D-NOMINATE After 10 Years: A Comparative Update to *Congress: A Political Economic History of Roll Call Voting*

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Abstract

This paper updates *Congress: A Political-Economic History of Roll Call Voting*. *Congress* is based largely on an analysis of the first 100 Congresses and is devoted to showing that important episodes in American political and economic history can be better understood by supplementing or reinterpreting more traditional analyses with the basic space theory of ideology. Ideology was measured by D-NOMINATE scores. Here we update some of our findings using new estimations that are complete through the end of the 105th Congress. We find that the trend to polarization and unidimensionality that we identified in *Congress* has continued unabated through the 105th Congress. The shift to Republican control after the 1994 elections is part of this trend and does not represent a sharp break in roll call voting behavior. Comparison of NOMINATE results for the United States to those for other parliaments indicates the ideological character of roll call voting in Congress.

1. Introduction:

Ten years ago this past spring we finished the last of our D-NOMINATE estimations on the Cyber 205 supercomputer at Purdue University. For each house of Congress, all recorded roll call decisions in the first 99 Congresses formed the basis of the simultaneous estimation of the spatial (ideological) positions of all members of Congress serving from 1789 to 1985.[1] These estimations became the foundation of our book *Congress: A Political-Economic History of Roll Call Voting* (Poole and Rosenthal, 1997) that was published in January 1997. *Congress* is devoted to showing that important episodes in American political and economic history can be better understood by supplementing and/or reinterpreting more traditional analyses with the basic space theory of ideology[2] as measured by the D-NOMINATE scores. The purpose of this paper is to update some of our findings in *Congress* with new estimations that are complete through the end of the 105th Congress.

We begin in the next section with some brief comments about how the evolution of computers from 1982 to 1999 has affected the development of NOMINATE. We also discuss the successor to D-NOMINATE -- DW-NOMINATE (dynamic, weighted, nominal three-step estimation) – which we designed to run on the new generation of personal computers. A brief outline of the technical details of DW-NOMINATE can be found in the appendix. In Section 3 we report the overall fits of DW-NOMINATE to Congresses 1 – 105 and in Section 4 we compare these fits to an optimal classification method developed by Poole (1997, 2000). Section 5 is devoted to a substantive analysis of the Post Reconstruction Democrat/Republican party system with a special focus on more recent Congresses. In Section 6 we briefly compare the U.S. Congress to other legislatures in terms of the fit of the spatial model. We conclude in Section 7.

Throughout this paper we will refer back to tables and figures in *Congress: A Political Economic History of Roll Call Voting*. We use the convention -- *Congress* (page number, Table/Figure number) – in our discussion below.

2. NOMINATE and the Evolution of Computers

Ten years is more than a lifetime in computer technology. When we began our work on the NOMINATE model in early 1982 it took several hours on a state of the art VAX to analyze a single Senate roll call matrix. To analyze a House matrix with about 500 roll calls required that we run the program overnight in the batch queue. This took at least 7 hours of CPU time. Consequently, when NSF announced the supercomputer initiative in the summer of 1985 we jumped at the chance to get some real computing horsepower to perfect our model.

We applied for and were granted time on the Cyber 205 vector supercomputer at Purdue University. This turned out to be a stroke of incredibly good fortune for us. The architecture of the Cyber 205 – its use of vector pipelines -- and the programming language – VECTOR FORTRAN – that was implemented on it, were ideally suited to large discrete choice problems.

VECTOR FORTRAN allowed the declaration of *bit* vectors in the same way that in ordinary FORTRAN integer or real vectors are declared. Because a legislator's vote on a particular roll call is either Yea, Nay, or abstain, the legislator's choice required only *two bits* of memory storage on the Cyber 205. Namely, the appropriate entry in one bit vector was set to TRUE if the legislator voted Yea. Similarly, the appropriate entry in a second bit vector was set to TRUE if the legislator voted Nay. A logical comparison of the two vectors could be used to find abstention. Since bit vectors permitted storing 64 individual roll call votes in just two words of memory, the large memory of the Cyber 205 could be used very efficiently.

We soon realized that the memory and the speed of the Cyber 205 would allow us to analyze the data from more than Congress at a time. Hence, we began thinking about estimating *dynamic* spatial models and we developed D-NOMINATE over the 1986-88 period.

During the past ten years computers have grown ever more powerful in terms of processing speed and memory. This evolution progressed to the point that we thought it feasible to try to implement our dynamic spatial model on personal computers. Consequently, we developed DW-NOMINATE during the 1996-97 period (McCarty, Poole, and Rosenthal, 1997). For readers familiar with our work, DW-NOMINATE is a dynamic version of W-NOMINATE (*Congress*, Appendix A). If differs from D-NOMINATE in two ways. DW-NOMINATE is based upon normally distributed errors rather than logit errors and each dimension has a distinct (salience) weight. When we began our work in 1982 we used the logit model because of computer speed and memory limitations. These are no longer a serious issue, and we have switched to the normal distribution so that we can develop much more sophisticated models of error. We will only sketch the model in the appendix because it is developed in more detail in McCarty, Poole, and Rosenthal (1997, Appendix A).

In McCarty, Poole, and Rosenthal (1997) we report results for the 1947 – 1996 (80^{th} to 104^{th} Congresses) period. We limited ourselves to the Post WWII period simply because of memory and processor limitations. This is no longer a problem and we are now able to analyze the first 105 Congresses on a 550mhz PC with 384 megabytes of memory.

3. DW-NOMINATE Results For Congresses 1 – 105

Table 1 shows results for DW-NOMINATE estimations of various one and two-dimensional models for the House and Senate. In our original research we hypothesized that there would be few important changes in the positions of legislators during their careers in Congress. To allow for changes, we permitted legislator ideal points to be polynomial functions of time. Our research hypothesis was captured in the *constant* model where positions remain unchanged. We found that linear change captured most of the relatively small changes in the positions.

In estimating linear change, we estimated linear terms for legislators serving in as few as 3 Congresses. Because the threshold is only 3 Congresses, some legislators who are really "random walking" through the space will appear to be moving linearly. We permitted this bias in the estimated linear terms because we wanted to bias the comparison of the polynomial models against the constant model in favor of the polynomial models. However, in Table 1 we also report results for the linear model with a 5 Congress threshold. Finally, for purposes of comparisons with D-NOMINATE, we also report results for the first 99 Congresses using the 3 Congress threshold for the two dimensional linear model.

Table 1 about Here

The two dimensional DW-NOMINATE results for the first 99 Congresses are essentially the same as those for D-NOMINATE (*Congress,* p.28 Table 3.1). The correct classifications for the House and Senate are 85.4 and 84.6 respectively. The correct classifications for D-NOMINATE are 85.2 and 84.5 respectively. In addition, the legislator coordinates are essentially the same. The Pearson correlations between the corresponding first and second dimensions were .977 and .923 respectively for the House, and .974 and .901 respectively for the Senate.

For the first 105 Congresses, the second dimension picks up a bit less than 2 percentage points in classification for the House and about 2.5 percent for the Senate. The linear model is not a striking improvement over the constant model. The improvement is about 0.3 percent in both chambers. For the linear model, lowering the threshold from 5 to 3 Congresses to estimate a linear time trend term for a legislator only increases classification by about 0.1 percent in the House but 0.3 percent in the Senate. Finally, a comparison of the results for the first 99 Congresses with those for all 105 Congresses shows that recent Congresses clearly fit the model better than earlier Congresses. *Adding* Congresses 100 – 105 (an additional 2,225,279 choices in the House and an additional 345,238 choices in the Senate) *increases* the correct classification by about 0.6 percent for the House and 0.3 percent for the Senate.

Figures 1 and 2 show the two-dimensional linear model classifications by Congress for the House and Senate respectively. The pattern of the fits for the first 99 Congresses is essentially the same as that shown in *Congress* (p. 32, Figure 3.1) and the fit of Congresses 100 – 105 shows a clear upward trend. In addition, as Figures 1B and 2B show, the trend to unidimensionality since the early 1970s is dramatic. The second dimension now accounts for less than 1 percent improvement over the first dimension in both chambers.

Figures 1 and 2 about Here

Table 2 shows the utility function parameter estimates for the DW-NOMINATE estimations. The salience weight for the first dimension can be set equal to one so we only show the estimates for the second dimension. The standard errors shown in the table are technically not econometrically correct because they were *not* computed over the full outer product matrix of partial derivatives. In the case of the House, this would require inverting a 180,000 by 180,000 matrix. This is not yet practical on a PC. When it is possible, we will do it. However, we doubt it will substantially change the values reported in the table that were computed by holding the non-utility function parameters fixed (McCarty, Poole, and Rosenthal, 1997, Appendix A).

As is standard in probit models, the variance of the composite error in the utility comparison has been set equal to 1.0. The parameter b is an estimate of the importance of the spatial component of the utility function. The value of b increases between one and two dimensions because the fit is better in two dimensions. The parameter **w** measures the relative importance of the second dimension across the entire history of the United States.

Table 2 about Here

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4. A Comparison With Optimal Classification Analysis

Time waits for no one. We never expected our NOMINATE methodology to be the last word in the analysis of parliamentary roll call data. No one has developed a dynamic spatial methodology that can be compared to our dynamic NOMINATE method but there have been methodologies developed in the past ten years that can be used to analyze individual roll call matrices. None of these methodologies produce results markedly different than NOMINATE.

Heckman and Snyder (1997) have developed a factor analysis method that produces legislator coordinates that are essentially the same as those produced by W-NOMINATE (*Congress*, Appendix B).[3] Londregan (2000) develops an innovative one-dimensional methodology intended for the analysis of small legislatures or committees. Finally, Poole (1997, 2000) has developed a non-parametric methodology similar in structure to NOMINATE. The scaling method finds estimates of the legislator ideal points and cutting planes for the roll calls that maximize the number of votes classified correctly. When the dimensionality is higher than one, this method produces legislator configurations very similar to NOMINATE and Heckman-Snyder (Poole, 2000).

Poole's non-parametric method is a useful comparative benchmark because it can be applied to more than one Congress at a time. Because of computer limitations, we have only been able to complete the non-parametric analysis in one dimension (we expect to overcome this shortly!). In one dimension this amounts to finding a rank ordering of all the legislators who served in Congress from 1789 - 1998 that maximizes the number of correctly classified roll call voting decisions. This can be compared to the corresponding one-dimensional DW-NOMINATE constant results.

Table 3 shows the optimal classification results. The non-parametric method improves correct classification by about 2 percent over DW-NOMINATE for the House and about 3 percent for the Senate. Although DW-NOMINATE is maximizing a likelihood function and not trying to optimize correct classification, the two methods produce similar legislator configurations. The Spearman correlation between the rank ordering of the DW-NOMINATE legislator coordinates and the rank ordering estimated by optimal classification is .981 (n=1794) for the Senate and .960 (n=10,208) for the House.[4] If only legislators who voted at least 500 times during their careers are used in calculating the correlations, then these numbers rise to .985 (n=1183) for the Senate and .972 (n=5018) for the House.

Table 3 about Here

Table 3 also reports the result of a *joint* scaling of both the House and the Senate. By making the admittedly restrictive assumption that every member of the House or Senate adopts the same ideological position throughout his or her career, the two chambers can be combined into one scaling. The Presidents since Eisenhower are included in the analysis because the Presidents can be treated as members of Congress by using the *Congressional Quarterly* Presidential support roll calls. Presumably, if the President were able to vote, he would vote the direction indicated in the support roll calls (McCarty and Poole, 1995). Consequently, Presidents Eisenhower through Clinton are treated as members of both the House and Senate. In the first 105 Congresses there were 613 legislators (counting the 9 most recent Presidents) who served in both the House and the Senate and voted at least 25 times in each chamber. These 613 legislators act as the "glue" that allows a joint rank order to be estimated for all 105 Houses and 105 Senates simultaneously. Within each chamber the joint rank ordering gives essentially the same results as the separate House and Senate rank ordered DW-NOMINATE one-dimensional constant coordinates. The Spearman correlation between the rank ordering of the DW-NOMINATE legislator coordinates and the joint House-Senate rank ordering estimated by optimal classification is .965 (n=1794) for the Senate and .952 (n=10,208) for the House. If only legislators who voted at least 500 times during their careers are considered, then the Spearman correlations are .969 (n=1317) for the Senate and .960 (n=5232) for the House.[5]

The 613 members who acted as "glue" consisted of 565 members who served first in the House and then the Senate[6], 39 members who served in the Senate and then the House, and the 9 most recent presidents who "served" in both chambers simultaneously. The Spearman correlation between the relative rankings of the 613 in the separate House and Senate overall rank orderings was .790. For the 270 who voted 500 or more times in both chambers the Spearman correlation was .846. In terms of correct classification, table 3 breaks down the correct classification for the joint scaling for just those legislators serving in only one of the chambers along with the 613 who served in both. Those serving in only one chamber have almost the same correct classification as the corresponding separate chamber classifications. For the common members, 85.46 percent of the choices of the 613 in the separate House rank ordering and 85.10 percent of the choices in the separate Senate rank ordering were correctly classified. The corresponding figure for the joint rank ordering was about a percentage point less – 84.54

percent. In short, the assumption that members maintain fixed positions when they move from one chamber to the other is reasonably supported.

Although time waits for no one, the fact that different scaling methods based upon quite different models of error produce essentially the same results as DW-NOMINATE gives us confidence that the structure we uncovered with D-NOMINATE in Congressional voting over time is substantively meaningful.

5. The Post-Reconstruction Democrat-Republican Party System: 1879-1998

Because DW-NOMINATE and D-NOMINATE produce essentially the same coordinates for the first 99 Congresses, we will confine our substantive analyses to the Post Reconstruction Democrat/Republican party system with a special focus on more recent Congresses. Unless otherwise indicated, the two-dimensional linear (5 Congresses) DW-NOMINATE coordinates are the basis of the figures and discussion below.

Figures 3 and 4 show the party means on the first and second dimensions for the House and Senate respectively. For Congresses 46 – 99 (1879 – 1986) the patterns are essentially the same as those shown in *Congress* (p. 62-63, Fig. 4.3, 4.4).[7] The most notable features are: (1) the long rightward drift of the Southern Democrats on the first dimension clearly present in both houses after World War I, followed by a reverse movement to the left that began in the late 1960s; (2) the slow drift leftward of the Republicans on the first dimension with a turn back to right beginning in the late 1960s; and (3) the emergence of a significant second dimension related to Civil Rights that split the Northern and Southern Democrats from the late 1930s onward. The rapid recession in the importance of the second dimension -- as shown in figures 1 and 2 -- reflects the realignment of the South towards the Republican Party (Carmines and Stimson, 1989; McCarty, Poole, and Rosenthal, 1997). These trends have continued through the 105th Congress in both the House and the Senate.

Figures 3 and 4 about Here

The forces driving these changes in the party means over time are the same for both chambers. The correlation between Republican first dimension means is .911 and for the Democrats the correlation is .837. The correlation of the two chamber means was .722. As we noted in *Congress* (p. 63), cross-chamber differences are affected by party ratios within the respective chambers and these tend to lower the correlation between the chamber means.

Figures 5 and 6 about Here

Figures 5 and 6 show the median rank for each of the party contingents within each chamber for the 1879-1998 period based on the joint estimation reported in Table 3. We normalized the rank ordering to a 0 to 1 scale for graphing purposes by dividing by 11,389. The patterns shown in Figures 5 and 6 are essentially the same as those for the first dimension of DW-NOMINATE. In general, the Republicans in the two chambers have been about equally conservative over time but during the past 20 years the House Republicans are a bit more conservative than their Senate counterparts. The correlation between the two is .888. During the 20th Century, the two wings of the Democratic Party have been approximately the same in both chambers. The correlation between the Democrats as a whole is .850.

Both the DW-NOMINATE and the optimal classification methods show a persistent trend towards ideological polarization within both chambers (McCarty, Poole, and Rosenthal, 1997; Poole and Rosenthal, 1984; *Congress*, chapter 4; King, 1998). The Republicans especially have taken a marked turn to the right while the Southern Democrats have become increasingly like their Northern counterparts. These patterns show up clearly in Figures 7 and 8.

Figures 7 and 8 about Here

Figures 7 and 8 show for the House and Senate respectively the average within and between party distances for the 1879-1998 period. To measure how far apart the members of the parties are – the between party distance -- we compute the average distance between all pairs of members of opposing parties. To measure the dispersion of the parties – the within party distance – we compute the average distance between all pairs of members of the same party.

The patterns shown in Figures 7 and 8 are essentially the same as those in *Congress* (p.83, fig. 4.11). Polarization declined in both chambers from roughly the beginning of the 20th Century until World War II. It was then fairly stable until the late 1970s and has been increasing steadily over the past 20 years. Our original D-NOMINATE estimation ended with the 99th Congress. Interestingly, Congresses 100-105, if anything, mark an *acceleration* of the trend. Note, however, that the acceleration is smooth and does not show a particular jump in polarization induced by the large Republican freshman class elected in 1994.

Figure 9 about Here

The increase in polarization is confirmed by the other measure of polarization we discussed in *Congress* – party overlap (p.81, Fig. 4.10). Figure 9 shows the percent overlap of the Democrat and Republican parties for the Post-Reconstruction period. Overlap is measured by the percentage of a party's members that are closer to the mean of the opposing party than to the mean of their own party. As we discuss in *Congress* (p. 81–82), the 19th Century was highly polarized in both chambers. There was almost no overlap at all. The "hump" in the Senate series that peaked in the 1920s is due to a handful of farm belt Republican Senators (*Congress*, chapters 3-5). The "hump" in both chambers from the 1940s to the late 1970s is due to the split in the Democratic Party that began in the late 1930s over civil rights for African-Americans. Because race-related issues have become increasingly ones of *income redistribution* in the past 20 years, this second dimension has evaporated (*Congress*, chapters 5 and 11; McCarty, Poole, and Rosenthal, 1997). In the past 3 Senates *there has been no overlap at all* and for the past 5 Congresses overlap is less than 1.5 percent in both chambers.

Figure 10 gives some perspective on the recent trend to polarization of the two major parties. Figure 10 is the same as Figure 7 except it has been expanded to show the three major two-party systems in American history. (We only show the House because of the small size of the Senate in the early 19th Century.) Viewed over a longer time frame, the recent trend to polarization is quite significant and the party system is now as polarized as the Federalist/Jeffersonian Republican system was during the pivotal election year of 1800. However, we are far from the levels seen during the late 19th and early 20th Centuries during the conflicts over bi-metalism and the rise of industrial capitalism.

Figure 10 about Here

Figure 10 needs to be taken with a grain of salt. It actually measures polarization during *normal two-party periods* of American history. The most divisive period of American history – the decade before the Civil War and the Civil War itself – is not shown in the graph because there was no stable two-party system through this period.

In sum, during the past 20 years there has been a clear change in the political parties in Congress. The fit of the spatial model has increased and become more one dimensional (Figures 1 and 2), and the two parties have become more homogeneous and polarized (Figures 3 to 10). We have a polarized, unidimensional Congress.

6. Congress in a Comparative Perspective

Despite its reputation for weak political parties in comparison to many other Parliamentary democracies, the unidimensional United States Congress fits the spatial model as well as most other legislatures. Table 4 shows W-NOMINATE results for the 105th House and Senate along with the United Nations and several European legislatures in the 19th and 20th Centuries.

Table 4 about Here

In terms of classification and APRE, only the Czech Parliament, the 1841 British Parliament, and the French National Assembly of the French Fourth Republic are better fits to the spatial model than the 105^{th} U.S. Congress. The best fitting legislature is the French National Assembly. Although right-wing parties had little discipline (MacRae, 1967) in the French National Assembly, the large Communist and Socialist contingents had disciplined voting that improves classification. Moreover, the left-right ideological conflict was particularly strong in France in the 1950s.

In sum, what Table 4 shows is that voting in Congress is highly ideological – one dimensional left/right, liberal versus conservative, or at least as much so as in many European settings. The political parties in Congress are, for the most part, *spatially adjacent ideological coalitions* (Krehbiel, 1993) and party *per se* does not account for much roll call voting behavior over and above the spatial model (McCarty, Poole, and Rosenthal, 1999). Party discipline does not matter in roll call voting because individual-level ideological discipline has an increasing hold over members of Congress. We do not believe that party is irrelevant. Roll call voting behavior changes fairly dramatically when legislators *change parties*. Party discipline manifests itself *in the location of the legislator's ideal point* in the standard spatial model. The legislator, in choosing a spatial location, may be responding as much to the external pressures of campaign donors and primary races as to the internal pressures of the party (McCarty, Poole, and Rosenthal, 1999).

7. Conclusion

We wrote our conclusion to *Congress* in early 1996. We ended the book with the following statement:

> “The degree of polarization in Congress is approaching levels not seen since the 1890s. Race and redistribution have merged into one voting dimension in Congress and the polarization on both has sharply increased. This heightened level of conflict will not end, even after the hard-fought 1996 elections. The collapse of the old southern Democratic Party has produced, for the first time in nearly 60 years, two sharply distinct political parties. Intense conflict between these two “new” parties will continue” (*Congress,* p. 232).

The message of this paper is that the trends we discussed in *Congress* have continued unabated. Indeed, as the intensely partisan conflict over the impeachment of President Clinton shows, the current period of polarization is far from over.[8] However, compared to some earlier periods in the history of our Republic, the polarization in recent times is not terribly severe and there are no issues on the agenda that could destabilize the political system as slavery did in the 19th Century. Only the future can tell how polarization can be reconciled with political stability.

Appendix: The DW-NOMINATE Model

Let T be the number of Congresses which are indexed by t=1,...,T; s denote the number of policy dimensions (k=1,...,s); p_t denote the number of legislators in Congress t (i=1,...,p_t); q_t denote the number of roll call votes in Congress t (j=1,...,q_t); and T_i denote the number of Congresses in which legislator i served (t=1,...,T_i). Legislator i's coordinate on dimension k at time t is given by:

$$\mathbf{x}_{ikt} = \mathbf{x}_{ik0} + \mathbf{x}_{ik1}\mathbf{t} + \mathbf{x}_{ik2}\mathbf{t}^2 + \ldots + \mathbf{x}_{ikv}\mathbf{t}^v \qquad \text{(A1)}$$

where v is the degree of the polynomial.

We confine ourselves to estimating a constant (v=0) and linear (v=1) models because we found in our work with D-NOMINATE that higher order models, v=2 and v=3, added little explanatory power.

The two roll call outcome points associated with Yea and Nay can be written in terms of their midpoint and the distance between them; namely,

$$\mathbf{z}_{jkyt} = \mathbf{z}_{mjkt} - d_{jkt} \qquad \text{and} \qquad \mathbf{z}_{jknt} = \mathbf{z}_{mjkt} + d_{jkt}$$

where, for a Yea vote, $\mathbf{z}_{jkyt}$ is the jth outcome coordinate on the kth dimension in Congress t. Similarly, $\mathbf{z}_{jknt}$ is the outcome coordinate for a Nay vote. The midpoint is simply:

$$\mathbf{z}_{mjkt} = (\mathbf{z}_{jkyt} + \mathbf{z}_{jknt})/2$$

and d_{jkt} is *half* the "distance" between Yea and Nay points on the kth dimension (note that d_{jkt} can be negative); that is

$$d_{jkt} = (\mathbf{z}_{jkyt} - \mathbf{z}_{jknt})/2$$

The outcome actually chosen by legislator i will be denoted as $\mathbf{z}_{jkct}$ and the corresponding outcome not chosen by legislator i by $\mathbf{z}_{jkbt}$.[9]

The distance of legislator i to his chosen outcome, c, on roll call j at time t is:

$$\mathbf{d^2_{ijktc} = \sum_{k=1}^{s} (x_{ikt} - z_{jktc})^2}$$

Legislator i's utility for his chosen outcome, c, on roll call j at time, t, is:

$$\mathbf{U_{ijtc} = u_{ijtc} + \epsilon_{ijtc} = \beta \exp\left[-\sum_{k=1}^{s} w_k^2 d^2_{ijktc}\right] + \epsilon_{ijtc}} \qquad \text{(A2)}$$

where $\mathbf{u_{ijtc}}$ is the deterministic portion of the utility function, $\epsilon_{\mathbf{ijtc}}$ is the stochastic portion and $\mathbf{w_k}$ are the salience weights. Because the stochastic portion of the utility function is normally distributed with constant variance, β "adjusts" for the overall noise level and is proportional to $\mathbf{1/}\sigma^{\mathbf{2}}$ where σ is the standard deviation of the ϵ**;** that is:

$$\epsilon \sim \mathbf{N(0,}\ \sigma^{\mathbf{2}}\mathbf{)}$$

Hence, the probability that legislator i votes for his chosen outcome, c, can be written in terms of the distribution function of the normal; that is,

$$\mathbf{P_{ijtc} = P(U_{ijtc} > U_{ijtb}) = P(\epsilon_{ijtb} - \epsilon_{ijtc} < u_{ijtc} - u_{ijtb}) =}$$

$$\Phi\mathbf{\left\{\beta\left(\exp\left[-\sum_{k=1}^{s} w_k^2 d^2_{ijktc}\right] - \exp\left[-\sum_{k=1}^{s} w_k^2 d^2_{ijktb}\right]\right)\right\}} \qquad \textbf{(A3)}$$

If there is no missing data then the likelihood function is:

$$\mathbf{L = \prod_{t=1}^{T} \prod_{i=1}^{p_t} \prod_{j=1}^{q_t} P_{ijtc}} \qquad \textbf{(A4)}$$

The parameters of the model can be estimated using standard maximum likelihood methods in a manner very similar to D-NOMINATE (*Congress*, Appendix A; McCarty, Poole, and Rosenthal, 1997, Appendix A).[10]

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Table 1

Classification Percentages, Proportional Reduction in Errors, and Geometric Mean Probabilities for DW-NOMINATE: 1789-1998

House of Representatives

One Dimensional Models

Model	Number of Scalable Roll Calls	Number of Scalable Reps	Number Of Parameters	Number of Choices	Percent Correct Classification	APRE	GMP
Constant	38,740[a]	10,208[b]	87,689	10,495,639	83.82	.512[c]	.709[d]
Linear	38,740	10,208	90,007	10,495,639	84.03	.518	.712

Two Dimensional Models

Model	Number of Scalable Roll Calls	Number of Scalable Reps	Number Of Parameters	Number of Choices	Percent Correct Classification	APRE	GMP
Constant	38,740	10,208	175,378	10,495,639	85.65	.567	.731
Linear	38,740	10,208	180,014	10,495,639	85.96	.577	.736
Linear 3 Cong.	38,740	10,208	184,208	10,495,639	86.08	.580	.737
Linear 3 Cong. 1 - 99	33,346	9,776	161,134	8,270,360	85.41	.561	.727

Table 1 (Cont.)

Senate

One Dimensional Models

Model	Number of Scalable Roll Calls	Number of Scalable Senators	Number Of Parameters	Number of Choices	Percent Correct Classification	APRE	GMP
Constant	41,165	1,794	84,125	2,697,691	81.46	.450	.678
Linear	41,165	1,794	84,800	2,697,691	81.87	.462	.683

Two Dimensional Models

Model	Number of Scalable Roll Calls	Number of Scalable Senators	Number Of Parameters	Number of Choices	Percent Correct Classification	APRE	GMP
Constant	41,165	1,794	168,250	2,697,691	84.04	.526	.707
Linear	41,165	1,794	169,600	2,697,691	84.40	.537	.711
Linear 3 Cong.	41,165	1,794	170,780	2,697,691	84.70	.556	.717
Linear 3 Cong. 1 - 99	37,608	1,718	156,292	2,352,453	84.42	.539	.713

[a] Roll Calls with at least 2.5% in the minority
[b] A legislator must have voted on at least 25 roll calls in at least one Congress to be included in the estimation
[c] APRE stands for Aggregate Proportional Reduction in Error. The formula is:

$$\text{APRE} = \frac{\sum_{j=1}^{q} \{\text{Minority Vote - Classification Errors}\}_j}{\sum_{j=1}^{q} \{\text{MinorityVote}\}_j}$$

[d] GMP stands for Geometric Mean Probability: The exponential of the average log –likelihood; that is: GMP = exp[log-likelihood of all observed choices/N].

Table 2

Parameter Estimates for DW-NOMINATE: 1789-1998

House

	One Dimension	Two Dimensions	
Model	b	b	**w_2**
Constant	3.983 (.0021)	4.070 (.0022)	.3131 (.00024)
Linear	4.003 (.0021)	4.125 (.0022)	.3160 (.00022)

Senate

	One Dimension	Two Dimensions	
Model	b	b	**w_2**
Constant	3.990 (.0041)	4.064 (.0043)	.3124 (.00040)
Linear	3.987 (.0043)	4.078 (.0043)	.3087 (.00039)

Table 3

Classification Analysis 1789-1998: A Single Rank Order Computed With Respect to all Congresses Simultaneously

Chamber	Number of Scalable Roll Calls	Number of Unique Scalable Legislators	Total Choices	Percent Majority	Percent Correctly Classified	APRE
House	38,740	10,208	10,495,639	66.9[a]	85.95	.576
Senate	41,165	1,794	2,697,691	66.3	84.72	.546
Joint	79,905	11,389[c]	13,193,330	66.7	85.60	.567
Joint-House[c]	38,740	9,595	9,905175	66.9	85.98	.577
Joint-Senate[c]	41,165	1,181	1,708,407	66.3	84.51	.544
Joint-Common	79,905	613	1,579,748	66.7	84.54	.545

[a] Total choices on majority side on all roll calls divided by total choices and multiplied by 100. See table 1 for notes concerning other columns.

[b] A total of 613 legislators served in *both* the House and Senate. Hence: 10,208 + 1,794 – 613 = 11,389.

[c] Includes *only* members serving in the Chamber. Members serving in both the House and Senate excluded.

Table 4

W-NOMINATE Results For the 105th Congress and Several Non-U.S. Legislatures

Legislature	Number of Scalable Roll Calls	Number Scalable Legislators	Percent Correctly Classified	APRE
105th House 1997-98	946	443	One: 88.2 Two: 89.2	One: .644 Two: .674
105th Senate 1997-98	486	101	One: 88.0 Two: 88.5	One: .642 Two: .660
Third European Parliament: 1989-94[a]	2,283	589	One: 89.8 Two: 91.3	One: .543 Two: .610
Fourth European Parliament: 1995-97[a]	2,230	704	One: 89.4 Two: 91.4	One: .536 Two: .622
1841 British Parliament[b]	186	478	One: 89.7 Two: 92.5	One: .651 Two: .748
French National Assembly, 1951-56[c]	341	645	One: 93.3 Two: 96.0	One: .818 Two: .892

34 Sessions of Czech Parliament 1993-97[d]	----	200	One: 94.2 Two: 95.7	One: .770 Two: .863
1995 Polish Parliament[e]	1791	464	One: 88.9 Two: 92.1	One: .485 Two: .630
U. N. General Assembly 1946-53[f]	383	60	One: 85.9 Two: 88.0	One: .481 Two: .558
U. N. General Assembly 1954-69[f]	662	126	One: 86.5 Two: 88.2	One: .555 Two: .614
U. N. General Assembly 1970-88[f]	2279	158	One: 90.3 Two: 91.8	One: .468 Two: .548
U. N. General Assembly 1991-96[f]	344	186	One: 91.8 Two: 93.0	One: .621 Two: .677

[a] Source: Noury (1999, Tables 1 and 2)

[b] Source: Scaling performed by authors. See Schonhardt-Bailey (1999) for an analysis.

[c] Source: Scaling performed by authors.

[d] Source: Mielcova and Noury (1997, Tables 1 and 2). The numbers given in the table are averages.

[e] Source: Scaling performed by authors. See Mercik and Mazurkiewicz (1997) for an analysis.

[f] Source: Voeten (1999, Table 2).

End Notes

[1] More precisely, a member needed to have voted 25 times in at least one Congress to be included.

[2] For a comprehensive discussion of the basic space theory of ideology see *Congress* (chapters 1 –3) and Hinich and Munger (1994). The theory is based upon the work of Ordeshook (1976) and Hinich and his colleagues (Hinich and Pollard, 1981; Enelow and Hinich, 1984; Hinich and Munger, 1997).

[3] An advantage of the Heckman-Snyder method is that it can use standard factor analysis procedures and does not require the non-linear hill climbing methods of NOMINATE. However, the technique cannot be applied to even the constant form of dynamic model since it requires no missing data in the cross-product matrix.

[4] The two methods differ in how they place legislators who are poor fits to the respective models. See Poole (1999) for a discussion.

[5] The n's for these Spearman correlations are slightly larger because the 500 roll call criteria is applied to the legislator's *career*. For example, a member could have voted 300 times in the House and 300 times in the Senate so the total for his career would be greater than 500. Hence, the increase in the n's are due to legislators who served in both chambers.

[6] This number includes two legislators who served in both chambers during a single Congress. Quentin N. Burdick (D-ND) served in the House and then the Senate during the 86th Congress and William V. Sullivan (D-MS) served in the House and then the Senate during the 55th Congress.

[7] In the graphs in *Congress* we show the 100th House and Senate. The 100th Congress roll calls were unavailable when we did our original supercomputer work (1986-88). Consequently, we scaled the 100th House and Senate separately and transformed the coordinates so they best fit the previous Congresses.

[8] A NOMINATE analysis of the impeachment proceedings can be found at http://k7moa.gsia.cmu.edu/impeachment.htm.

[9] We are obviously forcing a legislator to do thumbs up or thumbs down. Abstentions are treated as missing data and discarded. Developing a model with abstention is an important avenue of future research. For analysis of abstentions, see *Congress*, ch. 10.

[10] Note, however, that the approach of DW-NOMINATE is "probit" rather than the "logit" approach of D-NOMINATE. The change is of little practical consequence. High speed "probit" was made possible by introducing fine mesh table look up rather than repeated computation of Normal integrals. An advantage of Normal error is that it facilitates error components models for multi-member constituencies, such as the Senate. See *Congress*, ch. 6.

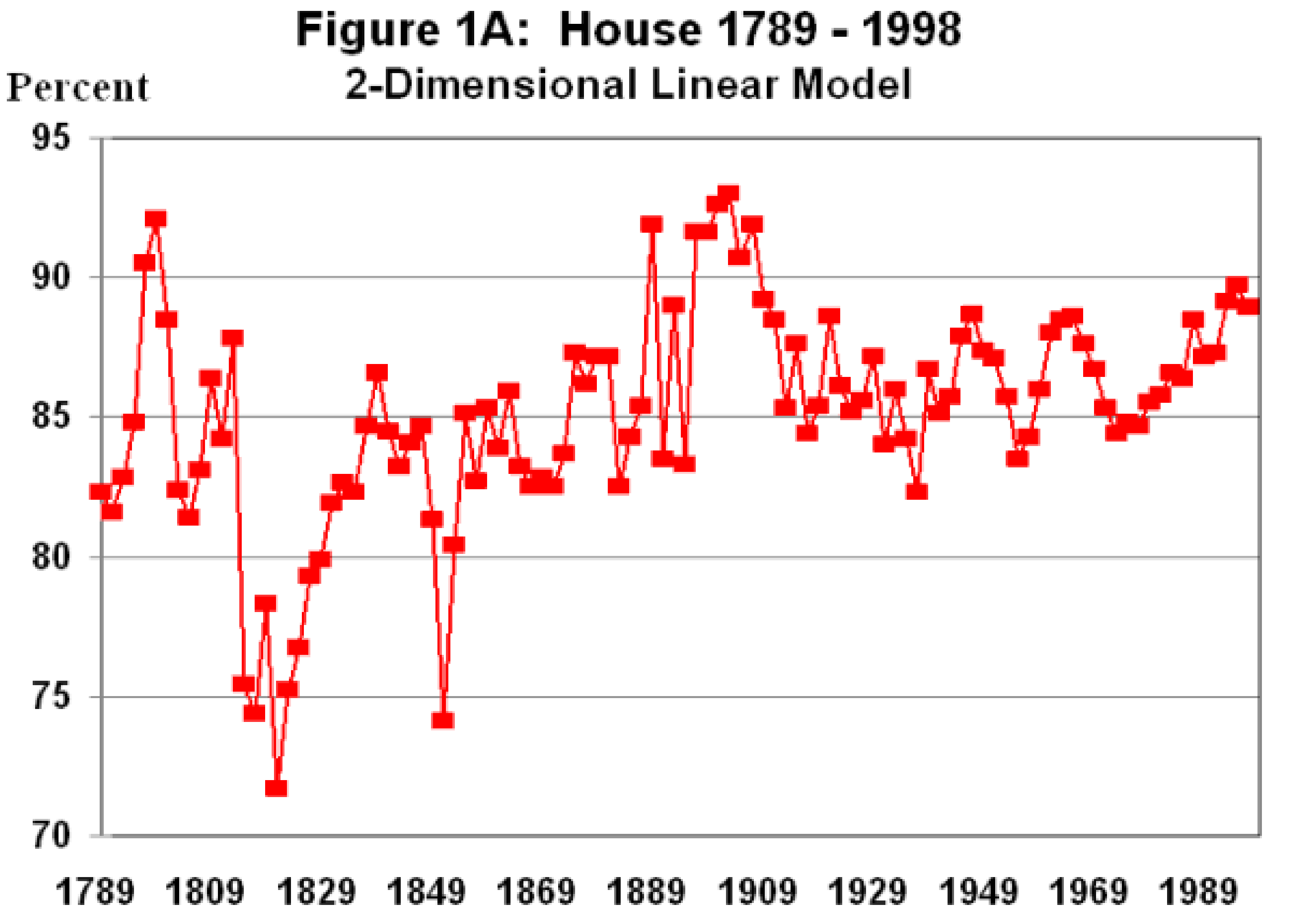
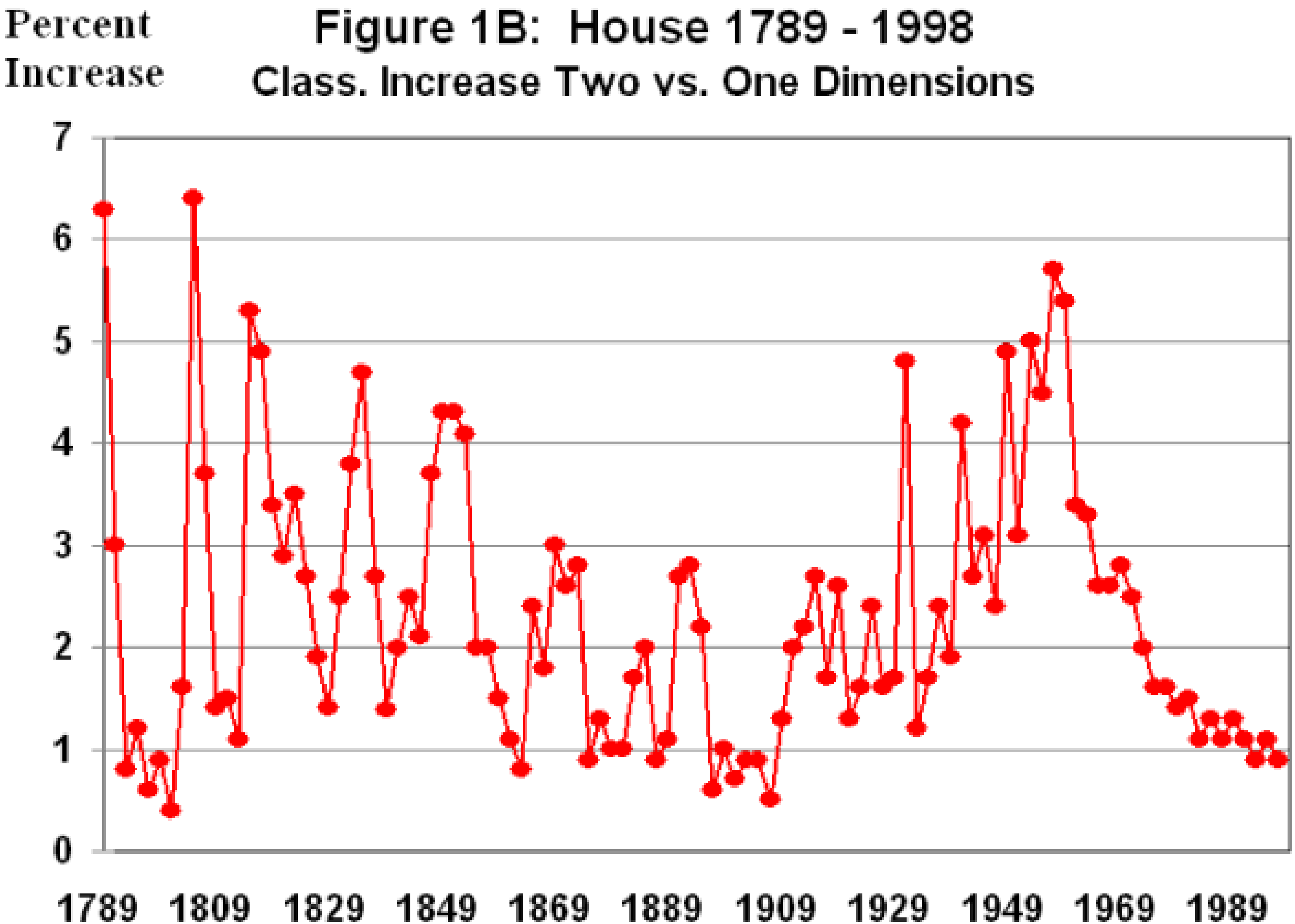


Figure 1A: House 1789 - 1998
2-Dimensional Linear Model
Percent
95
90
85
80
75
70
1789
1809
1829
1849
1869
1889
1909
1929
1949
1969
1989


Percent
Increase
Figure 1B: House 1789 - 1998
Class. Increase Two vs. One Dimensions
7
6
5
4
3
2
1
0
1789
1809
1829
1849
1869
1889
1909
1929
1949
1969
1989

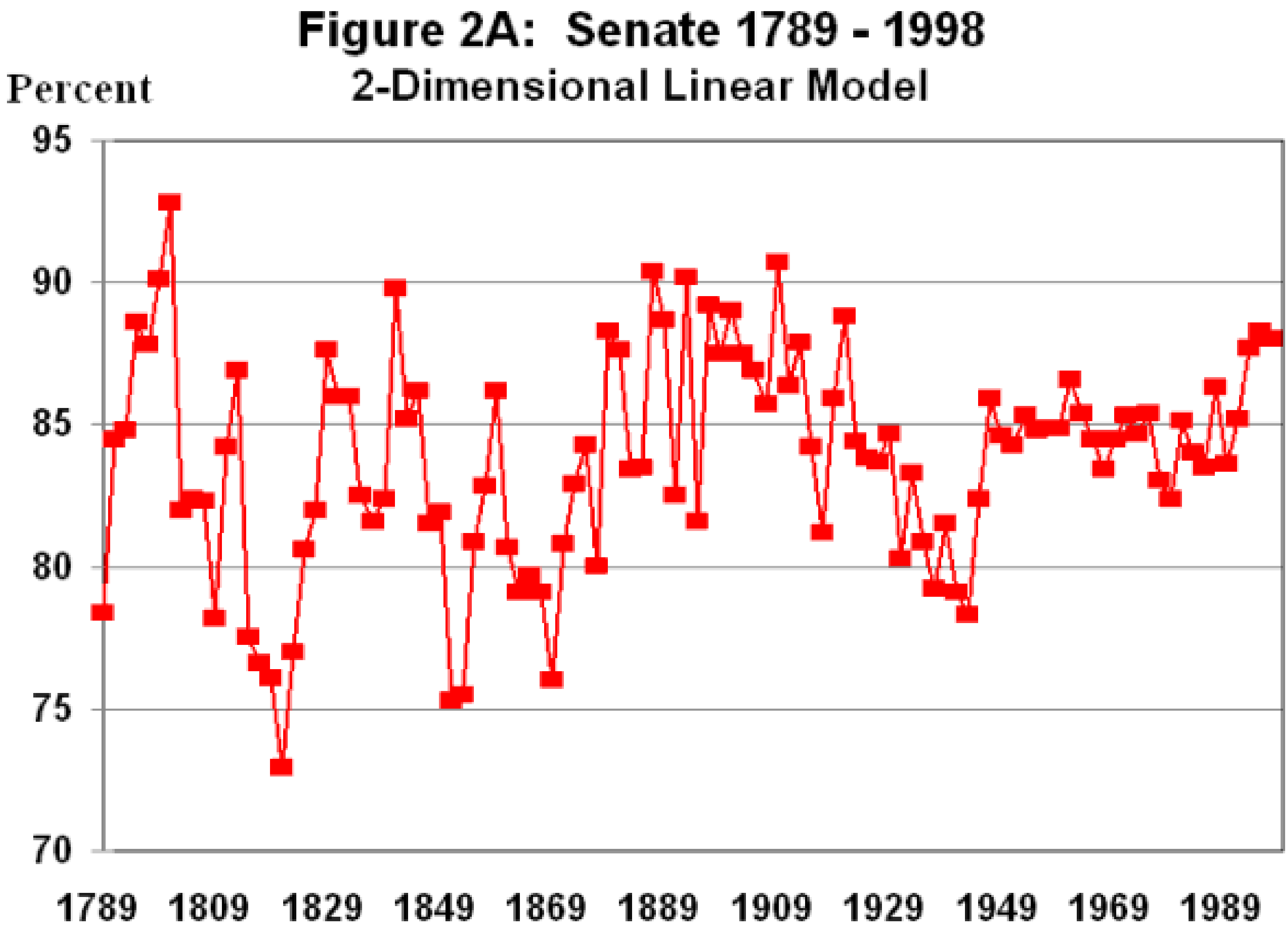


Figure 2A: Senate 1789 - 1998
2-Dimensional Linear Model
Percent
95
90
85
80
75
70
1789
1809
1829
1849
1869
1889
1909
1929
1949
1969
1989

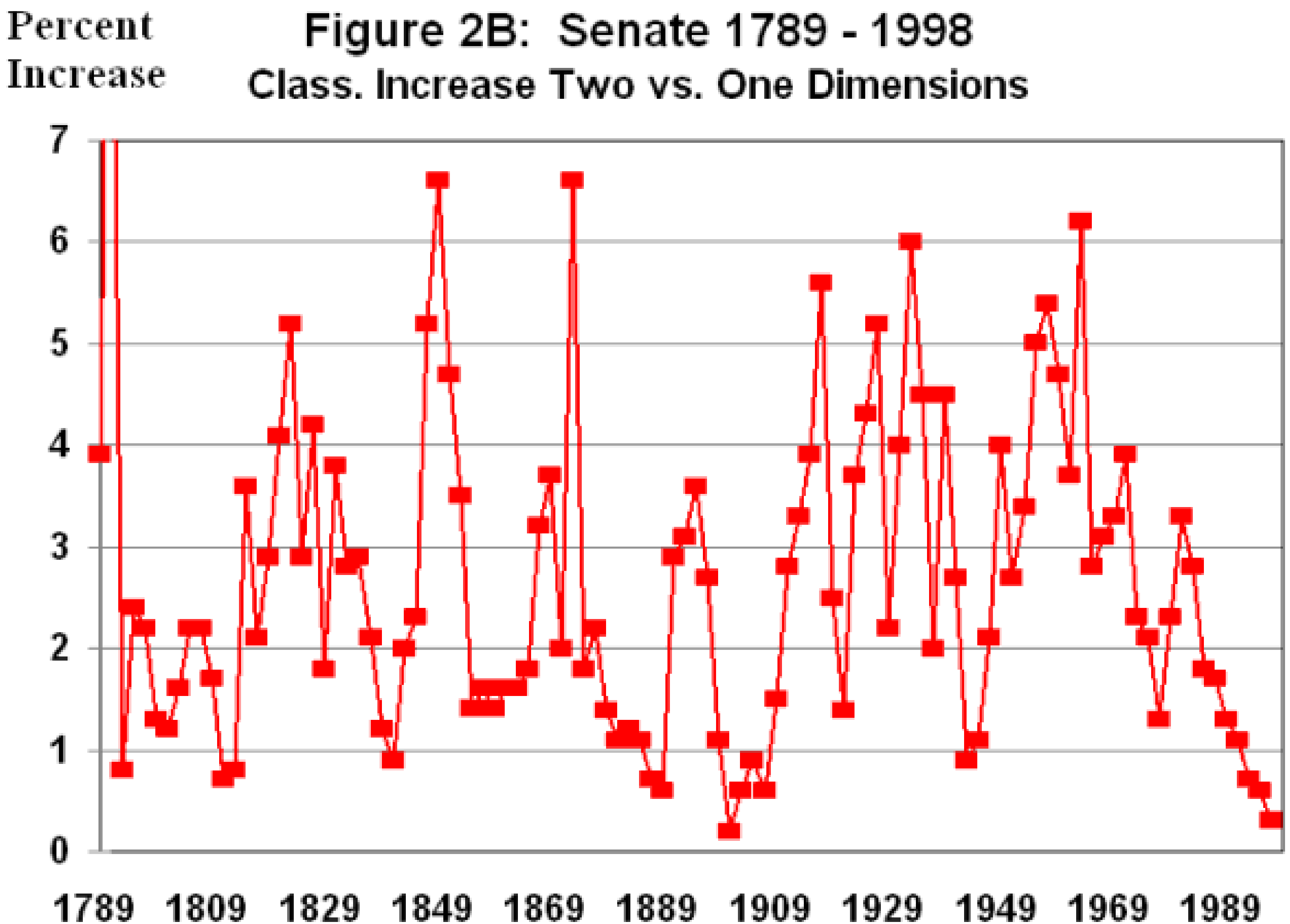

Percent
Increase
Figure 2B: Senate 1789 - 1998
Class. Increase Two vs. One Dimensions
7
6
5
4
3
2
1
0
1789
1809
1829
1849
1869
1889
1909
1929
1949
1969
1989

Figure 3A: House, First Dimension

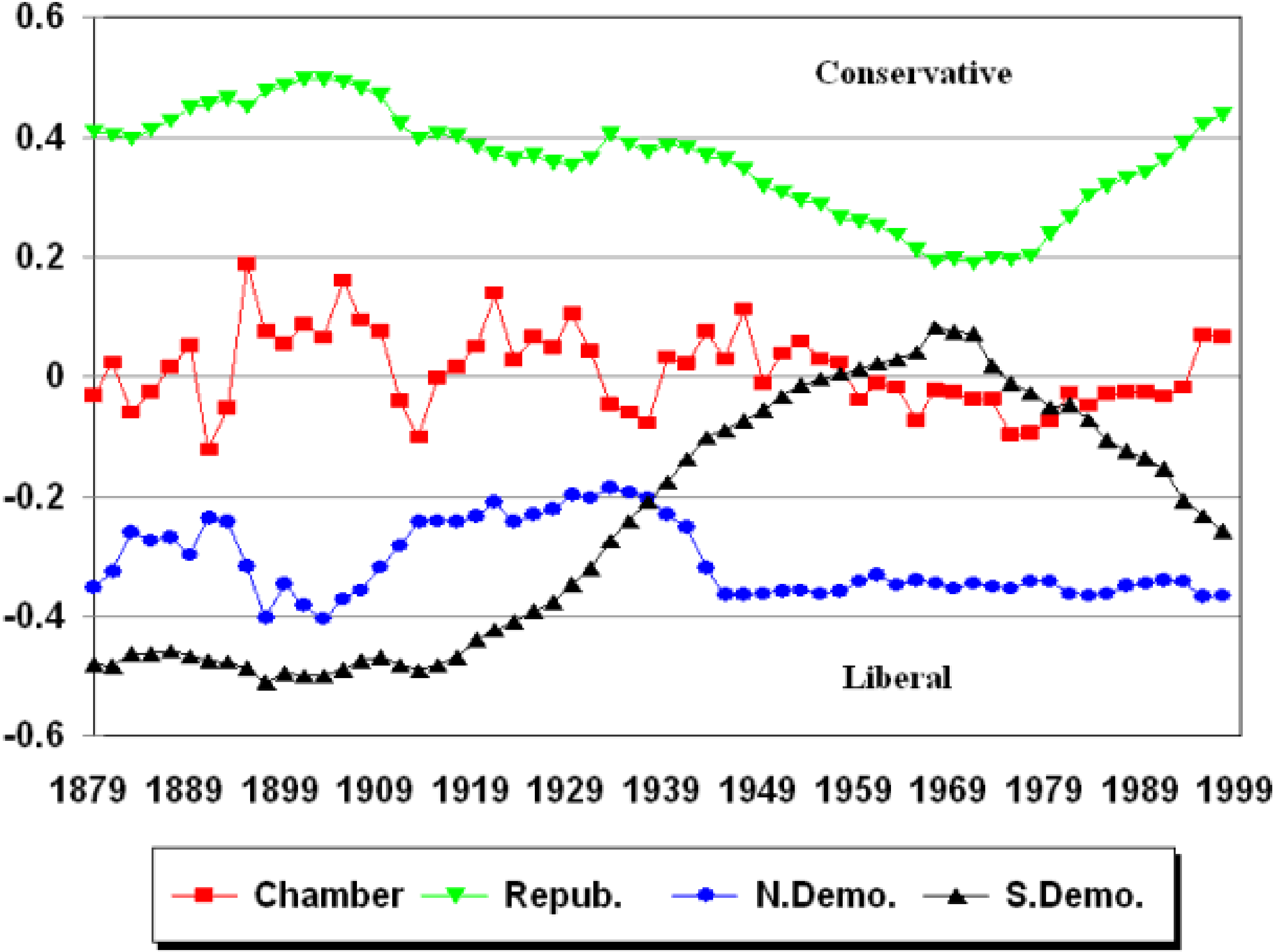


Figure 3B: House, Second Dimension

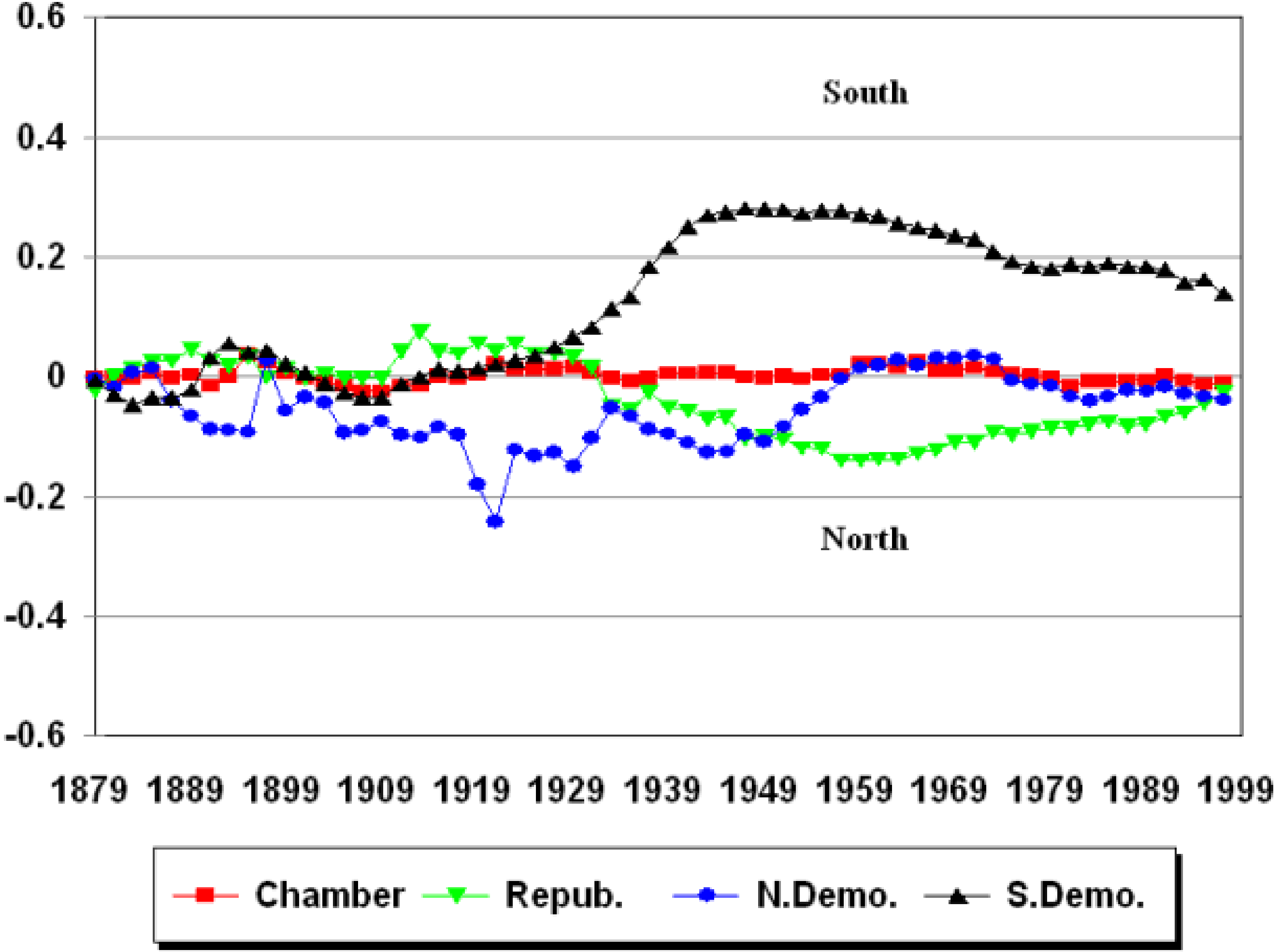


Figure 4A: Senate, First Dimension

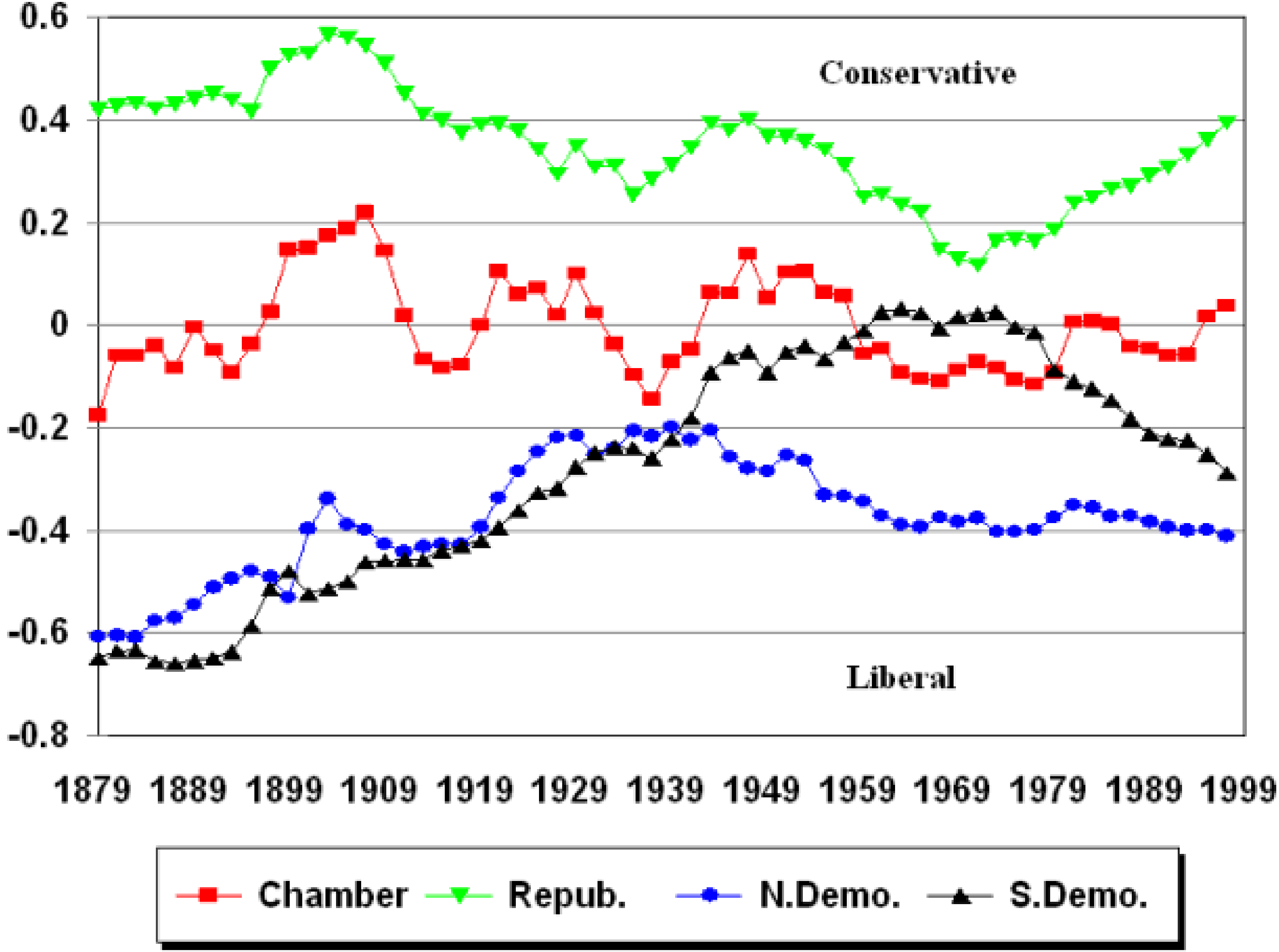


Figure 4B: Senate, Second Dimension

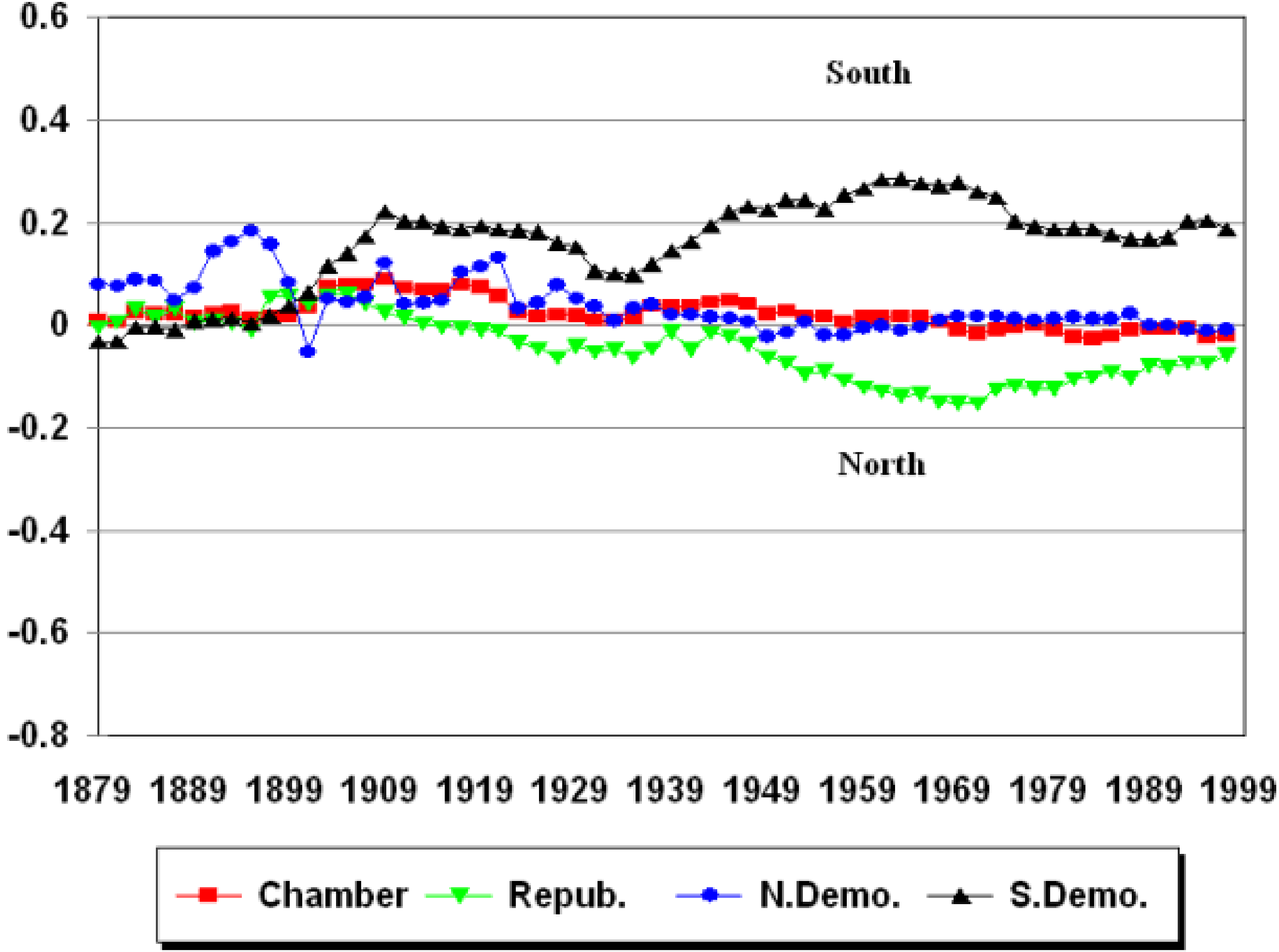


Figure 5: House, Median Ranks

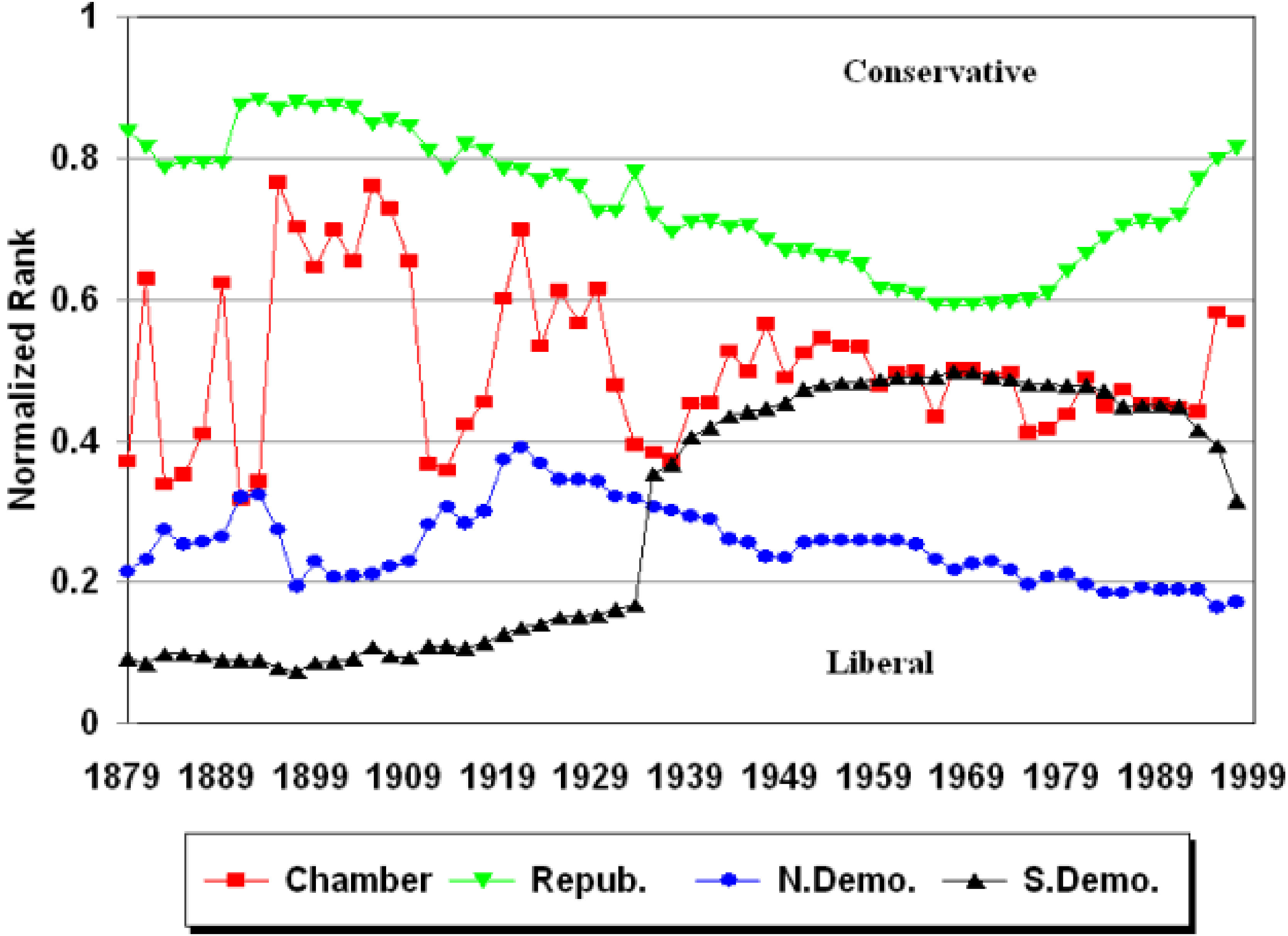


Figure 6: Senate, Median Ranks

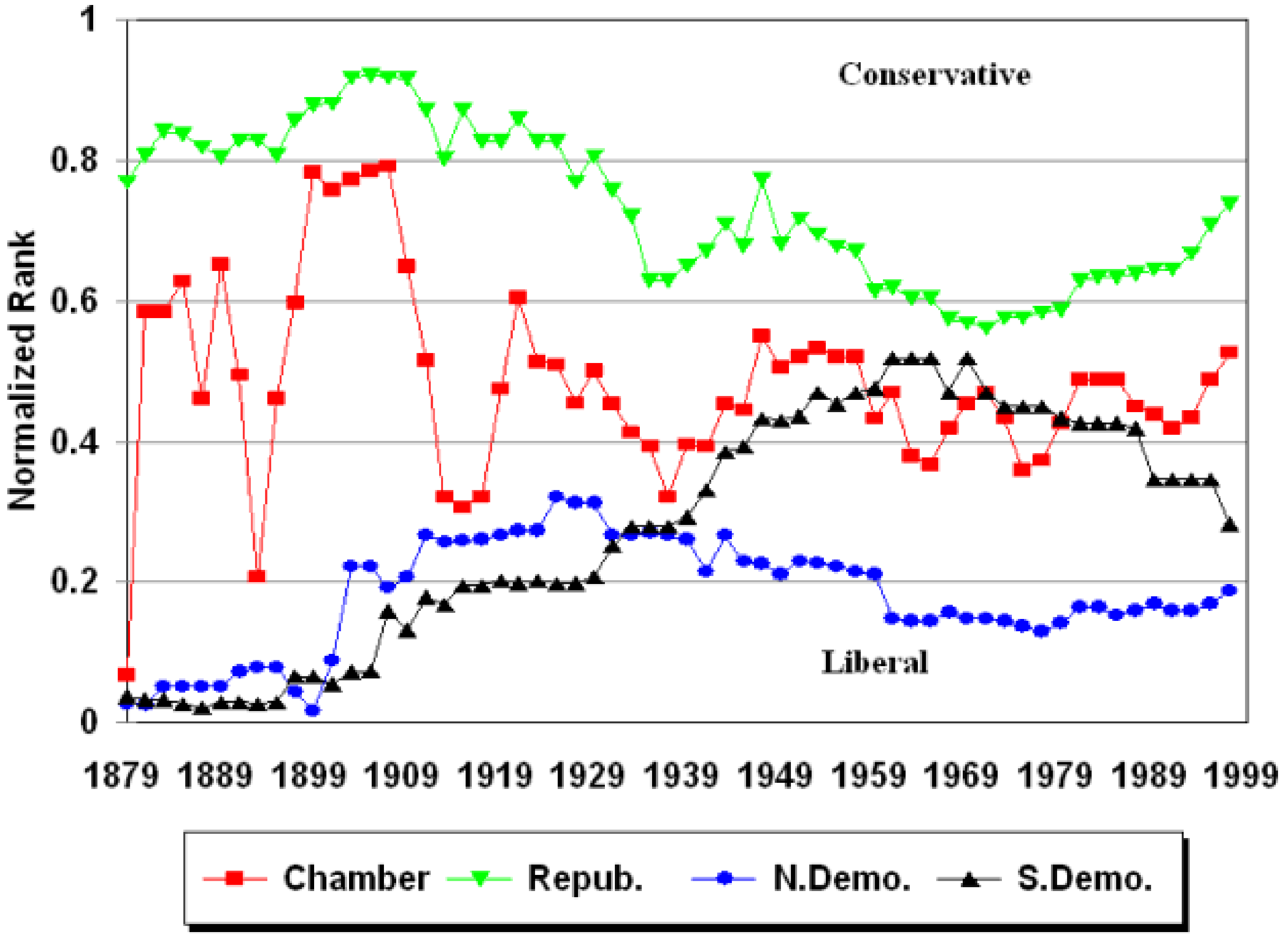


Figure 7: House, Within and Between Party Distances

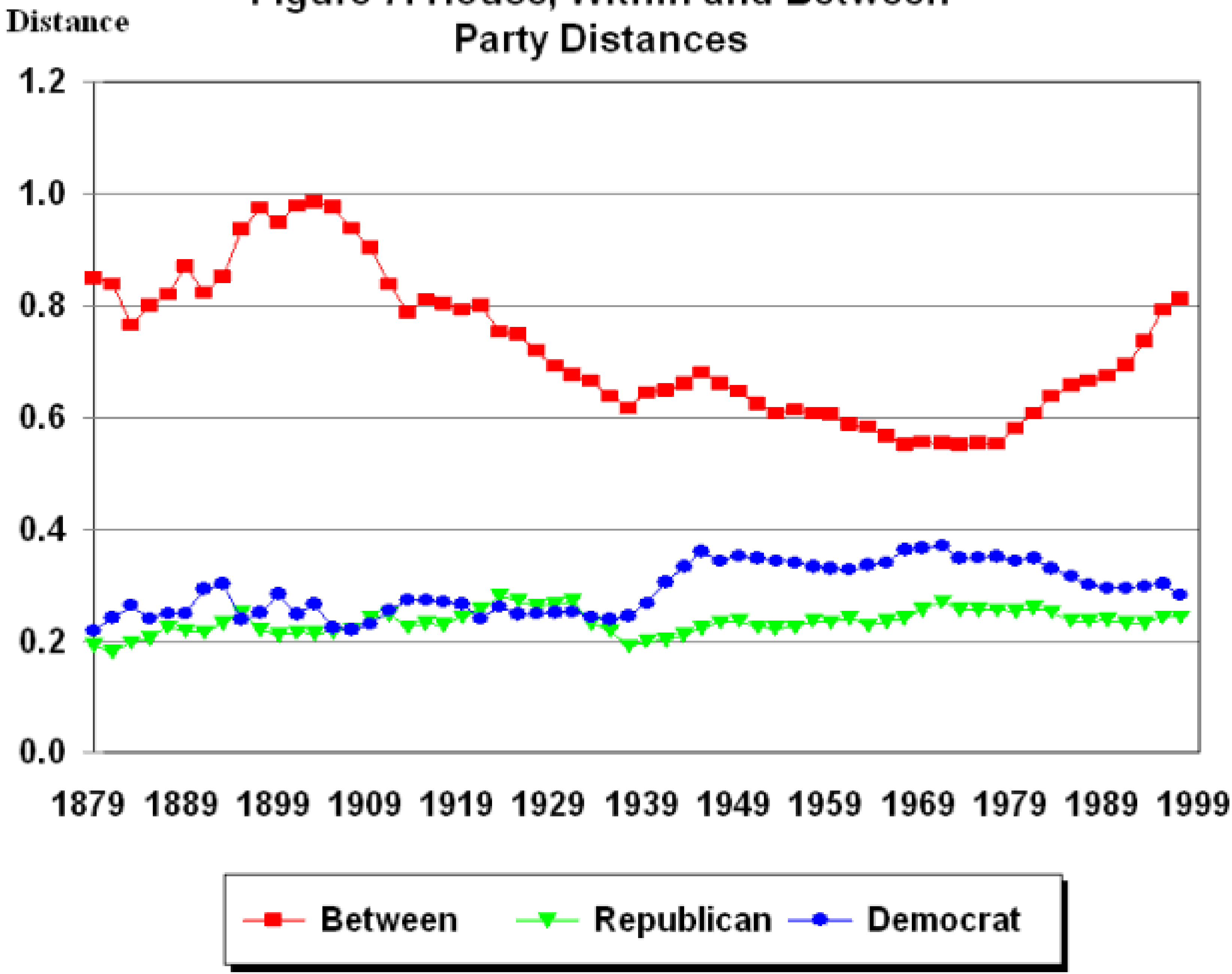


Figure 8: Senate, Within and Between Party Distances

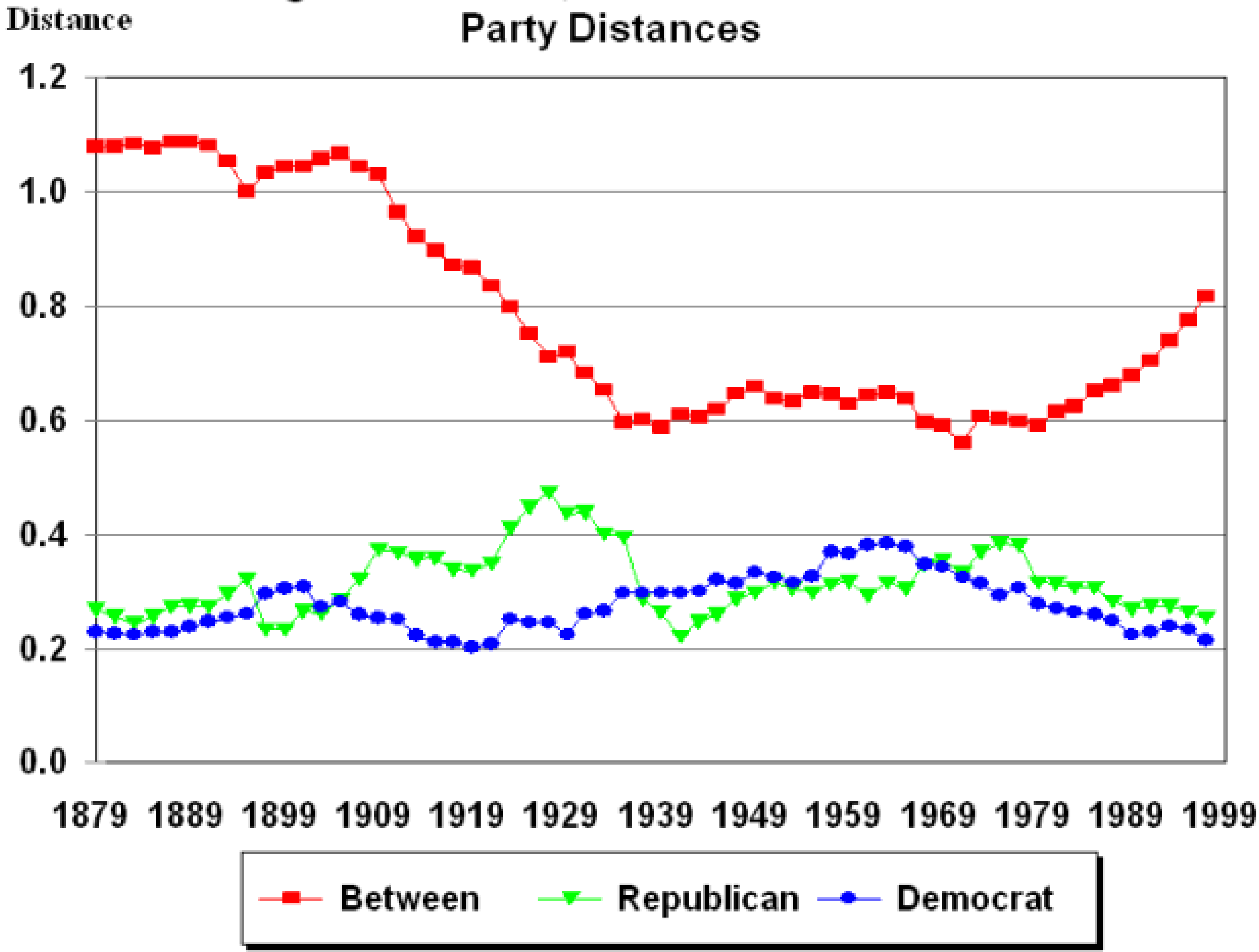
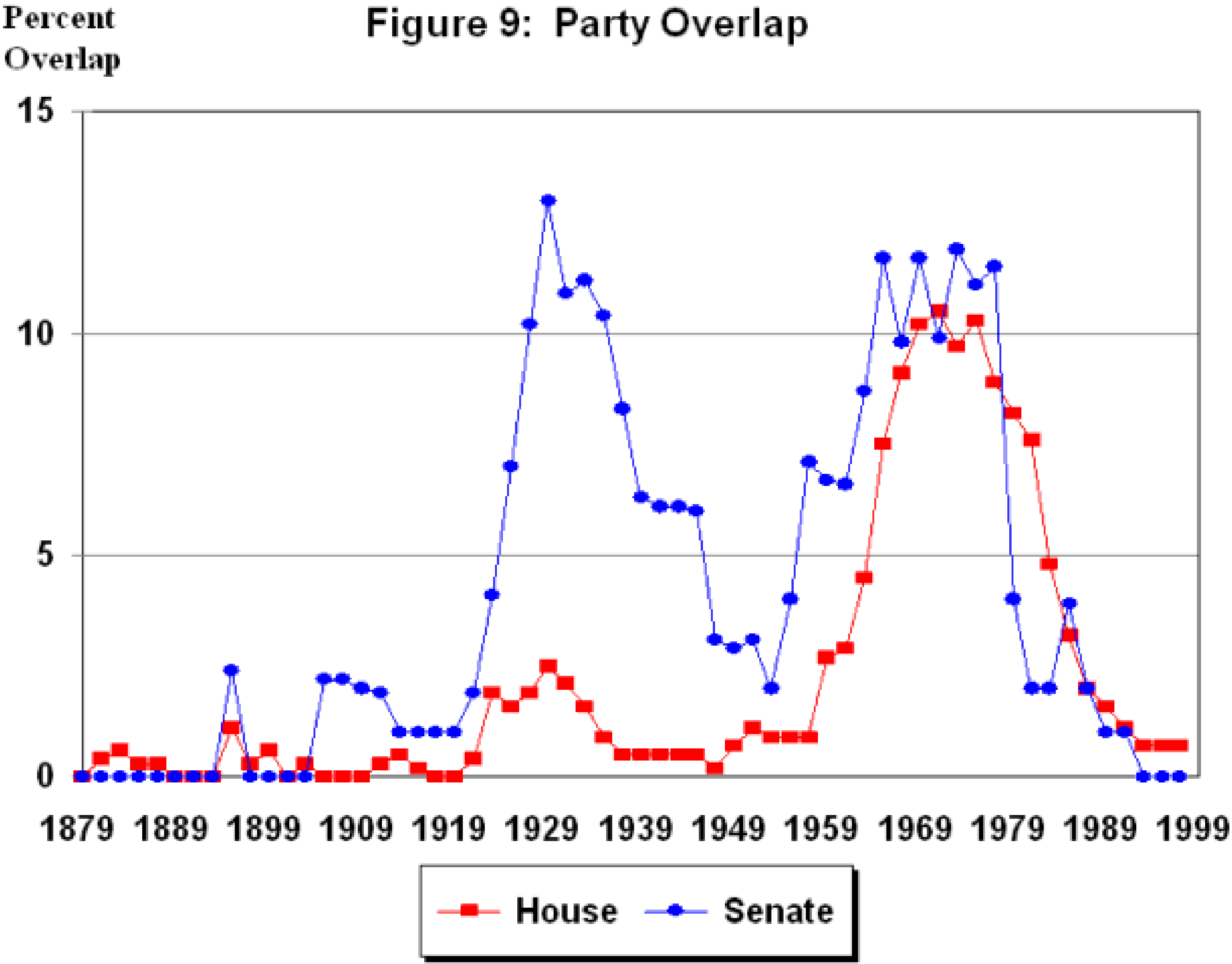


Figure 9: Party Overlap



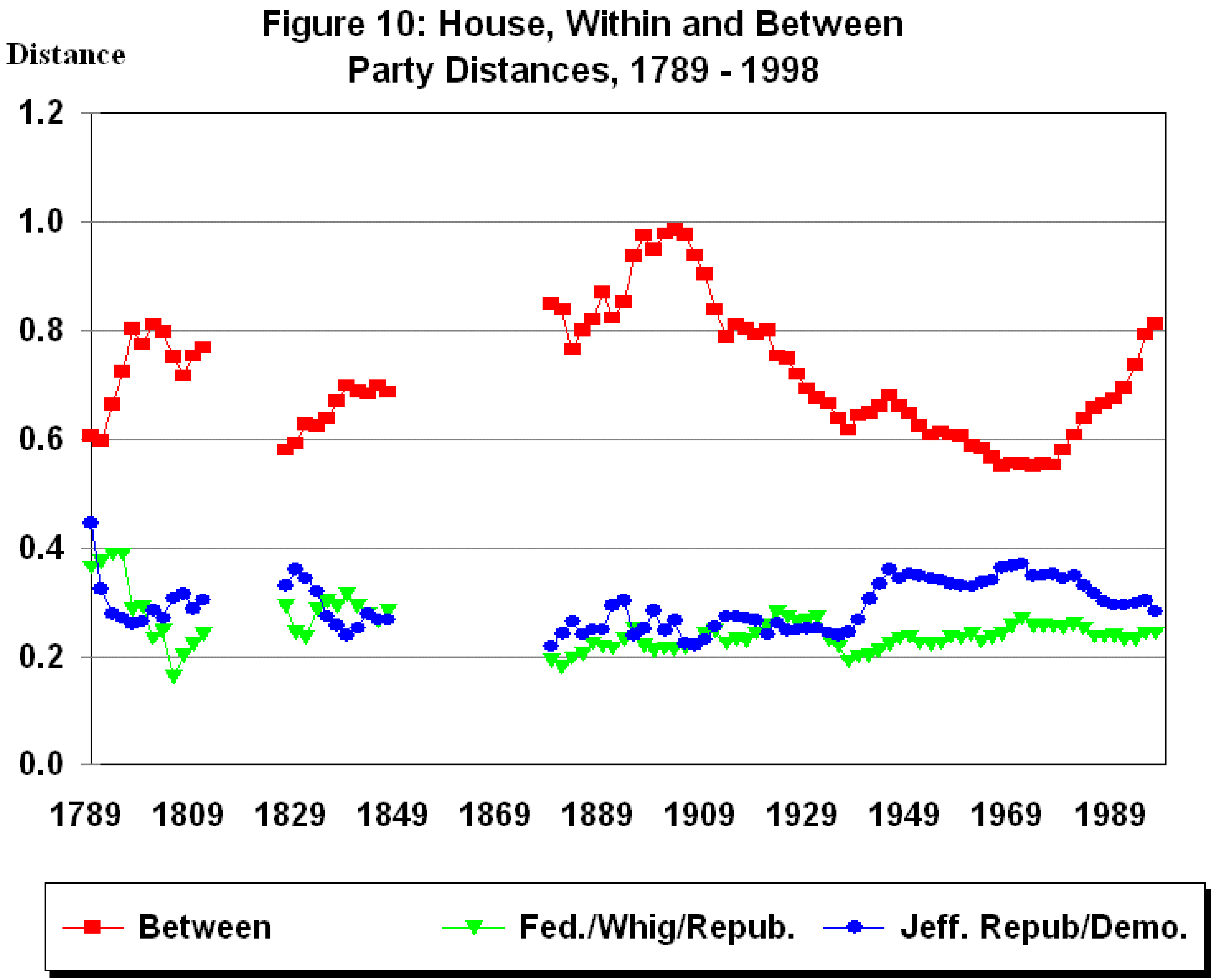


Figure 10: House, Within and Between
Party Distances, 1789 - 1998
Distance
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1789
1809
1829
1849
1869
1889
1909
1929
1949
1969
1989
Between
Fed./Whig/Repub.
Jeff. Repub/Demo.