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A SPATIAL MODEL FOR LEGISLATIVE ROLL CALL ANALYSIS

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SOCIAL SCIENCE WORKING PAPER 487

July 1983

ABSTRACT

A general nonlinear logit model is used to analyze political choice data. The model assumes probabilistic voting based on a spatial utility function. The parameters of the utility function and the spatial coordinates of the choices and the choosers can all be estimated on the basis of observed choices. Ordinary Guttman scaling is a degenerate case of this model. Estimation of the model is implemented in the NOMINATE program for one dimensional analysis of two alternative choices with no nonvoting. The robustness and face validity of the program outputs are evaluated on the basis of roll call voting data for the U.S. Senate, 1979-81. Extensive Monte Carlo studies are also presented. Substantive applications using the results for the Senate are briefly illustrated.

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I. INTRODUCTION

> One way to try to account for political choices is to imagine that each chooser occupies a fixed position in a space of one or more dimensions, and to suppose that every choice presented to him is a choice between two or more points in that space . . .
> One of the most difficult problems of defining dimensions in this way centers about the operational definition of distance . . . Scales of the sort we have used . . . appear to define only an ordering relation rather than an interval scale. . . . The definition of distance therefore marks a crucial gap between the model we shall propose and the data we have presented.
> MacRae (1958, pp. 355–56)

This essay bridges MacRae's "crucial gap." Using solely the nominal data of observed political choices, we are able to estimate metric spatial distances. We present our methodology in the context of legislative roll call analysis. These methods also apply to the analysis of voting in popular elections and other forms of political choice behavior when the choice set is a finite set of alternatives. Consequently, we develop the analysis with more generality than necessary for our illustrative example, an analysis of roll call voting in the U.S. Senate from 1979 through 1981.

The individuals making the political choices can be either voters or legislators. Typical choice sets would be {Yea, Nay}, for the U.S. Congress, {Carter, Ford, Did Not Vote}, for the 1976

Presidential election, {Extreme Left, Communist, Socialist Federation, Center, Independent Republican, Gaullist, Extreme Right, Blank or Spoiled Ballot, Abstention}, for French elections in the 1960s.

A long-standing [e.g., Rice (1924)] research method is to create an Euclidean representation of either the choices or the individuals. Various methods, such as factor analysis and nonmetric scaling, have been applied in an essentially black box, statistical-method driven fashion. For roll call examples, see Weisberg (1968) and Warwick (1977).[1]

Over a decade ago, researchers began to realize that, if choice behavior is consistent with the elementary multidimensional spatial model (Davis et al., 1970), these black-box methods would inaccurately recover the true Euclidean coordinates. At that time, almost all work was based either upon legislator-by-legislator analysis or roll call-by-roll call analysis. In either case, measures of association, such as Yule's Q or ϕ/ϕ_{max}, were input fodder to the black box procedures.

As to legislator-by-legislator analysis, Morrison (1972) pointed out that the most accepted methods were all based on the proportion of the total votes on which two legislators disagreed. Morrison showed that the proportion of disagreement can serve neither as a measure of angle nor as one of distance.[2] Since the black boxes assume their input is either distances or angles, they are unlikely to recover the "true" Euclidean space.

Independently, Weisberg (1968) presented a discussion similar to Morrison's and also covered roll call-by-roll call analysis. In addition, Weisberg addressed how error would affect the black box methods. In an errorless world, a legislator will always vote, in spatial terms, for the closest alternative, assuming sincere voting. That is, the legislator votes for the alternative with highest utility. But suppose these utilities are subject to error (perhaps from perceptual error or from omitted, idiosyncratic dimensions), so that the legislator no longer always chooses the closest alternative. In that case, citing an abundant psychometric literature, Weisberg shows that the black box methods will generally find a space with more dimensions than "truly" exist.

The problems that Weisberg and Morrison pointed out with the various multidimensional "black box" procedures also occur with Guttman scaling, a procedure even more widely used by political scientists. To see the relationship of Guttman scaling to spatial analysis, first assume a one-dimensional space where the Yea and Nay alternatives are points on the continuum.[3] Assume further that each legislator votes for the alternative closest to his ideal point. In this case, the "cutting point" equidistant from the alternatives for each roll call will divide the legislators into "left" and "right" camps, and one obtains a perfect Guttman scale. In such a case, we can never hope to learn anything about the spatial position of legislation since all pairs of alternatives with the same cutting

point generate the same roll call behavior. We can, at least ordinally, identify the cutting points, but we can never, in this perfect world, learn where the alternatives are. Hopefully, the strong behavioral assumptions underlying Guttman scaling will not hold in practice, and there will be some error in the choices. Somewhat paradoxically, we need error to learn about the location of alternatives.

Now if there is error but only one "true" dimension and we insist upon Guttman scaling [or related techniques such as MacRae's (1970) Q-cluster analysis] not all the roll calls will form a single scale. In fact, as acknowledged by Clausen (1967, p. 1023) in his discussion of Lingoes Multiple Scalogram Analysis, we might well find several scales and conclude that there are multiple dimensions or issue areas when in fact only one exists.

When the true space is multidimensional, Guttman scaling will also exaggerate dimensionality for another reason. To see this, consider a two-dimensional space where choice is again without error and legislators vote for the closest alternative. Now "Yea" and "Nay" voters are separated by a cutting line, the perpendicular bisector of the line joining the two alternatives. Draw any line through the space. All roll calls with cutting lines perpendicular to this line will form a perfect Guttman scale. These roll calls will generally not scale with roll calls that are not perpendicular to the line. As we try a variety of lines, we may find many Guttman scales, although the space is only two-dimensional. When we have both error and multidimensionality, we have two effects that cause ordinary Guttman scaling to exaggerate the true dimensionality.

To summarize the preceeding discussion, the multivariate black box methods are not based upon a spatial model of choice while ordinary Guttman scaling is based on a very limited model. Consequently, it is not surprising that traditional analyses often have to segregate the data by political party (MacRae, 1958, 1967), thus obscuring an overall picture of the legislature, or find a relatively large number of dimensions (Clausen, 1973).

While helping us to understand the perils of black boxes, Weisberg (1968) took a "least evil" approach in his dissertation. He sought to find which inputs would cause the fewest problems to the black boxes. In contrast, in his seminal piece, Morrison began the quest for a procedure that would be model-driven. By a model-driven procedure, we mean one that begins with a model of individual choice behavior, draws the implications of the model for how such observed data as roll call votes will be generated, and then develop methods for recovering the unknown Euclidean coordinates from the observed data in a manner that is consistent with the underlying choice model. Morrison's approach was based upon very restrictive assumptions, such as error free choice and a symmetric distribution of cutting lines, and was not followed by empirical applications.

In contrast to all of these earlier approaches, we here develop methods that derive from the basic spatial model of choice, allow for error, and make no assumptions regarding the distribution of

either legislator ideal points or the Euclidean coordinates of alternatives. Like the earlier analyses, we assume that the observations are independent across individuals and over time and that, on each roll call, sincere (in the usual sense of nonstrategic) voting prevails. Based on a model of probabilistic voting akin to Coughlin (1983) and Hinich (1977), our procedures permit simultaneous recovery of the Euclidean coordinates of both individuals and choices and the parameters of a utility function for the individuals. (In contrast, most conventional approaches do not place the choices or choosers in a common space.) In psychometric parlance, we have developed an <u>unfolding</u> methodology for nominal level data.

Substantively, what might appear to be the key limitation of our procedures is the sincere voting assumption. While whether the assumption is a limitation is partly an empirical question, there are theoretical reasons to downplay strategic voting. First, roll calls are in the public record. If a legislator's utility on a bill derives from the interests of some of his constituents, it will be difficult to oppose those interests even if doing so will eventually favor other interests. Second, as Fiorina (1974) has argued, the substantial uncertainties in legislative agendas leaves commitments on future votes as highly tenuous contracts.

Methodologically, our procedures rely on estimation of a stochastic utility function by the polytomous logit methods pioneered by McFadden (1974). Unlike standard logit models, however, the spatial model, as we shall show briefly, inherently necessitates nonlinear estimation. Such estimation has been prohibitively expensive for large data sets, but recent and anticipated developments in computer technology now make nonlinear maximum likelihood estimation an affordable procedure.

We continue our presentation with a formal development of our statistical model in Section II. Next, in Section III, we discuss, in terms of our one-dimensional implementation, a variety of theoretical issues that arise in estimation of the model. Then, in Section IV, we present NOMINATE, which performs unidimensional nominal unfolding. This is followed, in Section V, by an investigation of the robustness of the procedures with actual Senate roll call data. The content of the recovered coordinates is discussed in Section VI. Monte Carlo studies are presented in Section VII. Finally, Section VIII briefly mentions substantive applications.

II. THE MODEL OF INDIVIDUAL CHOICE

We denote p individuals (legislators) by generic index i, r choice sets (roll calls) by index t, and q^t alternatives in choice set t by index j. Henceforth, unless otherwise stated, we develop the analysis for a single individual making a single choice and omit indices t and i. The summations over individuals and choice sets are usually obvious.

Abstention or nonvoting requires special treatment. When such a choice is feasible, we adopt the convention that it has index q. The number of policy alternatives is denoted by q*. When abstention

is feasible, q* = q–1; otherwise, q* = q.

Basic Assumptions

(A1) Each individual is assumed to have an interval level utility function defined over the elements of the choice set. The utility is composed of a random component ε_j and a fixed component u_j. So, we write

$$U_j = u_j + \varepsilon_j$$

We may most conveniently think of ε_j as a specification error by the polimetrician, ε_j being uncorrelated with u_j.

(A2) Each stochastic disturbance ε_j is:

(i) independent of the disturbances for other individuals and choice sets. $E(\varepsilon_{tij}\varepsilon_{t'i'j'}) = 0$, $i \neq i'$ or $t \neq t'$

(ii) for the same individual, $E(\varepsilon_{tij}\varepsilon_{tij'}) = 0$, $j \neq j'$.

(iii) each ε_j is distributed as the log of the inverse of an exponentially distributed random variable.

Assumptions A1 and A2(i) are standard. They are obviously inappropriate if there is substantial strategic voting. Even when voting is sincere, the assumptions may not be appropriate. For example, disturbances are likely to be correlated across roll calls when there are a number of votes in the same substantive area (e.g., a sequence of amendments dealing with Federal funding of abortions).

Similarly, disturbances may be correlated across legislators (e.g., the two Democratic Senators from Georgia are likely to exhibit similar "disturbances"). For tractability, we must rely on the standard assumptions.

Assumption A2(iii) is known as the assumption of the logit (Weibull) distribution. This distribution closely resembles the normal and its use is without major consequence for the type of empirical work discussed here. Assumption A2(ii) is more critical, as we shall see shortly.

Define

$c_j = 1$ if alternative j is chosen

$= 0$ otherwise

(A3) <u>Sincere Voting</u>.

$c_j = 1$ if $U_j > U_k$ for all $k \neq j$

$= 0$ otherwise,[4]

Thus, we consider only the case where voting is sincere. The voter or legislator always chooses the alternative with highest utility. If voters determine their participation decision on the basis of whether their vote "makes a difference," the methods presented here are inappropriate in their basic structure in addition to the assumptions on errors. Log-rolling across bills would present a similar problem.

Assumptions A1, A2, and A3 imply that (see, e.g., Dhrymes, 1978, p. 347)

$$\Pr\{c_j = 1\} = e^{u_j}/\omega \tag{1}$$

where

$$\omega = \sum_{j=1}^{q} e^{u_j}$$

Note that (1) is mute as to whether individuals actually randomize in making choices. The only important consideration is that choice "looks" to be probabilistic from the viewpoint of the polimetrician.

Note further that the odds that one alternative is chosen relative to another depend only on a pairwise comparison of fixed utilities and are "independent of irrelevant alternatives." That is,

$$\frac{\Pr\{c_j = 1\}}{\Pr\{c_k = 1\}} = \frac{e^{u_j}}{e^{u_k}} \tag{2}$$

In general, this independence is a limitation of the model, as seen below.

<u>Evaluation of the Model's Predictions</u>

Assume the fixed components u_{ij} have been specified. How can we evaluate the model? The likelihood of an observed choice for an individual is given by:

$$L_{ti} = \prod_{j=1}^{q^t} \Pr\{c_{tij} = 1\}^{c_{tij}} \quad (3)$$

The total log-likelihood follows from (1) and (3) as

$$\ell = \sum_{t=1}^{r} \left[\sum_{i=1}^{p} \sum_{j=1}^{q^t} c_{tij} u_{tij} - \sum_{i=1}^{p} \ell n \omega_{ti} \right] \quad (4)$$

Obviously, the log-likelihood is increased when the utility of the actual choice increases or the utility of any other choice decreases:

$$\frac{\partial \ell}{\partial u_j} = c_j - e^{u_j}/\omega \quad (5)$$

The log-likelihood statistic itself, while useful for certain hypothesis tests, is not useful as a descriptive statistic. It can be transformed into a useful summary statistic as the geometric mean probability of the actual choices:

$$\bar{P} = e^{\ell/p} .$$

It should be noted that $\bar{P}$ is a "conservative" statistic and is always less than the mean probability of the actual choices.[5] It "penalizes" actual choices with low probabilities.

In addition to examining $\bar{P}$ as a summary of probabilities, in our application to binary choice, we also look at the percentage of choices correctly "predicted" by a maximum probability approach.[6]

This is just the percentage of the choices for which individuals choose the closer of the two alternatives.[7]

A. Spatial Model of Utility

As a model for the u_j, we use a spatial model. Both individuals and policy alternatives are represented as points in an appropriately normalized Euclidean space.[8] The fixed component of utility, in turn, depends solely on distance, or for convenience, its square:

$$u_j = f(d_j^2), \quad f'(\cdot) \leq 0 \quad (6)$$

Examination of (6) discloses why independence of irrelevant alternatives A2(ii) is a strong assumption. Assume there are initially two choices in a one-dimensional setup, one located at the -1 coordinate and the other at +1. Consider an individual at the origin, 0. This individual will make each choice with equal probability by (6) and (2). With no abstention, the probability will be ½. Assume another choice is added at -1. All alternatives now have probability 1/3. In some contexts, however, one might prefer a model where the single alternative at +1 was chosen with probability 1/2 and each alternative at -1 with probability 1/4. This issue need not be dealt with in terms of our present application to a dichotomous choice set {Yea, Nay}. For further discussion and suggested alternative models, see Amemiya (1981).

Using A2 in conjunction with (6) simplifies estimation considerably. We note immediately from (1) that adding a constant to all utilities does not change the choice probabilities. Hence, we can, without loss of generality, fix the utility of nonvoting at 0. So,

$$u_q = 0, \quad \text{for} \quad q^* = q-1 \tag{7}$$

A very useful restriction in the spatial model represented by (6) and (7) is that the utility of a policy alternative depends only upon that alternative's distance and not on any other distance. Therefore, the log-likelihood responds to changes in d_j solely through changes in u_j:

$$\frac{\partial \ell}{\partial d_j^2} = \frac{\partial \ell}{\partial u_j} \cdot \frac{\partial u_j}{\partial d_j^2} \tag{8}$$

Functional Specification of Utility

The functional form we employ for utility of policy alternatives is:

$$u_j = \alpha + \beta\, e^{\frac{-w^2 d_j^2}{2}}, \; j \leq q^* \tag{9}$$

This function generalizes the familiar, bell-shaped unit-normal. The function is the unit normal when $\alpha = 0$, $w = 1$, and $\beta = 1/\sqrt{2\pi}$. Six examples are shown in Figure 1. We have selected (9)

for several reasons:

1. Our substantive intuition is that political actors are relatively insensitive to small changes in distance from their ideal points; at somewhat greater distances, utility should change sharply; finally, at very great distances, changes in distance should have little effect on utility. Quasi-concave utility functions such as (9) have in fact been posited by spatial theorists. [See Riker and Ordeshook (1973).]
2. The ability to vary both w and β provides considerable flexibility. When nonvoting is not in the choice set, the parameter α cannot be identified and is set to zero. In this case, the range of u_{ij} is $(0, \beta]$, so β sets the maximum utility while w controls how fast utility falls with increases in distance.[9] This can be seen in Figure 1 by comparing the functions with equal β values.

Without loss of generality, we can constrain all individual coordinates to have magnitudes less than a certain predetermined number. By varying the parameters β and w, we can obtain a variety of shapes for the utility function. Thus, between -1 and 1, the functions shown in Figure 1 range from a bell-shape to a parabolic shape.

[Figure 1 here]

3. The function enables us to capture nonvoting from alienation. [Although nonvoting does not appear to have substantive importance in Congress, it is important in many European legislatures and the United Nations.] When nonvoting is possible, the parameter α must be included in the model. As $d_j \rightarrow \infty$, this second term in (9) approaches zero. If voting persisted as all alternatives become distant, perhaps by a sense of "citizen duty," we would have to have $\alpha > 0$ to allow for this behavior. If, on the other hand, voting was viewed as costly and voters abstained for u_j sufficiently small, we would need $\alpha < 0$. In summary, if all stochastic terms are zero, the voter will always select the "closest" choice, provided this choice has positive utility. Consequently, this model represents the nonvoting from alienation model proposed by Hinich and Ordeshook (1969) and, even more directly, the probabilistic extension in Hinich et al. (1972). As shown in Poole and Rosenthal (1982), our model can readily be extended to handle nonvoting from indifference.

Identification

If α and β are the only unknown parameters, (7) and (9) in fact give us a linear logit model. In such models, the coefficients are typically identified only up to an additive constant. Thus, we essentially identified α by arbitrarily setting $u_q = 0$. Atypically, β

is identified in this model. The nonlinearity serves to identify w.

The parameters would still be identified if a separate α_j, β_j, and w_j were estimated for each choice. The β_j are still identified because, in the equation for choice j, the model constrains to zero the coefficient on $e^{\frac{-w^2 d_k^2}{2}}$, $k \neq j$. The model can be estimated with and without the restriction that the coefficients are equal across equations. The results can be compared as a test of the sincere voting model. When strategic-voting is suspected, dropping the restriction may well result in a substantial improvement in fit.[10]

Distance

The distance for a one-dimensional model is calculated as:

$$d_j^2 = (x - z_j)^2 \qquad (10)$$

where x is the coordinate of the individual and z_j that of the alternative. In some applications, the x and z may be taken as known. For example in a mass voting context, the x and z may result from scaling survey thermometers (Cahoon et al. [1978], Rabinowitz [1976, 1978], Poole [1978], Wang et al. [1975], Poole and Rosenthal [1982]). In other cases, only the x may be known. For example, the scaling of interest group ratings by Poole (1981) and Poole and Daniels (1982) gives x for members of Congress but not the locations of the roll calls, the z. In other cases, both x and z may be unknown. This is the case of pure nominal unfolding, when one seeks to "bootstrap" the analysis solely from the observation of choices. Obviously, to estimate x accurately, r must be "large" and to estimate z, p must be large. This will be the case in roll call analysis; our examples will have p = 100 and r > 300. For mass voting, if we wish to base unfolding on observed or reported choices rather then thermometers, only the z can be estimated.

<u>Multidimensional Generalization</u>

The above discussion has a straightforward generalization to an s-dimensional space. We index the dimensions by k.

We now write

$$d_j^2 = \sum_{k=1}^{s} \sum_{k'=1}^{s} a_{kk'}(x_k - z_{jk})(x_{k'} - z_{jk'}) \tag{11}$$

where, for example, x_k is the individual's coordinate on the k-th dimension and the $a_{kk'}$ are Davis-Hinich saliency weights (Davis et al., 1970).

In some applications, it may be useful to estimate the a weights as an alternative to assuming that the dimensions are orthogonal and of equal salience. One can, without loss of generality, set $a_{11} = 1$. This and symmetry imply that there are only $s(s + 1)/2 - 1$ independent a weights.

One clear situation where the a should be estimated is when one constructs the space from a set of unidimensional issue scalings [e.g., via the Aldrich-McKelvey (1977) method]. Another situation is when one seeks to test the veracity of a metric unfolding. In this

case, finding nonorthogonal dimensions or unequal saliences from the choice data would cause one to question the unfolding. Whenever the a are estimated, they should be checked to see if they define a positive definite matrix; if not, the Euclidean model should be questioned.

To estimate the parameters, one can apply a gradient procedure to maximize the log-likelihood (4). Two basic derivatives have already been given in (5) and (8). As a result, we can compute the gradients, using the chain rule, by obtaining the partial derivatives of u_j with respect to the parameters of the utility function and of d_j^2 with respect to the x_i, z_j, and a. These are, for $j \leq q^*$,

$$\frac{\partial u_{ij}}{\partial d_{ij}^2} = -\frac{w^2}{2}[u_{ij} - \alpha] \tag{13}$$

$$\frac{\partial u_{ij}}{\partial \alpha} = 1 \tag{14}$$

$$\frac{\partial u_{ij}}{\partial \beta} = \frac{1}{\beta}[u_{ij} - \alpha] \tag{15}$$

$$\frac{\partial u_{ij}}{\partial w} = -wd_{ij}^2[u_{ij} - \alpha] \tag{16}$$

$$\frac{\partial d_{ij}^2}{\partial x_{ik}} = 2 \sum_{k'=1}^{s} a_{kk'}(x_{ik'} - z_{jk'}) \tag{17}$$

$$\frac{\partial d_{ij}^2}{\partial z_{jk}} = -2 \sum_{k'=1}^{s} a_{kk'}(x_{ik'} - z_{jk'}) \tag{18}$$

$$\frac{\partial d_{ij}^2}{\partial a_{kk}} = (x_{ik} - z_{jk})^2 \quad (19)$$

$$\frac{\partial d_{ij}^2}{\partial a_{kk'}} = 2(x_{ik} - z_{jk})(x_{ik'} - z_{jk'}) \quad k' \neq k \quad (20)$$

III. THE ONE DIMENSIONAL MODEL: THEORETICAL PROBLEMS OF ESTIMATION

In this paper, we implement the estimation for dichotomous choice in one dimension with no nonvoting. By convention, we designate the lesser of the two z as the "liberal" or "left" coordinate. We now discuss several issues that arise in estimation.

Perfect Roll Calls

Assume every individual to the left of a certain point on the dimension voted yea and every individual to the right of this point voted nay. As mentioned in the Introduction, we will be able to identify midpoints but not outcome locations for such "errorless" voting.

If we observe a set of perfect or near perfect roll call responses and attempt to estimate outcome locations for fixed legislator locations and a fixed, stochastic utility function, we will estimate a midpoint corresponding to a Guttman scale cutting line. Where will we place the liberal coordinate? Clearly, we will not place it close to the midpoint since all legislators would then be predicted to vote yea with probability 0.5. Similarly, we will not place the liberal outcome far to the left of the leftmost legislator.

In that case, the conservative outcome would be far to the right, and, given the functional form of our utility function, all legislators would be close to indifferent between these two distant alternatives and would vote yea with probabilities near 0.5. So we will get an intermediate outcome. However, a range of intermediate outcomes will give similar predictions, and we will not be able to recover the liberal outcome.

Unanimous Roll Calls

Unanimous roll calls are a special case of perfect roll calls. With unanimity, the cutting line must clearly lie outside the range of the legislators. In this case, even the midpoint cannot be located precisely. If the winning alternative were deemed "liberal," our estimation technique would put the liberal alternative near the centroid of the legislators and attempt to put the midpoint at infinity. To avoid such senseless estimates, we eliminate unanimous and near unanimous votes from the analysis.

Random Roll Calls and Extreme Placements

Assume, on a given roll call, the yea and nay alternatives were identical. Then, in our model, legislators would be effectively flipping coins to make vote decisions. Moreover, any "converged" outcome locations would lead to this behavior. Conversely, when the observed responses appear as randomly distributed along the dimension, our estimation method will find it difficult to identify outcome locations. It will either put the alternatives close to each other at a variety of locations, including locations outside the range of legislators, or, if unconstrained, make the alternatives very distant from one another. (In more conventional jargon, one would term these roll calls unscalable.)

More generally, attempts at strict maximum likelihood estimation of ill-behaved roll calls can result at coordinate estimates that are far from the limits of the space defined by the legislators. Political theory, however, suggests that one alternative should always lie within the space of legislators and that the cutting line should also fall within this space. We impose these constraints. Coordinate estimates for those roll calls with constraints imposed should, however, be viewed as unreliable.

Perfect Legislators

One can conceptualize a legislator who is similar to a perfect roll call. This individual always votes liberal on roll calls with midpoints to his right and conservative on those roll calls with midpoints to his left. That is, we would observe:

CCCCCCCCCCLLLLL . . . LLLL

This legislator would be located between the rightmost C and the leftmost L and is easily identified. However, if a legislator always votes liberal or always votes conservative, then he is like an unanimous roll call and his position cannot be identified. For a

perfect liberal, all we know is that this legislator is to the left of all the midpoints. As a consequence of this identification problem, we will obtain relatively imprecise estimates of the locations of legislators at the periphery of the space.

Bias and Consistency

It is well known that maximum likelihood estimates may be biased. In most common applications, they are consistent. As Chamberlain (1981) points out, the standard proof of consistency assumes that the set of parameters remains fixed as the sample size increases. But in our case, every additional roll call or every additional legislator adds additional parameters. In addition, our constraints imply that our estimates are not strictly maximum likelihood. Consequently, we report extensive Monte Carlo tests of the quality of our procedures.

Nonconvexity

Finally, one must cope with the fact that our likelihood function is not globally convex. Thus, the estimation procedure may converge to an inflection point or local maximum rather than to a global maximum. While there is no ultimate solution to this problem, we present procedures that, taking advantage of structure specific to political choice problems, appear to produce reasonable results.

IV. NOMINATE: Nominal Three Step Estimation

We now develop NOMINATE, a one dimensional implementation using the derivatives of Section II. In doing so, we use numbered paragraphs that correspond to the flow chart of Figure 2. All computations are made in single-precision FORTRAN on a DEC 2060.[11]

[Figure 2 here]

1. Preliminary Processing

The program beings by reading and processing raw roll call votes. Announced for and paired for are recorded as yes, announced against and paired against are recorded as no. Other forms of nonvoting are treated as missing data. The value of a control parameter determines the level at which unanimous and near unanimous roll calls are excluded from the analysis. The estimates of roll call coordinates for near unanimous votes will be unreliable.

2. Legislator Starts

To obtain high quality starting coordinates for legislators, a sample of 50 roll calls is drawn and subjected to a matrix decomposition method developed by Poole (1983).[12] A p by 50 roll call matrix R_o is decomposed into:

$$R_o = [\varphi_p v' + J_p c']_o + E_o \tag{21}$$

where φ_p is the starting estimate of legislator coordinates, E_o is a p by 50 matrix of residuals, and J_p is a vector of ones of length p.

The 50 element vectors v and c defined linear mappings for each roll call. The "o" subscript indicates the presence of missing data. Standard matrix methods such as singular value decomposition cannot be applied to matrices with missing data.

We normalize φ such that the leftmost legislator is at -1, the rightmost at +1.

3. Roll Call Starts

For each roll call we obtain starting coordinates for the midpoint (cutting line) by finding an optimal prediction conditional on the initial legislator configuration. As candidates for the starting midpoint, we consider all midpoints between each adjacent pair of legislators. For example, if all 100 U.S. Senators vote on a particular roll call, then there are 99 such pairs. For each of the 99 possible midpoints, every senator to the left of a candidate midpoint is assumed to vote yes and every senator to the right is assumed to vote no. The process is then repeated with the predictions reversed; senators to the left are predicted to vote no, those to the right, yes. As a start, we then pick the midpoint and the polarity that minimizes prediction errors. For example, if the minimum errors occur when senators to the left are predicted to vote no, then "no" is defined as the "liberal" alternative.[13]

As a start for the liberal outcome, we use:

$$LIB = M - \frac{1 + |M|}{2} \tag{22}$$

where LIB is the liberal coordinate and M the midpoint. This procedure guarantees that both the midpoint and at least one coordinate will be contained in [-1,1].

4. The Global Iteration Technique

After obtaining starts, the program enters its iterative estimation procedure. Because of the large number of parameters, it is impractical to estimate all the parameters jointly. We thus first estimate the utility function parameters holding the legislator and roll call starts constant. Then we estimate the roll call parameters, holding the utility function and the legislators constant. As a consequence of (A2), each roll call can be treated independently. Finally, the legislator coordinates are estimated. A convergence check is made and, in the event of failure, the process repeated.

This three step estimation procedure implies that the coefficient standard errors produced by the program are technically incorrect since they are not based on the full information matrix for the parameters. However, the only sizeable covariance we are ignoring is between the utility function parameters and the spatial parameters. Cross-derivatives between parameters for different roll calls and for different legislators are zero. Each cross-derivative between roll call parameters and legislator parameters contains only a single term, corresponding to the legislator's vote on the roll call. The magnitude of these cross-derivatives is thus likely to be quite small relative to the second derivatives of the parameters themselves which

are sums of p or r terms. Monte Carlo results (see below) suggest that we get reasonable estimates of standard errors. All estimation of parameters and computation of standard errors is carried out by an algorithm based on the Berndt, Hall, Hall, and Hausman (1974) method.

4-I. Utility Function

In estimating the utility function, a control option permits holding either β or w constant or estimating both parameters jointly.

4-II. Roll Calls

When roll call coordinates are estimated, the midpoint and the liberal coordinate are estimated jointly; the covariance of these parameters is taken into account in computing estimated standard errors. We estimate these two parameters, rather than the two outcome locations because of the greater stability of the midpoint (see Section III) relative to the outcome coordinates. The following pair of constraints was imposed on the process.

A. Midpoint Constraint

If the maximum likelihood algorithm converged to a midpoint > 1, the midpoint was constrained to +1 and the interval [0,1] was grid searched for the liberal outcome that maximized the log-likelihood subject to the constraint. A symmetric procedure was used when the algorithm converged to a midpoint < -1.

Converging to a midpoint exterior to the legislators is tantamount to predicting an unanimous vote. Predicting unanimity can in fact maximize the likelihood even when the actual voting is nonunanimous. Assume each legislator determines his vote by a random flip of an identical unfair coin. Then predicting unanimity will almost certainly lead to a greater likelihood than the likelihoods associated with interior nonunanimous midpoints. For some roll calls, actual voting patterns may indeed look random, since not all roll calls will fit a unidimensional, two outcome spatial model and votes may be determined by factors orthogonal to the legislator configuration. While arbitrary, the procedure of constraining the midpoint usefully marks a roll call as one for which voting is not consistent with the model. Imposing the constraint does not appreciably affect the log-likelihood for the roll call.

B. Outcomes Outside Legislators Constraint

When both the liberal coordinate and the implied value of the conservative coordinate are exterior to [-1,1], we again place constraints on the estimates. The midpoint is held constant at its estimated interior value and the liberal coordinate is grid searched over the interval $[-1 + M - |M|, M]$. This guarantees that the outcome furthest from the midpoint will remain in the interior.

When the outcomes go off opposite ends of the dimension, this means that there are few voting errors on the roll call. Legislators are almost uniformly voting for the closest alternative. As explained in the Introduction, a certain amount of error is necessary to

identify the location of the outcomes but not the midpoints. When this constraint operates, the midpoint location is reasonably estimated but the liberal coordinate estimate is not reliable.

4-III. Legislators

Again as a consequence of A(2), estimating the legislators is a sequence of p one parameter estimations. In fact, we conjecture that the conditional likelihood function is convex in each legislator's coordinate.

5. Coordinate Renormalization

After each global iteration, all coordinates are renormalized so that the legislator space spans [-1,1]. We define convergence as occuring when the three sets of correlations with the previous global iteration results, legislators-to-legislators, midpoints-to-midpoints, and liberal coordinates-to-liberal coordinates, have all exceeded .99 for the two previous global iterations. When this happens the corresponding regressions have intercepts close to 0.0 and slopes close to 1.0. As defined, convergence with U.S. Senate data almost always occurs within five global iterations. In fact, nearly all the improvement in the likelihood function takes place within two global iterations and most of the improvement takes place within the first global iteration when the roll call coordinates are estimated. Our starting senator coordinates are generally very close to the final values.

A Byproduct: Ordinary Guttman Scaling

Even if a real legislature has perfect voting behavior, as implicitly assumed in much of the earlier literature on roll call analysis, NOMINATE will extract all the available spatial information. It will Guttman scale perfect data. (See the Perfect Voting Monte Carlo run below.) Of course, the liberal coordinate estimates should be disregarded in such a case.

The output of NOMINATE for noisy data shows that we obtain (1) higher geometric means and (2) fewer prediction errors for individuals at the extremes of the dimension. This result corresponds to the well-known "U-shape function of score distributions" (reviewed by Clausen, 1967, p. 1026) in ordinary Guttman scaling. From the viewpoint of our model, the U-shape is no longer solely an empirical relationship. The U-shape follows from our stochastic utility model and the theoretical expectation, from majority rule, that cutting lines will tend to fall near the center of a legislature.

V. ROBUSTNESS OF THE PROCEDURE

To test the robustness of our estimation procedure, we conducted a variety of alternative estimations of voting by the U.S. Senate. The topics we wished to study include:

1. Changes in the utility function.
2. Alternative iteration sequences for parameter estimation.
3. Deletion of near perfect senators.
4. Choice of roll calls used to generate starting values.

5. Alternative methods used to generate starting values.
6. Inclusion of "nonscalable" roll calls.
7. Inclusion of a "nonscalable" senator.
8. Assumption of a common utility function for all senators.
9. Inclusion of roll calls with small minorities.

Changes in the Utility Function

In developing NOMINATE, it became clear to us that estimates of β and w became highly collinear after a few initial iterations. Consequently, we fixed w at .5, a value in the range that led to good estimates, and estimated β. Since the likelihood function is globally convex in β, choice of a starting value for β is irrelevant. We will henceforth refer to estimation for the full set of 100 senators in 1979 with w fixed at .5 as the Initial case.

To study robustness of the utility function, we then fixed β at 15 and carried out an estimation, from the same starts as before, with w as the variable parameter of the utility function. We also did a run with β fixed at 35.

Changes in the Iteration Method

In each global iteration in NOMINATE, we first estimate the utility function, then the roll call coordinates, and then the senators. As an alternative, we estimated the utility function (with w fixed at 0.5) and then alternated between roll calls and senators until we met our convergence criterion. Then we reestimated the utility function, alternated, and so on.

Near Perfect Senators

When we ran the Initial case, we found that Ted Kennedy anchored the left end at -1.0 and Jesse Helms the right end at +1.0. The next leftmost senator was Paul Tsongas at .81 and the next rightmost senator was Gordon Humphrey at .59. These very substantial separations didn't accord with our intuition. Since Helms had cast only 25 liberal votes in the 412 roll calls we included and Kennedy only 28 conservative votes, we had reason to believe we were confronted with a perfect senator identification problem. (In contrast, Tsongas had 44 conservative votes and Humphrey 45 liberal votes.) To study whether including Kennedy and Helms had distorted our estimates of the locations of the other senators and the roll calls, we reran the Initial case with Kennedy and Helms deleted.

Alternative Starts

The base case and all variants previously mentioned were conducted with starts generated on the basis of the first 50 roll calls included in the estimation for 1979. Since likelihood functions that are not globally convex may be sensitive to starting values — one may go to a local rather than global maximum, we generated three alternative sets of starting values based on roll calls 101-150, 151-200, and 201-250, all with Kennedy and Helms deleted.

Alternative Starting Methods

To generate roll call starts in the Initial case, we first got starts for the senators. We next used these starts to compute centroids of the senators voting "liberal" and "conservative" and averaged these centroids. The "liberal" centroid was our liberal coordinate start and the average was the midpoint start. We later tried the optimal prediction procedure described in Section IV.

Nonscalable Roll Calls

With our optimal prediction starting method, we can compute an initial proportionate-reduction-in-error measure:

$$\text{pre} = \frac{(\text{number on losing side} - \text{number of errors using optimal midpoint})}{\text{number on losing side}}$$

When alternative starts were generated, we had observed that roll calls whose estimates differed strongly were all roll calls with low pre. We thus made runs, using the optimal prediction start method and without Kennedy and Helms, with low pre roll calls deleted.

The "Nonscalable" William Proxmire

In addition to roll calls not belonging to the dimension, it is possible that a given senator demonstrates behavior that is totally inconsistent with the hypothesized spatial model. Indeed, we found, in all three years, that William Proxmire had geometric means near .40 while no other senator fell below .50. We therefore duplicated the Initial case with Proxmire deleted to see whether his behavior had had an appreciable effect on the estimation.

Evaluating the Utility Function Assumption

Empirical work in economics typically assumes a common underlying utility function with individual differences arising only in endowments. Our model makes a similar assumption since individuals differ only in their ideal points. We conducted over time comparisons to test this hypothesis.

Near Unanimous Roll Calls

When there is no opposition on a roll call, the roll call provides no information about the senators and its own coordinates cannot be identified. Problems may also arise when there is only a small minority on a roll call. Consequently, we varied the level at which we excluded roll calls from 10 percent minority to 0.5 percent minority.

Results

Basically, our results are extremely robust to the variants indicated. Table 1 shows the correlations between the Initial case and the estimated coordinates for all the variants based on the same set of starting values. The lowest correlation occurs between the roll call coordinates when Kennedy and Helms are deleted. This drop from the .99 level was readily explained by examining scatter diagrams. It could be seen that the correlation is virtually perfect for

coordinates interior to the original locations of Tsongas and Humphrey. The deviant roll calls are at the end of the dimension in the 98 senator run but, in the 100 senator run, are given (unreliable) interior locations, as a result of the Kennedy and Helms votes. Thus, the deviations come exactly where expected.

As to the four runs used to compare starting values -- all had Kennedy and Helms deleted and w fixed at 0.5 — the lowest pairwise squared correlation for senator coordinates was .9993. When we initially conducted the roll call correlations, we found substantially lower correlations. Upon examining scatter diagrams, we learned that the departures from the .99 level were produced by a small set of roll calls that were of the "random looking" variety. Typically, these roll calls would have the midpoint placed at one end of the dimension in some of the runs, and at the other end in the others. After eliminating the 17 such roll calls from the correlation analysis, we found that the minimum pairwise squared correlation for liberal coordinates was 0.9965 and for midpoints was 0.9985. These results demonstrate that including nonscalable roll calls in the analysis does not affect our recovery of the senator locations.

We also find little difference in results when using alternative methods for generating roll call starts. Generating starts from the first 50 roll calls without Kennedy and Helms with the final "optimal prediction" alternative method, we find the squared correlation of the senator coordinates with the corresponding Initial case to be .9995. After deleting 17 "random looking" roll calls, the midpoint squared correlation was .9989 and the liberal coordinate, .9893.

We have already established that the nonscalable or random-looking roll calls appear to have little influence on our ability to recover senator locations. Might they, however, be affecting utility function estimates in a way that affects our recovery of the other roll calls? To investigate this possibility, we conducted two experiments, with alternate starts, where only roll calls with pre in excess of 0.1 were included. In each case, there were 357 such roll calls, none of which had flipped midpoint estimates, etc. relative to the Initial case analysis. We ran one similar experiment with Kennedy and Helms deleted. The results all showed squared correlations for senators and midpoints above 0.99 and for liberal coordinates above 0.97. However, deleting these roll calls led to a shrinking in of the senators and midpoints. Their standard deviations were only about 80 percent of those in the corresponding cases where no roll calls had been excluded. What had happened was that whereas Kennedy and Helms had been the only "perfect" senators previously, we had begun to make perfect senators out of other extreme liberals and extreme conservatives.

In addition to analyzing problems posed by senators at the extremes of the dimension, such as Kennedy and Helms, whose votes are "too" predictable, we investigated a potential problem arising from a senator who was totally unpredictable. We made one 1979 run with William Proxmire deleted from the analysis. Again we found very

robust results in the form of high squared correlations, although there was some variation in the dispersion of liberal coordinates from the center of the space (see below). We conclude that our results are not overly sensitive to the inclusion of a small proportion of "deviant cases."

Proxmire himself is deviant in all three years; in each case his estimated position is in the center of the space, a likelihood maximizing position for a coin-flipper. In fact, for all senators, predictability tends to increase as one moves away from the center of the space in either direction. The quadratic regression of each senator's geometric mean on his coordinate explains about 2/3 of the variance in geometric means. When we added the 1979 geometric mean to this regression for 1981 (2.5 percent minority run), we found a positive coefficient that was 3.52 times its estimated standard error. But deleting Proxmire from the set of observations lowered this ratio to 1.77. We thus conclude, that, Proxmire excepted, there is little systematic variation in predictability that is not accounted for by spatial position. Thus, our assumption of a common utility function is not overly unrealistic.

A Limitation

As discussed above, while our results generally appear highly robust in terms of squared correlation measures, we appear to encounter problems in dealing with either senators or roll calls that are "near perfect." In fact, decisions about perfect senators and perfect roll calls are critical as to how the set of senator coordinates locates relative to the set of roll call coordinates and to the estimate of the utility function.

We encountered the effects of perfectness when we began to vary the cutoff level for near unanimous votes from the 10 percent level used in our earliest runs. Our results with "nonscalable" roll calls had suggested to us that the nearly unanimous roll calls might improve our location of senators at the ends of the dimension, even if these roll calls would not have accurate coordinate estimates. Indeed, as we lowered the cutoff level, the standard deviation of the distribution of estimated senator coordinates increased (see Table 2) and we eliminated the wide separation between Kennedy and Helms and the rest of the Senate. For example, Tsongas is moved from −.81 in the 10 percent run to −.94 in the 0.5 percent run and is acceptably close to Kennedy. Similarly, Humphrey moves from +.59 to +.89.

[Table 2 here]

Further indication that the cutoff level mainly affects how the 98 interior senators are located relative to Kennedy and Helms is provided in Table 2. It can be seen that the correlations with the 10 percent level fall less as the cutoff level is reduced when the correlations are computed over only the 98 interior senators than when they are based on all 100 senators.

However, we appear to have introduced particularly noisy roll calls in lowering the cutoff level. As can be seen in Table 17, the estimate of β falls with the cutoff level; a lower level of β

corresponds to an increase in the magnitude of the stochastic component relative to the fixed component of the utility. To compensate for this lower value of β, roll call coordinates for roll calls above the 10 percent cutoff level have to be moved further away from the center of the dimension. Thus, Table 17 also shows that we have to invoke the constraints more frequently as the cutoff level is lowered. This happens even for roll calls that were above the old cutoff levels. Consequently, as we lower the cutoff level, the price one pays for more "reasonable" senator coordinates is less "reasonable" roll call coordinates.

These problems do not arise in the Monte Carlo studies we conducted (see below). There all "true" roll call coordinates were located at the interior of the space. Even though a particular random sequence could lead to a near unanimous vote, the constraints were needed much less frequently in Monte Carlo runs than with the Senate data.

Several explanations for these contrasting results need to be considered:

1. There is a significant multidimensional component to Senate voting. Omission of these dimensions leads to a bias in results that is affected by the cutoff level.

2. The stochastic part of the model largely reflects perceptual error. This perceptual error varies with the location of the senators and the alternatives (as suggested in Coombs, 1958). Near unanimous votes would thus have error levels that differ

systematically from votes with lesser levels of unanimity. These different error levels affect the estimation.

3. For certain votes, which tend to be near unanimous, our two alternative model should be replaced by an alienation model. For example, on final passage of a bill, there may be no alternative to the bill and negative votes may reflect only the bill's distance to the ideal point and not some other alternative.

4. For some roll calls, both alternatives could, in contrast to our Monte Carlo runs, lie outside the space of senators. How could this arise? The work of Poole (1981) and Poole and Daniels (1982) shows that interest groups tend to have positions that are at or beyond the periphery of the senator space. Assume an interest group only invests in changing status quos that are remote from its ideal point (see Romer and Rosenthal, 1978). Thus, a liberal group will be most active when it perceives a status quo that is off the conservative end of the dimension. The group then induces a senator to propose legislation that is almost as extreme as the status quo, but in the other direction.

While all of these topics merit further research, we summarize our investigation of robustness by emphasizing the positive results:

1. Within each set of coordinates, correlations across different runs are very high. Thus, it is quite appropriate to use these results to ask whether one senator is more liberal than another or whether one bill is more liberal than another bill.

2. Midpoint and senator estimates move together. That is, when regressions across different runs are computed, the linear transformations of the senator coordinates and the midpoints are highly similar. Thus, comparisons can be made in the locations of midpoints relative to senators. It is only in dealing with liberal (or conservative) coordinates relative to senators that a high degree of caution must be exercised.

3. All our senator coordinate estimates have squared correlations above .95 with coordinates computed by Poole (1981) from a least squares metric unfolding of interest group ratings. This result increases our confidence in our own coordinates, especially since the Poole model has an entirely different mathematical structure (but one that appropriately links the spatial model to ratings rather than votes).

4. Given its simplicity, the one-dimensional probabilistic model does remarkably well in accounting for Senate roll call behavior. For further evidence on this point, see Section VIII.

VI. SCALING RESULTS AND THE CONTENT OF ROLL CALLS

Senator coordinates, shown in Table 3, generally accord with common notions of the liberal-conservative spectrum in American politics and need not receive further attention. The substantive validity of our roll call coordinates is a more interesting question.

[Table 3 here]

To address this question, we have classified the roll calls into a set of categories that should indicate, subject to the impressionistic nature of content analysis, whether our recovery is meaningful. In each table, we give the ICPSR code for the roll call, the geometric mean, the liberal coordinate, the midpoint, and a capsule content summary. The results are based on a 10 percent cutoff level.

Our first classification (Table 4) deals with roll calls where we had exceptionally low geometric means. To a substantial extent, these roll calls include bills dealing with pork barrel or regional funding (tobacco subsidies, solar power in California, Tombigbee waterway, energy impact assistance) that will always lie outside of any low dimensional spatial model. Several other votes, without geographic ties, also do not enter into common liberal-conservative frameworks. Pay of Congressmen and high ranking civil servants serve as examples. There is little indication of a clustering of votes in specific issue areas that escape the liberal-conservative dimension and would be captured by an additional dimension.

[Table 4 here]

All the roll calls with low geometric means have their estimated coordinates placed very close together. Conversely, as shown in Table 5, the roll calls with the least separation of coordinates also have low geometric means. In that table, there is a continued emphasis on geographic distribution (railroad service, D.C. airports, revenue sharing, home assistance).

[Table 5 here]

In contrast to the close together, low geometric mean roll calls, the high geometric mean roll calls (Table 6) contain votes on key policy issues of the session such as the windfall profits tax in 1979, the Federal Trade Commission in 1980, and the Reagan budget cuts and tax bill in 1981. There are also votes on straight liberal-conservative issues without strong regional allocation content such as fair housing and Chile. The midpoints on these high geometric mean roll calls are generally in the center of the space, with alternative coordinates somewhat outside the space. While the midpoint placements are undoubtedly accurate, the extreme locations of the policy alternatives are unrealistic. They are an adjustment to the apparent situation that error on these key issues is less than that on more "average" roll calls.

[Table 6 here]

Correspondingly, Table 7 shows that the roll calls with the most widely separated coordinates also tend to be ones in which the geometric means are far above the average. In 1981, they overlap with the roll calls in Table 6. In 1979, the visible Taiwan debate joins the oil issue, while in 1980 there are votes related to the erosion of the welfare spending and regulation of the previous decade. The roll calls in Tables 6 and 7 cover a wide variety of foreign and domestic issues, suggesting that a common liberal-conservative dimension may underlie the multiplicity of scales found in earlier analyses (e.g., Clausen, 1973). However, social control issues (abortion, school prayer, the draft) are not represented.

[Table 7 here]

A means of examining roll calls that are more "typical" on the liberal-conservative scale is to study roll calls whose midpoints are near the mean midpoint for the scale, as in Table 8. The geometric means in this table tend to be close to the overall geometric mean. We here find a very broad range of policy items covering domestic, foreign, and defense policy, social control issues again excepted. The only obviously geographically linked issue concerns a hydroelectric project in Maine.

[Table 8 here]

In Table 9, we have tabulated all roll calls whose midpoints were constrained to the end of the dimension represented by the minority party. Again, we find some roll calls that don't fit the dimension because of their implications for geographic distribution (gasohol, Mt. St. Helens, water resources). More importantly, we find roll calls on which members of the majority party were cross-pressured between ideology and support for the President. These include MX in 1979, the draft in 1980, and sugar subsidies in 1981. (The sugar subsidies had geographic implications but were also the price the President had paid for Boll Weevil support.) The votes are votes that are generally one sided. Everyone is predicted to vote with the majority. The analysis of votes with the midpoint constrained to the majority end, shown in Table 10, is similar to the above.

[Tables 9 and 10 here]

To summarize this section, the various categorizations of the roll call coordinates have disclosed that NOMINATE produces sensible results. The items that least fit the dimension seem to be primarily those where geographic distribution is the paramount consideration. One social control issue, draft registration, tended to go off the end of the dimension. Another, abortion, appeared only once in our tables, despite many votes. Other feminist issues never appeared. This indicates that they are fairly standard "noisy" issues on the dimension. Classical foreign policy issues and domestic policy issues involving income redistribution (including taxation) and business regulation appear to be the least noisy issues.

VII. MONTE CARLO RESULTS

Having established that our results for the Senate are very robust to several variations in the technique used for recovery and have face validity in their political interpretation, we next sought to ascertain how well our techniques would perform if the real world in fact corresponded exactly to the behavioral assumptions underlying our model of probabilistic voting. To that end, we conducted 12 simulations. In 11 of these, we assumed that the true senator coordinates were those from the 1979 run with 98 senators other than Kennedy and Helms. In the twelfth, denoted the "50 Senator" run, we used 50 of these coordinates drawn, basically, by alternating along the continuum. In eleven runs, we generated random Weibull errors by using the IMSL uniform distribution generator and then inverting the

Weibull cumulative distribution. In order to minimize random effects on the comparisons, we used the same seed across runs, except runs G-I (Table 3). This decision is of little consequence since 2pr random numbers are generated for a simulation. In another run, denoted "Perfect Voting," we allowed each senator to vote, without error, for the closest alternative.

In 10 of the 11 cases where utility had a random component, we used (9) as the utility function. In the eleventh case, denoted "Linear Utility," we assumed that the nonstochastic portion of utility was given by $15.0-1.725d_j$.

Roll call coordinates were generated as follows. In the case of Linear Utility, Perfect Voting, and simulations A through E, we assigned 97 midpoints at the midpoints of adjacent senator pairs. We then assigned three liberal coordinates for each midpoint, using the formula

$$LIB = M - \frac{1 + |M|}{k}, \; k = 1.75, 2.00, 2.25$$

In the A run, we set $\beta = 15.0$ and $w = 0.5$. In runs B-E, we used other values of β in order to study how recovery was affected by the level of error relative to the fixed portion of the utility.

The runs A-E result in liberal coordinates that are correlated .95 with the midpoints. Consequently, a good fit to the liberal coordinates in these simulations could be due solely to our ability to recover the midpoints. In the F run, we rendered the liberal coordinates independent of the midpoints. We used only the 26

midpoints between -.4999 and -.1686. With each of these midpoints, we assigned 11 liberal coordinates from -1.0 to -0.6 in steps of 0.04. This resulted in 26 X 11 = 286 roll calls. Still another method was used in simulations G to I. For all 97 midpoints previously used in runs A to E, we generated liberal coordinates by

$$LIB = M - (1 + |M|)k,$$

$$\text{where } k \sim U[0,1].$$

For the 35 midpoints with $|M| < .51$, only one liberal coordinate was generated. For the other 62 midpoints, four coordinates were generated. This resulted in a total of 283 roll calls on each run.

Utility Function Results

Estimates of β, shown in Table 11, contain upward bias, although the recovered values in runs A-E retain the order of the true coefficients. This bias does not substantially impinge upon our ability to recover those parameters that are of primary substantive interest, the spatial coordinates.

[Table 11 here]

Senator Results

The results for the senators, also shown in Table 11, are exceptionally good both in terms of R^2 values and regression standard errors (the square root of the average squared residual). Since the Weibull errors are independent across senators, it is not surprising that senators are recovered as well in the 50 Senator run as in the 98 Senator runs. Recovery of the senators would also appear to be quite robust to misspecification of the utility function, as demonstrated by the results for the Linear Utility model. There is a noticeable drop in R^2 only when there is Perfect Voting. In this case, however, we almost perfectly recover the ordering of the senators, as shown in Figure 3. (Of course, the Perfect Voting run did not converge; the program was stopped after five global iterations.) While interval information cannot be identified with perfect voting, our program accurately recovers all the ordinal information in this case.

[Figure 3 here]

Since all the senator simulations are based on over 100 fewer roll calls than our results for the 1979 and 1980 Senates, there is every reason to believe our results for the Senate are extremely accurate.

Roll Calls

For coordinates other than the senators, we report, in Tables 12 - 14, information in addition to R^2 and regression standard errors. Since a space is defined only up to a linear transformation, it is appropriate to evaluate the senators on the basis of the regression between the true and recovered coordinates. But even if, for example, the regression between true and recovered liberal coordinates showed low errors, the liberal coordinates could vary systematically with

respect to the senators. Such systematic variation would result in inappropriate substantive comparisons of bills and senators. Consequently, in addition to computing regressions, we have also transformed recovered roll call coordinates by the regression estimated for the senators and then computed the root mean square error between the transformed coordinates and the true coordinates. Comparison of the root mean square error to the standard error of the regression indicates the extent to which the space of the roll call coordinates has been "deformed" relative to that of the senators. We have also computed the mean error of the transformed coordinates in order to indicate any bias in our recovery methods.

Tables 12-14 correspond to the midpoints, the liberal coordinates, and the spreads or differences between midpoints and liberal coordinates. We report "unfiltered" results for all roll calls and "filtered" results where roll calls whose untransformed coordinates differed from the true midpoint, liberal coordinate, or spread by more than 0.5 were eliminated.

[Table 12 here]

Midpoints

In the case of the midpoints, results are excellent for runs A-F, the Linear Utility run, and Perfect Voting. The low R^2 for run F is due solely to the low variance in true midpoints; standard errors are still good. All the standard errors are somewhat larger than those for the senators simply because each senator is estimated via

280+ roll calls whereas each roll call is estimated from only 98 senators. Once again, as shown in Figure 4, there is near perfect recovery of the ordinal information under Perfect Voting. Figure 5 provides the comparison for run E. Thanks to the error in run E, we recover the metric information in the midpoints. While there is obviously more scatter than with perfect voting, the plot is linear. A similar linear plot, with less scatter, is obtained for senator coordinates.

[Figures 4 and 5 here]

There are larger errors for runs G–I. The reason for this is that some of the randomly generated liberal coordinates were very close to the midpoints. When this happens, all senators are close to flipping fair coins on the roll call, and the recovered placements can occur anywhere. Filtering out 20 or fewer particularly bad roll calls improves results dramatically. In practical use of the program, one would not take seriously midpoint estimates where the heuristic constraint on midpoints was imposed or where the geometric mean was exceptionally low. Using these criteria would have filtered similarly to our ex post filtering for runs G–I.

Like the senators, bias is not a serious problem in recovery of the midpoints. Although the midpoints vary over a range of two units, the highest mean error on a 98 Senator run was only .013. This occurred on simulation C, the run for which the noise component was greatest relative to the systematic utility.

<u>Liberal Coordinates</u>

Liberal coordinates are recovered less accurately than midpoints (compare Figure 6 to Figure 5). This is not surprising, since liberal coordinates cannot be identified in the limiting case of Perfect Voting. The high R^2 in that case results solely from correlation between true midpoints and true liberal coordinates. In fact, there is substantial bias to the Perfect Voting recovery. However, with stochastic utility, we recover liberal coordinates with more acceptable root mean square errors even when the distribution of midpoints is independent of that of the liberal coordinates as in simulation F. (The low R^2 for this simulation reflects the low variance of liberal coordinates.) In fact, simulation F has the lowest root mean square error, presumably because the independence allows the data to provide more information about the liberal coordinates.

[Figure 6 here]

The substantial root mean square errors are greatly reduced by filtering. The filtered roll calls almost without exception correspond to roll calls where a midpoint was constrained to one end of the dimension. With real data, liberal coordinates recovered without the use of constraints are likely to be reasonably accurate.

[Table 13 here]

There is some evidence of modest bias, with the liberal coordinates being too far to the "left" of the true. The worst case was -.083 for run B, the run closest to Perfect Voting. In any event, comparison of the 50 Senator run with run A suggests that small sample bias for both midpoints and liberal coordinates attenuates asymptotically and that our estimates are essentially consistent.

Spreads

The story for the spreads essentially parallels that for the liberal coordinates. Note, though, that the R^2 on the spreads is virtually 0.0 for Perfect Voting, as expected theoretically. There is also a very low R^2 for the misspecification of the Linear Utility Model. In that case, the root mean square error is not substantially reduced by filtering. Despite having quite small standard errors, runs A-E show modest R^2 values. This is because the spreads have low variance on these runs, a condition resulting from the high covariance between midpoints and liberal coordinates. The spreads are most accurately recovered on run F where the liberal coordinates do not covary with the midpoints.

[Table 14 here]

Standard Errors

NOMINATE produces, in addition to the parameter estimates, an estimate of the standard error for each estimate. As explained in Section III, these standard errors should be viewed with caution. To evaluate the accuracy of the estimates we can compare the root mean square errors produced in the Monte Carlo runs with the average standard errors computed from the Senate data. Comparing Tables 11-13 to Table 15 shows that the two quantities are reasonably similar for roll calls without constrained estimates.

[Table 15 here]

These Monte Carlo resuts are echoed by our time series for the Senate. We took the β and Senator coordinates estimated for 1979 (2.5 percent cutoff) and used these parameters both as fixed parameters to estimate the 1980 roll call parameters ("Start" column in Table 16) as well as starting values to estimate <u>all</u> parameters for 1980 ("Final" column in Table 16). When we treat the 1979 results as fixed parameters, we are computing the estimated covariance matrix correctly since β and the x are fixed and there is no covariance among z from different roll calls. Consequently, in that case, we are appropriately computing standard errors (for unconstrained roll calls). As can be seen in Table 16, there are no major differences between the two sets of standard error estimates.

[Table 16 here]

Summary of Monte Carlo Analysis

In one dimensional legislatures the size of the Senate, interval spatial positions can be recovered to a high degree of accuracy. Even more accurate recovery would be possible in a larger legislature the size of the House of Representatives. There, root mean square errors for midpoints and liberal coordinates should approach those found for senator coordinates and the small bias in the recovery of the liberal coordinates should be further attenuated.

VIII. THE LIBERAL-CONSERVATIVE CONTINUUM IN THE SENATE 1979-81

In this section, we provide a brief interpretation of our results for 1979-81. First, we show that our results correspond well to an elementary spatial model of how the majority party would conduct business in the Senate. Second, we show that a one dimensional model correctly classifies about 4/5 of the individual votes in the Senate. Third, we use our results to interpret the conservative shift brought about by the 1980 elections. Finally, we indicate some results in terms of the substance of individual roll calls. For further substantive application of our results, see Poole and Smith (1983).

Spatial Behavior in the Aggregate

In a one dimensional legislature with probabilistic voting, majority leadership should plan votes such that midpoints lie somewhat away from the median voter. By moving a slight distance away from the median voter, the probability of passage can be increased substantially. Thus, when the Democrats control the Senate, the average midpoint should be to the right of the median senator; when the Republicans control, it should be to the left. As Table 17 shows, the empirical results correspond with this spatial model. Note that, except for overall shifts in the space, the locations of "median" senators are quite stable and that the location of the average midpoint relative to the median senator holds for all cutoff levels.

[Table 17 here]

Explanatory Power

An overall assessment of the model's fit to the data is indicated by the geometric mean probability values in Table 17, which are substantially larger than the 0.5 implied by random voting.

If we want to "predict" individual votes, we need only know a senator's location relative to the midpoint. Thus, the analysis shown in Table 18 is only a partial examination of our model, which estimates the outcome coordinates as well as the midpoint. Nonetheless, the table provides some interesting comparisons with relevant null models. The first null prediction we consider is "Democrats always vote the Liberal side of an issue and Republicans vote the Conservative side." (Recall that the Liberal and Conservative sides of an issue are identified in our procedure for obtaining starting values.) The second null prediction is that Liberals always vote Liberal and Conservatives always vote Conservative. We identify as a Liberal (Conservative) any senator who votes the Liberal (Conservative) side on a majority of the roll calls. Comparing the second prediction to the first shows the gain in using general liberal-conservative preference over party. Comparing the third to the second shows the gain in using the metric information that locates a senator's liberal-conservative position relative to the midpoint on each roll call.

[Table 18 here]

Estimating the midpoints is indeed very useful in classifying outcomes. As shown in the table, about 80 percent of the individual votes, substantially more than in the straight liberal-conservative predictions, are correctly classified by NOMINATE. Note that 1981 differs from the prior Congress in two ways. First, classification is improved. Second, there is less of a gain for the liberal-conservative model over the party model. These results are consistent with our earlier claim, based on coordinates developed from interest group data through 1980, that American politics are becoming increasingly polarized along a unidimensional, party-linked continuum (Poole and Rosenthal, 1983).

It should be further noted that the entries in the table understate the advantage of estimating the midpoints. Our classifications are least correct in the center of the space. Regressions show that we correctly classified about 3/4 of the votes for senators near zero and almost all of the votes at the periphery. However, at the periphery we obviously improve little over a straight liberal-conservative model. Kennedy and Helms are almost as predictable as the tides. In contrast, we make substantial improvements at the center. Here regressions show that we predict about 13 percent more of the votes correctly (as against 10 percent overall).

Estimating the Conservative Swing in 1981

One additional point is made by Table 18. When the Democrats control the Senate, there are more Liberals than Democrats while with Republican control, there are more Conservatives than Republicans.

There are two complementary reasons for this phenomenon.

The first factor leading to an increase in Conservatives is that a risk-averse Senate leadership will place midpoints somewhat away from the median member of the Senate in order to increase the likelihood of successful passage. This means that senators in the middle of the distribution will tend to vote on the Liberal side under a Democratic majority and on the Conservative side under a Republican majority. Thus, the shifting distribution of midpoints will affect how we classify senators as Liberals or Conservatives.

The complementary reason is that senators in the center "go along to get along." As shown in Table 19, while the most liberal third of the Senate barely changed positions between 1979 and 1981, the other two-thirds moved very substantially to the right.[14] (Recall that the standard errors with which we estimate senator positions are on the order of 0.05; consequently, an average shift on the order of .2 to .3 in a group of nine senators is highly significant.) The only exception is the rightmost set of nine senators who were already at or close to 1.0; any rightward movement on their part is constrained.

Indeed, these results illustrate the interesting substantive analysis that can be done with spatial coordinates. It is well-known that the senators elected in 1981 were far more conservative than those they replaced. This change is readily picked up in our coordinates. Eighteen senators present in 1979 and gone in 1981 had a mean position of -.28. Their replacements had a mean position, in 1981, of .58. What our data further indicate is that much of the 1979

Senate followed these new entrants to the right. Indeed, while Helms no longer anchors the conservative end, three of the six senators now ranked as more conservative than Helms were to his left in 1979. The net effect of these changes can be summarized by comparing the mean Conservative (now winning) coordinates for 1981 to the mean Liberal coordinates for 1979. On average, the winning policy position shifted about one unit or half the length of the Liberal-Conservative space in the Senate.

These results suggest that NOMINATE and later evolutions of the program will provide a useful methodology for analyzing the abundant recorded history of roll call votes.

FOOTNOTES

* This work was initiated while Poole was a Political Economy Fellow at Carnegie-Mellon and completed while Rosenthal was a Fairchild Scholar at Caltech. We also acknowledge the substantial computational support of the Graduate School of Industrial Administration at Carnegie-Mellon. This version of the paper has benefited from seminars at Caltech and Stanford.

1. Weisberg (1968) contains a comprehensive review of the literature up to 1968.

2. Even when legislators always vote for the closest alternative, the proportion of disagreement depends upon both the distance between the two legislators, the angle they form with the (arbitrary) origin of the space, and the distribution of cutting lines of bills.

3. While MacRae (1958) should be credited with the model that each roll call is <u>two</u> points on the continuum, his roll call analysis methods do not recover the points.

4. Because the ε_j have a continuous distribution, equal utilities can be ignored.

5. Over an entire data set, $\bar{P} = e^{\ell/A}$ where A denotes the total number of choices actually made over all choice sets and individuals.

6. For further approaches to summarizing the results of logit estimation, see Amemiya (1981).

7. Ties can be dealt with, say, by random assignment.

8. Allowing for various elements of the model to depend upon exogenous characteristics (e.g., education, race, income) is a straightforward generalization of the methods presented here.

9. The quantity β also controls the maximum choice probability. If the choice set is binary, this probability is simply $e^{\beta}/(e^{\beta} + 1)$.

10. Tests of this type, omitted here, are illustrated in Poole and Rosenthal (1982).

11. Experimentation showed that single-precision gave virtually identical results to double-precision. Of course, single precision is much less costly.

12. When not all legislators serve for the full length of the data set, the sample must be drawn so as to include some votes for all legislators.

13. Of course, a tie is possible for the fewest prediction errors. In such a case, the start is that tied midpoint closest to the center of the legislator configuration. In case this midpoint gives the same number of errors for both polarities, "yes" is defined as "liberal." In this latter case, the roll call will fit the dimension poorly regardless of the start decision.

14. This result holds when 1980 is compared to 1981. The R^2 of 1981 on 1979 is 0.83, on 1980, 0.82. The even stronger monotonic relationship, showing the non-linear shifts in position, is similar in both years. The results also hold for runs of different cutoff levels. Note that we are not making statements about absolute ideological shifts in time. What the data show is that about 2/3 of continuing Senate members moved away from Kennedy and Toward Helms.

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TABLE 1

COMPARISON OF THE INITIAL CASE AND ALTERNATIVE ESTIMATIONS

Alternative	Geometric Mean	Squared Correlations With Initial Case		
		Senators	Midpoints	Liberal Coordinates
β = 35, w free	0.6547*	0.9999	0.9998	0.9969
β = 15, w free	0.6541	0.9982	0.9969	0.9921
w = 0.5, β free, Altern. iter. method	0.6545	0.9996	0.9990	0.9843
w = 0.5, β free, Helms, Kennedy out	0.6491**	0.9991	0.9687	0.9628

* Equal to base case.

** Is lower than initial case because Kennedy and Helms voting records served to raise overall geometric mean.

TABLE 2

EFFECTS OF NEAR UNANIMOUS VOTING CUTOFF LEVELS

Cutoff level	Senator Std. Dev.	Senator R^2 With 10%		Number of Roll Calls
		100 Senators	98 Senators*	
10 percent	0.361	1.000	1.000	412
5 percent	0.408	0.991	0.996	415**
2.5 percent	0.410	0.958	0.991	415**
0.5 percent	0.459	0.958	0.971	415**

* Computed only for 98 senators other than Kennedy and Helms.

** Current program limitation is 415 roll calls. First 415 roll calls in 1979 meeting cutoff criterion were included.

TABLE 3

SENATOR COORDINATES

	1979	1980	1981
KENNEDY, E	-1.00	-0.79	-1.00
DODD, C JR			-0.83
TSONGAS, P	-0.81	-0.56	-0.62
BRADLEY, W	-0.71	-0.68	-0.47
WILLIAMS, H	-0.69	-1.00	-0.57
SARBANES, P	-0.66	-0.63	-0.71
MCGOVERN, G	-0.66	-0.32	
LEVIN, C	-0.66	-0.44	-0.88
METZENBAUM	-0.63	-0.36	-0.71
RIEGLE, D	-0.62	-0.48	-0.66
CULVER, J	-0.60	-0.63	
RIBICOFF, A	-0.60	-0.42	
NELSON, G	-0.56	-0.48	
PELL, C	-0.56	-0.43	-0.51
CRANSTON, A	-0.52	-0.59	-0.68
MOYNIHAN, P	-0.52	-0.46	-0.48
BAYH, B	-0.49	-0.19	
STEVENSON	-0.49	-0.37	
JAVITS, J	-0.45	-0.12	
LEAHY, P	-0.44	-0.32	-0.57
MUSKIE, E	-0.43	-0.15	
JACKSON, H	-0.42	-0.29	-0.22
MATSUNAGA	-0.42	-0.46	-0.43
INOUYE, D	-0.41	-0.24	-0.41
BIDEN, J	-0.40	-0.23	-0.44
BAUCUS, M	-0.38	-0.30	-0.30
EAGLETON, T	-0.36	-0.13	-0.64
MITCHELL, G		-0.32	-0.36
HART, G	-0.36	-0.15	-0.54
GLENN, J	-0.34	-0.12	-0.20
DURKIN, J	-0.33	-0.20	
MAGNUSON, W	-0.30	-0.25	
MATHIAS, C	-0.27	-0.16	0.19
BUMPERS, D	-0.25	-0.11	-0.50
BURDICK, Q	-0.24	-0.16	-0.15
BYRD, RC	-0.22	-0.11	-0.26
CHILES, L	-0.21	0.06	-0.06
WEICKER, L	-0.21	-0.04	0.19
GRAVEL, M	-0.20	-0.23	
HUDDLESTON	-0.20	-0.12	-0.17
MELCHER, J	-0.19	-0.04	-0.07
SASSER, J	-0.18	-0.04	-0.12
STAFFORD, R	-0.17	0.06	0.46
CHAFEE, J	-0.16	0.03	0.38
CHURCH, F	-0.16	-0.17	
PERCY, C	-0.13	0.19	0.57
RANDOLPH, J	-0.13	-0.16	-0.27
HATFIELD, M	-0.12	0.16	0.42
CANNON, H	-0.12	0.09	-0.07
STEWART, D	-0.11	0.03	
BENTSEN, L	-0.09	0.03	0.12
PRYOR, D	-0.09	0.03	-0.17
PACKWOOD, R	-0.07	0.07	0.53
HEINZ, J	-0.06	0.22	0.32
EXON, J	-0.06	0.22	-0.02
DIXON, A			-0.06
HOLLINGS, E	-0.05	0.11	
NUNN, S	-0.05	0.20	0.08
DURENBERGER	-0.03	0.19	0.44
TALMADGE, H	-0.03	0.16	
FORD, W	-0.02	-0.02	-0.22

	1979	1980	1981
JOHNSTON, J	-0.02	0.11	0.16
DECONCINI	-0.02	0.02	-0.04
STONE, R	-0.02	0.08	
LONG, R	-0.01	0.18	0.27
MORGAN, R	-0.01	0.21	
STENNIS, J	-0.01	0.19	0.27
PROXMIRE, W	0.02	0.13	0.22
DANFORTH, J	0.03	0.32	0.55
COHEN, W	0.04	0.30	0.43
HEFLIN, H	0.06	0.13	0.07
BELLMON, H	0.07	0.37	
PRESSLER, L	0.08	0.37	0.33
BOSCHWITZ	0.14	0.36	0.48
BAKER, H	0.15	0.47	0.71
ZORINSKY, E	0.16	0.33	0.19
BOREN, D	0.17	0.24	0.11
KASSEBAUM	0.18	0.30	0.48
STEVENS, T	0.18	0.43	0.60
SCHWEIKER	0.20	0.37	
YOUNG, M	0.21	0.42	
DOLE, R	0.26	0.36	0.74
COCHRAN, T	0.26	0.48	0.64
DOMENICI, P	0.27	0.44	0.70
SCHMITT, H	0.30	0.52	0.70
HAYAKAWA, S	0.31	0.60	0.89
ROTH, W	0.31	0.55	0.48
SPECTER, A			0.32
WARNER, J	0.42	0.51	0.74
BYRD, HF	0.43	0.46	0.52
LUGAR, R	0.43	0.55	0.79
SIMPSON, A	0.44	0.56	0.76
WALLOP, M	0.45	0.57	0.82
TOWER, J	0.47	0.69	0.84
ANDREWS, M			0.50
GOLDWATER	0.52	0.72	0.84
RUDMAN, W			0.55
HAWKINS, P			0.55
JEPSEN, R	0.55	0.63	0.79
THURMOND, S	0.57	0.65	0.82
GORTON, S			0.58
DAMATO, A			0.59
ABDNOR, J			0.63
MURKOWSKI			0.64
KASTEN, R			0.67
GARN, J	0.71	0.78	0.88
LAXALT, P	0.73	0.79	0.87
GRASSLEY, C			0.73
MCCLURE, J	0.74	0.83	0.94
ARMSTRONG	0.76	0.84	0.81
QUAYLE, J D			0.80
HUMPHREY, G	0.82	0.89	0.75
HATCH, O	0.82	0.64	0.85
MATTINGLY			0.84
DENTON, J			0.86
NICKLES, D			0.91
EAST, J			0.95
HELMS, J	1.00	1.00	0.87
SYMMS, S			1.00

TABLE 4

ROLL CALLS WITH LOW GEOMETRIC MEANS (< .510)

ICPSR Code	Geometric Mean	Lib. Coord.	Midpoint	Topic
1979				
108*	0.51	0.19	0.23	Heinz: Amd. to Pressler Amd., VA payments
158	0.51	-0.56	-0.48	Chiles: Subst. to Jepsen Amd., borrowing for food stamps
328	0.50	-0.32	-0.27	Weicker: Liveable cities, HUD appropriation
342	0.51	-0.59	-0.53	Randolph: Make Energy Mobilization Board full time, Reduce Power Chair
364	0.51	-0.35	-0.28	Byrd, W. Va.: Table Weicker Amd. to eliminate Cong. pay raise
365	0.50	-0.29	-0.23	Magnunson: House Abortion Amd., Continuing Approp.
417*	0.50	-1.02	-1.00	Muskie: Table Dole sub. to Boschwitz amd., residential energy assistance allocations
1980				
522*	0.51	-1.04	-1.00	Pressler: Vietnam Veterans training
617*	0.50	0.98	1.00	Bellmon: Table Cohen Amd. reducing Water Resources spending by $500 million
626	0.51	-0.44	-0.37	Hollings: Table Stevens Amd., Civil Service retirement benefits
649*	0.51	-0.86	-0.81	Hollings: Table Pryor Amd. to Glenn amd., post office subsidies
696*	0.50	-1.01	-1.00	Sustain chair on germaneness of comm. amd. to funding for draft

Table 4 (cont.)

FCPSR Code	Geometric Mean	Lib. Coord.	Midpoint	Topic
781*	0.50	0.98	1.00	Johnston: Table Cranston amd. for solar power plant in Cal.
788	0.51	-0.67	-0.61	Chaffee: Kill Tombigbee waterway
851	0.51	-0.34	-0.26	Dole: Table Hatfield notion, nuclear waste
852	0.51	-0.37	-0.28	Hatfield: Reconsider nuclear waste
854*	0.50	0.58	0.59	Javits: Table Ford amd. on DOE auth. regarding energy impact assistant
906*	0.51	0.97	1.00	Pressler: Vietnam Veterans training
953*	0.50	0.99	1.00	Heflin: 2% reduction in HUD applop
958*	0.50	0.06	0.08	Agree to disapprove uranium sales to India
1010*	0.50	-0.64	-0.61	Huddleston: increase budget of FCIC
<u>1981</u>				
196*	0.51	-1.03	-1.00	Kasten: Noise Control Abatement
272	0.51	-0.34	-0.29	Helms: Tobacco price supports
320*	0.51	-1.03	-1.00	Boschwitz: Telecommunications deregulation
363*	0.50	-0.19	-0.17	Percy: Tombigbee waterway
414*	0.51	-0.59	-0.56	Stevens: Pay cap federal employees
428	0.51	0.08	0.14	Hatfield: Table Proxmire Amd. to Baker amd. foreign aid
507*	0.51	-1.03	-1.00	Conference report, foreign aid bill

* Liberal and Conservative Coordinates Closer than 0.1.

TABLE 5

ADDITIONAL ROLL CALLS LIBERAL AND CONSERVATIVE COORDINATES CLOSER THAN 0.1

ICPSR Code	Geometric Mean	Lib. Coord.	Midpoint	Topic
1979				
85	0.52	-1.05	-1.00	Ketak nomination (Legal Services Corporation). See Table 4
237	0.53	0.96	1.00	Proxmire: Reduce Revenue Sharing $684 million
253	0.52	-1.05	-1.00	Melcher: Continue Amtrak service
389	0.51	0.59	0.63	Proxmire: Table Morgan amd., banking regulation
1980				
588	0.51	0.70	0.75	Cochran: Railroad abandonments
599	0.51	0.96	1.00	Durkin: Allocation of funds to states, home purchase assistance
942	0.51	0.79	0.83	Melcher: D.C. airports
1981				
140	0.51	0.61	0.66	Cochran: rescind migration and refugee assistance funds
429	0.52	0.95	1.00	Proxmire: Amd. Baker amd., foreign aid
459	0.51	-1.05	-1.00	Hatfield: Defense spending

TABLE 6

ROLL CALLS WITH HIGH GEOMETRIC MEANS (> .850, 1979, 1980; > .880, 1981)

ICPSR Code	Geometric Mean	Lib. Coord.	Midpoint	Topic
1979				
16	0.88	-1.00	0.02	Final passage, cloture rules
421	0.88	-0.48	0.21	Final passage, approp. bill
430	0.89	-1.16	-0.08	McClure: Amd. Idaho Wilderness Act
432	0.88	-1.04	-0.02	Final passage, Idaho Wilderness Act
475	0.85	-1.36	-0.18	McClure: 90% Windfall profits tax, oil
512	0.88	-0.81	0.11	Linowitz nomination
1980				
574	0.90	-1.00	0.15	White nomination (El Salvador)
583	0.90	-1.00	0.22	Final passage, FTC funded for 45 days
609	0.89	-0.78	0.28	Final passage, continuing approp. FTC
749	0.85	-0.31	0.37	Jones nomination, joint chiefs
1025	0.85	-1.12	-0.06	Byrd, Table Hatch motion to reconsider Fair Housing
1981				
53	0.89	-1.13	-0.06	Chiles: restore funds, Veterans' Medical Services
60	0.89	-1.17	-0.08	Reigle: restore funds, social security min. benefits
71	0.88	-1.71	-0.35	Metzenbaum: restore funds, youth training

Table 6 (cont.)

ICPSR Code	Geometric Mean	Lib. Coord.	Midpoint	Topic
131	0.91	-1.00	0.07	Hatfield: Table Moynihan amd., social security benefits
147	0.89	-1.24	-0.12	Proxmire: Community Development Funds
192	0.92	-2.02	-0.51	Budget
198	0.89	-1.00	0.03	Baker: Table Moynihan amd. to 1981 ERTA
207	0.89	-1.17	-0.09	Dole: Table Boren amd., lower interest rates
208	0.91	-1.09	-0.05	Durenberger: Table Reigle amd. corporate tax credits
222	0.90	-1.20	-0.10	Bradley: tax schedules
259	0.91	-1.07	-0.04	Byrd (WV): Adjourn
323	0.89	-1.00	0.01	Dole: Table Byrd amd. to Pressler amd., social security min. benefits
334	0.88	-1.44	-0.22	Kennedy: Table Helms amd., arms to Chile
425	0.90	-1.07	-0.03	Hatfield: Table Deconcini amd., cuts in VA budget
435	0.88	-1.00	0.00	Stevens: Table Moynihan motion, continuing appropriations
441	0.90	-1.14	-0.07	Stevens: Table Byrd amd., increased scientific research funding
444	0.90	-1.23	-0.11	Stevens: Table Hollings amd., $148 million, extra for ammunition
446	0.88	-1.26	-0.13	Exon: Increase $60 million, for modernization
462	0.91	-1.22	-0.11	Dole: Table Metzenbaum amd., aging

Table 6 (cont.)

ICPSR Code	Geometric Mean	Lib. Coord.	Midpoint	Topic
469	0.88	-1.00	0.01	Byrd: Table Baker subst., small business and Federal Reserve
473	0.89	-1.00	0.00	Johnston: Amd. Domenici amd. balanced budget amd. inflation
484	0.92	-1.16	-0.08	Bumpers: Child care approp.
485	0.89	-1.56	-0.28	Kennedy: Unemployment assistance
486	0.90	-1.14	-0.07	Kennedy: Headstart
487	0.91	-1.23	-0.11	Dodd: low income housing
488	0.89	-1.53	-0.27	Eagleton: CETA

TABLE 7

ROLL CALLS WITH LIBERAL AND CONSERVATIVE COORDINATES
SEPARATED BY MORE THAN 2.5

ICPSR Code	Geometric Mean	Lib. Coord.	Midpoint	Topic
<u>1979</u>				
23	0.77	-1.55	-0.28	Percy: Taiwan
43	0.76	-1.52	-0.26	Heinz: Council on Wage and Price Stability to spend funds to monitor federal inflation policy
131	0.83	-1.76	-0.38	Byrd, VA: Taiwan
377	0.77	-1.52	-0.26	Kreger nomination (Mexican affairs)
473	0.79	-1.60	-0.30	Bumpers: Subst. to Armstrong Amd. oil price decontrol and windfall profits
480	0.76	-1.57	-0.29	Long: Table Ribicoff Amd., windfall profits tax
<u>1980</u>				
830	0.78	-1.52	-0.26	McGovern: Table Cochran Amd. School Lunches
831	0.84	-1.69	-0.35	Boren: School Lunches, Farm Labor Contract Act
839	0.79	-1.67	-0.34	Wallop: exclude some mining from ERISA
842	0.79	-1.66	-0.33	Boren: Small business exemption, OSHA
<u>1981</u>				
71	0.88	-1.71	-0.35	See Table 6
192	0.92	-2.02	-0.51	
211	0.86	-1.60	-0.34	Bradley: Tax cut
485	0.89	-1.56	-0.28	See Table 6
488	0.89	-1.53	-0.27	

TABLE 8

ROLL CALLS WITH MIDPOINTS WITHIN 0.1 OF MEAN MIDPOINT

ICPSR Code	Geometric Mean	Lib. Coord.	Midpoint	Topic
<u>1979</u>				
37	0.81	-1.41	-0.21	Long: Table Armstrong amd., income tax cuts
60	0.77	-1.25	-0.22	Roth: Reduce spending and cut taxes
101	0.76	-1.23	-0.21	Church: Table Helms Amd., UN funding
110	0.58	-0.50	-0.21	Huddleston: Table Cochran Amd., SBA interest rate
174	0.68	-0.76	-0.20	Armstrong: Amd. HUD authorization to tighten income restrictions on public housing
175	0.72	-0.96	-0.22	Garn: Exempt nonprofits from labor standards
221	0.72	-1.03	-0.22	Helms: Amd. Mcgovern amd., food stamps
230	0.52	-0.35	-0.22	Mathias: Collective Bargaining, Employees Panama Canal Commission
300	0.74	-1.09	-0.22	Bellmon: Amend Muskie Amd. to conform approp. to budget
305	0.76	-1.23	-0.21	Roth: Reduce spending and cut taxes
306	0.75	-1.16	-0.22	Armstrong: Reduce spending and cut taxes
309	0.61	-0.57	-0.21	Muskie: Table Bumpers Amd., 2.5% across the board spending cut
347	0.59	-0.53	-0.21	Pass committee amd., IDA restrictions on Vietnam, Egypt, Sudan
349	0.66	-0.72	-0.21	Pass committee amd. IDA restrictions, Taiwan

Table 8 (cont.)

ICPSR Code	Geometric Mean	Lib. Coord.	Midpoint	Topic
361	0.60	-0.53	-0.21	Pass foreign aid bill
428	0.80	-1.41	-0.20	Dole: Oil windfall profits tax
459	0.74	-1.01	-0.21	Bradley: Oil windfall profits tax
1980				
520	0.81	-1.31	-0.15	Byrd: Table Tower amd. Salt II
555	0.76	-1.17	-0.14	Simpson: FTC
582	0.72	-0.93	-0.15	Budget resolution with Muskie substitutes
606	0.70	-0.83	-0.14	Baker: Table Byrd motion to reconsider failed cloture vote
615	0.64	-0.62	-0.15	Hollings: Table Thurmond amd. increasing spending for veterans, decreasing for social services
637	0.62	-0.56	-0.15	Schweiker: Reduce Federal Reserves
669	0.60	-0.50	-0.15	Final passage, Central American aid
681	0.75	-1.12	-0.16	Proximire: Reconsider Dole amd., wage-price guidelines
750	0.74	-0.99	-0.14	Moynihan: Table Jepsen amd., exemptions from Davis-Bacon
774	0.68	-0.75	-0.15	Bentsen: Table Armstrong amd., tax indexing
804	0.65	-0.65	-0.15	Culver: Table Wallop amd. funding ABM
805	0.68	-0.78	-0.16	Tower: Table Exon amd. War Powers Resolution
809	0.68	-0.73	-0.15	Glenn: Table Tower Subst. to Glenn amd. B-1

Table 8 (cont.)

ICPSR Code	Geometric Mean	Lib. Coord.	Midpoint	Topic
810	0.75	-1.01	-0.15	Glenn: Table Tower Subst. to Glenn amd. B-1
835	0.75	-1.14	-0.16	Byrd: Table Helms appeal ruling of chair
853	0.51	-0.26	-0.15	Hatfield: Nuclear Waste
911	0.58	-0.44	-0.15	Johnston: Table Cohen Amd., Hydroelectric Project, Maine
<u>1981</u>				
60	0.89	-1.17	-0.08	Reigle: restore funds, soc. sec. min. benefits
202	0.78	-0.81	-0.10	Schmitt: Tax bill
207	0.89	-1.17	-0.09	Dole: Table Boren amd., lower interest rates
447	0.76	-0.71	-0.09	Glenn: Add $75 million for battle group in Indian Ocean

TABLE 9

MIDPOINT PLACED AT MINORITY END

ICPSR Code	Geometric Mean	Lib. Coord.	Midpoint	Topic
<u>1979</u>				
135	0.60	0.91	1.00	Hart: Delete funds F-18
200	0.56	0.93	1.00	Melcher: Add $200M, soil conservation service
237	0.53	0.96	1.00	Proxmire: Reduce Revenue Sharing $684 million
302	0.67	0.88	1.00	Exon: Subst. Hollings Amd., defense spending
406	0.67	0.88	1.00	Hatfield: Kill MX
504	0.55	0.94	1.00	Sustain chair on Bumpers Amd., Gasohol
<u>1980</u>				
561	0.62	0.87	1.00	Final passage, motor vehicle safety
599	0.51	0.96	1.00	Durkin: Allocation of funds to states, have purchase assistance
617	0.50	0.98	1.00	Bellmon: Table Cohen Amd. reducing Water Resources spending by $500 million
701	0.56	0.92	1.00	Warner: Table Comm. Amd., concientious objectors
702	0.59	0.89	1.00	Cranston: Table Byrd motion to reconsider #701
708	0.63	0.87	1.00	Hatfield: Table Nunn amd., draft registration funds
762	0.56	0.91	1.00	Moynihan: Pell grants to education

Table 9 (cont.)

ICPSR Code	Geometric Mean	Lib. Coord.	Midpoint	Topic
781	0.50	0.98	1.00	Magnunson: Table Helms amd., Mt. St. Helens disaster relief
879	0.64	0.86	1.00	Byrd (WV): Table Melcher motion on chair ruling regarding cloture
886	0.57	0.91	1.00	Byrd (WV): Table Metzenbaum apped to chair rule on McGovern amd., strip mining.
889	0.58	0.90	1.00	Ford: Table Metzenbaum motion to reconsider, strip mining
906	0.51	0.97	1.00	Pressler: Vietnam Veterans Training
953	0.50	0.99	1.00	Heflin: Reduce HUD approp. by 2%
979	0.70	0.82	1.00	Adopt Conference report, railroad regulation
984	0.64	0.86	1.00	Weicker: Recommit State-Justice approp.
1002	0.71	0.82	1.00	Stafford: Agree to substitute, Hazardous Waste Cleanup
<u>1981</u>				
73	0.64	-1.16	-1.00	Hollings: Reduce funds, Federal cost of living adjustments
75	0.62	-1.14	-1.00	Proxmire: Reduce spending beyond approp. comm. recommendation
76	0.60	-1.13	-1.00	Proxmire: Restore funds Ex-In Bank
95	0.53	-1.06	-1.00	Deconcini: Table Percy amd., African Development Bank
196	0.51	-1.03	-1.00	Kasten: Noise Control Abatement

Table 9 (cont.)

ICPSR Code	Geometric Mean	Lib. Coord.	Midpoint	Topic
241	0.64	-1.16	-1.00	Heinz: Industrial Dev. Banks, pollution control
247	0.71	-1.22	-1.00	Kennedy: Business meal allowance
270	0.52	-1.06	-1.00	Helms: Table Quayle amd., sugar price supports
274	0.54	-1.07	-1.00	Inouye: Table Humphrey amd., sugar price supports
320	0.51	-1.03	-1.00	Boschwitz: Telecommunications deregulation
459	0.51	-1.05	-1.00	Hatfield: Defense spending
497	0.60	-1.13	-1.00	Agree to conference report, Agriculture approp.
507	0.51	-1.03	-1.00	Agree to conference report, Foreign Aid approp.

TABLE 10

MIDPOINTS PLACED AT MAJORITY END

ICPSR Code	Geometric Mean	Lib. Coord.	Midpoint	Topic
1979				
85	0.52	-1.05	-1.00	Kutak nomination (Legal Service Corp.)
92	0.59	-1.12	-1.00	Huddleston: Table Thurmond Amd. Alcoholism Warning Lable on Bottles
105	0.65	-1.17	-1.00	Final passage, State Dept. auth.
120	0.60	-1.14	-1.00	Eagleton: withold funds from states failing to administer child feeding programs
141	0.69	-1.21	-1.00	Lugar: Gasohol
159	0.56	-1.10	-1.00	Jepsen: Amd. IDA bill
160	0.66	-1.18	-1.00	Weicker: germaneness of Stennis amd. on interest rate or disaster loans
249	0.65	-1.18	-1.00	Byrd (WV) Table Weicker amd. adjourn.
253	0.52	-1.05	-1.00	Melcher: Amd. Leahy Amd. continue Amtrak
321	0.68	-1.20	-1.00	Brown nomination
366	0.67	-1.19	-1.00	Agree to salary increases for member of Congress
386	0.57	-1.11	-1.00	Johnston: concern in House amd., details of antitrust reg.
390	0.52	-1.06	-1.00	Stewart: banking regulation
417	0.50	-1.02	-1.00	Muskie: Table Dole Sub. to Boschwitz amd., residential energy allocations
479	0.69	-1.21	-1.00	Stevens: Table Deconcini Amd. on IRS info. disclosure to federal agencies

Table 10 (cont.)

ICPSR Code	Geometric Mean	Lib. Coord.	Midpoint	Topic
1980				
522	0.51	-1.04	-1.00	Pressler: Vietnam Veterans training
523	0.54	-1.09	-1.00	Cranston: Subst. Bellmon amd., VA and HEW coordination, nursing home care
524	0.62	-1.18	-1.00	Muskie: Table Cranston amd. 15% increase GI education benefits
552	0.74	-1.30	-1.00	Levin: FTC veto
638	0.72	-1.27	-1.00	Hollings: Table Weicker Amd. increasing health funding
642	0.56	-1.12	-1.00	Heflin: Reduce Int'l. Affairs budget, increase Justice
650	0.52	-1.06	-1.00	Pryor: Amd. Glenn Amd. Congressional budget
651	0.56	-1.11	-1.00	Hollings: Table Glenn Amd., postal subsidies
694	0.53	-1.07	-1.00	Cloture on funds for draft registration
696	0.50	-1.01	-1.00	Sustain chair, germaneness, conscientious objectors
710	0.58	-1.14	-1.00	Nunn: reduce appropriations drafting registration forms
714	0.55	-1.11	-1.00	Hatfield: Table draft registration
740	0.57	-1.13	-1.00	Huddleston: immigration quota
782	0.68	-1.24	-1.00	Sustain chair that Cranston amd., solar power in CA violated budget resolution
790	0.65	-1.20	-1.00	Magnunson: bring approp. bill within budget ceiling

Table 10 (cont.)

ICPSR Code	Geometric Mean	Lib. Coord.	Midpoint	Topic
880	0.53	-1.08	-1.00	Cloture: strip mining
887	0.63	-1.18	-1.00	Nunn: Table Metzenbaum motion to reconsider, strip mining
888	0.63	-1.18	-1.00	Warner: Table Metzenbaum appeal
915	0.67	-1.24	-1.00	Byrd (WV) Federal pay ceiling
1000	0.71	-1.28	-1.00	Jepsen: Restore $200 million, personnel, military
1014	0.66	-1.21	-1.00	Byrd: request attendance of members
<u>1981</u>				
33	0.57	0.89	1.00	Passage: Debt Limit Increase
63	0.58	0.88	1.00	McClure: Restore funds strategic Petroleum Reserve
110	0.65	0.83	1.00	Domenici: Table Proxmire amd., balanced budget 1982
190	0.52	0.94	1.00	Helms: reduce funding handicapped
263	0.59	0.88	1.00	Passage: Military pay increases
296	0.62	0.85	1.00	Proxmire: outside earned income, elected or appointed members of gov't.
355	0.64	0.84	1.00	Pass: agriculture approp. aid bill
377	0.59	0.87	1.00	Percy: Amd. Percy amd. on agricultural embargos
429	0.52	0.95	1.00	Proxmire: Amd. Baker amd., foreign aid
495	0.55	0.91	1.00	Agree to conference report, Expt. Admin. Act

TABLE 11

MONTE CARLO RESULTS FOR SENATORS AND UTILITY FUNCTION

Run		R^2	Std. Error of Regression	Recovered β
A β = 15.00	97 roll call midpoints generated	.990	.047	16.47
B β = 22.50	at midpoints of adjacent senators.	.990	.047	27.46
C β = 7.50	Three liberal coordinates per	.980	.068	8.72
D β = 18.25	midpoint. Total of 291 roll	.990	.048	20.53
E β = 11.75	calls.	.988	.053	12.45
F β = 15.0	Liberal coordinates and midpoints uncorrelated	.987	.055	12.45
G β = 15.0	Midpoints throughout but concen-	.988	.054	17.96
H β = 15.0	trated in center. Liberal coordi-	.986	.057	19.87
I β = 15.0	nates generated by random process.	.987	.055	19.87
Linear Utility	Roll calls identical to	.980	.069	11.75
Perfect Voting	A-E	.923	.134	*
50 Senators, β = 15.0		.991	.047	16.88

* With Perfect Voting, the estimate of β explodes as iterations continue.

TABLE 12

MONTE CARLO RESULTS FOR MIDPOINTS

Run	R^2	Std. Error of Regression	Root Mean Sq. Error	Mean Error	Number of Roll Calls
<u>Unfiltered</u>					
A	.974	.073	.074	.006	288*
B	.981	.063	.062	.007	286*
C	.930	.124	.127	.013	291
D	.979	.066	.068	.008	287*
E	.967	.085	.085	.004	291
F	.537	.066	.091	-.001	286
G	.747	.172	.188	-.003	283
H	.653	.202	.230	.001	283
I	.598	.218	.243	-.010	283
Linear Utility	.953	.102	.105	.003	291
Perfect Voting	.909	.141	.144	-.002	291
50 Senators	.676	.268	.330	-.179	291
<u>Filtered</u>					
A	.970	.073	.073	.004	269
B	.979	.060	.062	.006	260
C	.933	.118	.122	.015	275
D	.977	.064	.066	.005	267
E	.965	.084	.085	.003	276
F	.538	.066	.091	-.001	285
G	.895	.103	.110	-.002	267
H	.896	.105	.108	.008	264
I	.847	.125	.130	-.002	263
Linear Utility	.952	.097	.101	.007	277
Perfect Voting	N too small for analysis.				
50 Senators	.724	.240	.282	-.133	212

* Differs from 291 because roll calls with less than 2.5% minority not analyzed.

TABLE 13

MONTE CARLO RESULTS FOR LIBERAL COORDINATES

Run	R^2	Std. Error of Regression	Root Mean Sq. Error	Mean Error	Number of Roll Calls
<u>Unfiltered</u>					
A	.767	.250	.269	.012	288
B	.709	.276	.301	-.013	286
C	.792	.238	.252	.025	291
D	.747	.260	.276	-.000	287
E	.817	.223	.251	.024	291
F	.375	.150	.162	-.028	286
G	.743	.262	.278	-.042	283
H	.748	.272	.294	-.014	283
I	.695	.274	.305	-.014	283
Linear Utility	.808	.229	.244	-.077	291
Perfect Voting	.930	.138	.408	.373	291
50 Senators	.497	.371	.433	-.141	291
<u>Filtered</u>					
A	.862	.182	.185	-.031	269
B	.867	.178	.197	-.083	260
C	.855	.197	.210	.021	275
D	.884	.169	.182	-.060	267
E	.874	.180	.193	-.014	276
F	.380	.144	.157	-.030	285
G	.856	.185	.195	-.037	267
H	.870	.190	.195	-.035	264
I	.835	.196	.211	-.009	263
Linear Utility	.838	.205	.216	-.070	277
Perfect Voting	N.A.				
50 Senators	.811	.228	.250	-.098	212

TABLE 14

MONTE CARLO RESULTS FOR SPREADS

Run	R^2	Std. Error of Regression	Root Mean Sq. Error	Mean Error	Number of Roll Calls
<u>Unfiltered</u>					
A	.382	.123	.255	-.006	288
B	.295	.131	.296	.020	286
C	.338	.129	.223	-.012	291
D	.343	.127	.266	.008	287
E	.379	.125	.234	-.020	291
F	.536	.108	.145	.027	286
G	.753	.189	.198	.038	283
H	.829	.163	.174	.051	283
I	.810	.163	.176	.005	283
Linear Utility	.069	.154	.233	.080	291
Perfect Voting	.034*	.156	.408	-.375	291
50 Senators	.154	.147	.353	-.038	291
<u>Filtered</u>					
A	.334	.118	.174	.035	269
B	.314	.124	.199	.090	260
C	.327	.129	.198	-.006	275
D	.323	.123	.181	.065	267
E	.374	.123	.176	.017	276
F	.545	.107	.140	.029	285
G	.818	.153	.161	.035	267
H	.843	.149	.160	.043	264
I	.821	.150	.161	-.007	263
Linear Utility	.076	.149	.218	.073	277
Perfect Voting	N.A.				
50 Senators	.149	.150	.303	-.035	212

* The correlation is -0.1841.

TABLE 15

AVERAGE OF STANDARD ERRORS ESTIMATED BY NOMINATE

Year and Cutoff Level	Senators	Midpoints	Liberal Coordinates	N*
10% - 1979	.049	.093	.179	412/379
1980	.039	.112	.187	390/329
1981	.049	.106	.172	354/283
2.5% - 1980c	.049	.135	.253	415/248
1981	.049	.131	.214	397/250

* First number is total roll calls. Second is roll calls estimated without constraints. Figures in table for roll calls refer to only estimates without constraints. Output of standard errors was not added to NOMINATE for runs not in table.

c See Table 17.

TABLE 16

STANDARD ERRORS ESTIMATED BY NOMINATE: 1980 DATA
USING 1979 SENATOR COORDINATES AS STARTS

	All Constrained Roll Calls Eliminated		Only Roll Calls with Constrained Midpoints Eliminated	
	Start	Final	Start	Final
N*	314	314	346	346
Midpoint:				
Mean Std. Error	.122	.108	.115	.102
Std. Dev. of Std. Errors	.146	.132	.141	.127
Minimum Std. Error	.033	.029	.033	.028
Maximum Std. Error	1.470	1.226	1.470	1.226
R^2 - Start Std. Error and Final Std. Error	.882		.884	
R^2 - Final Std. Error on Quadratic of Coordinates	.465		.465	
Liberal Coordinate:				
Mean Std. Error	.225	.232		
Std. Dev. of Std. Errors	.144	.148	N.A.	
Minimum Std. Error	.092	.077		
R^2 - Start Std. Error and Final Std. Error	.736			
R^2 - Final Std. Error on Quadratic of Coordinates	.456			

TABLE 17

SUMMARY OF U.S. SENATE ESTIMATES, 1979-81

Year and Cutoff Level		Geometric Mean	Median Senator** Name	Median Senator** Coordinate	Mean Sen. Coordinate	Mean Midpoint	Mean Lib. Coordinate	N*	Average Geometric*** Mean
10% - 1979	30.27	.654	Exon	-.30	-.25	-.21	-.67	412/379	.659
1980	24.03	.648	Proxmire	-.26	-.22	-.15	-.59	390/329	.650
1981	24.72	.686	Pressler	+.05	+.02	-.09	-.50	354/283	.673
5% - 1979	19.98	.663	Bentsen	-.12	-.09	-.02	-.51	415/344	.657
2.5% - 1979	18.87	.665	Pryor	-.09	-.06	-.01	-.52	415/274	.643
1980a	14.63	.667	Stone	+.00	+.02	+.08	-.47	415/278	.634
1980b	16.51	.668	Packwood	+.06	+.08	+.13	-.42	415/286	.642
1980c	13.51	.664	Johnston	-.19	-.16	-.08	-.65	415/248	.634
1981	15.10	.694	Pressler	+.33	+.22	+.05	-.47	397/250	.657
0.5% - 1979	12.69	.671	Heinz	+.05	+.02	+.08	-.55	415/274	.643

a,b,c Three partially overlapping runs for 1980 data. Three runs together span all 1980 data.

* See note to Table 15.

** Coordinates for the "four" median senators in 1979 differed by at most 0.09 on any single run. Similarly, the maximum difference in 1980 runs was 0.05.

*** Average of roll call geometric means for unconstrained roll calls.

TABLE 18

PERCENTAGE OF INDIVIDUAL VOTES CORRECTLY CLASSIFIED

	Model				
Year and Cutoff Level	Party	(N Dem.)	Lib.-Cons.	(N Lib.)	Midpoint
1979 - 10%	57.5%	58	71.0%	64	79.2%
1979 - 5%	66.8	58	70.5	63	80.0
1979 - 2.5%	66.1	58	70.0	64	80.3
1979 - 0.5%	65.3	58	69.7	70	81.1
1980 - 10%	67.9	58	70.4	61	78.7
1980* - 2.5%	66.5	58	69.3	65	80.7
1981 - 10%	74.2	46	75.1	41	81.7
1981 - 2.5%	71.4	46	72.3	41	83.3

* Average over 3 runs that span entire data set. Figures in this table refer to <u>all</u> roll calls. (Estimates can be constrained.)

TABLE 19

AVERAGE CHANGE IN POSITION 1979-81*
GROUPS OF NINE SENATORS, ORDERED BY 1979 POSITION

	Group Range	Change
	-1.0 -- -.55	.023
	-.52 -- -.38	.033
	-.36 -- -.25	.055
	-.20 -- -.12	.280
	-.10 -- -.02	.209
	-.02 -- +.15	.250
	+.15 -- +.30	.325
	+.30 -- +.52	.332
	+.56 -- +1.0	.098
TOTAL	-1.0 -- +1.0	.182

* Based on 2.5% Cutoff Level Runs

Figure 1: Utility Function of a Voter Located at -1.0

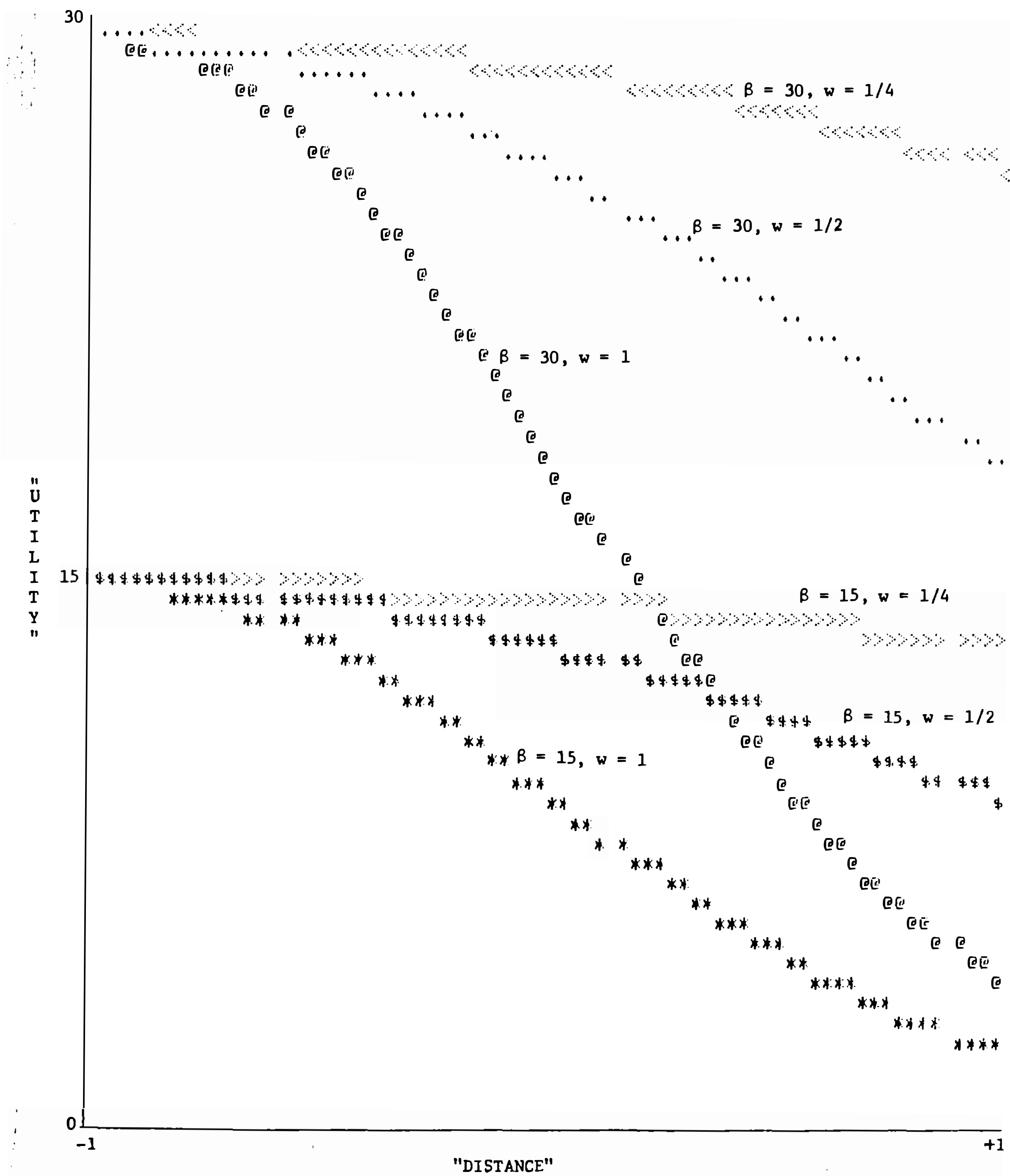

FIGURE 2

NOMINATE. NOMINAL THREE STEP ESTIMATION

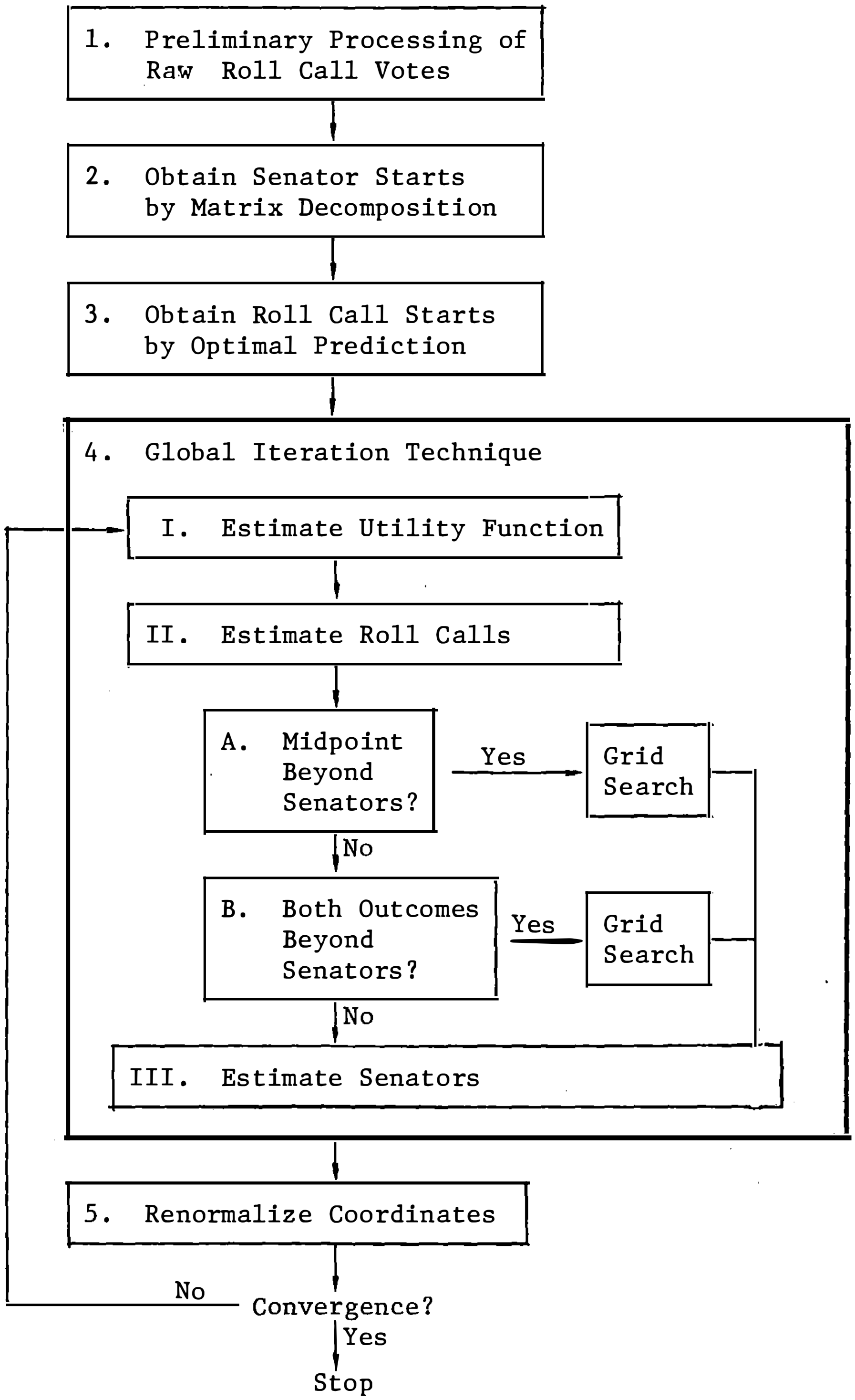

Figure 3: True and Recovered Senator Coordinates: Perfect Voting

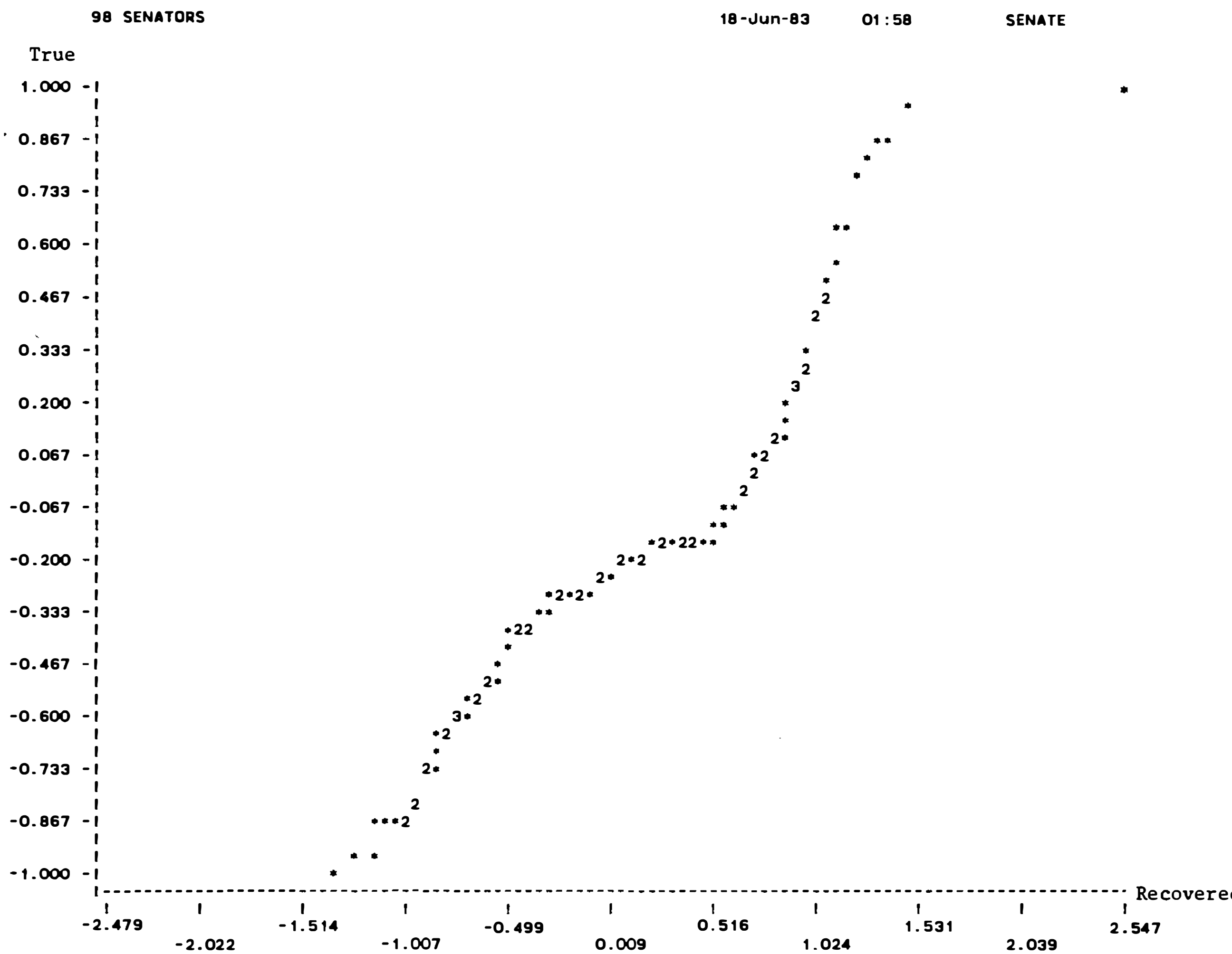

Figure 4: True and Recovered Midpoints: Perfect Voting

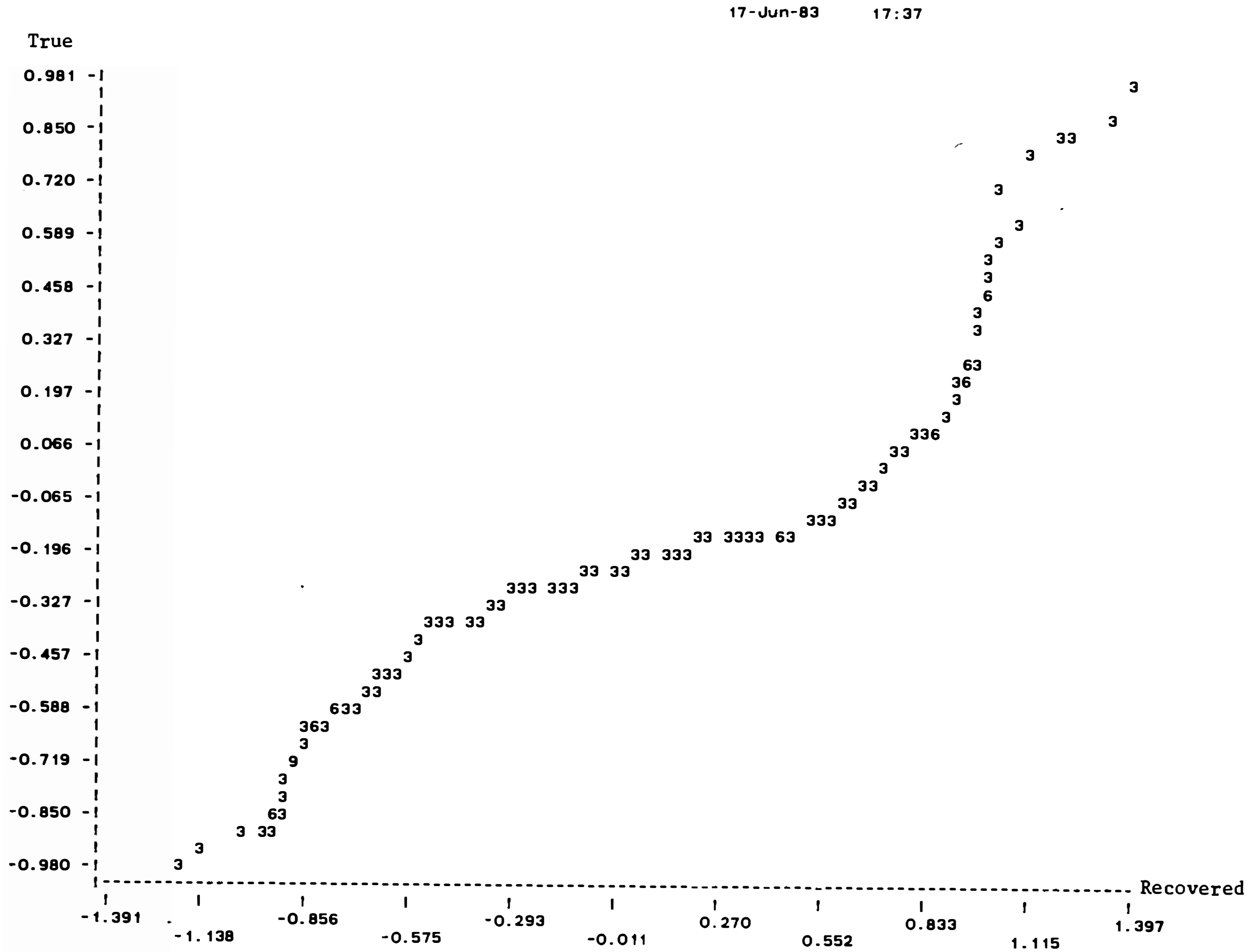

Figure 5: True and Recovered Midpoints: Stochastic Voting-Run E

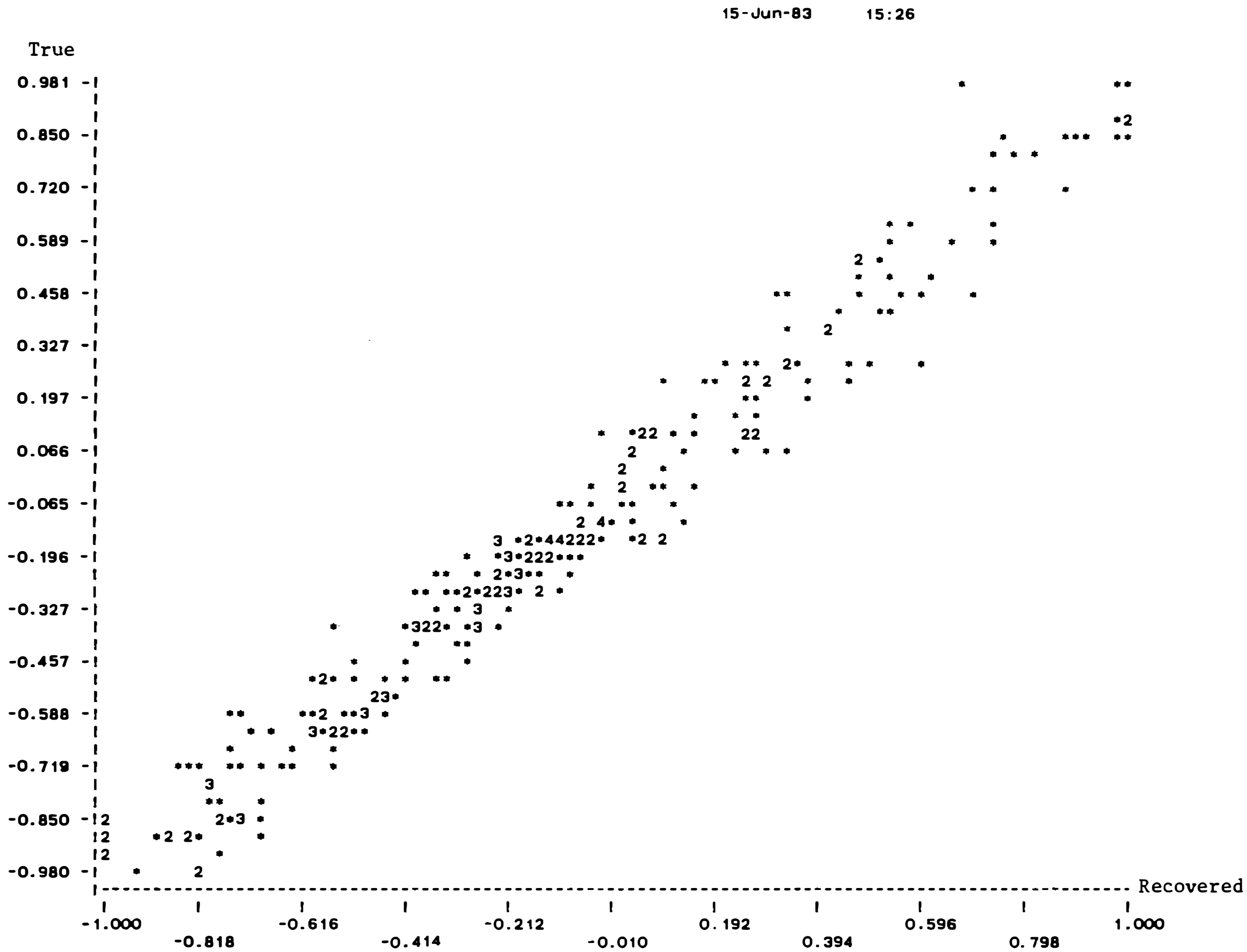

Figure 6: True and Recovered Liberal Coordinates: Stochastic Voting-Run E