ON DIMENSIONALIZING ROLL CALL VOTES IN THE U.S. CONGRESS

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Reprinted from

THE AMERICAN POLITICAL SCIENCE REVIEW

Vol. 85, No. 3, September, 1991

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Kenneth Koford has recently concluded: "Poole and Rosenthal's . . . claim to have developed a superior technique for finding dimensions remains warranted: the dimensions have substantial explanatory power. However, the dimensions, particularly the first, are not nearly as powerful as they imply" (1989, 960). This criticism is incorrect because it is based on assumptions that are not consistent with data on congressional roll call voting.

In addition, Koford presents a confused discussion of dimensional analysis and misinterprets other studies that he claims have found "ideology at best a secondary factor" (pp. 949–50). We address the dimensionality power issue first. We then comment on the proper interpretation of the result and, finally, discuss studies in which the liberal–conservative dimension (ideology) is compared to economic and other measures of constituency interests.

The Power of the First Dimension

Koford argues that the appropriate null model for dimensional studies of roll call voting is errorless spatial voting in a truly low-dimensional space—two to seven dimensions (pp. 957–58).[1] Under the null model,[2] one can compute the percentage correctly classified using a one-dimensional projection of ideal points. Since these null models show percentages in the range of 67%–75%, presumably the one-dimensional classifications[3] we obtain in the 80%–85% range are less impressive than they would be compared to a 50% benchmark.[4] This latter benchmark represents the limit of the one-dimensional classification percentage as the number of true dimensions grows indefinitely. Alternatively, the benchmark represents purely random voting.

The classical approach to a benchmark is found in Weisberg 1978. One picks a null model such as random voting, the majority, or two- or three-party models. This null model is conceptually simpler than the model being investigated. Hopefully, the model under investigation will have greater success at classification than the benchmark. The degree of improvement is evaluated by a measure of proportional reduction in error. Koford's alternative approach is radically different. He proposes adopting a more complex (because higher-dimensional) model as the null model and computing, for a hypothetical distribution of legislators and roll calls, how the model being estimated would perform if the null model

Table 1. Recovery for Simulated Voting Models

Voting Models and Dimensionality Used by NOMINATE	Geometric Mean Probability[a]	Percent Correct[b]	β^c
Perfect voting in three dimensions[d]			
one dimension	.609–.629	70.6–72.5	19.6–21.0
two dimensions	.743–.758	83.8–85.6	28.3–31.5
three dimensions	.885–.899[e]	Computer Overflow	
Recovery of simulated one-dimensional voting with error[f]			
one dimension	.618–.635	75.5–77.0	12.7–14.3
two dimensions	.626–.638	76.0–77.7	13.7–15.1
three dimensions	.630–.642	76.7–78.2	14.5–16.1

[a]Geometric mean probability = exp(log-likelihood/(220 × 440).

[b]Percent of choices correctly classified.

[c]Signal-to-noise parameter.

[d]The entries give the lowest and highest values obtained from five simulations with 220 legislators drawn randomly through the unit circle, 220 legislators radially symmetric to these 220, and 220 roll calls whose cutting lines were defined by the 220 pairs of legislators.

[e]Geometric mean probability at last converged legislator estimates before computer overflow occurred.

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were true. The actual performance is then compared to the hypothetical standard.

The null model of errorless voting in seven or fewer dimensions is not even remotely supported by the data. If it were correct, one would obtain *perfect* (or, to be realistic, near-perfect) classification of congressional votes with a low-dimensional Euclidean model. There is no conceptual basis for such a model. Errorless voting can always be obtained by having as many dimensions as there are legislators (or as many dimensions as there are roll calls). The number of dimensions required to achieve errorless spatial voting is an *empirical* question, not a theoretical one.

The theoretical question is, What portion of roll call voting behavior is consistent with a spatial model and what portion must be ascribed to nonspatial considerations? From a statistical standpoint, the nonspatial aspects of voting are lumped together in an "error" term. In this regard, estimating a spatial model of voting is no different from fitting any other multivariate model. All such models divide the observed behavior into deterministic and stochastic components. The equivalent of Koford's null model in the context of linear regression would be, *A perfect fit will be obtained when K independent variables are used.*

The NOMINATE and D-NOMINATE (Poole and Rosenthal 1985a, 1991) procedures are not based on the restriction to errorless spatial voting but on probabilistic voting, as suggested in the seminal paper of Hinich (1977). D-NOMINATE estimates the legislator and roll call parameters and a signal-to-noise ratio β.[5] When voting tends to perfection, β goes to infinity; and the computer analysis "blows up" and does not converge.[6] If the true dimensionality is three, for example, we will get a relatively low value of β and an imperfect fit from estimating a one-dimensional model, a higher value of β

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Table 2. Recovery Using Actual Data from the House of Representatives

Dimensionality Used by D-NOMINATE	House of Representatives				
	91st	93d	95th	97th	99th
Percent Correct					
1	84.6	82.4	83.2	84.5	85.0
2	86.5	84.5	84.2	85.5	86.4
3	87.4	85.1	84.9	86.1	87.0
4	87.4	85.6	85.8	86.3	87.4
5	87.7	85.8	85.9	86.6	87.8
6	88.3	86.3	86.0	86.8	88.0
7	88.5	86.4	86.5	86.9	88.5
8	88.8	86.5	86.5	87.1	88.8
9	89.2	86.7	86.7	87.4	88.8
10	89.5	87.0	86.9	87.8	89.0
Estimated β Value					
1	13.7	12.2	13.5	12.5	13.5
2	15.8	13.3	14.8	13.8	15.3
3	17.4	14.4	15.8	14.6	16.0
4	18.1	15.0	16.4	15.7	16.7
5	18.6	15.7	17.1	16.5	17.4
6	19.3	16.6	18.0	17.1	18.2
7	19.8	17.3	18.6	17.7	19.2
8	20.5	17.6	19.0	18.5	19.6
9	21.3	18.5	20.0	19.4	20.4
10	22.3	19.4	20.5	20.4	21.0

and a somewhat better fit in two dimensions, and blowup when trying three dimensions. The upper half of Table 1 shows the results of estimating various models for ideal points uniform through the unit sphere and a uniform distribution of roll call cutting lines and cutting planes, with all of the cuts designed, as in Koford, to produce 50/50 splits. Clearly, D-NOMINATE will, by blowing up, let us know if actual data support Koford's null model.

In Table 2, we present results of running D-NOMINATE on the 91st, 93d, 95th, 97th, and 99th Houses. It can be seen, that unlike the hypothetical errorless data, D-NOMINATE does not blow up at low dimensionality. Even at seven dimensions, the upper end of Koford's null models, classifications reach only 88%. If "errorless" voting of any dimensionality is an appropriate benchmark, the benchmark dimensionality would appear to be 435, leading to a 50% criterion.

Moreover, the pattern of incremental gains to classification in D-NOMINATE discloses a highly unidimensional structure. With the exception of the second dimension, higher dimensions are basically fitting "nonspatial noise" in the data.

To see what happens in a "true" one-dimensional world with noise consider the simulation results presented in the lower half of Table 1. These simulations had a uniform distribution of ideal points in one dimension. All roll calls had expected 50/50 splits. "Noise fitting" generates gains in classifications with higher dimensions similar to those we observe with actual data. Thus, while one- and two-dimensional models do not provide perfect fits, little is gained by increasing the dimensionality.

It is important to recognize that NOMINATE does not seek to maximize classifications but to maximize a likelihood. When optimal, one-dimensional classification procedures are used (as is appropriate for Koford's models), even higher percentages are obtained (see Table 2).

In analyzing the entire two-hundred-year history of roll call voting, we (1991) have found that a second dimension improves classification only by about 3%. Koford makes a valid point in arguing that just looking at the marginal contribution of an extra dimension can understate the importance on the dimension. For example, in his Figure 3 (Koford 1989a, 953), he presents a two-dimensional example with two equally important dimensions. Since any one-dimensional projection will correctly classify 75%, the marginal contribution of the second dimension will be only the remaining 25%. However, if we project directly onto the second dimension, we also find 75% classification. In general, if two dimensions are of equal importance, separate projections will lead to equal success in classification. However, we (1991) establish that the second-dimension projection is much less successful than the first at classifying the actual roll call data. In fact, the second dimension barely betters the marginals.

To sum up, to the extent that a Euclidean analysis can capture voting in Congress, one dimension—or at most two—will do. The first dimension is very strong. Two-to-seven dimensional models of errorless voting are not an appropriate standard of comparison.

The Purpose of Dimensional Analysis

What is accomplished by Euclidean scaling? To address this question, we return to an errorless, perfectly symmetric, two-dimensional world. Legislator ideal points might be uniformly distributed on the circumference of a circle, as in Koford's Figure 3 or, more realistically, uniformly distributed throughout the circle. Suppose, following Koford, that all roll call votes could be represented as cutting lines through the center of the circle, generating even, 50/50 splits. In such a world, any cut through the circle will do equally well as a classifying dimension (75%). On the other hand, if ideal points become correlated, so that the distribution is ellipsoidal, the major axis of the ellipse will do better than any other cut. As the circle gets squashed into a cigar shape and then into a line, the major axis will improve to classifying 100%. Similarly, if roll call cutting lines are not uniformly distributed, one axis will do best at classifying.

Roll call scaling thus presents strong similarities to eigenvector extraction. In that procedure, the first eigenvector is chosen to "explain" as much variance as possible and so on. The pattern of eigenvalues and eigenvectors discloses important aspects of the structure of the data.

Roughly speaking, dimensional analysis reveals the extent to which the world is cigar-shaped, for whatever reason. When either roll call alternatives or legislators are concentrated along a single axis, a one-dimensional model will be excellent at classification. In our two-dimensional example, the major axis will be much more important than the dimension perpendicular to it.

Of course, axes can always be rotated to create dimensions of more nearly equal importance. If, instead of using the major and minor axes of the ellipse, we used a 45-degree rotation of the axes, we would find two dimensions that classified equally well. But using this rotation would obscure the key point—we are looking at a highly squashed ellipse, not a circle.

Koford simply misses this point in his example of seven voters and two roll calls (p. 950). In that example, the ideal point distribution is correlated so that in essence, the major axis of the two-dimensional ellipse would be on the 45-degree line. A one-dimensional analysis of the votes, rather than recovering either of the two axes Koford plots, would array voters along the major axis and, as Koford points out, successfully classify 12 out of 14 votes. A two-dimensional analysis would add an axis perpendicular to this and, in addition, recover roll call cutting lines that correspond to Koford's axes.

In other words, scaling would disclose all the important features of the example. The first dimension is "more important" than the second because ideal points are correlated. However, as evidenced by the roll call cutting lines, the two "issues" voted on are perpendicular to one another.

Koford's discussion, in contrast, confounds the correlation of ideal points in his example with the orthogonality of the two roll call votes in the same example. The discussion becomes hopelessly confused: "Votes are perfectly estimated, . . . implying three dimensions. But regression can overstate the number of dimensions" (p. 950)—indeed, since with only two roll calls, it is well known that a two-dimensional model is guaranteed to provide a perfect fit to the data! Koford goes on to state, "Dimensional analysis also fails to fit a second dimension properly if it is fitted to the residuals from the first dimension" (p. 950). But our roll call methods are not based on fitting residuals.

Our recovery of legislator positions, we should point out, is *not*, given large enough samples, dependent on the distribution of roll call votes. Suppose, for example, we had αN orthogonal roll call votes ($0 < \alpha < 1$), as in Koford's Figure 1 and $(1 - \alpha)N$ roll call votes uniformly distributed about a circle, as in his Figure 3. Then, for N sufficiently large, our recovery will essentially be independent of the value of α. In all cases in this example, our first dimension would be the major axis of the legislator ideal point distribution.[7] Presumably, for $\alpha = 1$ Koford wants to define the dimensions on the basis of the orthogonal roll call cutting lines. But how would he define the dimensions when $\alpha = 0$ and roll calls are symmetrically distributed? The natural route to go is the conventional one of maximizing some criterion—explained variance, classifications, or likelihood. When this is done, we find a powerful first dimension.

Koford rightfully emphasizes that unidimensionality can result from several different sources—cognitive limitations, restrictions on the agenda, coalitions, and logrolls. This is true. We have not provided a structural model of congressional behavior but have uncovered what we believe is an important aspect of the "reduced form" of the political process.[8] As Koford points out, some earlier research found higher dimensionality simply by imposing it a priori. Other research found higher dimensionality because it used techniques not designed to recover Euclidean voting (see Morrison 1972 for a critical analysis).

Ideology and Constituency Interests

Finally, we take up the claim that "ideology [is] at best a secondary factor" (Koford 1989a) in studies that consider constituency interests. One can operationalize ideology as Americans for Democratic Action (ADA) ratings or our scaled estimates on the first dimension. Ideology and constituency characteristics are likely to be collinear. As such, any conclusions are likely to be hostage to the problem of marginal evaluation that Koford raised in regard to scaling. We addressed this issue some years ago (1985c) in an article not discussed by Koford. We briefly summarize the findings.

Using NOMINATE, we estimated β and the spatial coordinates for the Senate in

1977. We used 100 senators and 568 roll calls with more than 2.5% voting in the minority. This means we estimated 1,238 parameters. We correctly classified 82.3% of the votes. For the same roll calls, we then ran a linear logit using as variables party, income, growth, education, urbanization, union membership, age, and manufacturing. This set is similar to that used in Peltzman (1984), cited by Koford. Separate coefficients were estimated for each roll call, leading to a total of 5,680. Nonetheless, classification was improved only to 82.8%, despite the more than quadrupling of parameters. We next added an ideological residual as a regressor. For senators serving prior to 1977, we used their 1976 coordinates (Poole and Daniels 1985). For the remaining senators, we used their 1978 coordinates. Thus, we used only out of sample information. These coordinates were then regressed on the "constituency" variables. The regression residual was entered in the linear logit. This raised classification by 3.4% to 86.2%. So even attributing as much as we can to constituency variables, our first dimension adds (slightly) more to classification than adding a second dimension to a one-dimensional spatial model. As a stand-alone model, the far more parsimonious ideological model does almost as well as a constituency interest model. These results show that ideology is not a secondary factor.

Moreover, we applied the same strategy to the 10 strip-mining roll calls analyzed by Kalt and Zupan (1984), another study cited by Koford. Here we estimated the linear logit model using the seven issue-specific constituency variables chosen by Kalt and Zupan. Our finding was reinforced. In fact, the log-likelihood for the linear constituency model is actually less than that for the more parsimonious NOMINATE model. Again introducing the residual leads to significant improvement. Our findings confirm and generalize Kalt and Zupan (1984, 291), who comment: "The striking finding is how well voting on an issue with as much pocketbook content as [strip mining] can be explained by senators' positions on the death penalty, sex education, the neutron bomb, the ceding of the Panama Canal, the immigration of avowed communists, and so on." In other words, a single dimension relates to a wide range of issues. In their concluding sentence Kalt and Zupan write, "For now, it appears that the economic theory of regulation will have to keep the door open to ideological behavior" (1984, 298). Clearly, in contradiction to Koford's assertion, these authors do not view ideology as a "secondary factor."

While we do not deny that constituency-specific factors affect some individual decisions on some roll calls, we find that Koford has simply misread the evidence that results when one compares the constituency studies to the ideological alternative. In addition, we have pointed out that the quantitative assessments in his article are based on an inappropriate benchmark. To the extent that congressional voting can be described by a spatial model, a unidimensional model is largely (albeit not entirely) sufficient.

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This controversy is largely about how to determine the "true" number of dimensions in roll call data. In my original article I questioned Poole and Rosenthal's claim of high "prediction success" for a single dimension by pointing out that alternative, null hypotheses also did well. A single dimension was able to correctly classify only around 30%–50% of the roll call votes that would not also be classified correctly by two-to-four-dimensional spaces.

Poole and Rosenthal make two points. First, they respond to my (1989a, 1990) analysis of their dimensional findings—that while there is an important first dimension in congressional roll-call voting, they overstate its importance. They restate their original analysis and describe new work that advances their analysis of legislative roll calls. They also admit my main claims. In particular, they have examined more complex null hypotheses (1991; Poole, Sowell, and Spear N.d.) with findings similar to mine.

Second, they criticize Peltzman and others who claim that roll call votes are based upon specific economic interests rather than ideology. In so doing, they misstate Kalt and Zupan's views and misquote me; while I have some sympathy for Peltzman's view, I have argued that it *overstates* the dimensionality of roll calls much as Poole and Rosenthal *understate* it.

I begin with a look at Poole and Rosenthal's new arguments for the unidimensional model and its extension to as many as 50 dimensions. Their new work leaves a puzzle: How can a high proportion of roll call votes fail to fit even high-dimension models? I show why their method cannot find dimensions on which legislators place differing importance. Finally, I show that econometric studies of roll call voting find that personal ideology is an important secondary factor after constituency. However, these studies miss the true degree of unidimensionality by omitting its effects when correlated with constituency variables. Analysis of roll call votes need a theory of the sources of legislators' choices, which is still absent from Poole and Rosenthal's work. The unidimensional findings could be due to constituency preferences, the effect of the two-party system in constituencies, congressional coalitions, or legislators' genuinely ideological feelings. Available data gives some hints favoring the party system in constituencies and suggests additional tests.

What Is a Proper Null Hypothesis?

The purpose of a *null* hypothesis is to identify a standpoint from which to judge the statistical success of a particular theory. For example, in econometric analysis, an R-squared of zero is the null hypothesis that no independent variables are statistically significant. Poole and Rosenthal confuse a null hypothesis with another approach, comparing the relative merits of two *alternative* hypotheses. But there are no alternative theories to compare their results against.[9]

An appropriate null hypothesis can be defined in several ways. Poole and Rosenthal prefer the hypothesis of an infinite number of equally important dimensions.[10] That is a very remote alternative to their original hypothesis of a single dimension that explains all voting. Parsimony suggests a small number of dimensions (such as two) to compare with a one-dimensional model. Are the results sensitive to increasing the number of dimensions beyond two? Using moderately different assumptions, several researchers have examined this question. The proportion of votes correctly classified falls, but Poole and Rosenthal (1991) and Snyder (N.d.) obtain correct classification percentages close to mine for the null hypothesis of a moderate number of equally important dimensions fitted to a single dimension (see Table 3)[11] (I calculated two percentages. They differ by the weighting assumption in the *n*-dimensional space. The first assumes that roll calls occur at vertices, which means in high-dimensional spaces that most roll calls are "close" to the assumed cleavage. The second assumes an equal number of roll-calls on each dimension.)
Thus, my original small (two-to-four) dimension null hypothesis of 67% is conservative compared to other scholars, including Poole and Rosenthal. My alternative null hypothesis of 75% is close to their average.

In recent work, Poole and Rosenthal

Table 3. Correct Classification Percentage by Number of Dimensions

Number of Dimensions	Koford 1989a	Koford 1989a	Poole & Rosenthal 1991	Snyder N.d.
2	.75	.75	.789	.85
4	.625	.75	.732	.787
7	.588	.719	.699	.696

have considered large numbers of dimensions. For this work, a high-dimension null hypothesis is reasonable. Poole and Rosenthal (1991) propose a 65.9% null hypothesis representing an infinite-dimensional space with the empirical average majority for Congress. Their comment proposes a 50% null hypothesis. Yet whatever the null criterion chosen, the bottom line is the same. A large share of roll call voting remains unexplained by the dimensional model.

The proportion of roll call voting not explained by Poole and Rosenthal's (1985b) House estimates is given below, for the various null hypotheses just described. Those estimates correctly classified 84.03% of the roll call votes. For the three low-dimensional null hypotheses, the average of correct classification for two, four, and seven dimensions are used.

Koford 1989a	45.6%
Koford 1989a	61.3%
Poole and Rosenthal 1991	61.4%
Snyder N.d.	75.7%

Alternative, and infinite-dimension null hypothesis, such as Poole and Rosenthal's two proposals, could be used. In my original article I proposed that dimensions could vary in importance by a constant ratio, here chosen to be 1.5:1.

Koford 1989a	45.4%
Poole and Rosenthal 1991	46.8%
Poole and Rosenthal comment	31.9%

When Poole and Rosenthal extended their model to fit large numbers of dimensions I anticipated that the additional dimensions would fit most unexplained voting. But Poole and Rosenthal (above and 1991) try to fit up to 50 additional dimensions to the roll call data and find that they cannot fit most of the remaining variation. Their Table 2 fits dimensions to House voting for six Congresses; average correct classification for one dimension is 83.9%, while for 10 dimensions it rises to 88.04%. It is striking how much of the voting does not fit even 10 dimensions and also how little fits the added 9 dimensions.[12] Dimensional analysis' biggest theoretical problem now, it seems to me, is to explain how such a large share of roll call votes can fail to fit so many dimensions.

One possible explanation is that these votes are just "mistakes." Legislators are busy, sometimes fail to identify their true interests, and err. However, the proportion of "noise" votes is too high for this explanation to be plausible. If legislators who choose randomly are correct half of the time, the true proportion of randomly made votes is *twice* the number that are

Table 4. Explanatory Power of One and Many Dimensions (%)

Votes Explained by	Koford 1989a	Poole & Rosenthal 50%	Poole & Rosenthal 65.9%
1 Dimension	54.3	67.8	52.8
2–10 Dimensions	11.7	8.3	12.1
Unexplained	34.0	23.9	35.1

not correctly classified. For Poole and Rosenthal's proportion correctly classified by one dimension of 84.03%, 15.97% of the votes are "errors" and 31.94% of all votes are cast randomly. If randomly choosing voters vote for a bill in the same proportion as the average voter, 55% of votes will be correct and 35.5% of all votes are "random."[13] That seems too high to be credible.

Is "Noise" Voting Really Individual Differences in Intensity?

It is puzzling that adding dimensions to the unidimensional model does so poorly. It makes sense to view issue choices as locations in a dimensional space. So Poole and Rosenthal's basic approach seems correct. Rather, the failure could be due to an inappropriate assumption. Specifically, some legislators care a lot about some dimensions, while other legislators care a lot about other dimensions. But Poole and Rosenthal's unfolding model assumes that all legislators have circular indifference curves and thus identical relative intensities of preference.

Yet in legislative politics legislators are often concerned with interests of special concern to a few legislators (Lowi 1964; Mayhew 1966). The economic theory of politics shows that Lowi's "distributive" and "regulative" issues imply differences in legislators' intensity of preferences across issues (Becker 1983; Peltzman 1976). Van Schurr (1987) has found that multidimensional models fail to fit some European party data due to differences in the intensity of concern for certain dimensions. The puzzle of why additional dimensions fail to fit roll call data could be explained by this difference in intensity.

Figure 1 shows the basic point with a simple example. Poole and Rosenthal's method assumes that all legislators have circular indifference curves.[14] In Figure 1 all legislators care equally about the horizontal dimension but vary in the intensity of their preferences on the vertical dimension. Legislator I values the two dimensions equally, Legislator II considers the horizontal dimension three times as important as the vertical dimension, and Legislator III values the vertical dimension at three times the horizontal dimension.

Legislator I always prefers the alternative closer to I's ideal point, but that is not true of either Legislator II or III. Comparing points A and B, A is closer to II's ideal point, but II prefers B. A is also closer to III's ideal point, but III also prefers B. No renormalization of the space can eliminate this problem.

We can now see how well the best one-and-two-dimensional fits will classify legislators who have different relative intensities of preferences in a two-dimensional basic space. There are three types of legislators, as just described. To simplify, all three types are assumed to be uniformly distributed over a circle (as in Poole and Rosenthal's comment, Table 1).

The example is illustrated in Figure 2. Type I voters care equally about both dimensions, while Type II voters care most about the horizontal dimension, and Type III voters care most about the vertical dimension. Roll call votes occur all around the circle, arranged so that they divide the voters equally. An example in Figure 2 is proposal P, opposed to the alternative P'.[15] Correct classification of these roll calls is examined for *two* dimensions and for a single dimension. It turns out that *no* dimensional framework produces perfect classification, even though the model fitted has as many dimensions as the data.

With the alternative proposals P and P' on the floor, the best-fitting cleavage is CC'. That fits the Type I legislators perfectly. Type II voters have the cleavage II–II', while Type III voters have the cleavage III–III′. These cleavages are chosen to assure that points on II–II′ are equidistant between P and P′, weighting the horizontal direction at twice the vertical direction, and that the points on III–III′ are equidistant between P and P′ while weighting the vertical direction at twice the horizontal direction (for the method, see the Appendix). The result is that the Type II voters in the lightly shaded area are correctly classified, and the Type III voters in the darkly shaded area are incorrectly classified. Clearly, no adjustment of the cleavage CC′ can improve the fit. This example shows that adding more dimensions will not produce a perfect fit when not all voters have the same relative intensity.

Calculations for any specific relative intensity of preference r may be made with this approach (see the Appendix). The proportion of votes correctly classified are presented in Table 5. This evidence indicates that a two-dimensional model will not fit perfectly with two-dimensional data when voters differ in their relative intensity across dimensions. The fit becomes worse as the relative intensity increases. If there were not Type I voters who valued the two dimensions equally in this example, correct classification would approach .75 as a limit. While only a two-dimensional case has been considered, the principle behind this case implies that higher-dimensional models will also fail to fit this data and that data with a higher-dimensional structure and different intensities across the different dimensions will fail as well. As the number of dimensions rises and the distribution of intensities

Figure 1. Legislators with Varying Relative Intensities of Preference

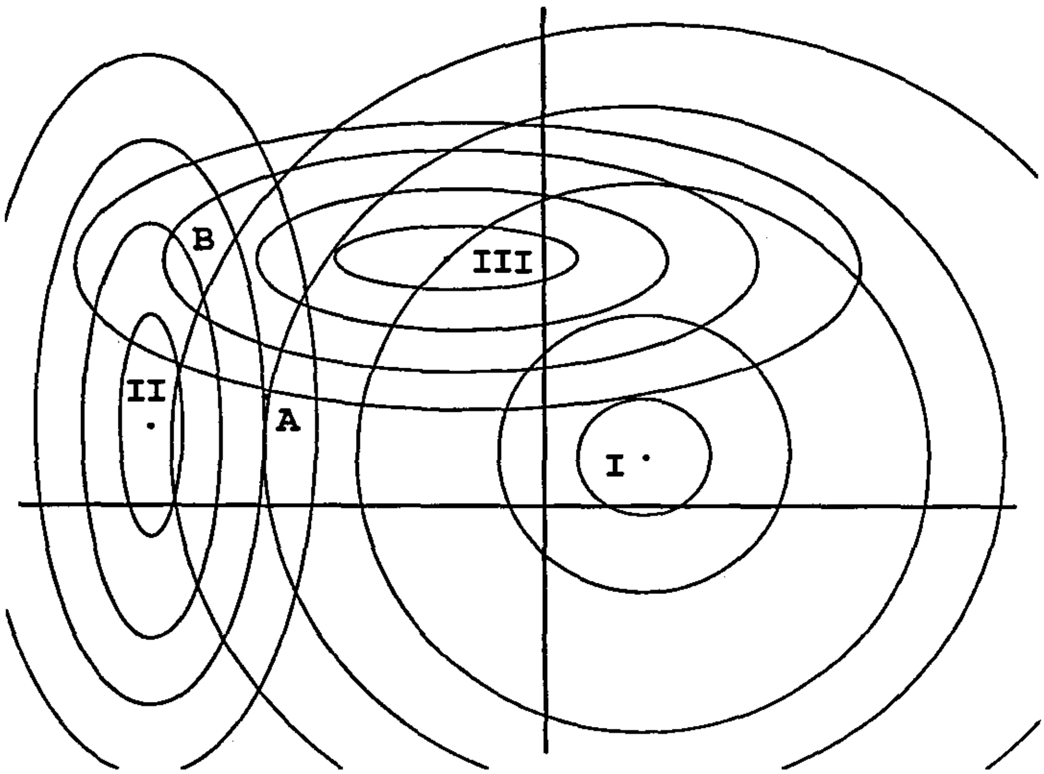
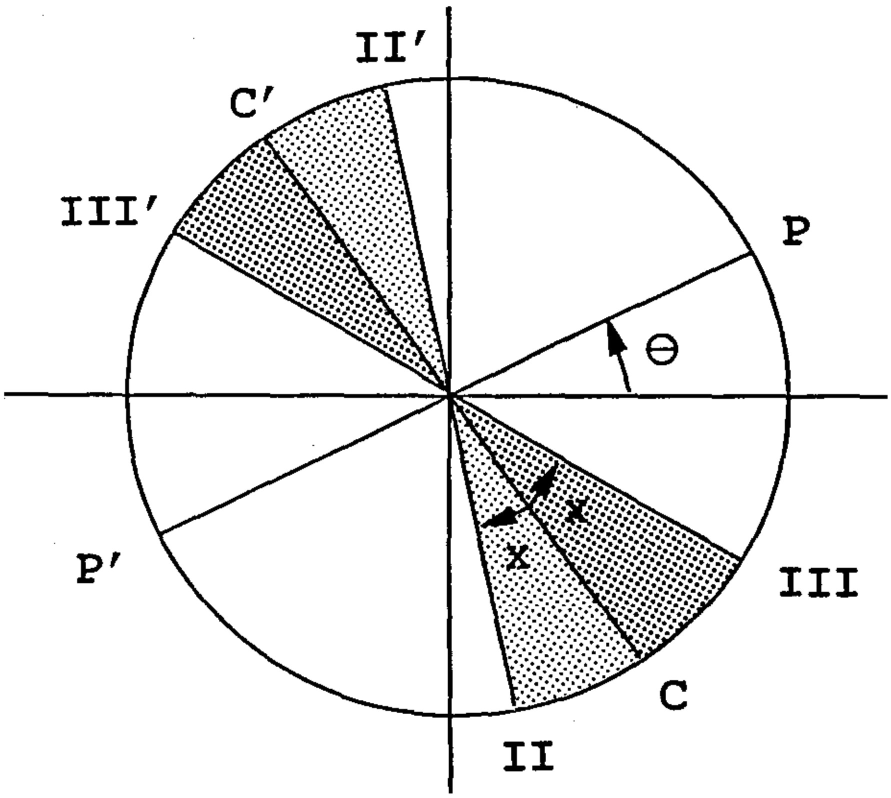


Table 5. Correct Classification by Relative Intensity

Relative Intensity	Unidimensional Correct Classification	Two-Dimensional Correct Classification
1:1	.75	1.00
1.414:1	.75	.958
2:1	.775	.915
3:1	.800	.882
4:1	.812	.867
5:1	.820	.861
∞:1	.833	.833

Figure 2. Optimal Cleavage with Three Different Relative Intensities of Preference in Two Dimensions



becomes more complex, fitting the data should become more complex as well.

Given the theoretical importance of differences in the relative importance of issues across legislators, it would be desirable to examine their actual distribution. How great are the differences in issue importance across legislators? How do they vary across issues? In addition, it is likely that the locations of legislators may determine their relative intensities. Do outliers on intensity tend to have "high" demand in terms of location, as one might predict of cotton or peanut bills? Effort could be put into identifying the locations in the issue space of legislators with high *gradients* on the issue.[16]

Poole and Rosenthal's results seem most consistent with one important dimension on which all legislators have similar intensity of preference and a number of other dimensions on which relative intensity varies. They successfully fit the first dimension; but their method fails for the other dimensions, creating "noise."[17]

Empirical Studies of the Importance of Constituency and Ideology

Poole and Rosenthal quote me out of context twice as claiming that "ideology [is] at best a secondary factor" (pp. 955, 959). In fact, I described the conclusion of most econometric roll call voting studies, as the context makes clear. McArthur and Marks state the same view: "Recent contributions to the empirical literature on legislative voting start from the premise that constituent interests are systematic determinants of voting behavior. In order to get reelected, legislators must further the pocketbook interests and ideological views of their constituents. Whether legislators also vote partly on the basis of their own ideologies is the subject of some controversy" (1988, 461). For them, constituency variables largely determine roll call votes, while ideology is "at best a secondary factor." Similarly, Peltzman states:

> The tendency for legislators to shirk serving their constituents' interests in favor of their own preferences (ideology) seems more apparent than real. Ideology measures can explain much legislative voting behavior statistically. But they turn out to be proxies for something more fundamental: liberals and conservatives tend to appeal to voters with systematically different incomes, education, and occupations, and to draw contributions from different interest groups. And these systematic differences prove, by and large, capable of rationalizing voting patterns without much need for relying on explanations that involve shirking. (1984, 210)

Richardson and Munger state, "Our results indicate that far from shirking, representatives painstakingly voted in the interests of their constituencies (1990, 12).

Numerous studies of roll call votes first estimate the importance of constituency variables and then evaluate the significance of ideology. Table 6 lists these studies and their description of the ideology variable.[18] Mueller's (1989, 213) review of this literature concludes that both economic and ideological factors matter. Weingast and Marshall find that "all studies provide substantial evidence that [constituent interest] systematically—though not necessarily completely—affects congressional voting," supporting their Assumption 1, namely, "Congressmen represent the (politically responsive) interests located within their district" (1988, 137). In contrast, they describe the possibility of "ideological voting" as controversial.

Kalt and Zupan (1984, 1990) find ideology to be of great importance in their analysis of roll call voting on energy issues. They originally expected that constituency variables would dominate, but ideological measures were equally successful in explaining their roll calls, as Poole and Rosenthal (p. 960) state. Never-

Table 6. Econometric Estimates of Ideology in Roll Call Voting

Study	Year	Issue	Description of Ideology	Statistical Importance of Ideology
Abrams	1977	NOW accounts	Party: logrolling or philosophy	Most important
Chappell	1981	Cargo preference	Ideology	Marginal
Chapell	1982	Seven issues	Ideology	Very significant; importance not stated
Coughlin	1985	Domestic content	Personal ideology	Unimportant
Danielsen & Rubin	1977	Decontrol of crude oil, 1973–74	Party: probusiness philosophy	Important
Davis & Porter	1989	Coal strip-mining	Personal ideological consumption	29% of total variation
Dougan & Munger	1989	Senate voting	Shirking	Not found
Jackson	1974	61 votes on varied issues	Trusteeship; Coalitions	Not important; Very important
Kalt	1981	36 crude oil price votes, 1973–77	Public interest goals	Important
Kalt & Zupan	1984	Coal strip-mining	Personal ideological consumption	43% of total variation
Kau & Rubin	1978	Minimum wage	Ideology or coalition	Very significant; importance not stated
Kau & Rubin	1979	26 votes on varied issues	Ideology	Significant; importance not stated
Kau, Keenen & Rubin	1982	Eight bills on economic regulation	Constituent ideology	Very significant; appears important
Ladha	1984	Coal strip-mining, 10 roll calls, 1977	Ideology	Very significant; very important
Langbein & Lotwis	1990	Gun control	Ideology	Very significant; important
McArthur & Marks	1988	Domestic content of automobiles	Personal ideology	Modest
Nelson & Silberberg	1987	National defense	Shirking	Sometimes significant; importance not stated
Nollen & Iglarsh	1990	International trade	Party and region	Most important
Peltzman	1984	331 votes on many issues	Ideology independent of constituency	8–11% of variance
Peltzman	1985	835 votes on economic issues	"Inertial" voting similar to ideology; Unidimensional economic interests	Important; Very important
Richardson & Munger	1990	Social security	Constituent values	Very significant; usually important
Vesenka	1989	Agricultural issues	Shirking	Important

theless, Poole and Rosenthal take Kalt and Zupan's quote out of context. Kalt and Zupan's *full* last paragraph reads:

> If the concept of ideological shirking does prove to be significant, its usefulness will depend on the development of models that can predict the conditions (for example, types of issues, institutional settings, economic contexts) under which ideological shirking is likely to be an important phenomenon. Of course, *it still may be that the phenomenon does not even exist. There may yet be constituent interests missing from this and previous analysis that will explain away ideology's importance in specific-issue politics.* The search for these interests should continue. For now, it appears that the economic theory of regulation will have to keep the door open to ideological behavior. (1984, 298; emphasis mine)

Thus, Poole and Rosenthal distort Kalt and Zupan's (1984) view that ideological shirking may not exist but just reflects imperfect constituency measures and that ideology is a *residual* that measures failure to vote for one's constituency. Thus, statements that "ideology matters" in the econometric studies are very different from Poole and Rosenthal's unidimensional findings.[19]

In contrast, I claimed that "regression estimates [have] biases that overstate the number of dimensions. Overall, fewer dimensions are found than seem consistent with the wide variety of constituents' preferences on issues" (1990, 59). I concluded, "The unidimensional model's success is greater than would be expected if voting represented constituencies" (1989a, 960). My view has been very different from the view Poole and Rosenthal attribute to me and more favorable to their work.

The basic difference between the econometric and dimensional approaches is that they ask different questions. The econometric studies try to explain *individual* legislators' behavior. They use the principal–agent model to see whether legislators are loyal agents of their constituents or whether they shirk and pursue their personal political agendas. In contrast, dimensional studies examine *aggregate* behavior. They try to explain the overall pattern of roll call votes. That pattern could be due to the distribution of constituency preferences, to party cohesion, or to personal or constituency ideology. Since the overall pattern of voting determines outcomes, the dimensional approach has an essential key to explaining legislative politics.

The personal ideology found in econometric studies could have been idiosyncratic, with highly personal tastes on many dimensions; but it is not. Rather, Kalt and Zupan (1990) find that legislators' personal ideology is a choice to move along the left–right ideological dimension. Poole and Rosenthal (and Poole and Daniels 1985) have shown that this left–right ideology dimension is very prominent and essentially the same as their first dimension. Whether it represents 35%–45% of roll call votes (as I conclude) or 50%–70% (as Poole and Rosenthal prefer), it is a crucial causal factor in legislative politics. Yet its source remains unclear. I have suggested (1990) that it is due to natural legislative coalitions serving the function of logrolling (as Jackson [1974] and Kau and Rubin [1979] previously argued). Or voters may use the liberal–conservative dimension to conceptualize candidates' political positions. Alternatively, Peltzman (1985) may be correct in arguing that this main dimension represents pure constituency voting based on redistributive economic issues. Some hints regarding which answer is correct are given by past studies.

"Personal ideological shirking" occurs along the liberal–conservative ideological dimension, which is also Poole and Rosenthal's major dimension. Several theories of unidimensionality imply a pressure toward unidimensional voting. First, the two-party system in each constituency could force legislators' ideal points toward the ideological dimension orthogonal to the party cleavage. This im-

Table 7. Ideology Residuals of Senators in Quartiles in Order of Estimated Conservative Ideology

Most Conservative		Moderate Conservative		Moderate Liberal		Most Liberal	
Number	Residual	Number	Residual	Number	Residual	Number	Residual
1–5	2.97	26–30	1.02	51–55	.39	76–80	-1.03
6–10	2.87	31–35	.37	56–60	.20	81–85	-1.38
11–15	1.06	36–40	-.93	61–65	1.76	86–90	-1.83
16–20	2.54	41–45	-1.84	66–70	.56	91–95	-1.99
21–25	.17	46–50	.35	71–75	-1.38	96–100	-1.85
Average	1.83		-.21		.31		-1.62

Note: Positive residuals = more liberal than predicted; negative residuals = more conservative than predicted.

Source: Residuals from Kalt and Zupan 1990; liberal ideology from Zupan, personal communication, 6 Nov. 1990.

plies a strong national influence on district cleavages, which could be party ideology, party control, or special interests. Since the influence has existed for at least a century, it is not a recent influence like political action committees. This influence must vary across districts, since "personal shirking" varies across districts. This theory implies that the unidimensional residual could be explained by the two separate party constituencies, including elites, contributors, and activists (Fiorina 1974; Peltzman 1984).

This explanation implies that unidimensionality is caused by the fundamental differences between the parties' constituencies. The party cleavage should center on the most prominent difference among constituents—perhaps to minimize transactions costs (Koford 1990). The conflict between rich and poor over redistributive taxing and spending is the obvious difference (Peltzman 1985).

A second explanation is internal coalitions within the legislature. The parties (and related coalitions) take opposing locations in the issue space. Legislators join these coalitions, moving their *identified* ideal points closer to the coalition ideal points. While the individual legislators' preferences are not unidimensional, the coalitions' observed voting positions will be unidimensional.

The coalition ideal points tend to be located between the centers of the two coalitions.[20] This theory implies that relatively *extreme* legislators will tend to move toward the center to join coalitions. So the "personal ideological preferences" of extreme legislators should be more moderate than their constituency-based ideal points. In contrast, the "different constituents" explanation makes no such prediction but, rather, implies that errors should be random. This test is shown in Table 7 for the 1977–78 U.S. Senate. It compares predicted ADA liberalism ratings (Zupan, personal communication, 6 Nov. 1990) with the "ideology residual" (Kalt and Zupan 1990, Table 2). The data support the coalitional hypothesis.[21] Senators who are predicted to be relatively "extreme" turn out to be considerably less extreme in fact. The most reasonable explanation for this pattern is that the ideal points of relatively extreme legislators are pushed toward the center by some omitted factor. And the most likely influence is the process of establishing coalitions in the legislature.

Another possible explanation is that proposed by Peltzman (1984), namely, that constituency preferences are fundamentally mismeasured, by neglecting the fact that reelection constituencies are skewed along party lines. This difference in constituencies must be fully modeled empirically to determine whether ideology really is an influence—or merely omitted constituency factors. For example, interaction terms between party and constituency may improve the specification. Peltzman's (1984) measure of party-related individual constituency differences (based on county-level data) was creative but not a full measure. Fiorina (1974) gives a complete theoretical model of these party-related differences in constituent voting, elite influences, and activist preferences. Peltzman (1985) argues that the ideological dimension should be due to a single economic variable, which he finds is economic redistribution between rich and poor. He finds strong evidence of a large redistributive dimension in economic roll call voting since 1910.

Peltzman has shown that the numerous econometric studies of Table 5 could be omitting party-related factors that cause unidimensionality. The "personal ideology" variables may well reflect the absence of correctly specified constituency-based party variables. However, the alternative hypothesis of party cohesion or logrolling needs to be fully tested against this hypothesis.[22] Empirical tests of these alternatives were developed by Jackson (1974) and include such variables as committee membership, the president's announced position, and the committee leadership position. With the superior constituency data developed in such studies as Kalt and Zupan (1984), this alternative hypothesis could be considered.

Nevertheless, Peltzman's approach suggests that the constituency and unidimensional results can be reconciled. Econometric studies have found constituency variables that explained voting but have made little effort to determine whether the independent variables as a whole could be a single "factor" like the rich-poor redistributive conflict that Peltzman describes. The unidimensional findings may be explained by such redistributive politics.

The remaining issues have yet to be explained. Such issues as abortion, civil rights, and many local distributive and regulative issues do not fit the single dimension (as Poole and Rosenthal point out [1985a, 373]). They presumably fit *some* dimensional structure. Such redistributive issues as abortion and civil rights should fit Poole and Rosenthal's model as additional dimensions. Distributive and regulative issues appear to require a modified fitting method to deal with the variation in intensity of preferences (as discussed earlier) before dimensions can be found for these issues.

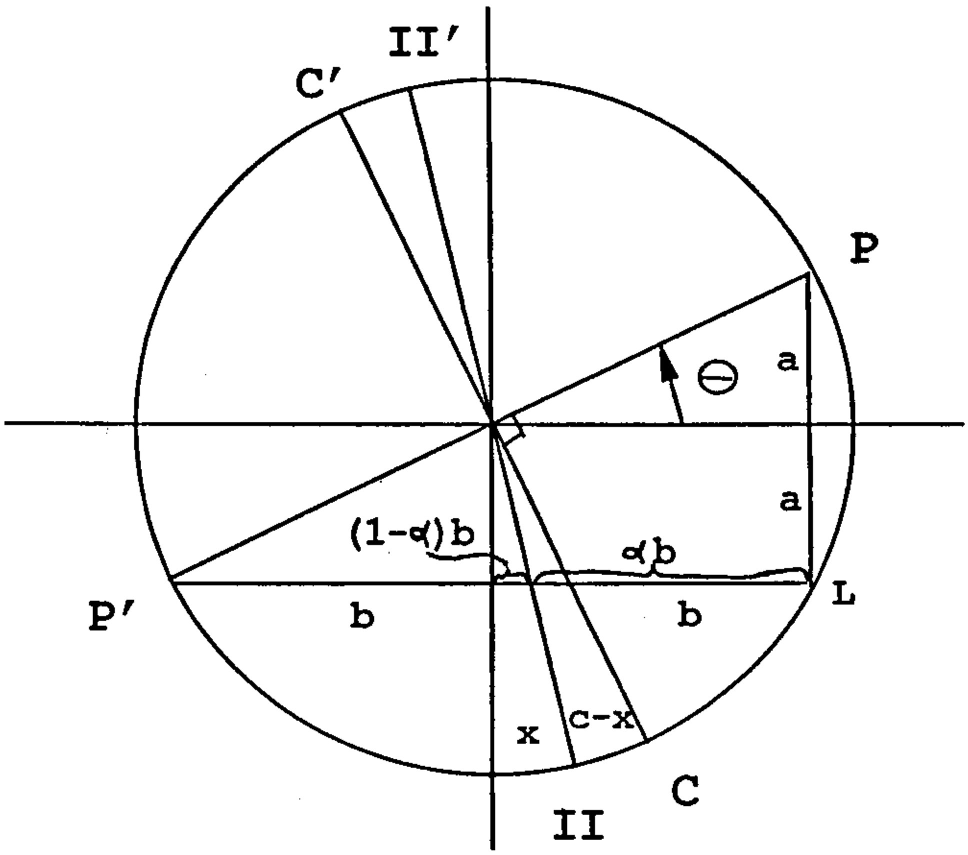
Conclusion

In my original article I showed that much roll call voting in Congress does not fit a single dimension, a point now supported by other studies (Poole and Rosenthal 1991; Poole, Sowell, and Spear N.d.; Snyder N.d.). These studies show that roll call votes that are high-dimensional nevertheless give high levels of correct classification for a single dimension. Thus, such levels of correct classification cannot be taken as evidence of unidimensionality.

Much roll call voting remains unexplained by a single dimension. Yet Poole and Rosenthal have failed to explain it by additional dimensions. I have shown that it may be caused by the incorrect modeling assumption that legislators have the same relative intensity of preference for all issue dimensions. This problem must be solved to learn the "true" number of dimensions and their relative importance.

Most econometric studies have found a significant ideology dimension; its cause

Figure A-1. Calculation of Correct Classification with Varying Intensity of Preferences



is unclear. It may be due to the omission of variables based on the party cleavage in each constituency (as Peltzman has argued) or to the effect of coalition building and logrolling in the legislature.

Appendix: Optimal Cleavages for Voters with Varying Intensity of Preferences

Voter Types II and III have cleavages symmetrically around the Type I equal-intensity voters' cleavage. In Figure A-1, which replicates Figure 2, the angle from the horizontal axis Θ defines the proposals P and P′. For these proposals the Type I voters will divide on the CC′ cleavage that is equidistant between P and P′. CC′ represents the optimal two-dimensional classification, as noted in the text. Now, the Type II voters' cleavage II–II′ will cross the horizontal line P′L where the distance

$$[(2a)^2 + (\alpha r b)^2]^{1/2} = (1 - \alpha) r b + r b.$$

Solving for α gives

$$\alpha = 1 - (1/r^2)(a^2/b^2).$$

Finding Angle X in the figure will give all of the required information. Now, tan X

$= (1 - \alpha)b/a$; and substituting for α, $\tan X = (1/r^2)(a/b)$. Since, from the figure, $\tan \Theta = a/b$, so $\tan X = \tan \Theta/r^2$. With this formula, one can calculate X for any r and Θ. The calculations used angles at 5-degree intervals. The proportional error is then $(\Theta - X)/180$. Given the symmetry, the Type III voters have exactly the same correct classification as the Type II voters.

The calculation of error in the unidimensional case takes the chosen dimension as the horizontal dimension, so the unidimensional cleavage is vertical. Any cleavage will do as well. Type I legislators are identical to those I considered in my original article and so have a correct classification of 75%. For the Type II legislators, Angle X gives the incorrectly classified voters and $X/180$ the proportion incorrectly classified. For type III legislators, Angle $\Theta + (\Theta - X)$ gives the number incorrectly classified, so long as this angle is less than 90 degrees. For Type II and III voters together, then, the proportion incorrectly classified is $\Theta/180$, for Θ such that $2\Theta - X < 90$. For Θ s.t. $2\Theta - X > 90$, a higher correct classification is obtained by reversing the assumed liberal and conservative directions, and then the number incorrectly classified is $180 - 2\Theta + X$.

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Notes

Koford's research was funded in part by the National Science Foundation (SES 9003074).

1. Koford does not support this view by addressing roll call voting directly; instead he uses a content analysis of energy bills.

2. Assumptions about the distribution of legislator ideal points and roll call cutting lines are required. Koford places the legislators at vertices on the n-dimensional hypercube. This seems unrealistic, as it makes all legislators extremists and allows for none of the "moderates" that are commonly believed to exist in Congress. Koford also assumes a 50/50 vote division on every roll call. Again, this is unrealistic. Better null models can be computed by assuming a uniform distribution of ideal points over the unit hypersphere and a radially symmetric distribution of marginals in Congress. See Poole and Rosenthal (1991).

3. To save space, we focus the discussion on the NOMINATE procedure we developed and its multidimensional, dynamic extension, D-NOMINATE (1985a, 1991). Koford also discusses the work of Poole (1981) and Poole and Daniels (1985). The NOMINATE procedure is superior to the earlier work, since it uses all roll call votes directly, whereas the earlier work scaled interest group ratings that were constructed from roll call votes. However, the two procedures cross-validate. Therefore, the spirit of our discussion applies to both methods.

4. The 50% standard is appropriate only when, as Koford assumes throughout, all roll calls are even splits. Otherwise, the average percentage voting on the majority side is the correct benchmark. In Poole and Rosenthal 1985b (cited by Koford), we show that NOMINATE does better than 80% in one dimension, even on close roll calls with less than 60/40 margins, while we elsewhere (1987) show that NOMINATE outperforms the majority model.

5. We estimate an additional parameter, w (1985a). In later work, we have fixed w at 1/2.

6. In other words, like standard probit and logit methods, D-NOMINATE blows up when the model achieves perfect classification.

7. More generally, the placement of the first dimension will change as the distribution of roll calls changes. Assume, however, that the data is generated by a true n-dimensional world with error as specified in the D-NOMINATE model. Then, as long as the sample of roll calls gives sufficient coverage of the space, the interpoint distances between legislators recovered by D-NOMINATE will not depend on the distribution of roll calls.

8. Nonetheless, Poole and Rosenthal (1987) show that the coalitional process is more complex than two-party or three-party benchmarks (Weisberg 1978). Unidimensionality is more than a story of two parties voting against one another.

9. In any case, they do not have a *theory* of roll call votes but rather an empirical regularity, which cannot be compared with a theory.

10. Poole and Rosenthal (p. 955) define the 50% criterion as "the limit of the one-dimensional classification percentage as the number of true dimensions grows indefinitely." In fact, this result requires three additional assumptions. First, the dimensions must be equally important. Otherwise, the effective number of dimensions remains small, and the criterion does *not* converge to 50% (Koford 1989a, 957–58). An infinite number of dimensions, all equally important, seems implausible. Second, the dimensions must be orthogonal; correlated dimensions are equivalent to a smaller number of dimen-

sions. A large number of dimensions with purely random levels of correlation (i.e., at the .5 level of significance) could reduce to a smaller number of orthogonal dimensions. Simulations (as in Poole and Rosenthal 1991) with random draws of proposals from an n-dimensional unit circle can give these correlations and calculate lower-dimensional fits. Third, all votes must have exact minimum winning coalitions; for if the probability that a legislator will vote on a bill is a random variable less than one, the average winning vote will be greater than the minimum winning coalition. Even if legislators propose bills with expected minimum winning coalitions and perfect knowledge of legislator preferences, the fact that some legislators may not vote implies that the actual majority will be a random variable greater than 50%.

11. Poole and Rosenthal (1991, Table 2) use the empirical average majority of 65.9% as their theoretical majority and calculate correct classifications similar to those in my original article, using simulations for three-plus dimensions. Snyder (N.d.) examines roll calls caused by random shocks that cause divergence from one of the vertices of my n-dimensional cubes.

12. Poole and Rosenthal's discussion of the additional dimensions they find implies that these dimensions are not very important and that their statistical method may not be capturing any real factors (p. 5).

13. The proportion is $p = .1597/(.659 \times .341 \times 2)$.

14. If all legislators have the same relative intensity of preferences across issue dimensions, a linear transformation of the issue dimensions will assure circular indifference curves.

15. These alternatives could be at any distance from the center, so long as both P and P′ are equally distant from the center.

16. High *demands* for change by legislators with bliss points far from the status quo are something different (Koford 1989b, Figure 1), since legislators with bliss points far from the status quo have high demand for change even when all legislators have the same gradients.

17. Methods of estimating models with heterogenous agents are described in economics as the "aggregation problem" (Jorgenson 1990).

18. Studies that did not include ideology or a related variable are omitted. Numerous studies examined constituency and party but not ideology. Ideology is never mentioned in Collie's (1985) review of roll call voting studies.

19. Kalt and Zupan (1990) examine the nature of this residual; part of it acts like a legislator's personal value, and it is this part that is successful in estimating roll call votes. They find that the ADA scale worked well as "a choice along the liberal–conservative ideological spectrum." But they also found that the League of Conservation Voters and other "social" ideology variables did better than the ADA scale in explaining energy votes. They did not examine the *number* of dimensions; rather, they examined the specific nature of the social preferences involved in "shirking."

20. Each coalition faces a trade-off between choosing a position at the coalition median and a position at the coalition's central point.

21. Using predicted ADA liberalism ratings from Ladha 1984 on the Zupan residuals gives a similar pattern. Seven of the "ideology residual" values in Kalt and Zupan (1990, Table 2) are incorrectly labeled, according to Zupan (personal communication 16 Nov. 1990).

22. For example, "selection bias" by committees choosing which issues to bring for a vote could cause this unidimensional effect (see Snyder N.d.).

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