The Dimensionality of Congressional Voting Reconsidered

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Abstract

This paper reports findings for a decomposition of the roll-call voting record of the U.S. Congress to determine the effect of the level of aggregation on the observed dimensionality of the policy space. In doing so, we identify some—but certainly not all—of the ways in which the aggregation of the voting record affects the observed dimensionality of the policy space. For the 1955-1994 period (84th-104th Congresses), we apply optimal classification (OC) to votes aggregated to the level of the individual bill and policy area to measure dimensionality. We examine reported eigenvalues and the marginal proportional reduction in error (MPRE) across dimensions. In both cases, our results demonstrate that complexity in voting patterns of individual bill episodes is the norm, that aggregating to higher levels reduces the observed dimensionality, and that the liberal-conservative dimension appears more dominant in more highly aggregated analyses. These results call into question many of the conclusions from the theoretical and empirical literature on the U.S. Congress that employs a unidimensional model.

Introduction

The dimensionality of congressional voting behavior is critical to the development and application of spatial voting theories to congressional policy making. Yet, the dimensionality of voting in the U.S. Congress remains a contested empirical issue. Numerous studies in the literature on the U.S. Congress assume, either implicitly or explicitly, that the underlying policy space can be characterized by one or at most two dimensions. However, as we demonstrate in this paper, the clear patterns of unidimensionality that are often observed in voting aggregated to whole Congresses are not duplicated when the unit of analysis is the individual bill or subsets of bills. In fact, we find considerable evidence that multi-dimensionality is the norm for most major bills and policy areas across both the House and Senate.

In this paper, we report findings for a decomposition of the roll-call voting record. In doing so, we identify some—but certainly not all—of the ways in which the aggregation of the voting record affects the observed dimensionality of the policy space. For the 1955-1994 period (84th-104th Congresses), we apply optimal classification (OC) algorithms to votes aggregated to the level of the individual bill policy area to measure dimensionality. We examine reported eigenvalues and the marginal proportional reduction in error (MPRE) across dimensions. In both cases, our results demonstrate that complexity in voting patterns of individual bill episodes is the norm, that aggregating to higher levels reduces the observed dimensionality, and that the liberal-conservative dimension appears more dominant in more highly aggregated analyses.

Dimensionality and Theories of Legislating

In studies of legislative behavior, it is well understood that there are fundamental differences between unidimensional and multidimensional spaces. Unidimensional policy spaces are well behaved—pivotal legislators such as the median can be identified. Multidimensional policy spaces generally do not have identifiable pivots. Consequently, outcomes are predicted with great precision in unidimensional space, while multidimensional spaces often lead to predictions of the possibility of cycling or chaos. For this reason, most empirical applications of spatial theory assume unidimensionality (Krehbiel 1998, Cameron 2000).

That was not always so. Through the 1950s and 1960s, political scientists posited multidimensionality as the basic expected pattern in a pluralistic polity. Perhaps most prominently, Truman (1951), MacRae (1958), Miller and Stokes (1963), Lowi (1964), and Clausen (1973) argued that the forces influencing legislators varied from issue to issue as did the voting alignments that they produced. Party, constituency, and ideology were emphasized as the primary forces in the equation, but considerable attention was also given to presidential influence. Variation in the character of lobbying groups was given attention, although systematic study of group influence was very limited (see Bauer, Pool, and Dexter 1972). The relevance of these large forces in American politics was thought to vary systematically across large domains of public policy.

In more recent studies, the theoretical convenience of assuming a unidimensional space is often given empirical justification by reference to the findings of Poole and Rosenthal (1997; 2007). Poole and Rosenthal observe that, in analyses in which the DW-NOMINATE method is applied to whole Congresses, it is difficult to improve upon the predictive value of a single liberal-conservative dimension in most Congresses (2007, 34). The aggregate proportional reduction in error, taken as the difference between errors based on the DW-NOMINATE estimates and those based on the marginal vote distribution, averages about 0.5 for the first dimension with only a slight improvement, about 0.06 on average, by adding a second dimension. Poole and Rosenthal (2007) draw the following inferences:

- "A reasonable fit is obtained from a one-dimensional model in which each legislator's position is constant throughout his or her career." (33)
- "Introducing more parameters in a dynamic model—through extra dimensions or higher order polynomials [to capture changing ideal points]—does not appreciably add to our understanding of the political process." (35)
- "A one-dimensional model typically provides a good fit to the data, with a second dimension needed in periods when race issues are distinct from economic ones." (59)

Poole and Rosenthal reinforce these inferences by observing that the correlations among first-dimension W-NOMINATE scores for four large policy categories (each encompassing hundreds of votes) are very high. The concluding chapter of the 2007 edition of the Poole-Rosenthal book captures their views well in its title, "The Unidimensional Congress."

The Poole-Rosenthal findings were foundational for an important body of theory and associated empirical tests. The books and paper that employ their scores are far too numerous to cite here so we focus on a few examples. Krehbiel (1998) uses first-dimension DW-NOMINATE scores to test a one-dimensional model that identifies super-majority pivots in the contexts of veto overrides and Senate cloture votes. Cameron (2000) limits his analysis of presidential leverage gained through vetoes to a cutting-point analysis based on first-dimension DW-NOMINATE scores. The theory in both studies is unidimensional but in neither theoretical account is it necessary that the dimension be the liberal-conservative dimension. Nevertheless, both studies, each a winner of the Fenno Prize for the best book on legislative politics, use first-dimension DW-NOMINATE scores to test unidimensional theory. The predictions of both accounts would have been very different if a multidimensional space was assumed.

We are not alone in questioning the assumption of unidimensionality. In fact, most investigators who focus on legislative episodes associated with individual bills rarely find a unidimensional account adequate. There are too many accounts of congressional politics to mention in this regard, but three studies warrant brief discussion.

Jones (1961) examined the expressed preferences and behavior of House Agriculture Committee members on a farm subsidy bill. He observed that legislators approved of federal support for agricultural interests in their own districts but otherwise followed their parties. We can readily infer that multiple dimensions were present—the dimensions representing the multiple agricultural commodities that were the subject of the bill and the one dimension, and a liberal-conservative dimension that produced a division between the parties.

Hurwitz, Moiles, and Rohde (2001) argue that three theories of legislative organization—distributive, informational, and partisan—can be readily accommodated if we realize that legislators often perceive multiple dimensions in the bills they construct and vote upon. Examining the agricultural appropriations and farm bills of 1996, this team found the bills to be complex and the voting alignments to vary across parts of the bills in a way that defined distinctive dimensions. Some votes on key amendments generated the "first dimension" liberal-conservative or partisan alignment, while others yielded more parochial or distributive divisions. Moreover, committee members showed distinctive support for farm interests. Plainly, the bills, which incorporated several distinguishable issues, generated multiple dimensions in the observed voting behavior of legislators.

Smith (2007) examined voting for all bills during the 2001-2005 period that were subject to a "key vote," identified by Congressional Quarterly as a vote on an issue of national significance. For 23 of 98 bills, Smith found that the House key vote represented a dimension of voting different from the final passage vote. To be sure, 75 key and final passage votes appeared to reflect the same underlying dimension, but nearly a quarter of the most important votes cast in the House, spanning a wide range of subject matter, appeared to reflect dimensions other than the one represented in the vote on final passage.[1]

In more recent work, Crespin and Rohde (2007) break apart the roll-call record into subsets consisting of votes on the 13 Appropriations bills that must pass in some form during each two year Congress. They then estimate the dimensionality of the policy space using DW-NOMINATE and find multiple dimensions. They also find that the one-dimensional model rarely explains half of the variance in roll-call voting when the record is decomposed in this manner. They conclude that while the unidimensional model does a good job of explaining votes over an entire Congress it misses much of the complexity in voting on specific subsets of bills.

If the studies of individual legislative episodes are a guide, we should be careful about limiting our theory to unidimensional spatial models and about empirical claims that complex

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[1] In addition to the studies mentioned in the text, other studies address dimensionality. Potoski and Talbert (2000) and Talbert and Potoski (2002) follow Poole and Rosenthal in arguing that floor voting is characterized by low- or uni-dimensionality, but that legislation and bill sponsorship shower higher dimensionality. Our hunch, reflected in the argument of this paper, is that the high level of aggregation of roll-call votes in these studies masks even greater dimensionality at the level of bill episodes. Jenkins (1999, 2000), Wright and Shaffner 2002, Wright and Winburn 2003, Wright and Clark 2005) find that the presence of strong parties and parity in the two parties in state legislatures and the Confederate Congress reduce the dimensionality of the observed policy space. These studies, too, were conducted on highly aggregated sets of roll-call votes.

models add little to our understanding of the political process. Our working hypotheses are simple:

> Proposition 1. *The observation of a powerful first dimension in highly aggregated analyses of roll-call voting is explained by the high frequency of bills for which the liberal-conservative dimension of conflict emerges.*
>
> Proposition 2. *The observation of multiple dimensions in many, if not most, individual bill episodes is explained by the high frequency of bills for which infrequently occurring, non-liberal/conservative dimensions of conflict emerge.*

In short, we believe that the inference of unidimensionality is largely an artifact of the estimation process aggregated to the two-year Congress. In this paper, we take the first steps to decompose the voting record to determine how voting patterns aggregate to generate the powerful first dimension and to undertake a preliminary investigation of the determinants of the observed dimensionality.

Levels of Aggregation and Dimensionality

We have conducted a dimensional analysis for a recent period, the 21 Congresses of the 1955-1994 period, to explore the dimensionality of the policy space exhibited in voting associated with three levels of aggregation: (a) two-year Congresses, (b) broad policy domains within Congresses (the Clausen domains, Clausen 1973 and Clausen and Van Horn 1977), and (c) individual bills. We use Optimal Classification (Poole 2000, 2005) to explore the underlying dimensionality of congressional voting.[2]

[2] Optimal classification (OC) is a non-parametric technique for estimating the ideal points of legislators and the underlying dimensions present in voting. Poole (2000, 2005) demonstrates that optimal classification is robust with a small number of votes. For the analysis reported, we eliminated all votes with less than 0.5 percent of legislators on the losing side of the vote. OC, unlike NOMINATE methods, can be used when votes scale perfectly, an important feature when

Estimating Dimensionality with Eigenvalues

While eigenvalues are computationally convenient quantities to examine when assessing the dimensionality of roll call data, they do not provide nor rely on measures of fit of OC or NOMINATE. The eigenvalues reported by OC and NOMINATE are the eigenvalues of the double-centered squared distance matrix.

Other than using a different default threshold, there is no difference between the eigenvalues reported by OC and NOMINATE. The eigenvalues have nothing directly to do with the models assumed by OC or NOMINATE; rather, they depend on the assumptions of principal component analysis.

Why do we use eigenvalues instead of some measure of dimensionality based directly on OC or NOMINATE? Our experience suggest that it is computational cheaper, while yielding the same substantive answers,[3] at least when the number of votes is large. However, it is not clear that this is the correct approach when the number of votes is smaller, such as when we focus on the votes for a single bill.

Harding (2008) shows that eigenvalue analysis of finite samples bias toward the identification of unidimensionality. This suggests that our eigenvalue-based analysis of dimensionality will *underestimate* the number of dimensions. To be certain, we verified our results using an alternative measure that is based on the reduction of classification errors as we assume a higher dimensional OC model.

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scaling just a few votes. First dimension OC scores correlate with DW-NOMINATE scores at 0.98 or higher in each of the Congresses in our series.

[3] See Poole and Rosenthal (2005, p. 144) and Poole, Sowell, and Spear (1992).

Estimating Dimensionality with Marginal Proportional Reduction in Error

Consider, for example, a Senate vote that is 60 'aye' and 40 'nay.' A "zero" dimensional model that predicts all senators vote with the majority will have 40 classification errors, exactly the size of the minority. Suppose a 1-dimensional OC analysis correctly classifies 75 senators' votes, and a 2-dimensional OC analysis correctly classifies 85 votes.

Aggregate proportional reduction in error (APRE) is defined as

$$\text{APRE} = \frac{\sum_{j=1}^{q}[\text{minority vote} - \text{classification errors}]_j}{\sum_{j=1}^{q}[\text{minority vote}]_j}$$

The reasons for using APRE instead of just measuring the fraction of votes classified correctly are twofold. First, we do not want to give "credit" to the 1-d model for explaining the 60 votes of the majority, because those can be classified correctly just by noting that the measure passed, so we only count the improvement in the number of correctly classified votes, "minority vote - classification errors." Second, the most improvement the 1-d model can show is to explain all of the 40 minority votes misclassified in the simpler model; dividing by the number of minority votes puts APRE on a [0,1] scale.

We proceed by comparing the fraction classified correctly and APRE in our example. The fraction correctly classified by the 0-d model is .600 and the fraction correctly classified by the 1-d model is .750, a difference of .150. The APRE for the 1-d model is .375, which is the fraction of votes that were misclassified under the 0-d model but that are correctly classified under the 1-d model. Is this a good measure? That depends on the inference one wishes to draw based on the measure. APRE has face and construct validity when used to describe *how much better the 1-d model is than the 0-d model* because it chooses quantities for both the numerator and denominator relating to the inference in question (the difference between the two models.)

Moving on to the two dimensional model, Poole and Rosenthal (1997 and 2007, chapter 3) measure the contribution of adding a second dimension by calculating the APRE for both models and subtracting. $APRE_1$ is .375 and $APRE_2$ is .625, a difference of .250. The problem with using this difference, in our view, is that it is a measure of how much *more* the 2-d model improves on the 0-d model than the 1-d model does; it is not a measure of how much the 2-d model improves on the 1-d model. For the same reason, the 1-d model is not a .250 improvement on the 0-d model, it simply reflects the change in the fraction correctly classified.

To measure the improvement of 2-d over 1-d, we want to use the quantity

$$\frac{25-15}{25}=\frac{2}{5}=.400$$

which is the fraction of the classifications the 2-d model could make correctly above and beyond those classified by the 1-d model. Generalizing APRE, we define the **marginal proportional reduction in error** from model A to model B as

$$\mathrm{MPRE}_{\mathrm{AB}}=\frac{\sum_{j=1}^{q}[\text{errors by A}-\text{errors by B}]_j}{\sum_{j=1}^{q}[\text{errors by A}]_j}$$

In terms of APREs, this can be calculated using

$$\mathrm{MPRE}_{\mathrm{AB}}=\frac{(1-APRE_A)-(1-APRE_B)}{1-APRE_A}$$

For convenience and clarity, we report the results obtained by using eigenvalues in the analysis that follows. The results obtained using MPRE are substantively similar and are reported in the reviewer's appendix.

Congresses

We find considerable variance in the dimensionality of voting over the 21 congresses in our sample.[4] Figure 1 demonstrates that the first dimension eigenvalue increases in strength over the period, implying that the dimensionality of the policy space is not fixed over time, even when measured at a highly aggregated level. Both chamber exhibit a first dimension, the liberal-conservative dimension, that captures an increasing share of the variance and reaches a very high level in the 1990s. The figure suggests that we must exercise care in assuming that the first dimension is uniformly strong, even over the period since the 1950s.

The scree plot for each chamber in two Congresses, 1973-1974 and 1993-1994, is shown in Figure 2. In each Congress, the two chambers are remarkably similar. In both Congresses, the first dimension is much stronger than the second dimension, although the figure shows a stronger first dimension and weaker second and third dimensions in the more recent Congress. The figure is consistent with Poole-Rosenthal NOMINATE findings, which show some variation in the strength of a second dimension but with a dominant first dimension.

The mean *unadjusted* eigenvalue for the second dimension is 4.8 for the House and 1.4 for the Senate, the difference reflecting, we think, the relative size of the two chamber. Both means exceed the 1.0 level that often is suggested as a rule of thumb for significance. However, the “elbow” test—counting the number of dimensions above the elbow in the plot—suggested by others indicates that only one dimension is significant.

Clausen Domains

The policy domains, conceptualized by Clausen (1973) and coded by Poole and Rosenthal, exhibit more widely varying dimensionality. The first dimension, the liberal-conservative dimension, shows increasing strength over the period for three policy domains (Figure 3)—

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[4] First dimension OC scores correlate with DW-NOMINATE scores at 0.98 or higher in each of the Congresses in our series.

government management of the economy, social welfare, and foreign and defense policy. By the end of the period, the eigenvalue for the first dimension constitutes about two-thirds of total eigenvalues. The eigenvalue for the first dimension in the civil liberties domain shows no clear trend, but the trend for the agriculture domain is downward. This mixed pattern comports with the Clausen argument that congressional behavior is not necessarily consistent across domains. It also hints that dimensional analyses aggregated to the two-year Congress may mask important variation.

Due to space constraints, we forgo a presentation of the scree plot of eigenvalues for five policy domains over 21 Congresses. Instead, we consider the scree plot for the first six dimensions for the same two Congresses considered above in Figure 4. Four of the five domains show similar patterns—a stronger first dimension and a sharper elbow after the first dimension in the 103d Congress than in the 93d Congress—as in the pattern for all votes. The exception is the agriculture domain, which shows two dimensions in both Congresses. Again, the House and Senate exhibit similar patterns.

Bills

In Figure 5, the mean eigenvalues of each dimension through the 20th dimension is plotted for bills that received at least 5 recorded votes. House eigenvalues are on average higher than Senate eigenvalues because of the larger number of legislators in the House (we adjust for this below). The number of dimensions with mean eigenvalues greater than 1.0, the conventional standard for significance, is eleven for the House and five for the Senate. Even with a higher benchmark, an eigenvalue of at least 2.0, the number of bills with multiple dimensions visible in associated votes is remarkably high. The proportion of bills associated with at least one roll-call vote with at least two dimensions that meet that standard is approximately 11 percent in the

House and 26 percent in the Senate. This basic result confirms the observation in case studies of legislative battles that it is common that legislators' expressed preferences are more complex than is fairly characterized by a single dimension.

Eigenvalues as a proportion of total eigenvalues are reported in Figure 6. Plainly, the two chambers of Congress show nearly identical patterns. On average, the first dimension accounts for nearly half of total eigenvalue, the second dimension accounts for about one sixth of total eigenvalue, and the third dimension accounts for about one tenth of total eigenvalue. Keeping in mind that the substantive identity of the dimensions is not necessarily consistent across bills, it is clear that, on average, there is a strong first dimension with two other dimensions showing strength before reaching the "elbow" in the scree plot.

Another perspective is gained by asking how many dimensions are required to explain most of the observed variance in voting behavior. To do this, we report a histogram in which each bar shows the proportion of bills (with five or more votes) for each number of dimensions that have eigenvalues that sum to 90 percent of total eigenvalue (Figure 7). For about 40 percent of the bills, it takes five to seven dimensions to achieve 90 percent of the total eigenvalue. Few bills achieve 90 percent of total eigenvalue with just one or two dimensions. At the level of individual bills, complexity is the norm, unidimensionality is rare.

Identity of the First Dimension

A final but essential consideration is a comparison of the substantive identity of the first dimension generated at the three levels of aggregation. We are confident that the first dimension OC results for the entire Congress define a liberal-conservative dimension. For each chamber in each Congress, the Spearman's *r* between the first dimension OC scores and the first dimension DW-NOMINATE scores, calculated across all roll-call votes, exceeds 0.98. The issue is how those first dimension OC scores are correlated with the first dimension scores for the policy domains and bills. We summarize those correlations in Figure 8, which reports the mean absolute value of the correlations over time in each policy domain.

The first dimension scores derived from votes associated with individual bills exhibit a much lower mean correlation with liberal-conservative scores than the scores derives from the more highly aggregated policy domains. In fact, the bill correlations are very modest while the policy domain correlations vary from uniformly high (government management of the economy) to fluctuating and often low (agriculture). Plainly, as we move from bills to policy domains to Congresses, we reduce the measured dimensionality of the policy space and enhance the strength of the liberal-conservative dimension.

Dimensionality in the House and Senate

Our main inference—that dimensionality varies with level of aggregation—appears to apply to both chambers with equal force. Moreover, in the results of dimensional analyses presented so far, the House and Senate do not appear to differ systematically. Yet, there are very good reasons to think that the two chambers would differ systematically in the dimensionality of the observed policy spaces in floor voting.

The rules and practices of the House and Senate differ in several significant ways that might lead to us expect systematic differences in the dimensionality of floor voting. First, until 1971, very few amendments to bills received recorded votes in the House. In 1971, for the first time, the House allowed recorded votes in the Committee of the Whole where the only votes on most amendments occurred. The result is that far fewer House bills had as many as five roll-call votes and House bills were subject to far fewer votes, at least on average. With fewer amendments subject to votes, the observed dimensionality in voting associated with House bills would be expected to be lower than for the companion action in the Senate.

Second, as a matter of standing rules, nongermane amendments are allowed in the Senate but not allowed in the House. This creates the possibility that a wider variety of issues and divisions among legislators will emerge during consideration of a bill in the Senate. The possibility of a wider variety of issues and divisions in the Senate may yield more observed dimensions in voting behavior.

Third, special rules in the House may further limit amendments and the observed dimensionality of the related voting behavior. However, waivers of standing rules also are common in special rules, waivers that allow some amendments to receive votes that otherwise would not be in order. On balance, we are quite certain that the revolution in the use of special rules in the 1980s (Bach and Smith 1988, Roberts and Smith 2007, Smith 1989) reduced the number and variety of floor amendments and should have reduced the observed dimensionality of floor voting.

To further explore House-Senate differences, we have identified the House and Senate bills associated with the list of important measures on the Clinton-Lapinski list (Clinton and Lapinski 2006). Of the 500 top measures on the Clinton-Lapinski list, 124 fall in the period studied here and have identifiable companion bills in both chambers, but only 32 pairs of those 124 have a minimum of five votes associated with both bills. We generated OC results for each bill in 32 matched pairs of bills with a minimum of five votes and for all votes associated with the 124 bills. These more limited comparisons give us a basis for hoping that the House and Senate analyses are based on roughly the same range of policies.

Contrary to expectation, but consistent with the patterns reported above, there are no significant differences between the House and Senate (data not shown). This is true for both the 32 matched pairs with a minimum of five votes per bill and for all votes associated with the 124 pairs. Thus, for the time being, it does not appear that the larger number of Senate votes yields more observable dimensions

Conclusion

This paper reports findings for a decomposition of the roll-call voting record of the U.S. Congress to determine the effect of the level of aggregation on the observed dimensionality of the policy space. In doing so, we identify some—but certainly not all—of the ways in which the aggregation of the voting record affects the observed dimensionality of the policy space. For the 1955-1994 period (84th-104th Congresses), we apply optimal classification (OC) algorithms to votes aggregated to the level of the individual bill policy area to measure dimensionality. Whether examining eigenvalue or the marginal proportional reduction in error, our results demonstrate that complexity in voting patterns of individual bill episodes is the norm, that aggregating to higher levels reduces the observed dimensionality, and that the liberal-conservative dimension appears more dominant in more highly aggregated analyses. These results suggest that many of the conclusions from the theoretical and empirical literature on the U.S. Congress that employs a unidimensional model may not be based on sound empirical footing.

Figure 1. First Dimension Eigenvalue as a Proportion of Total Eigenvalue.

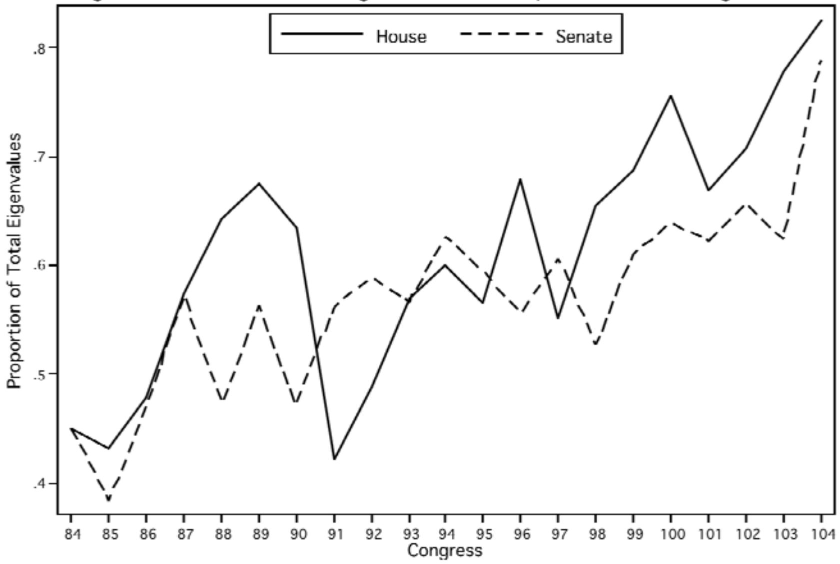


Figure 2. Proportion of Total Eigenvalues for First Six Dimensions
Selected Congresses

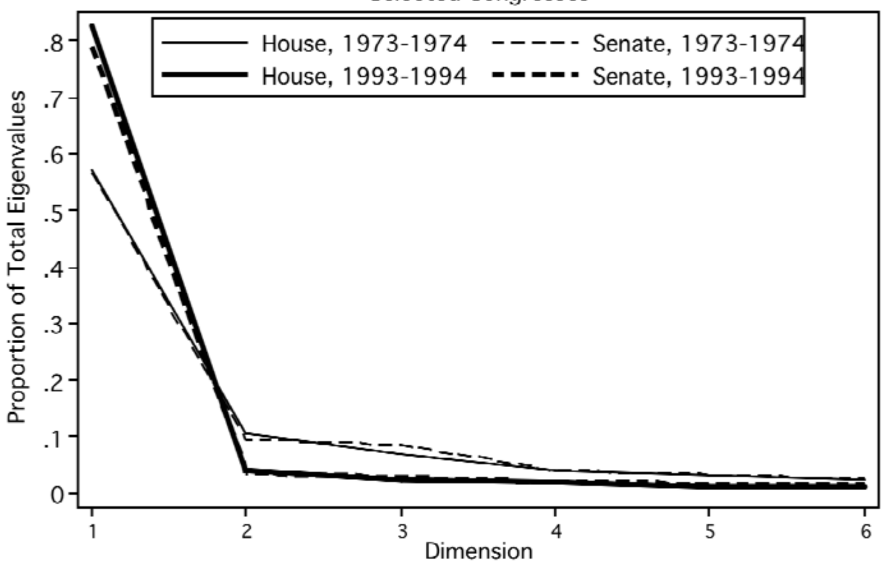


Figure 3. Proportion of Total Eigenvalues for First Dimension by Policy Domain

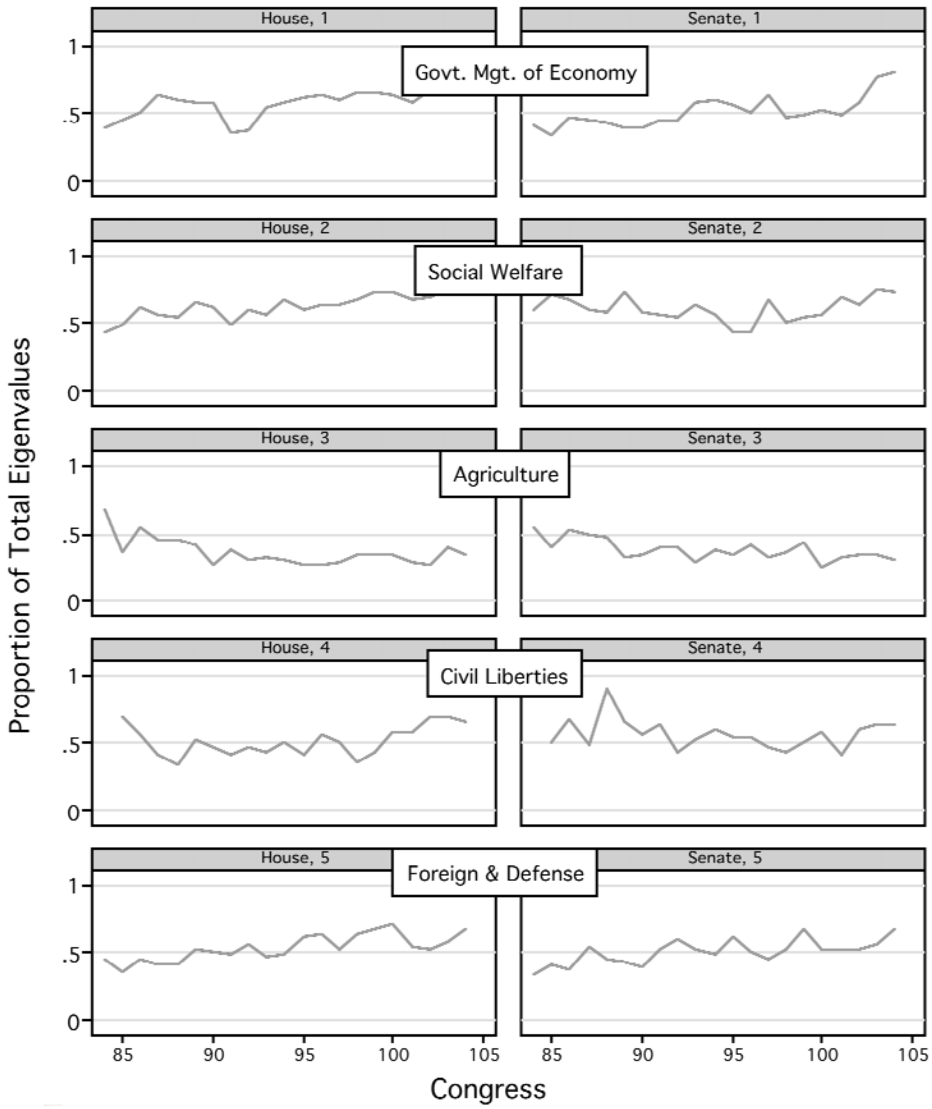


Figure 4. Proportion of Total Eigenvalues for First Six Dimensions by Policy Domain, 93d Congress (1973-1974) and 103d Congress (1993-1994).

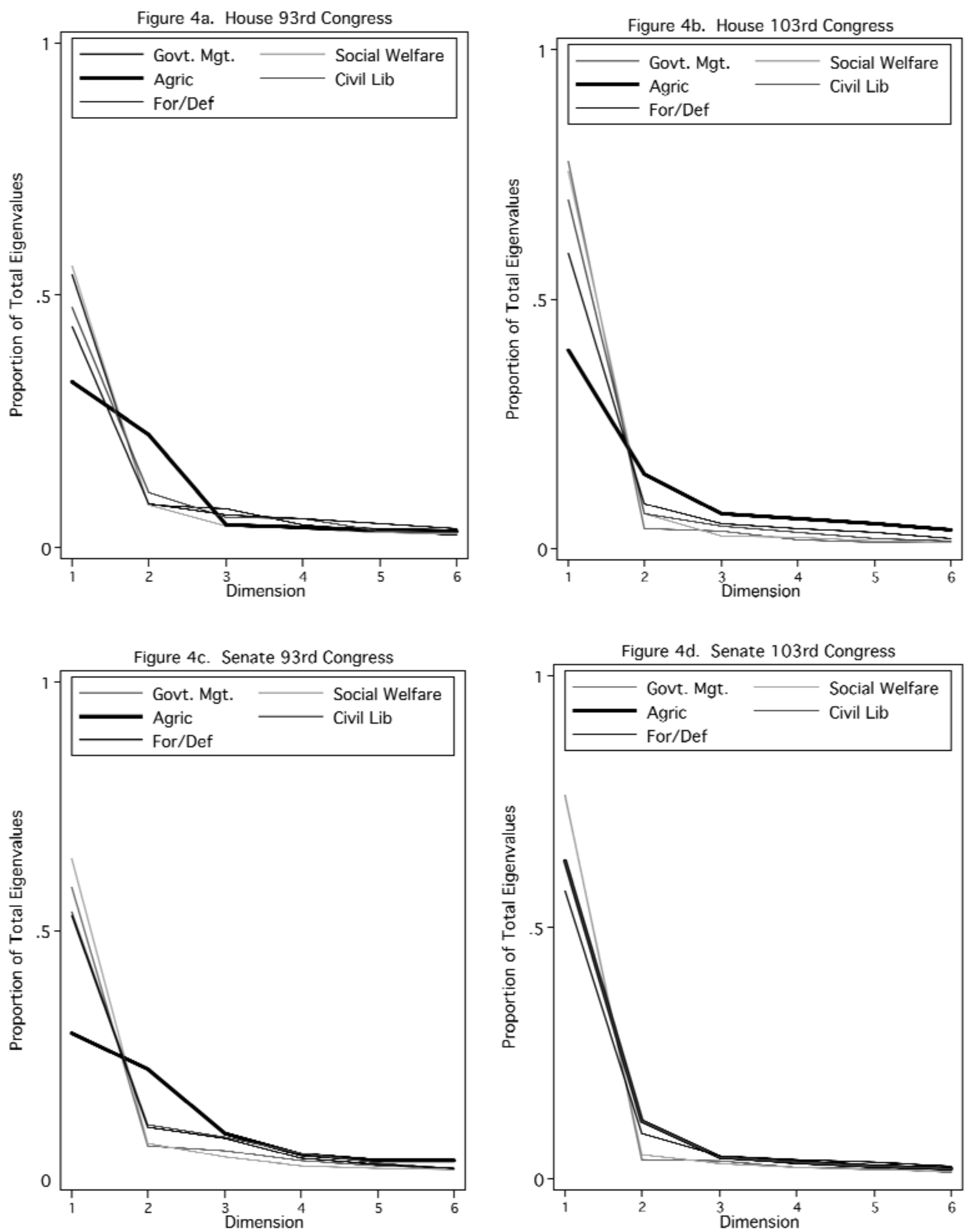


Figure 5. Mean Eigenvalue by Dimension, Bills With Five or More Votes.

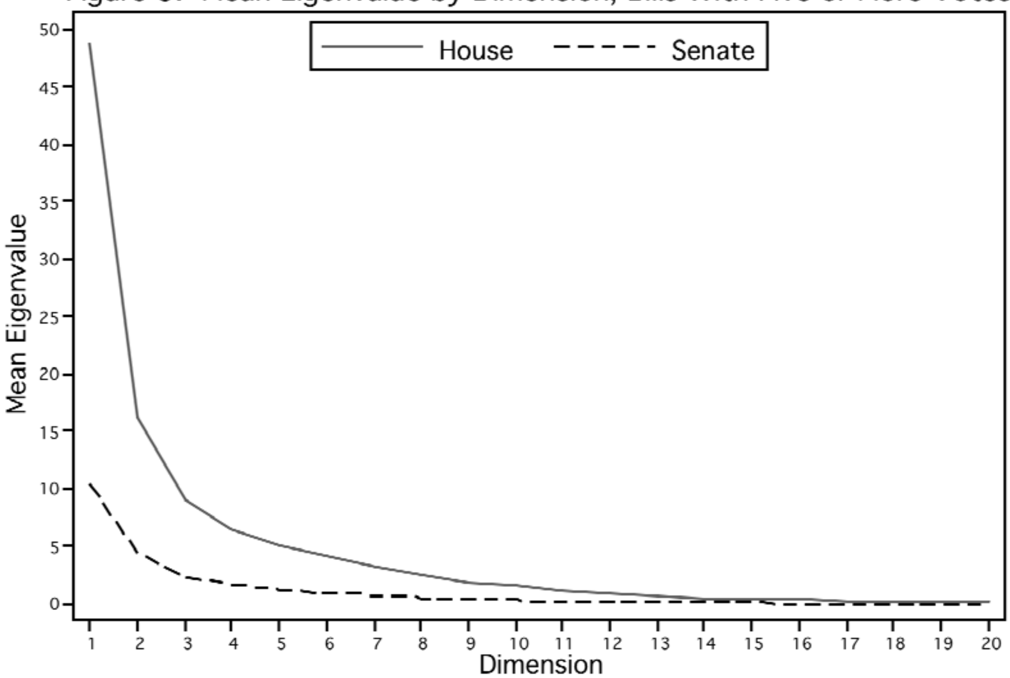


Figure 6. Mean Proportionate Eigenvalue by Dimension, Bills with Five or More Votes.

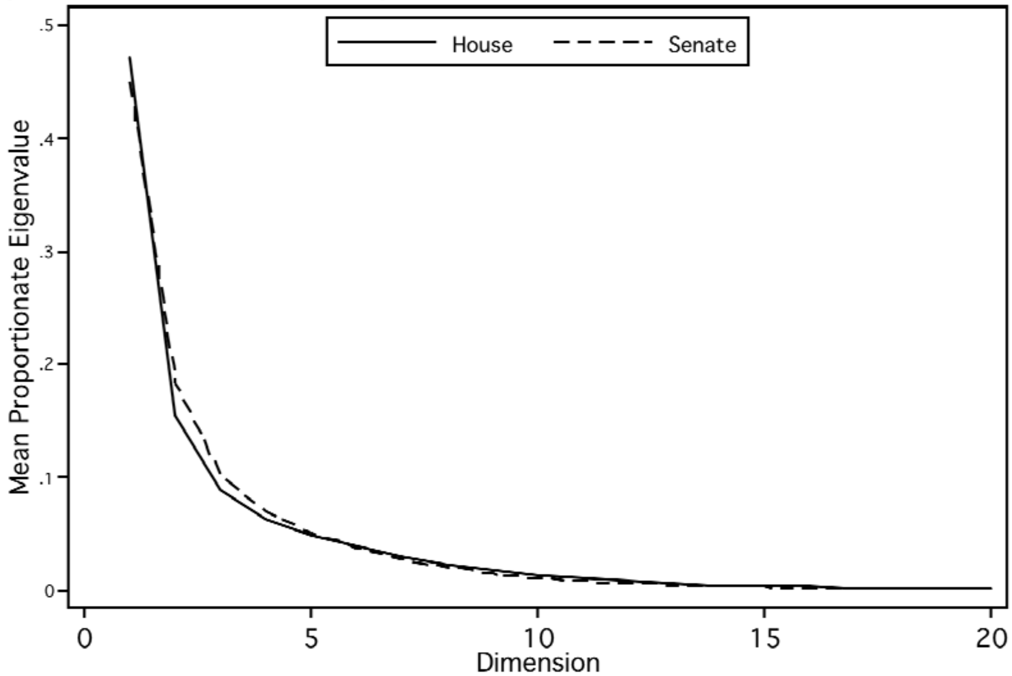


Figure 7. Histogram of the Number of Dimensions Summing to 90 Percent of Total Eigenvalue, Bills with Five or More Votes.

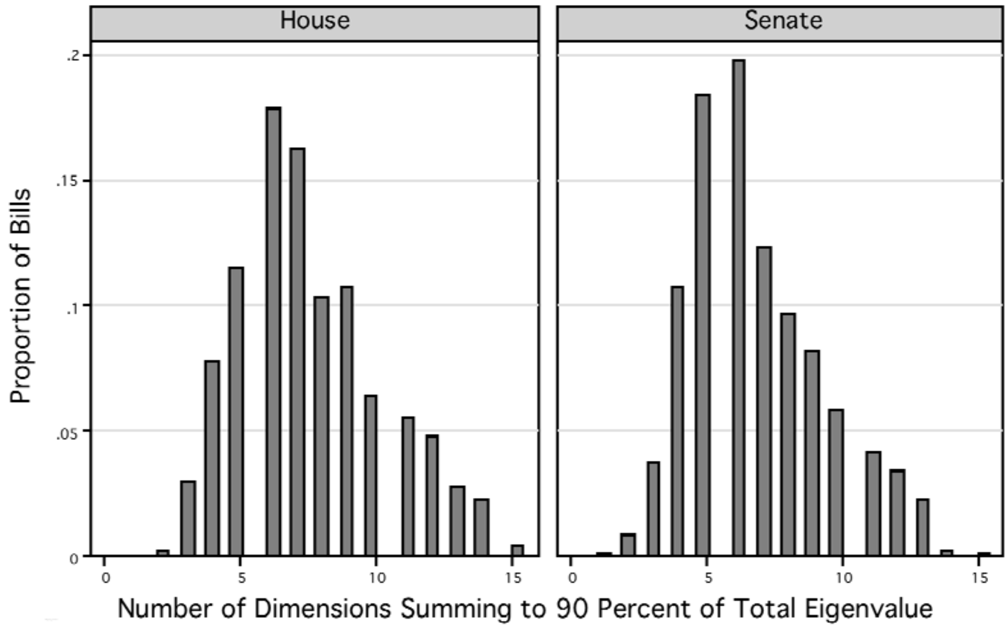
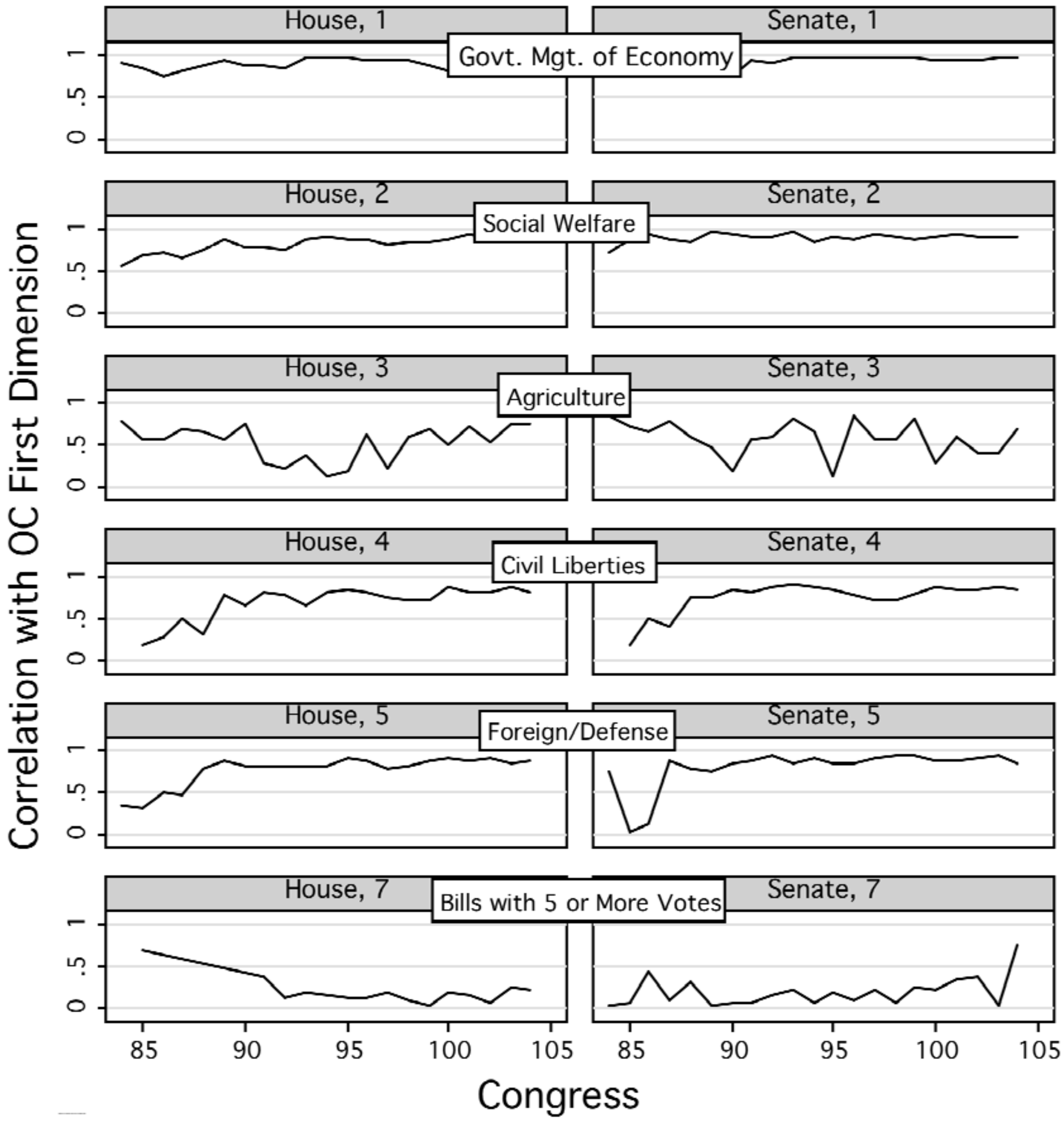


Figure 8. Correlations with OC First Dimension Scores for Policy Domains and Bills with 5 or More Votes.



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