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Testing the Predictions of the Multidimensional Spatial Voting Model with Roll Call Data

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This paper develops a procedure for locating proposals and legislators in a multidimensional policy space by applying agenda-constrained ideal point estimation. Placing proposals and legislators on the same scale allows an empirical test of the predictions of the spatial voting model. I illustrate this procedure by testing the predictive power of the uncovered set—a solution concept of the multidimensional spatial voting model—using roll call data from the U.S. Senate. Since empirical tests of the predictive power of the uncovered set have been limited to experimental data, this is the first empirical test of the concept's predictive power using real-world data.

1 Introduction

The gap between the development of theoretical models and the test of empirical implications of theoretical models has been narrowed by the development of statistical methods. One of the most advanced areas in this regard is the tests of the empirical implications of spatial voting models using ideal point estimation. Particularly, NOMINATE measures from Poole and Rosenthal (1997) and other applications of item response theory (IRT) models to roll call voting analysis have allowed estimation of the ideal points of legislators (Londregan 1999; Jackman 2001; Clinton, Jackman, and Rivers 2004) and justices (Martin and Quinn 2002; Bafumi et al. 2005). Yet an empirical test of the predictions of the multidimensional spatial voting model is still limited because estimation of bill[1] locations is problematic in a multidimensional policy space. Since most important concepts of the spatial voting model concern the predicted location of the final voting outcome, estimation of bill locations is important for testing the empirical relevance of the predictions of the spatial voting model. The core, the uncovered set, and the Pareto set are the concepts of the spatial voting model that predict final voting outcomes. Thus, to test these concepts' predictive power, we need to estimate not only the ideal points of legislators but also the locations of proposals.

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[1] In this paper, I use the term "bill" and "proposal" to denote any motions that are presented for a vote on the floor of a legislature. Thus, bill and proposal can be perfecting amendments, substitutes, or resolutions.

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The importance of estimating bill locations can be illustrated by examining the recent contribution of a multidimensional spatial voting model and its limitations. Applying the uncovered set[2] to the "conditional party government" debate, Bianco and Sened (2005) show that the potential for party influence through agenda control exists in the modern United States Congress and that, at the same time, the room for party influence is affected by the preferences of legislators. Since the uncovered set represents a set of enactable proposals, the fact that the shape of the uncovered set is affected by the configuration of legislators' ideal points supports the argument that party influence is an artifact of legislators' preferences (Krehbiel 1999, 2000). On the other hand, the fact that the uncovered set does not collapse to a single point indicates that there is room for party influence through agenda control (Aldrich and Rohde 1998, 2001).

Bianco and Sened show this by computing the uncovered set using the estimates of ideal points. However, there are two limitations. First, their argument is based on the predictive power of the uncovered set, which has not been verified with real-world data. Although there is experimental evidence of the predictive power of the uncovered set (Bianco et al. 2006), there is no evidence that real-world legislatures actually produce the outcomes that the theory predicts. Furthermore, the multidimensional spatial voting model predicts the final outcome to be in the uncovered set, not because the proposals in the uncovered set are unbeaten, but because the covered proposals are less enactable (see Section 3.4 for details). That is, unlike a proposal in the core, a proposal in the uncovered set can be beaten by a proposal outside of the uncovered set. Thus, without empirical evidence from real-world legislatures, we cannot take the predictive power of the uncovered set for granted. Second, Bianco and Sened stop short of showing whether parties actually exert influence on legislative outcomes. They show the existence of the potential for party influence, not the existence of party influence itself. Without estimating and examining the location of final outcomes, their discussion is limited to potential legislative outcomes.

Thus, being able to estimate the location of proposals is an important step forward because it allows us to trace the locations of winning and losing proposals and thus to study legislative politics using the actual outcomes rather than potentials or proxies. In other words, estimating bill locations allows us not only to test the predictive powers of a formal model but also to make substantive contributions to legislative politics. This paper tries to narrow this gap between theoretical models and the empirical tests of the predictions of those models by creatively applying an existing method to estimating bill locations in addition to the ideal points of legislators.

The problem in estimating bill locations in a multidimensional space is that it requires more information than estimating the ideal points of legislators. The use of the IRT model allows us to estimate only the midpoint between a "nay" position and a "yea" position. Since each vote has these two bill parameters (nay and yea positions) to be estimated in each dimension, estimation of bill locations in a multidimensional space is not possible without additional information (details in the next section). One of the innovations in estimating the locations of proposals is the use of information on agenda structure. Clinton and Meirowitz (2001, 2003, 2004) estimate the locations of bills using agenda information.[3] The logic utilizes the fact that a nay vote means the legislator prefers the state proposed by the last successful proposal to the state proposed by the current proposal.

[2]The uncovered set is a solution concept in a multidimensional voting game. Formally, the uncovered set includes all proposals that are not covered. We say proposal x is covered by proposal y if y is majority preferred to (beats) x and every proposal that beats y also beats x. Thus, covered proposals are said to be bound to be defeated, whereas proposals that are not covered are more enactable. See Bianco, Jeliazkov, and Sened (2004) for detalis.

[3]See Krehbiel and Rivers (1988) for an earlier application of the idea.

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Thus, we constrain the nay position of the current vote to be same as the yea position of the last successful proposal. Clinton and Meirowitz call this a *relational constraint*.

However, the limitation of this method in a multidimensional setting is it requires that each bill be an attempt to change the status quo in only one dimension. The bills that attempt to change the status quo in more than one dimension still cannot be estimated even with agenda constraints. Here, I show that this problem can be solved by examining substantive relationships between proposals. Typically, there are two types of proposals in a legislature: perfecting amendments and substitutes. A perfecting amendment is a motion that either strikes language from the pending measure or inserts new language. Thus, perfecting amendments tend to be short and one dimensional. A substitute seeks to replace texts of existing proposals by new texts. Because of this, substitutes tend to be longer and multidimensional and tend to be aggregates of the perfecting amendments that were voted on earlier. Thus, we can use this information on substantive relationships between perfecting amendments and substitutes to estimate the location of the multidimensional proposals by introducing such information as a substantive constraint.

In the following section, I explain the procedure with an illustration. Next, using roll call data from the U.S. Senate, I illustrate how we can utilize the U.S. Senate amending procedure to estimate the locations of multidimensional bills and how we can test the predictive power of the uncovered set. Then, I discuss the robustness of the results, followed by the conclusion.

2 A Statistical Model of Roll Call Voting and Bill Location Estimation

The basic spatial voting model assumes that each legislator has a most preferred policy position: *the ideal point*. Legislator i's ideal point in a two-dimensional policy space is denoted by $X_i \in \mathbb{R}^2$, where the row vector $X_i = (x_{i1}, x_{i2})$. Let ζ_j denote the location associated with the passage of yea on vote j and let ψ_j denote the location associated with the rejection of ζ_j. Assuming a quadratic utility function, we can write the random utility function of legislator i voting yea and nay on vote j as follows:

$$U_{ij}(\zeta_j) = -(X_i - \zeta_j)(X_i - \zeta_j)' + u_{ij}, \tag{1}$$

$$U_{ij}(\psi_j) = -(X_i - \psi_j)(X_i - \psi_j)' + v_{ij}, \tag{2}$$

where u_{ij} and v_{ij} are errors with Type I extreme-value distributions. Then, the probability of legislator i voting yea on vote j is

$$\begin{aligned} P(Y_{ij} = 1) &= P(U_{ij}(\zeta_j) > U_{ij}(\psi_j)) \\ &= P(-(X_i - \zeta_j)(X_i - \zeta_j)' + (X_i - \psi_j)(X_i - \psi_j)' > \varepsilon_{ij}) \\ &= \Lambda(-(X_i - \zeta_j)(X_i - \zeta_j)' + (X_i - \psi_j)(X_i - \psi_j)'), \end{aligned} \tag{3}$$

where $\Lambda(3)$ denotes the logistic distribution function of the iid error $\varepsilon_{ij} = v_{ij} - u_{ij}$. Y_{ij} is 1 if legislator i voted yea on vote j and 0 otherwise. Since our interest is in estimating bill parameters, we do not reparameterize the model into a two-parameter IRT model. Instead, the strategy is to estimate the bill parameters directly. Thus, the likelihood is

$$\begin{aligned} L(\zeta, \psi, X|Y) = \prod_{i=1}^{N} \prod_{j=1}^{M} &[\Lambda(-(X_i - \zeta_j)(X_i - \zeta_j)' + (X_i - \psi_j)(X_i - \psi_j)')]^{y_{ij}} \\ &\times [1 - \Lambda(-(X_i - \zeta_j)(X_i - \zeta_j)' + (X_i - \psi_j)(X_i - \psi_j)')]^{1-y_{ij}}, \end{aligned} \tag{4}$$

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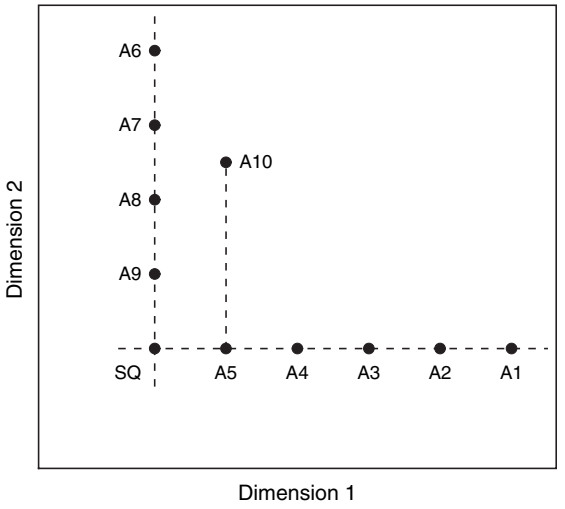


Fig. 1 An illustrative example of the locations of the status quo and amendments. The locations of amendments 1 through 9 are assumed to be different from that of the status quo in one dimension only. Amendment 10 is assumed to be different from the status quo in both dimensions.

where Y is a $N \times M$ matrix of roll call votes. N is the number of legislators. M is the number of votes.

The difficulty in estimating bill parameters comes from their large number. For example, when the number of votes is 10 as in the illustrative example in Fig. 1, the total number of bill parameters becomes 40 as in the left half of Table 1. This is because each vote has two locations (yea and nay) and two dimensions (i.e., $40 = 2 \times 2 \times 10$).

For the purpose of simple illustration, I assume that the status quo remains as the status quo throughout the hypothetical legislative voting session depicted in Fig. 1. Thus, $SQ = \psi_1 = \ldots = \psi_{10}$. That is, nay votes mean a vote for the status quo in the example. We can think of the status quo as a House bill introduced in the Senate. Note that the status quo in this example means the initial bill or proposal introduced on the floor, not the state where no new bill is passed. In the example, the first vote is choosing between the initial bill "SQ" and the first amendment "A1." Since A1 is an amendment to the initial bill SQ, voting against the amendment means that the legislator prefers the original bill under consideration to the amendment. In this sense, the initial bill under consideration is set to be the initial status quo.[4]

In Fig. 1, it is assumed that the first five votes are related to dimension 1 only and the next four votes are related to dimension 2 only. The final vote is assumed to be related to both dimensions. The first five votes can be thought of as votes on perfecting amendments that attempt to change the status quo location in dimension 1. The next four votes are votes on perfecting amendments that attempt to change the status quo location in dimension 2. Then, the last vote can be thought of as a vote on a substitute that attempts to change the status quo location in both dimensions.

[4]See Clinton and Meirowitz (2004) for a similar usage of the status quo concept. The state where no new bill is passed in the legislature is the nay position on the final passage vote. However, although the yea location of the final passage vote is identified by the agenda constraints, this nay location cannot be identified without more information in a multidimensional setting.

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Table 1 An illustration of bill parameters before and after agenda and substantive constraints

	Before agenda constraints				*After agenda constraints*			
	Yea (j)		*Nay (j)*		*Yea (j)*		*Nay (j)*	
j	*Dim 1*	*Dim 2*	*Dim 1*	*Dim 2*	*Dim 1*	*Dim 2*	*Dim 1*	*Dim 2*
1	ζ_1^1	ζ_1^2	ψ_1^1	ψ_1^2	ζ_1^1	SQ^2	SQ^1	SQ^2
2	ζ_2^1	ζ_2^2	ψ_2^1	ψ_2^2	ζ_2^1	SQ^2	SQ^1	SQ^2
3	ζ_3^1	ζ_3^2	ψ_3^1	ψ_3^2	ζ_3^1	SQ^2	SQ^1	SQ^2
4	ζ_4^1	ζ_4^2	ψ_4^1	ψ_4^2	ζ_4^1	SQ^2	SQ^1	SQ^2
5	ζ_5^1	ζ_5^2	ψ_5^1	ψ_5^2	ζ_5^1	SQ^2	SQ^1	SQ^2
6	ζ_6^1	ζ_6^2	ψ_6^1	ψ_6^2	SQ^1	ζ_6^2	SQ^1	SQ^2
7	ζ_7^1	ζ_7^2	ψ_7^1	ψ_7^2	SQ^1	ζ_7^2	SQ^1	SQ^2
8	ζ_8^1	ζ_8^2	ψ_8^1	ψ_8^2	SQ^1	ζ_8^2	SQ^1	SQ^2
9	ζ_9^1	ζ_9^2	ψ_9^1	ψ_9^2	SQ^1	ζ_9^2	SQ^1	SQ^2
10	ζ_{10}^1	ζ_{10}^1	ψ_{10}^1	ψ_{10}^2	ζ_5^1	ζ_{10}^2	SQ^1	SQ^2

Note. Superscripts denote the dimension. The total number of votes is 10.

Following Clinton and Meirowitz (2004), we can constrain the yea and nay positions of the first nine bills to be the same in the dimension that each of the bills is not different from the location of the status quo because they are all related to changes from the status quo only in one dimension. Thus, for the first five votes, we can constrain their yea and nay parameters in dimension 2 to be the same (i.e., $\zeta_1^2 = \psi_1^2; \zeta_2^2 = \psi_2^2; \zeta_3^2 = \psi_3^2; \zeta_4^2 = \psi_4^2; \zeta_5^2 = \psi_5^2$). For the next four votes, we can constrain their yea and nay parameters in dimension 1 to be the same (i.e., $\zeta_6^1 = \psi_6^1; \zeta_7^1 = \psi_7^1; \zeta_8^1 = \psi_8^1; \zeta_9^1 = \psi_9^1$). Now, the bill parameters of the last vote need to be constrained. Because there are two free parameters for the yea position of the vote (the nay position of the vote is constrained to be the same as the status quo by the agenda information), we cannot estimate the parameters without extra information. However, this extra information is available if one of the previous amendments has the same component as this last vote. Suppose a legislator who wanted to amend the original bill (the status quo) proposed a perfecting amendment and his amendment was voted down by the majority during the 5th vote. Also, he proposed a substitute that had the same component as his previous amendment in one dimension at the end of the legislative session. In this case, we can constrain the yea position of the last vote in that dimension to be the same as that of the previous amendment (i.e., $\zeta_{10}^1 = \zeta_5^1$). Actually, it does not have to be the previous amendment. As long as his substitute includes one of the same components as one of the amendments, the location of the substitute can be identified. The opportunities for this identification will increase as the number of amendments increases. Also, when legislation involves discrete choices like choosing between different levels of government (local versus state versus federal) for certain policy implementation authority, it is very likely that perfecting amendments and substitutes have common components.

Thus, by combining the constraints on dimensionality of each bill, substantive relationships between the bills, and the relational constraints (agenda information), we can reduce the 40 bill parameters to 12 bill parameters, as in the right half of Table 1. Among these 12 parameters, four parameters are constrained for model identification. We need to pin down at least two bill parameters in each dimension to set the scale and direction of each dimension.

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Bill locations and ideal points are estimated via a Markov Chain Monte Carlo method. For this, we assign a prior distribution for each parameter. Uniform distributions with a fairly wide range can be assigned as prior distributions for bill parameters. For ideal points, we can use a multivariate normal distribution with means of 0 and relatively large variances to assign relatively diffuse priors. Nevertheless, if more substantive information on bill locations and ideal points is available, the use of informative priors is desirable (Jackman 2001). To explore the posterior distribution, the Metropolis-Hastings algorithm can be used because there is no known conjugate prior distribution for this type of model.

In the next section, I illustrate how we can test the predictions of multidimensional voting models applying this procedure to U.S. Senate roll call data.

3 An Application to the Roll Call Votes on the Federal Reserve Act of 1913

In this section, I use agenda-constrained ideal point estimation to test the predictive power of the uncovered set. The prediction of the multidimensional voting model is tested with U.S. Senate roll call data on the creation of the Federal Reserve System (the Fed). This data set is chosen for two reasons. First, the main issue of the day was clearly two dimensional, making it a proper case to apply a two-dimensional spatial model. Regarding the structure of the new agency, Senate debate concentrated on the degree of independence from the President and the degree of centralization. Second, it sheds light on legislative politics at the turn of the century when institutionalization of the U.S. Congress had just begun. Thus, legislative politics during this period can be useful as a benchmark for legislative politics in the modern Congress.

3.1 *Data*

In 1913, the 63rd Congress[5] created the Fed by passing the Federal Reserve Act. The structure of the new agency was important for many social groups. After a series of banking crises, Eastern and Midwestern city bankers wanted a centralized system that allowed for bankers' participation in decision making. Large city bankers wanted a centralized banking system because it would allow them to profit from the emergence of the dollar as a world currency (Broz 1997). On the other hand, farmers and Progressives wanted a publicly controlled and decentralized banking system that they hoped would prevent the dominance of large city bankers (Greider 1987). When the Democrat-controlled House passed the Glass bill, which resolved the issue of "public versus private" control by creating a publicly controlled banking system, the city bankers focused their lobbying efforts in the Senate on the issue of centralization (Glass 1927).

In the Senate roll call votes, this push for more centralization was reflected in several amendments and one substitute. In the Senate, there were 27 votes regarding the creation of the Fed. Among these votes, 10 were related to the structure of the Fed. The other 17 were about various issues like gold reserve requirements and the nature of bank notes. Since these issues were not necessarily related to the issues of the structure of the new agency, I exclude them from the roll call analysis. Further, none of these 17 amendments received a majority. Thus, omitting these votes does not affect the agenda structure. The remaining 10 votes were all related to the structure of the Fed. Some of them were related to the degree of centralization (the number of the Reserve Banks and the authority

[5]Woodrow Wilson (D) was the president. The House and the Senate were dominated by the Democrats for the first time after a long dominance by Republicans. Ninety senators participated in the Fed creation roll calls: Democrats (48), Republicans (41), and Progressive (1).

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of the Federal Reserve Board over the Reserve Banks). Others were about control over the Fed.

A close reading of the *Congressional Record* reveals that the control issue in the Senate was mostly about the degree of presidential control over the new agency. Specifically, the issue concerned the tenure structure of the Federal Reserve Board members and civil service law requirements for Fed employees. Increasing the number of Board members and the tenure of these members would make the Board more independent from the President, who appoints them with the consent of the Senate. The civil service requirements for the Fed employees were important because exempting them from the civil service law requirements was thought to take away the control of Congress and give to an executive body the determination as to the number of appointments and the determination of salaries (Congressional Record, Vol. 51, No. 2, p. 1215). Thus, Senate roll call votes regarding the structure of the Fed can be analyzed by a two-dimensional model.[6] I set the first dimension to be the degree of independence from the president (the "control" dimension). The second dimension is set to be the degree of centralization.

3.2 *Agenda Constraints and the Senate Amending Procedure*

Table 2 shows the relational constraints reflecting the agenda structure. First, the Owen bill was set to be the status quo because the first four votes in the Senate were on the amendments to the Owen bill. That is, the senators who voted against the amendments were voting for the Owen bill. Second, of the nine remaining votes, two votes—votes on the Hitchcock substitute and the amended Owen bill—were related to both dimensions. That is, the yea and nay positions for these votes have two free parameters, making it impossible to estimate them without extra constraints. However, this problem can be solved with more information from the Congressional Record. First, the location of the yea position on the vote on the amended Owen bill can be estimated using the agenda constraints. That is, the yea position on the amended Owen bill is the nay position on the Hitchcock substitute. However, the location of the nay position on the amended Owen bill—the state where no new bill passed the Senate—cannot be identified. Since our interest lies in the yea location of the vote on the amended Owen bill and the inclusion of the vote causes identification problems, the final passage vote on the amended Owen bill was not included in the analysis. Finally, the yea location of the vote on the Hitchcock substitute in the control dimension is identical to the nay position of ICPSR 160. ICPSR 160 was a motion to table Hitchcock's amendment to the Owen bill. Senator Hitchcock proposed to amend the Owen bill by increasing the number of members of the Federal Reserve Board from six

[6]While the assumptions on the dimensionality—the number of dimensions and the dimensionality of each vote—should be justified on a substantive ground, we can check the appropriateness of the assumptions by fitting a commonly used two-parameter IRT model. The basic structure of this model is $P(Y_{ij} = 1) = \frac{e^{\beta_j(X_i - \alpha_j)}}{1+e^{\beta_j(X_i - \alpha_j)}}$, where β_j is a discrimination parameter, X_i is an ability parameter (or ideal point), and α_j is a difficulty parameter. If a discrimination parameter (β_j) is zero, it suggests that the vote is not relevant to the dimension because it means $P(Y_{ij} = 1) = 1/2$, regardless of the values of the ideal points and the difficulty parameters. Thus, if the estimate of the discrimination parameter is not different from zero, it suggests inappropriate dimensionality assumptions (See Jackman 2001 for details). I fit the two-parameter IRT model—with the constraints on the dimensionality of each vote in Table 2—to the Senate roll call data and examine the estimates of the discrimination parameters. None of the 95% credible intervals for the unconstrained discrimination parameters include zero, suggesting that the assumptions on the dimensionality are not inappropriate. (Note the similarity of this to confirmatory factor analysis, with the discrimination parameters being equivalent to factor loadings. On the other hand, comparing the results with those from NOMINATE is not useful here because it is like comparing the results from confirmatory factor analysis with those from exploratory factor analysis.) Nevertheless, this is only supplementary. The decisions should be guided by the investigation of the substances of the proposals.

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Table 2 Agenda and substantive constraints on the Fed creation roll call votes in the 63rd Senate

				Yea (j)		*Nay (j)*		
j	*ICPSR*	*Issue*	*Pass/ Fail*	*Dim 1*	*Dim 2*	*Dim 1*	*Dim 2*	*Brief description of Yea (j)*
1	160	Control	Pass	SQ^1	SQ^2	θ_1	SQ^2	To table an amendment to the OW that increases the tenure of the Board members
2	166	Central	Pass	SQ^1	SQ^2	SQ^1	θ_2	To table an amendment to OW that reduces the number of Reserve banks
3	167	Central	Pass	SQ^1	SQ^2	SQ^1	θ_3	To table an amendment to OW that increases the influence of the Board on Reserve banks
4	170	Control	Pass	θ_4	SQ^2	SQ^1	SQ^2	To amend OW by suspending civil service requirements for the Fed employees
5	178	Control	Fail	θ_5	SQ^2	θ_4	SQ^2	To amend OW by placing the Fed employees under civil service
6	179	Control	Fail	θ_6	SQ^2	θ_4	SQ^2	To amend OW by placing the Fed employees under civil service
7	180	Control	Pass	θ_7	SQ^2	θ_4	SQ^2	To amend OW by authorizing the president to place Fed employees under civil service
8	182	Both	Fail	θ_1	θ_8	θ_7	SQ^2	To pass the Hitchcock substitute
9	184	Both	Pass	θ_7	SQ^2			To pass the amended OW

Note. OW, Owen bill. "Dim 1" denotes the control dimension. "Dim 2" denotes the centralization dimension. Bills 1 to 3 are motions to table an amendment to the OW. Thus, a yea vote is treated as a vote for the OW. SQ^1 and SQ^2 denote the positions of the OW in the control dimension and the centralization dimension, respectively.

to eight and their tenure from 6 to 8 years. Later, when he proposed his substitute, it had the exact same component. This allows us to constrain the location of the yea position on the Hitchcock substitute in the control dimension to be equal to the nay position on ICPSR 160.[7] Note that since the Senate amending procedure relies on the principle of "precedence"—which rules that the votes on the perfecting amendments precede the votes on the substitutes (Oleszek 1996)—we can estimate the one-dimensional component of the substitute from the votes on the amendments that had the same component. In our data, the Hitchcock substitute could be estimated by constraining the yea position on ICPSR 160 to be the same as the yea position on the Hitchcock substitute in the control dimension.

[7]Having a common component does not automatically justify this constraint. If the Hitchcock substitute had salient components that might have affected the senators' voting decisions other than the issues of centralization and control of the Fed, this constraint does not work. However, the existing studies on the creation of the Fed and the debate record in the Congressional Record all show that the issues of presidential control and centralization of the Fed dominated the Senate debate and voting. In particular, the Hitchcock substitute, based on a proposal by Frank A. Vanderlip of the National City Bank, reflected the desire of city bankers for more centralization and their fear of political interference (Glass 1927). Furthermore, as discussed earlier, fitting a standard two-parameter IRT model did not indicate the existence of other salient dimensions.

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In addition to these agenda constraints, I fixed the location of the status quo in the centralization dimension at 0, the location of the fourth amendment by Owen at −1 in the control dimension, the location of the second amendment by Hitchcock at 1 in the centralization dimension, and the location of the seventh amendment by Jones at −0.5 in the control dimension.[8] These constraints are necessary to set the scale and direction of each dimension. Thus, giving more control over the Fed to the president is equivalent to moving to the left along the horizontal axis, whereas centralizing the Fed is equivalent to moving up along the vertical axis. Finally, Owen's ideal point is constrained to be (−2, −2), reflecting the fact that Democratic party leaders preferred a more presidentialized (dependent) and decentralized central bank.

3.3 *Estimation of Ideal Points and Bill Locations*

I fit the model to the Senate roll call data using the agenda constraints and identification constraints discussed in the previous section.[9] Since the ideal points and bill parameters themselves are not informative about what they are representing, I present the estimates by mapping the parameters back onto a two-dimensional space. Figure 2 plots the modes of estimated ideal points and the modes of estimated bill locations.[10] In the figure, the modes of the bills are denoted by the number assigned to them in Table 2 (j). For example, "1" denotes the location of the amendment proposed by Hitchcock that was tabled by the first vote.

Voting in the Senate was highly partisan. Republicans supported a more centralized and independent Fed, while Democrats wanted to allow more presidential control over a decentralized Fed. This partisan difference is clear in the two-dimensional space in Fig. 2. Democrats are clustered at the bottom left side of the space, whereas Republicans are generally on the top right side of the space. The two successful movements of the status quo during the Senate voting on the Fed creation were amending the Owen bill by suspending the civil service requirements for Fed employees (ICPSR 170) and amending the Owen bill by authorizing the President to place Fed employees under the civil service law requirements (ICPSR 180). In the two-dimensional space, these movements were equivalent to changing the status quo from SQ to "4" and from "4" to "7". On the other hand, if the Hitchcock substitute passed, the movement would have been equal to creating a somewhat more centralized and more independent Fed (from SQ to "8").

Before I discuss the substantive use of the two-dimensional representation of ideal points and bill locations, I check the model fit. In Fig. 3, classification rates for the model are plotted. The top panel shows the classification rates by legislator. The bottom panel shows the classification rates by vote. Generally, the classification rates are high (at 100%). The cases with low classification rates are those senators whose ideal points are close to 0 and ICPSR 180, which received support from Democrats although it was proposed by

[8] Jones' amendment (the 7th vote) specified that the president has the authority to place Fed employees under civil service. Since President Wilson was known for advocating a civil service system, this slightly increased the chance that Fed employees would be placed under civil service. For this reason, I fixed the Jones' amendment at −0.5, a slight improvement from −1 (exempting the Fed employees from the requirements).

[9] The model was estimated using WinBUGS (Spiegelhalter et al. 1999). The total number of iterations was 50,000. The first 25,000 draws were discarded to remove the effects of initial values. Two chains were initiated. The chains were thinned every 50th draw to reduce autocorrelation. It produced 1000 draws from the posterior density. The chains converged to a stationary state, with the Gelman-Rubin statistics at 1 or very close to 1. The traceplots and posterior density plots are available on the author's Web site.

[10] I employed Hyndman's procedure to obtain the modes (Hyndman 1996).

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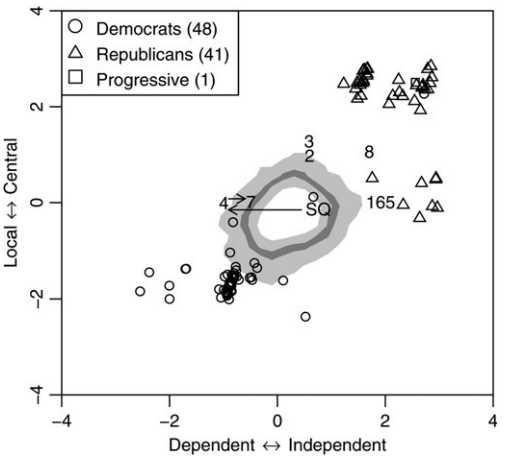


Fig. 2 The modes of ideal points, the modes of all the bills, and the uncovered set of the roll call voting on the Federal Reserve Act of 1913. The contour denotes the uncovered set at 95%, 70%, 50%, and 10% highest density levels. The location of each bill is denoted by its number (j) in Table 2. The successful changes of the status quo are denoted by the arrows: from SQ to "4" and from "4" to "7."

a Republican senator. Nevertheless, the overall classification rate (94.7%) suggests that the model fits the data reasonably well.[11]

3.4 *Testing the Predictive Power of the Uncovered Set*

In this section, I illustrate how estimation of ideal points and bill locations in the same metric space allows us to test the predictions of the spatial voting model by focusing on the uncovered set. The uncovered set is the solution concept in a multidimensional voting game with an empty core. The core is a set of undefeated proposals. Thus, once the status quo is in the core, it cannot be beaten by any other proposals. In one-dimensional voting games, the core is not empty because the location of the median voter is the core with simple majority rule. However, in multidimensional voting games, the core is usually empty. Because of this, the "chaos theorem" states that any outcome is possible in multidimensional voting games (McKelvey 1976; Schofield 1978). Nevertheless, as an alternative to the core, there has been growing attention to the uncovered set as a solution concept in multidimensional voting games (Miller 1980; Shepsle and Weingast 1984; McKelvey 1986; Bianco and Sened 2005). The uncovered set is a weaker concept than the core because a proposal in the uncovered set can be beaten by a proposal outside of the uncovered set, while a proposal in the core cannot be beaten by a proposal outside of the core. Formally, we say proposal x is covered by proposal y if y beats x and every proposal that beats y also beats x. In this case, we can expect that proposal x is less likely to be the final outcome as long as proposal y is available. Thus, we can exclude covered proposals from our prediction of the final outcome. In other words, when the core is empty, the uncovered set provides useful predictions of the location of final outcomes in multidimensional voting

[11]The classification rate of a model that uses only party identification to classify observations is 93.6%.

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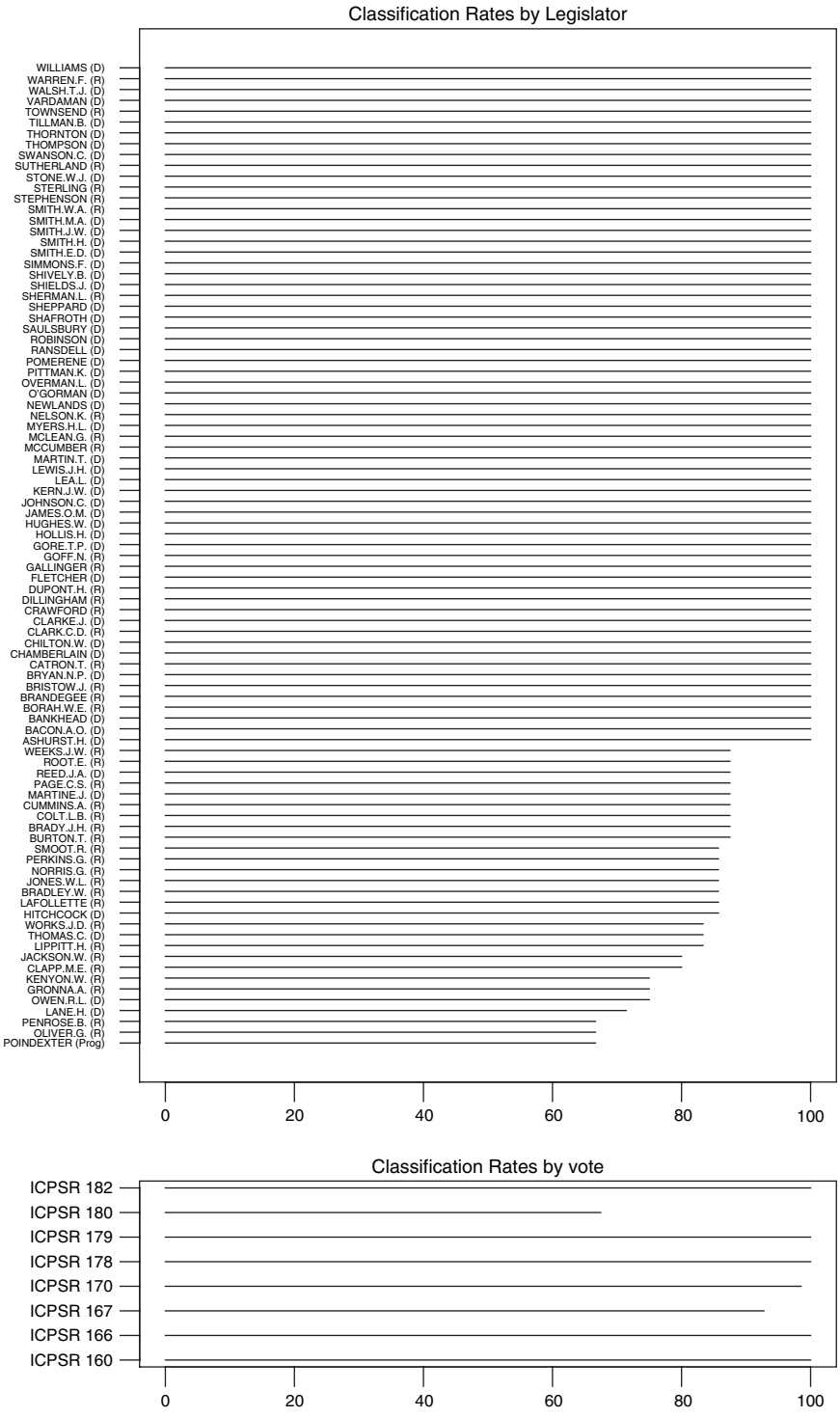


Fig. 3 Classification rates for the Senate roll call votes on the Federal Reserve Act of 1913. The classification threshold is 0.5. All parameters are fixed at their posterior medians.

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games (Bianco, Jeliazkov, and Sened 2004; Bianco and Sened 2005). However, the evidence for the predictive power of the uncovered set has been limited to experiments (Bianco et al. 2006). So far, the difficulty of estimating bill locations from roll call data has prevented researchers from testing the predictive power of the uncovered set using real-world data.

The contour in the middle of Fig. 2 is that of the uncovered set, calculated with each draw of ideal points from the Markov Chain Monte Carlo chains. Since the uncovered set is a function of ideal points,[12] we can compute it for each draw of ideal points as a quantity of interest.[13] The contour plot is based on 500 sets of such uncovered sets. First, the configuration of ideal points and the uncovered set shows that the uncovered set is located relatively in the center of the space. Even the center of the cluster of Democrats is out of the 95% level[14] of the uncovered set. Second, bills are located around the uncovered set, not around proposers' ideal points. Since the uncovered set represents enactable outcomes, it shows that legislators proposed bills not just close to their ideal points but also close to the uncovered set in order to increase their proposals' chance of being the final outcome. Third, the final outcome in this legislative session is indicated by "7" in the plot. This final outcome is in the 70% level of the uncovered set, while other proposals, except for the initial Owen bill (SQ), are outside the 95% level of the uncovered set. If we apply the conventional interpretation of the confidence interval, this means that we can reject the hypothesis that each of these other proposals is included in the uncovered set at the 95% level. However, we cannot reject the hypothesis that "7" is in the uncovered set at the 95% level. Therefore, this can be interpreted as confirmation of the predictive power of the uncovered set. This is the first time that real-world data have been used to do so. Future research on other major acts will provide a systematic test of the predictive power of the uncovered set.[15]

In addition to testing the predictive power of the uncovered set, we can use such tests to understand legislative politics. The theoretical predictions that the final outcome will be the median voter's location in a one-dimensional space and in the uncovered set in a multidimensional space are based not only on the assumption of spatial voting behavior of legislators but also on the assumptions like unlimited agenda access. Thus, the predictions of the theoretical model may not be realized when agenda access is restricted or when there is some uncertainty about the location of the median voter's ideal point (or the uncovered set). That is, the final outcome can be different from the predictions of the theoretical models because exogenous factors like party influence can affect the final outcome in reality. This is why testing the predictions of the theoretical model is substantively valuable. A discrepancy between the predicted outcome and the realized outcome may signal that there exist some exogenous factors affecting the final outcome.

[12]To be precise, the uncovered set is a function of the ideal points and the voting rule. If we take into account the supermajority procedures of the U.S. Senate, the size of the uncovered set will be larger. In general, as the voting rule requires more members' agreement to pass a proposal, the uncovered set will approach the Pareto set, the convex hull of legislators' ideal points.

[13]Each of these uncovered sets is computed by the grid-search method developed in Bianco, Jeliazkov, and Sened (2004).

[14]The levels of the contour denote the highest density regions. Thus, the 10% level means the top 10% most likely location of the uncovered set.

[15]The fact that the uncovered set is a weaker concept than the core calls for this type of empirical test before we take the predictive power of the concept for granted. As discussed earlier, the multidimensional spatial voting model predicts the final outcome to be in the uncovered set, not because the proposals in the uncovered set are unbeaten, but because the covered proposals are less enactable. In the Fed case, not all winning proposals are in the uncovered set. The movement from SQ to "4" represents a movement from the inside of the uncovered set to the outside of the uncovered set. Thus, in future research, we may encounter cases where the final outcome is outside of the uncovered set.

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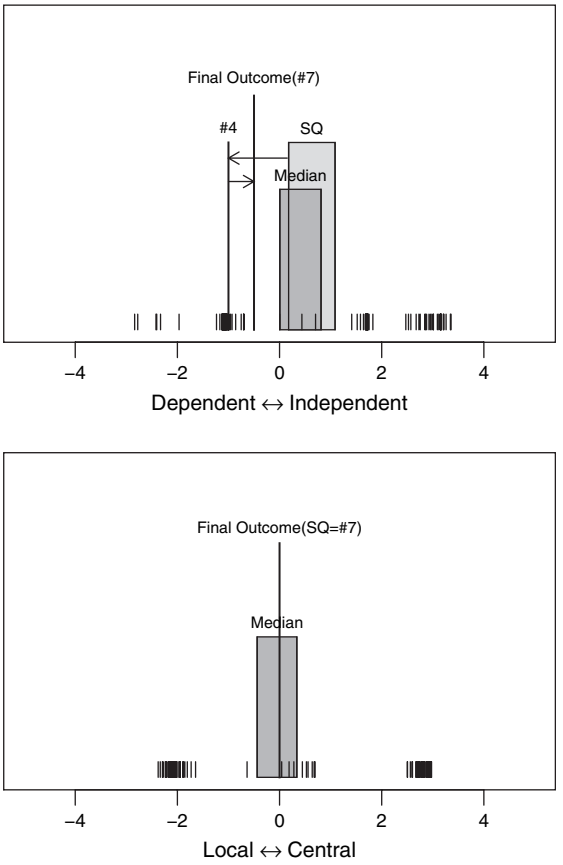


Fig. 4 Distribution of ideal points, winning proposals, and the median legislator in each dimension of the Federal Reserve Act of 1913. The dense areas represent 80% credible intervals of the median legislator locations. Since the status quo location in dimension 1 was estimated, its 80% credible interval is denoted by another dense area in the top panel. The means of ideal point estimates are denoted by the short bars at the bottom of the plots.

In our example, the final outcome is on the left edge of the uncovered set. In particular, the location of the final outcome is close to the cluster of Democrats—the majority party—in the control dimension. The location of the final outcome suggests that the legislative voting outcome was somewhat favorable to the majority party. In the legislative session, the two successful movements were from SQ to "4" and from "4" to "7". All attempts to move the final outcome toward the cluster of Republicans failed ("1," "2," "3," "5," "6," and "8" in the plot are the locations of defeated proposals.). The existence of this bias in the final outcome can be demonstrated by examining the one-dimensional distribution of ideal points and the location of the proposals. Figure 4 shows the distribution of ideal points and proposals in one-dimensional plots. The top panel includes the control dimension, and the bottom panel includes the centralization dimension. For the purpose of illustration, I computed the 80% credible intervals of the location of the status quo and the median legislator. In the top panel, these overlap substantially. Thus, if legislative voting was one dimensional, the prediction of the spatial voting model would be that the status

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quo could not have been beaten by any proposals. However, the realized final outcome was to the left of the median legislator, suggesting that the realized final outcome was favorable to the majority party on the control dimension.

While a substantive investigation into why the realized final outcome was somewhat favorable to the majority party is beyond the scope of this paper,[16] we can make some conjectures using the results. First, we can consider the possibility of agenda control by the majority party. Although we need another rigorous test to check for this possibility, tracing the locations of proposals suggests that agenda control is unlikely. For one thing, if the majority party had complete agenda control, the movement from "4" to "7" in Fig. 2 should not have happened. This is because the majority party would not have allowed "7" to be proposed if it had complete gate-keeping power, knowing that "7" would be preferred to "4" by the majority of legislators. This is clearer in the top panel of Fig. 4. In the figure, "7" is farther from the cluster of Democrats than "4." Thus, this result suggests that the majority party did not have agenda power, which is consistent with the notion that Senate debate, unlike House debate, is relatively open.

Another possibility is that there was some uncertainty about the location of the median legislator in the control dimension. While the statistical model is built on the assumption that legislators know the location of bills, there was no assumption that legislators' ideal points are common knowledge. Given the outcome, uncertainty over the location of the median legislator seems to be a plausible explanation. While it is reasonable to assume that legislators know each other's position on general issues, this assumption may not be true when it comes to specific policy issues like the structure of a bureaucratic agency. In the top panel of Fig. 4, if the median senator or any senators to the right of the median senator knew her location, they would have proposed a bill there. Then, it would have passed.

While a more systematic examination of the legislative outcomes in the 63rd Congress is needed to identify the pattern of legislative politics during the period, we can make conjectures such as those above because we have the estimates of ideal points and the estimates of bill locations. By examining the location of winning and losing proposals, we can infer whose positions are more represented in the final outcome and what might (or might not) have affected the legislative outcome.

3.5 *Discussion on the Robustness of the Results*

Before we conclude this paper, it is necessary to discuss the robustness of the results. Since we are estimating unobserved ideal points of legislators from their roll call votes, we have to consider the possibility that the true ideal points might differ from the estimated ideal points.

While the possibility of logrolling and strategic voting also raises such concerns, the focus in this section is on the possibility of misestimation of ideal points due to the small number of votes. This is partly because the possibility of logrolling and strategic voting in the Fed creation roll calls is low and partly because there is a solution to such problems. We can check the possibility of logrolling and strategic voting by comparing the estimated locations of bills. If the estimated locations of two proposals are similar despite their different contents, this implies that legislators somehow perceived the two proposals to be interchangeable. This indicates a strong possibility of logrolling (see Clinton and Meirowitz 2004 for details.)

[16]One thing we can do in the future is to do similar tests with other major acts passed in the 63rd Senate and see if the final outcomes are systematically closer to the majority party. Even further, we can apply this to major acts in the modern Congress and see whether the results are similar.

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A more common problem in studies like this is the possibility of misestimation of ideal points. When we use a small number of votes, we may not be able to obtain reliable estimates of ideal points. For example, if a bill that has a cutpoint between the ideal points of two legislators is never proposed, then the ideal point estimates of these two legislators will be identical because the two legislators will show identical voting behavior even when their true ideal points are different. In fact, almost every ideal point estimation with roll call votes will suffer from this problem. Ideal points of legislators whose positions are extreme are more likely to suffer from this problem. This is because a bill that divides extreme legislators—say, between Edward Kennedy and John Kerry—will almost never be proposed. As seen in the previous section, legislators tend to propose bills around the center of the distribution of ideal points, rather than around their own ideal points, because they want to increase the chance of their bills to win the support of the majority. Thus, this rational behavior of legislators creates a dilemma because we need bills that divide extreme legislators in order to obtain reliable ideal point estimates.

Given this possibility of discrepancy between ideal point estimates and true ideal points, the robustness of the test we conducted in the previous section is in question. Particularly, estimates of the uncovered set, which is a function of ideal points, can be affected by this problem.[17] Thus, in order to check the robustness of the uncovered set to the possible misestimation of ideal points, I compared the uncovered set computed from true (simulated) ideal points with the uncovered set computed from slightly misestimated ideal points. To examine the seriousness of the problem, I compared the results from two different sets of misestimated ideal points in Fig. 5. The left panels illustrate how the uncovered sets are affected when an extreme legislator's ideal point is incorrectly estimated. The right panels show how the uncovered sets are affected when a moderate legislator's ideal point is incorrectly estimated. The uncovered sets in the top row are computed from true ideal points, while the uncovered sets in the second and the third rows are computed from the set of ideal points with one misestimated ideal point. As is clear from the right panels of Fig. 5, when a moderate legislator's ideal point is incorrectly estimated, the shape of the uncovered set changes, although the location and size of the uncovered sets are relatively unchanged. On the other hand, the size, shape, and location of the uncovered sets are identical when an extreme legislator's ideal point is incorrectly estimated. The uncovered sets in the second and the third rows of the left panels are identical to that of the top left panel. In sum, this simulation experiment clearly demonstrates that the uncovered set is robust to extreme ideal points, just like the median is robust to outliers in a one-dimensional space.

The results in the previous section are therefore robust to misestimation of extreme legislators' ideal points. Since moderate legislators' ideal points are less likely to be misestimated than extreme legislators' ideal points, the size, shape, and location of the uncovered set in Fig. 2 and the location of the median legislator in Fig. 4 are robust to the possible errors in the estimation of ideal points.[18] The finding that the senators proposed bills around the center of the distribution of ideal points, rather than around their own ideal

[17] One might raise a question whether bill location estimates are affected by the same problem. In my Monte Carlo experiments with 10 votes and 100 legislators (not reported), bill locations are recovered quite well. The reason is that there are 100 ideal points for each bill that can be used to pin down the location of the bill. Thus, as long as the number of legislators is sufficiently large and there are no extreme bills—which receive unanimous votes—as in our Fed example, bill location estimates are reliable.

[18] Even if there are some errors in the estimation of ideal points of moderate legislators, the use of the contour plot computed using the uncovered sets estimated from each draw of ideal point estimates will cancel out the effects of the errors on the shape of the uncovered set, in addition to providing some measure of uncertainty.

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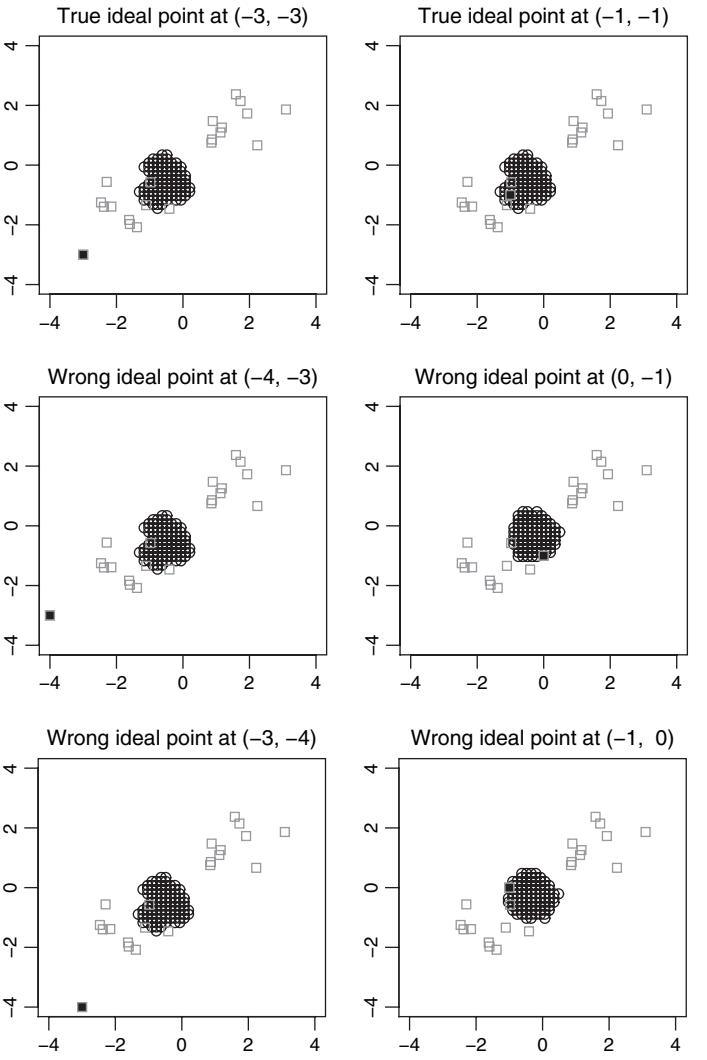


Fig. 5 Robustness of the uncovered set to extreme ideal points. The left panels show the change of the uncovered set (shaded area) when an extreme ideal point changes. The right panels show the change of the uncovered set when a moderate ideal point changes. The solid square represents an "incorrectly estimated" ideal point in the second and third rows. Open squares—10 at the lower left corner and 10 at the upper right corner—represent "correctly estimated" ideal points.

points, adds further support. Note also that the number of ideal points in the simulation experiment is 21, whereas the number of the senators in the Fed example is 90. The chance of one (or a small number of) misestimated ideal point affecting the computation of the uncovered set becomes smaller as the size of the legislature increases.

4 Conclusion

In this paper, I showed how to estimate bill locations in a two-dimensional space using roll call data. Utilizing agenda information and information on the substantive relationship between proposals, I estimated the locations of multidimensional proposals. Estimation of

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ideal points and bill locations in the same metric space is very useful because it allows us to test the empirical relevance of the predictions of the multidimensional spatial voting model. Now, we can test the predictive powers of the solution concepts of the multidimensional spatial voting model like the core, the uncovered set, and the Pareto set. Testing the implications of theoretical models with real-world data provides us with opportunities to consider the empirical validity of the theoretical models. Moreover, it helps us increase our substantive understanding of legislative politics. Using U.S. Senate roll call data, I illustrated how to use estimated bill locations to help understand legislative politics. We can trace the locations of winning and losing proposals and make inferences using the location of the final outcome. While determining what affected the final outcome requires another step, locating the final outcome is a useful way to start such an investigation.

Nevertheless, there are some limitations that this study could not overcome. First of all, estimation of bill locations in multidimensional space requires that substantial information be put into the statistical model. Since the number of parameters multiplies as the number of dimensions increases, the statistical model cannot be identified unless there is sufficient information on the substantive relationships between proposals. Perhaps, one of the reasons this method may not be easily adopted by other researchers is that we must spend time gathering substantive information on proposals in order to estimate their locations. However, putting substantive information in statistical models should not be regarded as a weakness of the method. This is because a substantively guided model will produce substantively more meaningful results. Furthermore, as Clinton and Meirowitz (2001) show, ignoring agenda information can lead to incorrectly estimated dimensionality of the policy space. Therefore, we should utilize available substantive information in order to build statistically robust and substantively meaningful statistical models. This will allow for the extraction of more valuable information from the data.

Related to the above, the second problem is the availability of the substantive information necessary to estimate the location of multidimensional proposals. In some cases, multidimensional proposals may not be estimated because there are no perfecting amendments that can be used to identify the location of the multidimensional proposals. This is likely to be the case when the issue involves choosing between continuous alternatives, like the amount of the budget. However, in many cases, proposals involve discrete choices. For example, in deciding who has the authority to implement a certain policy, Congress will face choices between the federal government, the state government, and the local government or some combination of governments at different levels. In cases like this, the number of choices is limited, although the policy space is still continuous. Thus, in situations of discrete choices, it is more likely that multidimensional proposals have the same component as one of the perfecting amendments. Therefore, the problem of the availability of information on substantive relationships between proposals is less serious than one might think.

Finally, this study is just one—but the first—confirmation of the predictive power of the uncovered set. Since gathering the required substantive information is time intensive, a systematic examination of the predictive power of the uncovered set will take a while. Nevertheless, further research on the accuracy of the predictions of the multidimensional voting model in the modern U.S. Congress or in other legislatures is due.

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