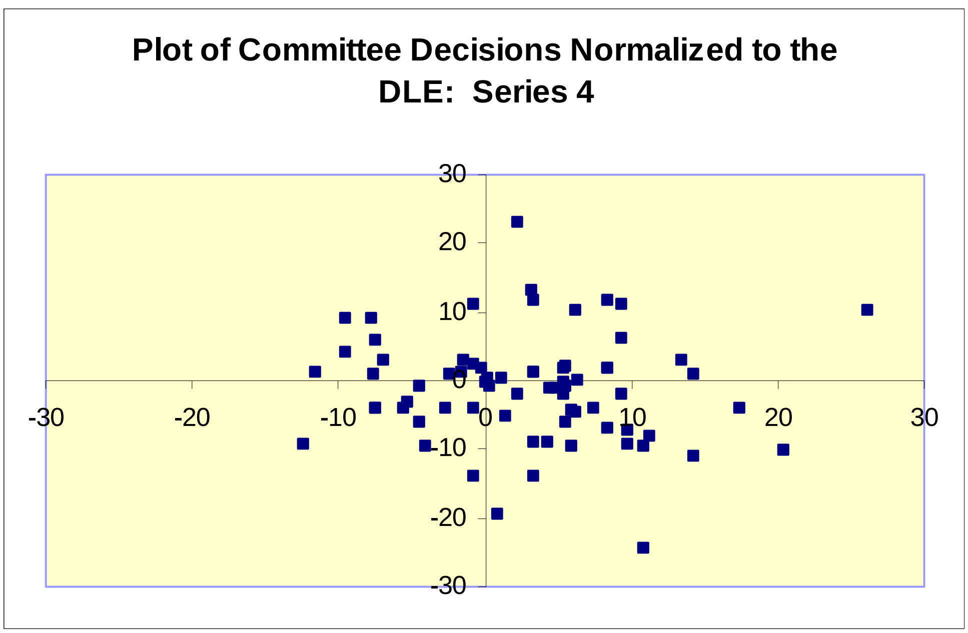


Figure 8.A:

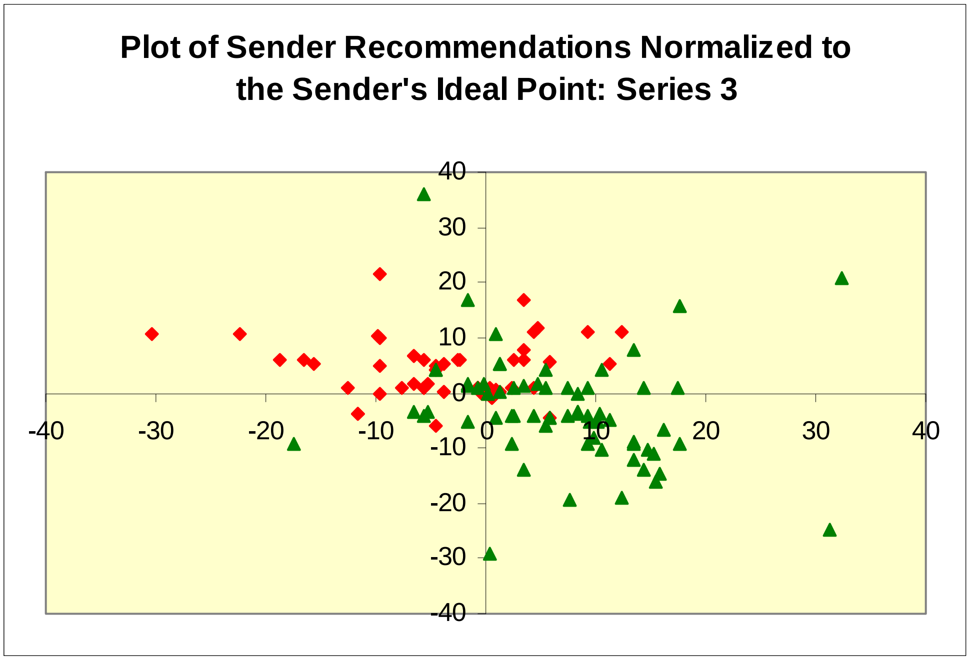


Figure 8.B: