Political Parties as Drivers of U.S. Polarization: 1927-2018

Nathan Canen, Chad Kendall, and Francesco Trebbi

June 2023

Abstract

The current polarization of elites in the U.S., particularly in Congress, is frequently ascribed to the emergence of cohorts of ideologically extreme legislators who replace moderate ones. Politicians, however, do not operate as isolated agents, driven solely by their preferences. They act within organized parties, whose leaders exert control over the rank-and-file, directing support for and against policies. This paper shows that the omission of party pressure as a driver of political polarization is consequential for our understanding of this phenomenon. We present a multi-dimensional voting model and identification strategy designed to decouple the ideological preferences of lawmakers from the pressure exerted by their party leadership. Applying this structural framework to the U.S. Congress between 1927-2018, we find that the influence of leaders over their rank-and-file has been a growing driver of polarization in legislative voting, particularly since the 1970s. In 2018, party pressure accounts for around 65% of the polarization in roll calls. Our findings qualify the interpretation of – and in some cases subvert – a number of empirical claims in the literature that measures polarization with models that lack a formal role for party organizations.

Canen: University of Houston, University of Warwick and National Bureau of Economic Research (nathan.canen@warwick.ac.uk).
Kendall: University of Southern California, Marshall School of Business, National Bureau of Economic Research (chadkend@marshall.usc.edu).
Trebbi: University of California Berkeley, Haas School of Business, National Bureau of Economic Research, Centre for Economic Policy Research (ftrebbi@berkeley.edu).

We thank David Baron, Matilde Bombardini, Kristy Buzard, Ernesto Dal Bó, Timothy Feddersen, Frederico Finan, Camilo Garcio-Jimeno, Tasos Kalandrakis, Keith Krehbiel, Vadim Marmer, Nolan McCarty, James Snyder, as well as seminar participants at various institutions for comments. Adlai Newson, Juan Felipe Riaño-Rodriguez, Federico Ricca, and Yihang Zhang provided excellent research assistance. We are grateful for funding from the Canadian Institute For Advanced Research and from the Bank of Canada.

1 Introduction

The sharp increase in political polarization over the last forty years in the United States is an uncontroversial phenomenon. In terms of political elite polarization, evidence stems from congressional voting records (McCarty, 2016), candidate survey responses (Moskowitz et al., 2017), congressional speech scores (Gentzkow et al., 2019), and campaign donation measures (Bonica, 2014). In the electorate at large, the picture appears less sharp in terms of the polarization of policy preferences of voters (Fiorina et al., 2005), but stark evidence of partisan sorting emerges more consistently in other dimensions – particularly in the affective polarization of citizens (Iyengar and Westwood, 2015; Iyengar et al., 2019; Boxell et al., 2020) and other indicators of culture (Bertrand and Kamenica, 2018) and beliefs (Alesina et al., 2020). Currently, both the political economy and political science literature characterize a context of growing mutual antagonism across political caucuses, and of increasing animus among voters identifying with different political parties (Gentzkow, 2016). Growing evidence of the adverse economic consequences of polarization also exists, arising through delay in fiscal stabilization, uncompromising obstructionism, political gridlock, and policy uncertainty due to partisan cycles and electoral shocks (Pastor and Veronesi, 2012; Baker et al., 2014; Mian et al., 2014; Davis, 2019; Binder, 2003).

To contribute to our understanding of this phenomenon, we study the role of the two main political parties and their leadership in driving elite polarization over the last ninety years in the U.S.[1] Specifically, we attempt to assess the extent of the influence that party leaders exert on the behavior of rank-and-file members, as they drive the passage of laws and create wedges across lawmakers belonging to different parties.

Within liberal democracies, political parties are more than just the sum of their individual members (Aldrich, 1995), having time horizons and strategies that span those of individual politicians. The party leadership devises, coordinates, and enacts the policy agenda (Caillaud and Tirole, 1999, 2002). In representative bodies, the relative strength, internal cohesion, and mechanisms of discipline utilized by political organizations are determinants of effective (if not efficient) policy making (Cox and McCubbins, 1993). Tight control exerted by political organizations on their members, however, may also act as an instrument of division and separation (Evans, 2018) and such divisions may be tactically valuable.[2]

In this context, we ask whether the sharp increase in polarization in congressional voting over the last forty years is the sole result of more ideologically extreme politicians replacing moderates

[1] As is typically the convention, we define the extent of polarization among members of Congress as the distance between the ideological medians of the two parties.

[2] E.g. Newt Gingrich, the architect of the 1994 Republican Revolution and former Party Whip, notably stated in 1984: "*The No. 1 fact about the news media is they love fights ... When you give them confrontations, you get attention; when you get attention, you can educate.*"

(Poole and Rosenthal, 1997; McCarty et al., 2006; Moskowitz et al., 2017), or whether strategic party pressure also plays a role in the progressive separation between partisan camps (Sinclair, 2014; Stonecash, 2018; Canen et al., 2020). How much pressure do the leaders of the U.S. parties of today exercise on their rank-and-file, by influencing member behavior and pulling them away from the middle ground (Snyder and Groseclose, 2000; Forgette, 2004)? How has the role of parties evolved over time or around structural breaks in political strategies?[3]

Because the decisions of politicians are functions of both their unobserved individual policy preferences (their "ideologies") and the (often unobserved) influence exerted by their political organizations, quantifying the role of these different drivers of behavior is nontrivial on grounds of identification (Krehbiel, 1993, 1999, 2000).

In previous work, Canen et al. (2020) leverage confidential party records for identification, showing that party pressure is an important component of political polarization in the decade between 1977 and 1986.[4] Because these detailed internal records are only available for the House of Representatives for that specific decade, however, this identification strategy does not generalize. That is, it cannot be used to systematically study how party pressure has evolved over the long term, one of the main goals of this work.

In this paper, we develop a novel, more general identification strategy that requires information on congressional vote choices ("roll call" votes in the terminology of the U.S. legislative branch) and on the party leadership positions on each vote.[5] With this method, we are able to address questions of how party control drives polarization over the last century.[6] Furthermore, because we study party pressure over periods in which a second dimension of policy preferences (in addition to the standard liberal-conservative ideological dimension) is relevant (e.g. the Civil Rights era), our approach incorporates multiple policy dimensions. This extension turns out to be non-trivial from the perspective of identification relative to the one-dimensional approach of Canen et al. (2020).

Focusing on congressional roll calls, we show how information about the direction of pressure implied by leaders' votes can be combined with an economic model of legislative choice to recover parameters related to the disciplining technology of each party. Our definition of party pressure is that of a set of features indicative of the organizational strength of the party. This may include

[3] See Jenkins (2011).

[4] The use of internal party records (i.e. whip counts by the leadership) in Canen et al. (2020) also allowed us to identify a rich model of agenda-setting to determine which bills are pursued by the party and which are dropped, and to produce counterfactuals demonstrating how this selection process interacts with the technology of party pressure. Absent whip counts, we do not have sufficient information to study agenda-setting over the last century. Thus, while we allow for a general form of agenda-setting in our empirical model, a quantitative assessment of policy counterfactuals over the 1927-2019 period is beyond the scope of this paper.

[5] As such, the method is applicable to any institution for which voting data is available and the direction of potential influence (via party leadership, special interests, etc.) is known.

[6] Reassuringly, in the subsample overlapping with Canen et al. (2020), we find very similar measures of party pressure, validating our identification strategy.

whipping (i.e. the ability of the party leadership to punish or reward members to tow the party line), timely information aggregation/sharing within the party hierarchy, peer pressure, and organizational culture – none of which are typically part of empirical voting models.[7] We parameterize party pressure by how far the party organization is able reach within the set of dissident members, to persuade them to vote with the leadership on occasions when they would not do so otherwise.[8]

The data consists of multiple votes of individual politicians observed over a series of bills. To build intuition on how the ideology and party pressure parameters are identified, consider a one-dimensional policy space where we observe the voting decisions of each member of Congress on whether or not they support a bill designed to change the status quo. As in standard models (Poole and Rosenthal, 1997; Heckman and Snyder, 1997; Clinton et al., 2004), one can apply a random utility framework to individual i's vote choices over multiple bills to identify and obtain consistent estimates of the preference parameters, θ_i, and of the bill-specific cutlines - the locations of hypothetical members that are indifferent between the proposed policy and the status quo. Importantly though, when parties can change the votes of their members, the cutlines will be party-specific, and the estimates of ideologies will be identified only *within* each party. Without further structure, the distance between the ideologies of members of different parties and the strength of parties cannot be separated.

Our model adds this additional structure in a straightforward way. Specifically, we assume each party can switch the votes of members only within a distance of y_p^{max} (for $p = D, R$) from the overall indifferent voter (the cutline in a model without party pressure; see Figures 1 and 2). Thus, y_p^{max} serves as a measure of the reach/strength of party p. This additional structure, combined with the fact that we observe, through the leaderships' votes on each bill, the directions in the policy space that each party prefers, allows us to identify the true polarization between parties (denoted $\triangle\theta$ and capturing the ideological distance across party members), as well as the strength of each party (y_p^{max}). Specifically, if party D supports the policy and pressures its members to vote Yes, and party R does the opposite, the difference in the Yes vote probabilities between parties is determined by $\Delta\theta + y_D^{max} + y_R^{max}$. This difference in probabilities increases in ideological polarization, increases in the strength in party D (because a Yes vote by a member of D becomes more likely), and increases in the strength of party R (because a Yes vote by a member of party R becomes less likely). If instead, both parties support the policy, this difference in vote probabilities is determined by $\Delta\theta + y_D^{max} - y_R^{max}$, and if both parties oppose the policy, it becomes $\Delta\theta - y_D^{max} + y_R^{max}$. Then, under the assumption that parties apply pressure to their members even when parties agree, we obtain three linearly independent equations from which the extent of

[7]Completely distinguishing the various subcomponents that make up party pressure would require detailed data that we do not possess. We do provide evidence that party leadership plays an explicit role (i.e. whipping versus peer pressure) through several extensions of the model.

[8]See Evans (2018).

polarization, $\Delta\theta$, as well each of the party strengths, y_D^{max} and y_R^{max}, are identified. Alternatively, if parties do not apply pressure when they agree, $\Delta\theta$, is identified directly from this subset of bills. Then, $y_D^{max} + y_R^{max}$ is identified from the subset of bills on which they disagree (the individual party strengths cannot be identified in this case). We can thus obtain unbiased estimates of polarization and party strength under different assumptions about exactly how and when party pressure is applied and without requiring that every politician is disciplined.[9]

For the more complex two-dimensional policy space, we constructively prove that our approach resolves the identification problem of separating politicians' preferences from the pressure exercised on them by their parties.[10] Although Cox and McCubbins (1993) discuss leadership votes in their analysis of party organizations and McCarty et al. (2001) allow for party-specific cutlines in assessing model fit,[11] the intuition of jointly using these insights is the key to identifying the model. In our formalization, we also clarify the role of agenda-setting for inference in our environment, showing that, under reasonable assumptions, the exact agenda-setting process need not be modeled – the model is identified regardless of which bills are proposed and when they are brought to the floor.[12]

Unlike our model, we show that formal identification results in a multi-dimensional setting (even absent a role for parties) are unavailable for what is arguably one of the most influential methods in the literature, DW-Nominate (Poole and Rosenthal, 1984, 1997), a statistical approach designed to recover policy preferences of legislators from a random utility framework within a spatial context similar to ours.[13] Because of DW-Nominate's relevance to the literature, in Appendix B we prove

[9] We can also identify both $\Delta\theta$ and $y_D^{max} + y_R^{max}$ using only bills where the two parties disagree, leveraging differences in the directions of pressure across bills.

[10] Typically, a first dimension of preferences captures the liberal-conservative stance on economic issues, while the second dimension is associated with other socio-cultural facets of policy (such as attitudes towards Civil and Voting Rights).

[11] The use of party-specific cutlines as in McCarty et al. (2001) is in itself insufficient for identification because data on leadership preferences, as well as variation in the exertion of party pressure, is required to separate party pressure from the degree of polarization, as the above discussion makes clear. More to this contribution, McCarty et al. (2001) focus on the gain in correctly predicting vote choices obtained by increasing the number of cutlines from one to two. Their argument is that party pressure may be accounted for by allowing party-specific cutlines and they argue that party pressure is of minimal quantitative importance, as this increase to two cutlines produces a minimal gain in fit. There are two issues with this argument. First, party pressure cannot be simply accounted for by allowing different cutlines without information about the direction of the leaders' pressure, as proven in our analysis. Second, assessing ideological polarization requires estimating the absolute distance between the two party distributions, but similar degrees of predictive accuracy can be obtained by ideal point distributions that are arbitrarily distant from each other. Therefore, focusing on predictive accuracy per se is not an appropriate metric for assessing whether or not omitting party pressure is of quantitative importance to the consistent estimation of ideal points (and hence of ideological polarization).

[12] We conduct Monte Carlo simulations to further bolster this theoretical claim. See Appendix E.

[13] Rivers (2003) proves a similar results for the special case of a random utility model with quadratic two-dimensional preferences. His identification result does not apply to the standard DW-Nominate method, which employs non-convex preferences within a random utility choice framework and multiple policy dimensions. Rivers (2003) is related to, but also does not apply to, the IDEAL estimator of Clinton et al. (2004). We expand on this

the lack of identification of the DW-Nominate two-dimensional case, and clarify the features of our methodology that allow us to improve upon this established approach.

When estimating our model with a large likelihood-based estimator, our principal finding is that political party influence bears a substantial weight in driving observed polarization in congressional voting behavior, a result which is robust to the assumption about whether or not parties exercise pressure on bills on which they both agree. We find substantially less ideological polarization than extant methodologies which omit a role for parties and show that the leaderships of both parties have played a similar role in driving an increasing wedge between the two parties. From the discussion above, we see that a misspecified model without a role for parties mistakenly loads the role of party pressure on the difference in preferences between parties, increasing the true difference, $\Delta\theta$, to $\Delta\theta + y_R^{max} + y_D^{max}$.[14] We estimate this misspecified model without a role of parties, and reject it against our baseline model at high confidence levels in every congressional cycle in our sample. We also show that the misattribution of party pressure to ideological polarization is large from a quantitative perspective.

In a second finding, we find that the ability of parties to push the leadership's line and forge internal rules has varied quantitatively (and non-monotonically) over time, both in the House and Senate. The low point of party pressure appears around the second half of the 1960s, during the Civil Rights Era, and early 1970s. In the early part of the 1980s, an increment in party pressure starts to appear and a sharp increment is detected after the mid-1990s, the time of Newt Gingrich's speakership and the Republican Revolution.[15] We also do not find support for the theory that the present levels of ideological polarization have been previously observed. Our results suggest, instead, that the U.S. Congress is currently in a period of unprecedented ideological polarization and of strong party pressure. By comparison, in the post-war period, while party pressure was high, ideological polarization was lower than today.

Overall, we find party leaders have been responsible for a significant share of polarization in congressional voting – conservatively 65% in the last decade in both the Senate and in the House – and the phenomenon appears fairly symmetric between the parties. These findings are present in both the one-dimensional and in the two-dimensional versions of our model. We also find that party pressure over the same period of time accounts for an extra 10 percentage points in the predicted fraction of votes that pin the majority of one party against the majority of the other party, corresponding to a substantial increase in the number of adversarial roll calls in Congress

discussion in Section 2.

[14]When a misspecified model forces a single cutline instead of party-specific cutlines, it forces an adjustment the ideology estimates to compensate. This adjustment overestimates polarization, but attains the same level of model fit. It is for this reason that model fit comparisons (as in McCarty et al. (2001)) are not an accurate means of assessing the strength of parties.

[15]This finding appears in line with extant quantitative, but less systematic evidence, e.g. Sinclair (2014), as well as Theriault and Rohde (2011); Theriault (2013).

(a 20% increase for the levels of party pressure present in 2018).

Having estimates of party pressure over time allows us to investigate the technology of internal party organization around known structural breaks (Theriault, 2013) and how it is affected by majority size and divided government. We therefore discuss which theories of party influence are consistent with our estimates (Smith, 2007), particularly with respect to the correlation of party and time varying within-party heterogeneity. Our findings are consistent with leading theories of party organization. This includes parties as effective organizers of policy for a common objective (i.e., controlling legislation for branding, as in Cox and McCubbins 1993, 2005) and, especially, the Conditional Party Government theory of Aldrich (1995) and Rohde (1991).[16] In line with the latter, we observe that increases in party strength appear positively correlated with within party ideological homogeneity (the variance of ideologies within a party).

Existing results from the literature emphasize asymmetric polarization, with a greater contribution to the increase coming from more extreme Republicans than more extreme Democrats. We instead find that Republicans and Democrats are both becoming more extreme at roughly the same pace. We attribute the difference to marginally higher Republican party pressure which, when ignored, shows up as more extreme members. However, we also note that the strengths of the parties tend to track each other closely over time. A conjecture is that technological innovations in political strategy may be an important piece of the explanation: when one party favorably innovates in its internal organization, the other party can follow closely by imitation. This hypothesis is consistent with qualitative and quantitative evidence on the spread of technological political innovation, both within the U.S. system and abroad.[17]

This paper relates to several strands of literature. Mayhew (2004) presents U.S. parties as exerting weak control and the members of Congress as having limited party loyalty. The debate on decoupling the drivers of political polarization is active (Moskowitz et al., 2017), and explicitly linked to economically consequential phenomena, such as changes in income inequality over time (e.g. McCarty et al., 2006, but also Rajan, 2011), the policy response to financial crises (Mian et al., 2014), policy uncertainty (Davis, 2019), and legislative gridlock more generally (Binder,

[16] The latter states that as parties become more homogeneous, party members are willing to delegate more (agenda-setting and control) power to party leaders, they will be more likely to get bills approved that are in the interest of a majority of the party. Our evidence supports this explanation over the past ninety years.

[17] Examples include the use of coordinated partisan vocabularies by the 1994 Revolution Republicans (e.g. Gentzkow et al., 2019), a practice also followed by Democrats, and by the simultaneous adoption of focus-group-tested language and messaging. This may also explain the diffusion of political strategies and tactics across political systems due to the international visibility of the U.S. system. For example, in 2001 Prime Minister Silvio Berlusconi in Italy hired strategist Frank Luntz, who inspired the 1994 Contract with America, and transposed the Republican public relations approach to the Italian context (see Luntz, 2007, p.138). President Emmanuel Macron of France notoriously adopted campaigning techniques form the 2008 Obama campaign. Another example appears to be the diffusion of certain strategies adopted by the Trump campaign to other populist movements in Europe and Latin America. These examples suggest a potential mechanism through which U.S. party-driven political polarization may spread internationally, via imitation of internal organization and branding tactics.

2003).

Snyder and Groseclose (2000) and Ansolabehere et al. (2001b) were among the first empirical contributions to spell out the quantitative implications of omitting political parties from the analysis of roll calls. Snyder and Groseclose (2000) focused on the exclusion of lopsided legislative bills from party discipline as an identification strategy to estimate party pressure, while Ansolabehere et al. (2001b) employed a contrast between roll call behavior and the National Political Awareness Test surveys of politicians' preferences. As a result of our identification method, we differ in many respects from these and other extant empirical approaches to the study of parties and political polarization. Alternative identification approaches include, to cite just a few prominent examples, the use of historical natural experiments during the American Civil War (Jenkins, 2000), functional form identification of voting models with heterogeneous legislators (Levitt, 1996; Poole and Rosenthal, 1997; Heckman and Snyder, 1997; McCarty et al., 2001; Clinton et al., 2004), and the use of detailed internal party records (Evans, 2018; Canen et al., 2020). We provide detailed comparisons to extant methodologies in Section 2.6.

This paper also relates to works on the study of political organizations. Parties play a crucial role in agenda-setting and in drafting statutes (Cox and McCubbins, 1993; Aldrich, 1995; Cox and McCubbins, 2005). Their leadership also systematically organizes and coordinates members' political behavior (Smith, 2007): setting policy platforms (Caillaud and Tirole, 2002), coordinating internal communication and the whipping of votes (Meinke, 2008; Evans, 2018), and coordinating policies so that politicians can manage the trade-off between policies and re-electability (Van Houweling, 2003). Making explicit the empirical role of these dimensions, which are latent and unobserved relative to the formal operations of government, has been an open question in political economy and political science for decades. It has resulted in a rich, but far from complete line of inquiry.[18] We contribute with an economic model and a structural estimation approach designed to consistently infer the extent of party influence over the last century in the U.S., one which is also applicable to other contexts.

Providing a measure for the degree of control exercised by one party against the other is important because it offers evidence of elite organizations driving partisan separation though action that is strategic and deliberate (Smith, 2007; Evans, 2011). These political actions may take additional forms that we do not explore here, but our time series evidence in recent times is consistent with a contemporaneous role for elites in driving systematic wedges in public opinion (Robison and Mullinix, 2016; Alesina et al., 2020) in part through the use of divisive speech (Gentzkow et al., 2019), which may ultimately manifest in affective polarization across voters.

[18]Most prominently, see Snyder and Groseclose (2000), but also see McCarty et al. (2001) for a critique of that approach. For a detailed discussion of the complexity and identification issues of party influence in the context of the U.S. Congress see Krehbiel (1993, 1999) and Cox and McCubbins (1993). For related work on the decomposition of polarization trends, see the analyses in Theriault (2008); Moskowitz et al. (2017).

2 Empirical Model

2.1 Setup

Legislators $i = 1, ..., N$, where N is large, belong to one of two parties $p \in \{D, R\}$.[19] Each legislator is characterized by constant policy preferences: a $d \geq 1$ dimensional characteristic of i, which we refer to as her ideology.[20] Specifically, each i has a fixed ideology denoted by her ideal point, $\bar{\theta}^i \in \mathbb{R}^d$. In what follows, an upper bar (e.g. $\bar{x}$) denotes a vector.

Each congressional cycle defines a set $\boldsymbol{\Theta} = \left\{\bar{\theta}^1, \bar{\theta}^2, ..., \bar{\theta}^i, ..., \bar{\theta}^N\right\}$ where $\boldsymbol{\Theta}$ may change from one congressional cycle to the next due to the potential replacement of some members of the legislature.[21] Within each congressional cycle (a two year period), let $t = 1, 2, ..., T$ indicate the discrete times at which a single bill may be introduced and voted on. We assume T is large for each congressional cycle. For exposition, we consider the case of a single congressional cycle, but discuss in Subsection 2.5 how our estimation procedure handles multiple cycles.

Individual i's preferences over policies are represented within a random utility framework. For any policy $\bar{k}_t \in \mathbb{R}^d$, we assume that i's preferences are given by:

$$u\left(\bar{k}_t, \bar{\theta}^i\right) = u\left(\left\|\bar{\omega}_t^i - \bar{k}_t + \bar{y}_t^i\right\|\right), \tag{1}$$

with $u'(\cdot) < 0$. $\|.\|$ indicates the weighted Euclidean norm with weights $w_1, w_2, ..., w_d$. We indicate by $\bar{\omega}_t^i = \bar{\theta}^i + \bar{\varepsilon}_t^i \in \mathbb{R}^d$, i's realized ideal point at t. $\bar{\omega}_t^i$ includes i's ideology plus a random shock, $\bar{\varepsilon}_t^i$, that is independently and identically distributed across individuals i and each vote t according to a continuous CDF, $G_t(\bar{\varepsilon})$.[22]

Utility is also a function of $\bar{y}_t^i$, the extent of party influence exerted on politician i on roll call t. We refer to $\bar{y}_t^i$ as 'party influence' or 'party pressure', and specify it in detail in Section 2.2.2. Party influence may be exerted in favor of or against the status quo, depending the preference of the politician's party. Each party can only influence its own members.

[19] $N = 435$ for the House and $N = 100$ for the Senate.

[20] We focus on the case $d = 2$ in this section, but we also study and estimate models for the $d = 1$ case, which is considered appropriate especially for the period between 1975 and 2018 (McCarty, 2016).

[21] Without additional assumptions, the model is not identified if one allows ideologies to move over time. Hence, we follow most of the literature and assume that ideological preferences are constant. Even if we could allow for ideologies to change over time, it seems unlikely it would have a major impact on our results: the literature has shown almost all the changes in polarization (ignoring party pressure) are due to replacement of members of Congress, rather than within-individual movements in ideology. Just to quote one such study, "*the replacement of relatively moderate legislators with more ideologically extreme legislators, driven almost entirely by Republicans, explains virtually all of the recent growth in partisan polarization.*" (Moskowitz et al., 2017) See Fleisher and Bond (2004); Theriault (2006) for similar conclusions.

[22] Assuming ideology shocks instead of utility shocks (similarly to Canen et al. (2020)) allows us to avoid making an assumption about the exact shape of the utility function (i.e. quadratic), as shown below.

Absent party influence, a member i votes for a policy $\bar{x}_t \in \mathbb{R}^d$ and against the status quo $\bar{q}_t \in \mathbb{R}^d$ if and only if $u\left(\| \bar{\omega}_t^i - \bar{q}_t \|\right) \leq u\left(\| \bar{\omega}_t^i - \bar{x}_t \|\right)$. Given that $u'(\cdot) < 0$, this inequality is equivalent to $\| \bar{\omega}_t^i - \bar{q}_t \| \geq \| \bar{\omega}_t^i - \bar{x}_t \|$.

The case of $d = 2$ is central to our empirical analysis, so we focus on it here. Additional dimensions could be included analogously, at a cost of higher identification requirements. For the case of $d = 2$, the set of members that vote for $\bar{x}_t = (x_{1,t}, x_{2,t})$, X_t, is the set:

$$X_t = \left\{ \bar{\omega}_t^i | \omega_{2,t}^i \geq \omega_{1,t}^i \frac{w_1\left(q_{1,t} - x_{1,t}\right)}{w_2\left(x_{2,t} - q_{2,t}\right)} + \frac{w_1(x_{1,t}^2 - q_{1,t}^2) + w_2(x_{2,t}^2 - q_{2,t}^2)}{2w_2\left(x_{2,t} - q_{2,t}\right)} \right\}, \qquad (2)$$

when $x_{2,t} > q_{2,t}$ (otherwise, the inequality is reversed).[23]

The formulation in (2) is useful because it makes explicit that the set of members that votes for $\bar{x}_t$ is the set of those who lie above a cutline in the two-dimensional space given by

$$\omega_{2,t} = m_t \omega_{1,t} + b_t \qquad (3)$$

where

$$m_t \equiv \frac{w_1\left(q_{1,t} - x_{1,t}\right)}{w_2\left(x_{2,t} - q_{2,t}\right)},$$

$$b_t \equiv \frac{w_1(x_{1,t}^2 - q_{1,t}^2) + w_2(x_{2,t}^2 - q_{2,t}^2)}{2w_2\left(x_{2,t} - q_{2,t}\right)}.$$

We make use of (3) to simplify the structure of the shocks. Recall that $\bar{\varepsilon}_t^i = \bar{\omega}_t^i - \bar{\theta}^i$. We assume that $G_t(\bar{\varepsilon})$ has the following structure: (i) shocks are assumed to shift a member's ideal point along the direction orthogonal to the cutline (3) with a positive shock increasing $\omega_{1,t}^i$, and (ii) the projection of $\bar{\varepsilon}_t^i$ onto the orthogonal to the cutline that passes through $\bar{\theta}^i$, denoted e_t^i, is distributed i.i.d. across i and t with $e_t^i \sim N(0,1)$.

This structure ensures that $\bar{\varepsilon}_t^i$ moves a politician in the direction most likely to change her vote, a feature which greatly simplifies the construction of the likelihood function and its computation. Notice further that an unrestricted $\bar{\varepsilon}_t^i$ vector shock could move politicians from $\bar{\theta}^i$ in any direction in $\mathbb{R}^2$, but this vector can be always represented in terms of its projection onto the line orthogonal to (3), resulting in the same vote choice.

Similarly, we assume that party pressure, $\bar{y}_t^i$ also acts along the direction orthogonal to the cutline (i.e. in the direction most likely to make politician i change her vote). We discuss further

[23]In the special case in which $x_{2,t} = q_{2,t}$, we have $X_t = \left\{ \omega_{it} | \omega_{1,it} \geq \frac{x_{1,t} + q_{1,t}}{2} \right\}$ for $x_{1,t} > q_{1,t}$ (and otherwise the inequality is reversed).

benefits of the structure induced by these assumptions in Section 2.6.

2.2 Timing and Structure

The timing of the legislative process is as follows:

(I) Each period t, one of two parties is recognized to set the agenda.[24]

(II) The agenda-setting party, p_t, draws (with replacement) a status quo, $\bar{q}_t$, from the distribution of possible policy status quo's $W(\bar{q})$ with support $Q \subseteq \mathbb{R}^2$. For each status quo, $\bar{q}_t$, the agenda setter can decide whether or not to propose an endogenous alternative, $\bar{x}_t = x(\bar{q}_t)$, or not pursue any alternative.

(III) If an alternative is proposed, preference shocks realize and then each party exercises influence on a subset of their members.

(IV) Politicians vote for $\bar{x}_t$ or $\bar{q}_t$, payoffs realize, and the chamber moves to $t+1$.

2.2.1 Parts (I) and (II): Agenda-Setting

A congressional cycle includes a series of recognition draws $\{p_1, p_2, ..., p_T\}$ and status quo draws $\{\bar{q}_1, \bar{q}_2, ..., \bar{q}_T\}$. Notice that, due to selection, only a subset of $\{\bar{q}_1, \bar{q}_2, ..., \bar{q}_T\}$ is considered, producing the actual vote data observable to the econometrician. We use $Q_p^1 \subseteq Q$ and $Q_p^0 \subseteq Q$ to denote the sets of status quo's that are considered and not considered for a vote by p_t, respectively, such that $Q_p^1 \cap Q_p^0 = \emptyset$ and $Q_p^1 \cup Q_p^0 = \{\bar{q}_1, \bar{q}_2, ..., \bar{q}_T\}$.

Agenda selection defines an optimal partition $Q_p^0(\mathbf{\Theta}, \bar{y}^{max})$ and $Q_p^1(\mathbf{\Theta}, \bar{y}^{max})$, which is a function of the vector of members' ideologies, $\mathbf{\Theta}$, and the party pressure technologies represented by the vector $\bar{y}^{max} = \{y_D^{max}, y_R^{max}\}$, where $\|\bar{y}_t^i\| \leq y_p^{max}$ for all i in both parties. For each element of Q_p^1, a corresponding $\bar{x}_t = x(\bar{q}_t)$ alternative is voted on the floor.

We assume that the random shocks $\bar{\varepsilon}$ are drawn after the partition $\left\{Q_p^1, Q_p^0\right\}$ is designed and policies are chosen. We do not need to restrict the game that induces the partition $\left\{Q_p^0, Q_p^1\right\}$ in any way, as long the game includes: i) large N, ii) a random component for the politicians' votes as above, and iii) the shocks are realized after the agenda is set. The first two conditions are used for the statistical identification of the model, as we show below, while the third guarantees that the party has uncertainty about whether a bill gets passed or not. This last condition is empirically relevant, as not all bills $\bar{x}_t$ that are brought to the floor pass a vote.

Under these conditions, we do not need to specify the legislative game in further detail. To understand why, consider a one-dimensional environment and two politicians i and j, with $\theta^i < \theta^j$. Take a Congress where only one policy is voted upon repeatedly T times so that we observe only

[24] For now, we allow for an arbitrary rule that picks the proposing party in each period. For example, we can let party D be recognized with probability γ and party R with $1-\gamma$, where γ can be allowed to vary by Congress or to depend upon party characteristics.

one cutline m. No matter how extreme the cutline, nor how the policy alternative is selected by the agenda setter, if one shocks the politicians with full-support shocks over repeated votes, each politician, i, will cross the cutline with a certain frequency given by the distribution of the shocks and her ideal point location relative to m. The politician with θ^j immediately to the right of θ^i will cross the cutline as well, but with a slightly different frequency. If, in the next Congress, the agenda-setter changes the cutline m, then the frequencies will change, but θ^i and θ^j cannot change given the structure and the nature of the shocks: the vote probabilities will adjust for the different cutline accordingly. Given unbounded shocks and large T, no two politicians with different ideologies can have identical voting records, no matter which bills are proposed: the ideal points will be separated asymptotically. Appendix E describes a series of Monte Carlo simulations that illustrate this intuition, demonstrating that we obtain unbiased estimates of our model independently of the agenda (provided the sample size of votes is large enough, a condition satisfied in our dataset).

2.2.2 Part (III): Party Pressure

We model party pressure as the discipline exerted by each party's whips. Whips are a subset of members of each party that are responsible for the votes of a subset of legislators within the same party (Meinke, 2008). Whips are rewarded $r_p > 0$ for each member under their oversight who votes with the leadership at t, consistent with organizational theories as Cox and McCubbins (1993). The party is deep-pocketed, in the sense that the rewards r_p are not scarce, so that no budget constraint (either within or across bills) limits the extent of party pressure. The cost of whipping is borne by the whip herself. Each whip bears a private cost, $c\left(\| \bar{\omega}_i - \bar{\omega}_i' \|\right)$ from moving member i from point $\bar{\omega}_i$ to $\bar{\omega}_i'$, where $\| \, . \, \|$ is the same Euclidean norm that enters the utility function (i.e. if members weight the first dimension more heavily, it costs more to move them along this dimension). We assume $c'(\cdot) > 0$ and $c(0) < r_p$. These assumptions ensure that any member that already prefers to vote for the party's preferred policy is not whipped and that a member that prefers to vote against the party's preferred policy will be whipped only if the distance she must be moved to get her to change her position is less than $y_p^{max} \equiv c^{-1}(r_p)$. Whips have full information about all members preferences and shocks.

Consider the case in which a party prefers the alternative $\bar{x}_t$ to $\bar{q}_t$ (i.e. the party "whips" for $\bar{x}_t$). In the case $d = 2$, the set of members that are whipped are those outside of X_t (the set that prefers $\bar{x}_t$ in the absence of whipping) and such that the distance between the member's ideology to a point within X_t is less than y_p^{max}. Because the boundary of X_t is a line, the set of whipped members is the set of members that lie within a distance y_p^{max} of the bounding line. Specifically, using equation (2), if a party p whips for policy $\bar{x}_t$ against $\bar{q}_t$ and $x_{2,t} > q_{2,t}$, we have that the set of members which vote for $\bar{x}_t$ is given by

$$X_{p,t}^{whipped} = \left\{\bar{\omega}_t^i | \omega_{2,t}^i \geq m_t \omega_{1,t}^i + b_t - y_{p,t}\right\} \tag{4}$$

where

$$y_{p,t} \equiv y_p^{max} \sqrt{\frac{w_1 + m_t^2 w_2}{w_1 w_2}}.$$

Let us indicate that a party p whips 'up' (for the policy with the largest second dimension) with the expression $W_{p,t} = 1$; $W_{p,t} = -1$, otherwise. Further define $\mathcal{I}_t \equiv I\left(x_{2,t} > q_{2,t}\right)$, where $I(.)$ is the indicator function. Then we have:

$$X_{p,t}^{whipped} = \begin{cases} \left\{\bar{\omega}_t^i | \omega_{2,t}^i \geq m_t \omega_{1,t}^i + b_t - W_{p,t} \times y_{p,t}\right\} & if\, \mathcal{I}_t = 1 \\ \left\{\bar{\omega}_t^i | \omega_{2,t}^i \leq m_t \omega_{1,t}^i + b_t - W_{p,t} \times y_{p,t}\right\} & if\, \mathcal{I}_t = 0. \end{cases}$$

Note that whips first observe the shocks of all members and then apply pressure to those closest to indifferent who intend to vote against the party. Hence, once shocks are observed, some party members will be pressured (which may include both extremists and moderates, depending on the realization of their shocks), while other ones will not. Those who are not pressured are, indeed, those too expensive to be convinced. However, the probability that one votes Yes before the shocks are realized depends on a politician's ideal point and party pressure, and how far those are from the policy. After all, for politicians who are close to indifference, even small shocks (i.e., with large probability) will likely make them switch their votes.

2.2.3 Part (IV): Voting

Let Y_{it} be a random variable taking value 1 if politician i votes Yes in favor of $\bar{x}_t$, conditional on $\bar{q}_t$ having been selected for consideration (i.e. $\bar{q}_t \in Q_p^1$) by party p, and 0 otherwise.

The probability that i from party p supports alternative $\bar{x}_t$ over the status quo $\bar{q}_t$ is then

$$\Pr\left(Y_{it} = 1 | \bar{q}_t \in Q_p^1, \bar{x}_t; \boldsymbol{\Theta}, y_p^{max}\right) = \Pr\left(\bar{\omega}_t^i \in X_{p,t}^{whipped} | \bar{q}_t \in Q_p^1, \bar{x}_t; \boldsymbol{\Theta}, y_p^{max}\right).$$

To calculate this probability, consider that the (signed) minimum distance of a member at $\bar{\theta}^i$ from the boundary line with slope m_t and intercept b_t, is given by

$$\sqrt{\frac{w_1 w_2}{w_1 + m_t^2 w_2}} \left(\theta_2^i - m_t \theta_1^i - b_t + W_{p,t} \times y_{p,t}\right).$$

Given that positive shocks increase $\omega_{1,t}^i$, a positive shock implies $\theta_2^i > m_t \theta_1^i + b_t - W_{p,t} \times y_{p,t}$. Since

e_t^i is distributed as a standard normal,[25] we have that the probability a member votes for $\bar{x}_t$ is given by:

$$\Pr\left(Y_{it}=1|\bar{q}_t \in Q_p^1, \bar{x}_t; \mathbf{\Theta}, y_p^{max}\right) = \tag{5}$$
$$\begin{cases} \Phi\left(\sqrt{\frac{w_1 w_2}{w_1+m_t^2 w_2}}\left(\theta_2^i - m_t\theta_1^i - b_t\right) + W_{p,t}\times y_p^{max}\right) \text{ if } \mathcal{I}_t = 1 \\ 1-\Phi\left(\sqrt{\frac{w_1 w_2}{w_1+m_t^2 w_2}}\left(\theta_2^i - m_t\theta_1^i - b_t\right) + W_{p,t}\times y_p^{max}\right) \text{ if } \mathcal{I}_t = 0, \end{cases}$$

where Φ indicates the standard normal CDF.[26]

2.3 Motivation of the Party

Our representation of the party is extremely simplified. In the model, party leaders wish to maximize unity in voting the party line rather than carefully balancing members' local electoral constraints, while still ensuring sufficient votes to pass policies that they desire. We make this simplifying assumption for tractability, as our goal is to develop a simple measure of party pressure rather than to explicitly model the multidimensional motivations of party leaders and how they may interact with polarization.[27] Focusing on maximizing support for the leadership vote choice achieves this goal.

We note, though, that good reasons exist that parties may want to appear unified even if (as Lebo et al. (2007) claims) it is electorally costly. Party identity and branding (e.g., Cox and McCubbins, 2005), for example, will be stronger when all members vote together, which may drive longer-term electoral success. One clear advantage to having a simple measure of party pressure, as in our case, is that it can be transparently validated using qualitative evidence and used to test different theories of party behavior (see Sections 4 and 6).

2.4 Identification

This section discusses the identification proof for the two-dimensional case of our model, that is whether the econometrician can prove a unique mapping between the available data moments and the model's parameters (preferences, party pressure, cutlines, etc.). A constructive derivation

[25] The use of a standardized distribution is necessary for statistical identification and is a common feature of discrete choice models. If we used a different normal distribution, we could simply rescale all parameters by the distribution's standard deviation and de-mean the model to obtain the same probability of voting Yes, implying a failure of identification.

[26] With the same expressions, but the sign of y_p^{max} reversed when the party exerts pressure for the status quo $\bar{q}_t$, we can construct a likelihood function, provided the direction, $x_{2,t} \lesseqgtr q_{2,t}$, is known at each t. We address this issue in the construction of the full likelihood below.

[27] Polborn and Snyder Jr (2017) theoretically study some of the mechanisms that may be in play.

is provided in Appendix A. Identification of the one-dimensional case is demonstrated in Canen et al. (2020). The analysis can be extended to three or more dimensions, but the set of identifying assumptions would need to increase for the higher number of parameters.

2.4.1 Preliminaries

Euclidean norm weights are imposed to be $w_1 = w_2 = 1$. This is an identifying condition, as even with $w_1 = 1, w_2$ cannot be identified. We emphasize that these weights cannot be identified in the DW-Nominate model either. In fact, even under $w_1 = 1$, $0 < w_2 < 1$ or $w_1 = w_2 = 1$, DW-Nominate is not identified, as we show in Appendix B.

Notice further that members' vote probabilities depend on $\mathcal{I}_t$, which is unobserved and must be identified from the data in conjunction with the other parameters. Once $\mathcal{I}_t$ is identified, we know each party's preferred direction, $W_{p,t}$, based on the direction of the leadership votes, as discussed in Section 3. We address the estimation of $\mathcal{I}_t$ in Subsection 2.5.

2.4.2 Main Identifying Assumptions

To identify the parameters $\left\{\mathbf{\Theta}, \{m_t, b_t, \mathcal{I}_t\}_{t=1}^{T}, \{y_p^{max}\}_{p\in\{D,R\}}\right\}$, we assume the following:

Assumptions ID:

1. The set of ideal points, $\mathbf{\Theta}$, has elements not perfectly collinear within at least one party.
2. (i) There exists a politician 0 such that $\bar{\theta}^0 = (0, 0)$. (ii) There exists a politician k whose first dimension ideology, θ_1^k, is known.
3. (i) There exists a bill 0 such that $m_0 = 0$. (ii) There exists a bill, s, for which $m_s \neq 0$.
4. The two parties exert pressure in the same direction on at least one bill, and opposite directions on at least one other.

In addition, we trivially require that the data include at least two roll calls with cutlines different from $t = 0$ (this restriction is satisfied, as the data includes thousands of bills), and at least one politician with ideology different from $i = 0$ or k (the data include hundreds of politicians). It is important to emphasize that we impose this set of assumptions only once (only a single bill's slope is normalized), and not separately for each congressional cycle. The assumption that the ideological parameters are constant produces the necessary linkages across Congresses.[28]

In terms of intuition, Assumptions ID1 and ID3(ii) ensure that two dimensions are in fact necessary. If the ideal points are collinear or all the cutlines are horizontal, then the problem is one-dimensional. ID2(i) is a natural location choice, equivalent to the normalization of a single

[28] As mentioned above, the ideologies must be assumed stationary. Without some constant reference point across Congresses, changes in ideology can not be recovered even in a model without party pressure. See Appendix B for further details.

individual fixed effect to zero in standard panel data models. Assumptions ID2(ii) and ID3(i) together pin down the rotation of the estimates in the two-dimensional space. In addition, Assumption ID3(i) facilitates identification of the second dimension of ideology, as for bill 0 only the second dimension is relevant. Assumption ID4 is necessary to identify the party influence parameters from changes in the parties' preferred directions. Hence, the role of Assumption ID4 is to identify separate party pressure parameters.[29] As described in the Introduction, given variation in the directions of party pressure, party-specific cutlines can be recovered, which in turn can be used to point-identify the party pressure parameters. As is standard in discrete choice models, the underlying normalization of the variance of the utility shock magnitude (implicit in equation (5)) pins down the scale of the estimates.

Under these assumptions, Appendix A proves identification of our model in two dimensions. The intuition is analogous to the one expressed in the Introduction for a single policy dimension, although more care has to be devoted in two dimensions to ruling out sets of ideal points that can explain the same vote choice by a legislator. Note further that several innovations in our structure are crucial for identification in addition to Assumptions ID1-4. First, shocks to ideology allow us to forgo any complication due to nonlinearity in $u(.)$ when comparing vote choices, and to maintain general utility functions (e.g. we are not restricted to quadratic or Gaussian loss functions). Renouncing the additive separability between the deterministic and stochastic components of the utility function might appear to complicate the analysis, but, as we show, in this instance it greatly simplifies it. Second, the assumption of the orthogonality of the shocks to the cutlines allows us to focus on simple univariate probability functions in describing vote probabilities even when preferences are two-dimensional. Third, the use of the specific information on each party's preferred direction allows us to separate the individual party pressure parameters.

2.5 Likelihood and the Role of Agenda-Setting

We now derive the likelihood function for the problem presented in Parts (I)-(IV) of Section 2.2.

Consider the sequences $\{p_1, p_2, ..., p_T\}$ and $\{\bar{q}_1, \bar{q}_2, ..., \bar{q}_T\}$, only partially observed by the econometrician. Without loss of generality, order periods so that all $\{\bar{q}_1, ..., \bar{q}_{\tau-1}\}$ belong to Q^0 and are therefore unobserved, while $\{\bar{q}_\tau, ..., \bar{q}_T\}$ belong to Q^1 and are potentially estimable by the econometrician, as actual roll calls occur on these bills.

For the i-th legislator, we observe $T-\tau$ vote choices, $\mathbf{Y}_i = \{Y_{i\tau}, ..., Y_{iT}\}$. Let us now define a theoretical sample likelihood constructed assuming we have complete information. Let γ denote

[29] To identify the aggregate party pressure, $y_D^{max} + y_R^{max}$, rather than its two component parts, ID4 can be weakened to ID4', "The two parties apply pressure in opposite directions on at least two bill". Thus, observing bills where the two leaders whip in the same direction is not necessary to pin down the total extent of party pressure, just but is instead only necessary to separately identify y_D^{max} and y_R^{max}.

the generic probability that party D is recognized as the proposer. Under full knowledge of the sequence $\{\bar{q}_1, \bar{q}_2, ..., \bar{q}_T\}$, the density for the i-th observation can be theoretically expressed as:

$$
\begin{aligned}
\mathcal{L}^*(\mathbf{Y}_i) \;=\; & \prod_{t=1}^{\tau-1} \left[\gamma \Pr(\bar{q}_t \in Q_D^0)\right]^{I[p_t=D]} \times \left[(1-\gamma)\Pr(\bar{q}_t \in Q_R^0)\right]^{I[p_t=R]} \\
& \times \prod_{t=\tau}^{T} \Big[\gamma \Pr(\bar{q}_t \in Q_D^1) \left(\Pr\left(Y_{it}=1|\bar{q}_t \in Q_D^1, \bar{x}_t; \mathbf{\Theta}, \bar{y}^{max}\right)\right)^{Y_{it}} \\
& \times \left(\Pr\left(Y_{it}=0|\bar{q}_t \in Q_D^1, \bar{x}_t; \mathbf{\Theta}, \bar{y}^{max}\right)\right)^{1-Y_{it}}\Big]^{I[p_t=D]} \\
& \times \Big[(1-\gamma)\Pr(\bar{q}_t \in Q_R^1) \left(\Pr\left(Y_{it}=1|\bar{q}_t \in Q_R^1, \bar{x}_t; \mathbf{\Theta}, \bar{y}^{max}\right)\right)^{Y_{it}} \\
& \times \left(\Pr\left(Y_{it}=0|\bar{q}_t \in Q_R^1, \bar{x}_t; \mathbf{\Theta}, \bar{y}^{max}\right)\right)^{1-Y_{it}}\Big]^{I[p_t=R]}.
\end{aligned}
$$

Notice that the terms $\Pr(q_t \in Q_p^0)$ which indicate the status quo policies not pursued by party p cannot be observed in reality. Notice further that, conditioning the vote probabilities on $\bar{x}_t$ implicitly conditions on $\mathcal{I}_t$, which, given data on leadership votes, determines $W_{p,t}$ for each party. In essence, both the parameters pertinent to the recognition and agenda-setting components of the model (Parts (I) and (II) of the structure in Section 2.2) and the parameters pertinent to the party pressure and voting components (Parts (III) and (IV)) enter $\mathcal{L}^*(\mathbf{Y}_i)$.

As the information concerning Parts (I) and (II) is unobserved, a consistent estimator of ideology, party pressure and the other voting parameters would seem infeasible. Consistent with this view, the literature has suggested that such omission may be consequential to the study of polarization. For instance, Clinton et al. (2014) and others[30] point out that agenda-setting may play a key role in producing polarization: politicians may vote more similarly with their co-partisans not because of ideologies or party pressure, but simply because divisive bills are left out of the agenda or bills that clearly separate the two parties are brought forth.

To the contrary, we now show how one can obtain consistent estimates of the vote parameters independent of the policies that are voted upon.[31] As our argument holds independently of how the proposing party is chosen, for illustrative purposes, consider the simplified case of $\gamma = 1$ (i.e. all bills are proposed by the same party D). In this case, the infeasible log likelihood is:

[30] E.g. McCarty (2019) ch. 5, pp.83-84.

[31] If one is explicitly interested in the agenda-setting parameters, one can explicitly model the agenda-setting process as in Canen et al. (2020).

$$\begin{aligned}\log \mathcal{L}^* \quad (\mathbf{Y}_i) = & \sum_{t=1}^{\tau-1} \log\left(\Pr(q_t \in Q_D^0)\right) + \sum_{t=\tau}^{T} \log\left(\Pr(q_t \in Q_D^1)\right) \\ & + \sum_{t=\tau}^{T}\sum_{i=1}^{N} \left[Y_{it} \log\left(\Pr\left(Y_{it}=1|\bar{q}_t \in Q_D^1, \bar{x}_t; \mathbf{\Theta}, \bar{y}^{max}\right)\right)\right. \\ & \left. + (1-Y_{it}) \log\left(\Pr\left(Y_{it}=0|\bar{q}_t \in Q_D^1, \bar{x}_t; \mathbf{\Theta}, \bar{y}^{max}\right)\right)\right].\end{aligned} \tag{6}$$

The log likelihood (6) is separable. The double summation corresponds to the conditional likelihood of roll call votes based on the selected status quo $\bar{q}_t$ that are brought to the floor for a vote, and the corresponding selected alternative $\bar{x}_t$. This likelihood component corresponds to Parts (III) and (IV) of the structure in Section 2.2.

Define $\Xi = \{m_t, b_t, \mathcal{I}_t\}_{t=1}^{T}$.[32] Consider maximizing the (feasible) conditional likelihood $\mathcal{L}$ of individual vote decisions:

$$\begin{aligned}\log \mathcal{L}(\mathbf{Y}_i) = & \sum_{t=\tau}^{T}\sum_{i=1}^{N} \left[Y_{it} \log\left(\Pr\left(Y_{it}=1|\mathbf{\Theta}, \Xi, \bar{y}^{max}\right)\right)\right. \\ & \left. + (1-Y_{it}) \log\left(1-\Pr\left(Y_{it}=1|\mathbf{\Theta}, \Xi, \bar{y}^{max}\right)\right)\right],\end{aligned} \tag{7}$$

where $\{\mathbf{\Theta}, \Xi, \bar{y}^{max}\}$ is the set of parameters to estimate. Equation (7) can be used to consistently estimate $\{\mathbf{\Theta}, \Xi, \bar{y}^{max}\}$ based on vote data alone even if (i) the range of party pressure y_p^{max} influences the selection decisions of status quo's (i.e. the sets $\{Q_D^0, Q_D^1\}$), and (ii) the policy alternatives $\bar{x}_t$ are endogenously set. The key reason for this result is that m_t, b_t, and $\mathcal{I}_t$ are predetermined at the time of the vote and can be consistently estimated using the vote data alone, so that it no longer matters how they come to be through agenda selection. More specifically, each parameter can be estimated because (i) preference shocks realize independently after the selection of the status quo, $\bar{q}_t$, and of the alternative, $\bar{x}_t$, have occurred, and (ii) the support of the preference shocks is unbounded – so that no matter the choices of $\bar{q}_t, \bar{x}_t$ the probability that each politician votes for either alternative is non-zero.

Given identification of the ideal points, we obtain consistent estimates of polarization, the ideological separation between parties, regardless of the agenda. Furthermore, as described intuitively in the Introduction and proven formally in Appendix A, we also identify $\bar{y}^{max}$. We further verify that the ideal points, extent of polarization, and $\bar{y}^{max}$ can be consistently estimated regardless of the bills being proposed via extensive Monte Carlo simulations (details in Appendix E). Specifi-

[32]Notice here that for each bill we can characterize vote choices as functions of the three parameters m_t, b_t, and $\mathcal{I}_t$, rather than the four parameters in $\bar{q}_t, \bar{x}_t$. We therefore have one less parameter per bill, which facilitates identification and estimation.

cally, given the number of bills that we observe in the data, T, we show that the parameters can be recovered whether the cutlines vary widely over the ideological space or are very divisive.[33]

Finally, notice that, using (5), $\mathcal{I}_t$ can be simply estimated as selecting for every bill t, $I\left(x_{2,t} < q_{2,t}\right) = 1$ if

$$\begin{aligned}
&\sum_{i=1}^{N} \left[Y_{it} \log\left(\Pr\left(Y_{it} = 1 | \mathbf{\Theta}, m_t, b_t, 1, \bar{y}^{max}\right)\right)\right. \\
&\left. + \left(1 - Y_{it}\right) \log\left(1 - \Pr\left(Y_{it} = 1 | \mathbf{\Theta}, m_t, b_t, 1, \bar{y}^{max}\right)\right)\right] \quad > \\
&\sum_{i=1}^{N} \left[Y_{it} \log\left(\Pr\left(Y_{it} = 1 | \mathbf{\Theta}, m_t, b_t, 0, \bar{y}^{max}\right)\right)\right. \\
&\left. + \left(1 - Y_{it}\right) \log\left(1 - \Pr\left(Y_{it} = 1 | \mathbf{\Theta}, m_t, b_t, 0, \bar{y}^{max}\right)\right)\right]
\end{aligned}$$

and $I\left(x_{2,t} < q_{2,t}\right) = 0$ otherwise. By calculating the likelihood for each $\mathcal{I}_t$, we avoid estimation of a binary parameter.

Consistency of the estimator for $\left\{\mathbf{\Theta}, \{m_t, b_t\}_{t=1}^{T}, \bar{y}^{max}\right\}$ is guaranteed for large $T - \tau$ and N. The requirement for a large number of bills, which holds in our application, is necessary in order to be able to estimate each $\bar{\theta}^i$ consistently by MLE without nuisance parameter problems (Fernández-Val and Weidner, 2016). Further, as N is also large, one can also consistently estimate all elements of $\{m_t, b_t\}_{t=1}^{T}$ and $\bar{y}^{max}$. To extend the likelihood function across multiple congressional cycles, one simply sums over the likelihood contribution of each congressional cycle.[34]

2.6 Comparison to Other Established Methodologies

Here we discuss how our methodology contrasts with established methodologies in the literature, focusing on three main approaches. As a first point of departure, note that none of the approaches below incorporates a role for party pressure in our current form.

The first method for comparison is the Bayesian approach of Clinton et al. (2004). This approach posits quadratic preferences for the deterministic component of utility and normally distributed idiosyncratic shocks. We share the use of the latter, but do not need to impose a quadratic utility function. The authors' use of Markov Chain Monte Carlo methods to estimate posterior densities, typical of Bayesian methods, is also in sharp contrast to our setup in terms of identification. The Bayesian approach allows the authors to sidestep classical identification issues, but also requires the reader to trust the assumed priors. When the authors extend their approach

[33] These results establish that agenda-setting can only potentially affect estimates in finite samples (as demonstrated in the simulations of Clinton et al. (2014)).

[34] As the preference parameters, $\mathbf{\Theta}$, are constant within individuals over time, this provides an intertemporal link across multiple cycles, which removes the need to impose ID2-3 at every congressional cycle (the assumptions have to hold in one cycle only).

to allow for parties to influence votes, they assume (as in Snyder and Groseclose (2000)) that lopsided votes are not subject to party pressure in order to be able to identify (only) the net effect (Republican-Democrat) of party pressure. By incorporating the leadership positions to identify each party's preferred direction, we do not need to assume some votes are not subject to party pressure and we can separately identify the influence exerted by each party.

Heckman and Snyder (1997) share our classical approach: their structurally-derived linear probability model is close in spirit to this paper, while their assumptions of quadratic preferences and additive separable uniform shocks differ from ours. We introduce non-separable additive shocks in the argument of the utility functions, an innovation that helps in terms of identification and estimation of the explicit effects of party pressure. The usefulness of our approach comes in two forms. First, we do not impose restrictive utility functions. Second, it allows for a simple characterization of the cutline in equation (4), becoming a function of an intercept, slope, and direction, rather than a function of $\bar{q}_t$ and $\bar{x}_t$. With two dimensions, this simplification reduces the number of parameters by one for each bill. Finally, for their analysis with an unobservable number of policy dimensions, Heckman and Snyder implement their linear model as a multi-factor model under an orthonormality assumption.[35] This grants their method high flexibility and fast estimation.

The most influential and cited approach in the analysis of congressional behavior and political polarization is arguably DW-Nominate (Dynamic Weighted NOMINAL Three-step Estimation), a method that has gone through multiple incarnations (Poole and Rosenthal, 1997, 2001; McCarty et al., 2006) and is at the core of the path-breaking VoteView.com repository. This well-established methodology relies on somewhat unique assumptions, however. Politicians' preferences are given by a Gaussian function (i.e. preferences are not globally concave). The model is also often written as if multiple policy dimensions could be estimated from the vote data without increasing the identification requirements. An unappreciated consequence of the former assumption is that strong nonlinearity in the preference parameters immensely complicates identification when one tries to map choice data into the model structure, even absent the weighting of different policy dimensions (the W, for Weighted in the name) or linear trends in legislator preferences (the D, for Dynamic in the name).[36]

To the best of our knowledge, no formal proof of identification for the Nominate method exists in two dimensions or higher. Indeed, we prove in Appendix B that DW-Nominate in two

[35]The authors estimate six latent policy factors using χ^2 and AIC methods. These tests however are known to produce over-estimates of the number of factors in small and medium samples. More conservative modern tests for the number of latent factors could be implemented to re-assess their PCA analysis (for instance, the eigenvalue ratio method of Ahn and Horenstein (2013)).

[36]Heckman and Snyder (1997) discuss the problem arising from the nonlinearity of the estimator explicitly in their analysis and point to its consequences for consistency of the MLE estimator.

dimensions is not identified. We show that specific nonlinear transformations of the parameters can in fact change the DW-Nominate ranking of legislators along any dimension. Notice further that this difficulty is not resolved by imposing additional identifying restrictions, such as that legislators' ideal points are constrained to lie within a unit circle. In fact, this often-emphasized "unit circle" identification constraint operates as an additional source of distortion: legislators are not allowed to simultaneously be extreme on both policy dimensions, as they would fall outside the circle. A substantial share of politicians are located at the artificial boundary of the circle (7% of our sample from the House, and approximately 8% of our sample from the Senate lie on the boundary) and all estimates are affected by this restriction through comparisons to the subset of politicians located on the boundary. We provide further details and discussions in Appendix B.[37]

After experimenting with several replications of the DW-Nominate approach, we can only surmise that the lack of point identification of the preference and (therefore, bill) parameters is being resolved by the addition of external information about the locations of a number of (initial) politicians. According to Boche et al. (2018) "*It has been said that Poole himself was the 'outer loop' of this estimation process: his judgment and expertise were required in the estimation of the original values*" (p.24). The additional identifying information of this outer loop continues to be important in estimates for new bills and legislators today, as in the current VoteView.com structure, Boche et al. (2018) avoid any adjustment in ideal point estimates for past members when new voting data is added (no "*back propagating*", p.24).

3 Data

Data on roll call votes for both the House of Representatives and the Senate comes from VoteView.com. This standard dataset was originally created by Keith Poole and Howard Rosenthal (Poole et al., 1997), who collected votes for each member of Congress over time and made them widely available.[38] We map these roll calls to the binary variable $Y_{i,t}$ (politician i voting Yes or No on roll call t) in the model and employ all roll call votes available.

Figure 3 shows the number of roll call votes over time in each chamber. The number of roll calls in the Senate increases from just under 200 in Congress 70 to a peak of almost 1,500 by Congress 94, before settling to around 500 in more recent Congresses. For the House, the average number of roll calls increases from around 200 in Congress 70 to around 1,200 in recent times. We present summary statistics for bills in Table 2 in Appendix D, including the number of bills

[37]See Figure 17 in Appendix B for an illustration of this problem. In summary, the unit circle limits the correlation of ideologies across both dimensions as no legislator can be set at $(1, 1)$, for example. The most extreme legislator in both dimensions would be located at $(\frac{\sqrt{2}}{2}, \frac{\sqrt{2}}{2})$, implying that they would seem less extreme in some dimension than legislators $(0, 0.8)$ and $(0.8, 0)$, for example, even though that may not be the case.

[38]See Boche et al. (2018) for a recent overview.

introduced, approval rates, and the number of bills passed in a congressional cycle, for both the House and the Senate, from the mid 1940's until the early 2010's. This data is drawn from the Vital Statistics on Congress by the Brooking Institute. In both chambers, the approval rate of bills has dropped sharply: for the Senate, from over 50% in Congress 80 to around 10-20% more recently, and from around 20% to under 6% in the same time period for the House.

We restrict our sample for the Senate to the post-WWI period from 1927 (Congress 70) to January 2019 (the end of Congress 115). We impose this restriction because our identification strategy requires clear party leadership positions for every roll call (necessary to obtain preferred directions, as described below). Formal leadership positions were not fully consolidated until the 1920's (Evans, 2018, ch.1). In the Senate (the focus of our main quantitative exercises in two dimensions), the first Republican leader was only officially nominated in 1925 (the beginning of Congress 69), while the first Democrat party leader was elected in 1920 (see Senate, 2020). Since the first Republican leader (Sen. Charles Curtis) was elected months into Congress 69, we begin our sample in Congress 70. For the House of Representatives, we use data from 1899 (Congress 56) as there is information on leadership over this period. However, leadership in the House between 1900-1920 looked significantly different from the subsequent period. Such institutional differences should be taken into account when interpreting our results.[39]

To determine the directions preferred by each party, $W_{p,t}$, we make use of leadership votes. For each roll call vote, we code whether the party leadership voted Yes or No using the decisions of the Majority and the Minority Leader. When such votes are unavailable, we use the Majority or Minority Whip's vote instead, and when those are also missing, the direction of the vote of the majority of the party. For the Senate, out of 25,824 roll calls in our time period, only 2,181 votes do not have the Democratic Leader's vote, 1,388 do not have the Republican Leader's vote, 161 do not have the vote of either the Democratic Leader or the Democratic Whip, and 355 do not have the vote of either the Republican Leader or Republican Whip. Out of 32,763 roll calls in the House, only 2,808 do not have the vote of the Democratic Leader and 285 have neither that of the Democratic Leader or Whip. For the Republicans in the House, 2,502 roll calls do not have the Republican Leader and 429 do not have either the Republican Leader or Whip.[40] The preferred

[39] While party leadership in the House of Representatives was formally established by both parties by the late 1890's, the scope, powers and election of those leaders changed significantly between 1900 and 1920. Most notably, the Democratic Party instituted elections for Majority Leader in 1911 (Congress 62) to limit the power of the Speaker (initially, the Majority Leader was appointed by the Speaker). Meanwhile, the Republicans only began electing Majority Leaders in the House in 1923 (United States House of Representatives History and Archives (2020b)). There were also changes in the committee membership and selection of Majority Leaders: between 1899-1919, the Majority Leader was also the chairman of the Ways and Means Committee regardless of party, although from 1919 onward it became commonplace that such leaders would not serve in committees. Finally, we face data limitations when using data earlier than 1921: no official records for the Democratic Whip between 1909-1921 exist due to missing documentation (see United States House of Representatives History and Archives (2020a)).

[40] The choice of using the Majority and Minority Leaders as the main information source for leadership behavior

directions of each party are then based simply on how the leader votes and the direction of the vote (which is estimated by the maximum likelihood estimator in equation (7)). If the Leader says Yes, the party's preferred direction is in the direction of Yes, and conversely if the Leader says No. This coding defines the variable $W_{p,t}$ and allows us to generate subsets of bills where leaders of both parties prefer the same and opposite directions.

In Figure 3, we provide summary information on the variation in preferred party directions in our sample. We present the number of roll call votes available in each Congress and then decompose this number into votes for which the two party leaders voted identically and differently. This decomposition is informative about the amount of variation available in the data, which is important for separately identififying the party pressure parameters (ID4). There is a large sample of each type of vote. Although it varies over time, in approximately 40% of roll calls the leaders of the two parties agree. Figure 3(b) shows the same information for the House of Representatives, again indicating many roll call votes in each group. The amount of data for the House is much larger than that for the Senate, with many more roll calls per Congress, and 435 member votes per roll call versus 100.

We use all available roll call votes in the sample to estimate both the two-dimensional model for the Senate and the one-dimensional model for both the House and the Senate. The computational cost of estimating our model increases sharply when moving to the two-dimensional case. Both the number of ideology parameters and the number of bill specific parameters double which makes estimation of our two-dimensional model for the House prohibitively time-consuming. However, as computational power is constantly improving, our approach should also soon be feasible for two dimensions in the House.

To give a better sense of the dimensionality of our problem, in Table 1 we include the total number of parameters estimated in our roll call analyses. It reports all classes of parameters for the Senate (two-dimensional and one-dimensional models) for the period 1927-2018 (i.e. up to Congress 115th) and for the House of Representatives (one-dimensional model) for the period 1899-2018.

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follows such seminal work as Cox and McCubbins (1993). We show in Section 4 that using only votes where both the Leaders and Whips agree, or using the Whip's votes when they disagree, yields qualitatively and quantitatively similar results. Another potential alternative would be to use the median party member's vote. However, this approach is problematic because we can only identify the median member after performing the estimation of the ideal points. Finally, one could simultaneously use the votes of the Majority/Minority Leader, Majority/Minority Whip and other ranking members of the party together to jointly determine the party's preferred direction. Unfortunately, it becomes unclear how to aggregate that data if the votes of one or more members are missing. Most of the missing values for Majority/Minority Leadership votes are due to unclear or missing data on leadership, particularly due to leadership transitions in the middle of a Congress, where the timing of a particular roll call is hard to assess (i.e. before or after the transition). For instance, in the middle of Congress 87, Majority Leader John McCormack became the Speaker of the House. As Speaker, he did not vote on roll calls. However, the previous Majority Whip (Carl Albert) became the Majority Leader, so using his votes when McCormack's are unavailable seems appropriate.

4 Results

Our main application for the empirical analysis is the U.S. Senate model in two dimensions, but we also include results for the one-dimensional House and Senate models. We refer to the two-dimensional model as 2D and the one-dimensional as 1D.

The likelihood presented in Section 2.5 is estimated jointly for the 70th-115th Congresses. Given the number of parameters, ensuring global convergence for every set of starting values is not guaranteed. We therefore evaluate the estimation results for a large number of vectors of initial parameter values. We also perform extensive Monte Carlo simulations of the model, to demonstrate that all parameters of the data generating process can be exactly recovered, providing additional assurance of the model's identification. More details on the implementation of our estimator are in Appendix C.

4.1 Party Pressure and Polarization

The large number of parameters (see Table 1) requires one to focus on the parameters of most interest. We begin with the party pressure parameters, $\bar{y}^{max} = \{y_D^{max}, y_R^{max}\}$. We estimate a different vector $\bar{y}^{max}$ for each Congress (therefore allowing party pressure to vary both between parties and over time). Figure 4 reports the point estimates for party pressure in the Senate 2D model for the time period 1927-2018, together with a nonparametric fit line to show the trends in party pressure for each party.

Figure 4 illustrates persistent, but evolving, levels of party pressure. For both parties, it traces a U-shaped profile over our time period. Neither party appears to lead or lag the other, with substantial contemporary correlation (0.515), but typically higher party pressure for the Republican Party in the Post-War period. Party pressure appears to be declining until the late 1960s, increasing until the end of the 1990s, and then taking on an even steeper increase in more recent Congresses. Interestingly, the time series evidence fits descriptive analyses, like the one in Sinclair (2014). The inflection points in the time series proximately match the qualitative discussions of Congressional experts, with a sharp separation between the Committee ascendancy period of 1933-1960 to the period of stronger leadership and realignment of 1960-1994 to the modern 1994-2018 Congress (Deering and Smith, 1997; Jenkins, 2011; Sinclair, 2014; Evans, 2018). The steeper turn in the mid-1990s is compatible with the putative changes following the Gingrich speakership - see Theriault and Rohde (2011); Theriault (2013), for example.

All point estimates of party pressure are statistically significant (p-values < 0.001),[41] implying that the data strongly rejects the null hypothesis of the absence of party pressure in every congres-

[41] We estimate the variance of the parameters using the empirical counterpart to the asymptotic variance of the MLE, as is standard.

sional cycle in our sample. This fact remains true even at its historical lows of around $0.3 - 0.4$ units in the 92nd-95th Congresses (1971-1976). More recent estimates of $\bar{y}^{max}$ are at historical high water marks, between 1.5 and 2. The 2018 level of y_R^{max}, for example, is 2.04, indicating a substantial ability by the Republican leadership to reach far into the set of dissenting members. Intuitively then, because of the powerful reach of the Senate leadership, even ideologically moderate Republican members of the 115th Senate, such as Sen. Susan Collins or Sen. Mitt Romney, may appear more conservative when party pressure is not accounted for (as in DW-Nominate) than when it is.

The U-shaped profile in party pressure is confirmed with both of the 1D Senate and 1D House models, and it is in fact more marked in these instances (see Figure 5(a) for the Senate 1D model and Figure 5(b) for the House 1D model). Qualitative studies for the House, like Sinclair (1992), match the timing and the sign of the time derivatives of our estimates and our estimates appear consistent with organizational changes over the 1960-1994 period and post-1994 period which happened in both the House and the Senate.[42]

Our second main result is the time series of ideological polarization reported in Figure 6 for the Senate 2D model over the 1927-2018 period.[43] As with DW-Nominate and other methods, our approach requires us to specify location, scale, and rotation through normalizations (Assumptions ID of Section 2.4). Although our assumptions pin down a rotation, the rotation is arbitrary, as it depends on the particular normalizing bill (chosen to have $m_0 = 0$). Thus, to make our results more comparable to DW-Nominate (a comparison we return to in the next section) – which is required for the correct interpretation of the correlations between approaches[44] – we rotate our estimates using the Procrustes rotation of our ideology estimates onto those of DW-Nominate. Procrustes analysis is a popular and theoretically-founded approach for comparing two multidimensional

[42]For example, Jenkins (2011) specifically mentions rule changes that affect the organization of the House and Senate over the 1960-1994 period ("*To control proceedings, the leadership began relying on special (restrictive) rules to structure debate and floor voting*") and explains the uptick in polarization for the post-1994 period ("*... as Senate parties have become more effective in recent years at steering the legislative agenda toward party cleavage issues—those on which there is internal party unity and wide divergence between the two parties—a strengthening of formal leadership structures in the Senate has also occurred, with party caucuses meeting more frequently and enhanced resources (both funds and staff levels) being devoted to party leadership offices.*") (p.13). Also see Canen et al. (2020) and the references therein for a discussion of rule changes in Congress that strengthened party leadership over the 1970s. Such rule changes, which occurred both in the House and Senate over the 1970s, include megabills, omnibus legislation, and time-limitation agreements, allowing leaders more control over the party rank-and-file and the agenda.

[43]Figures 27 and 28 in Appendix D report the time series for ideological polarization for the Senate and House 1D models, showing remarkably similar profiles to the results of the Senate 2D model. The fact that the House estimates are only slightly larger than those in the Senate may appear at odds with hypotheses that would predict unambiguously higher pressure in the House, where more tools may be available to leaders. However, it is difficult to know how much of a quantiative difference to expect from the qualitative differences discussed in the literature.

[44]As linear correlation is dependent on the specific rotation of the data, calculating the naive correlation of our first dimension estimates and DW-Nominate's first dimension would be uninformative. Appropriate transposition of our estimates into the DW-Nominate space is necessary.

scaling methods (Goodall 1991; Kendall 1989). A Procrustes rotation minimizes the sum of the squared differences between points in our matrix of estimates and the DW-Nominate matrix, which constitutes the reference space.

We derive estimates of ideological polarization from our estimates of politicians' ideologies, noting that we assume that these ideologies are constant across Congresses. We focus here on ideological polarization in the first dimension, but also report results for polarization along the second dimension (in Figure 18 in Appendix D). Following the standard in the literature, we define ideological polarization as the difference between the ideological positions of the median Republican and the median Democrat along each dimension.

The most salient fact in Figure 6 is the steady growth of ideological polarization over the sample period. Ideological polarization along the first dimension appears to double approximately every forty years, a higher growth rate than in DW-Nominate. Our results imply that the standard intuition that more moderate members are increasingly replaced with more extreme ones appears correct (although with lower absolute levels due to the presence of party pressure). Our analysis also suggests that part of the U-shaped profile observed in estimates where party pressure is ignored is in fact due to party pressure itself changing non-monotonically. While ideological polarization approximately doubles between 1965 and 2015, party pressure approximately trebles. Hence, it appears the latter is a significant driver of the polarization in legislative behavior.

To put the magnitudes of the party pressure parameters into perspective, we plot the share of polarization attributable to party pressure (i.e. total party pressure divided by party pressure plus ideological polarization) in Figure 7. As demonstrated in Canen et al. (2020) for a one-dimensional model, the denominator of this measure is the ideological polarization one would obtain with a model that ignores the role of party pressure (a "misspecified" model to which we also turn in the next section), a consequence of the fact ignoring party pressure results in a misattribution of vote differences solely to difference in ideologies across parties.[45] In our 2D model we measure the distance between the centroid of each party. The share of polarization attributable to party pressure has highs of over 80% in the 1930's, falls to around 60% in the Civil Rights Era, and is between 65-75% in recent decades. Results for the Senate and House 1D models are quantitatively similar (Figure 29 in Appendix D).

An alternative approach to assess the importance of party pressure for political behavior is to focus on votes that pin the majority of one party against the majority of the other party. These votes are commonly referred to as Party Unity votes and illustrate a clear lack of bipartisan agreement. Figure 8 reports the fraction of roll call votes that are predicted to be Party Unity

[45] In a one-dimensional model, neglecting party pressure shifts the ideologies of all members of a party by the same amount because of unbounded ideology shocks: each member will, with some probability, be subject to pressure on every bill. Although this result does not exactly hold in a two-dimensional model, we feel this measure of the share of polarization due to pressure is still natural.

votes based on our main estimates, and the fraction predicted by an alternative model that sets party pressure to zero. The time series for the two models' predictions appear in panel (a) and the relative increase in divisive Party Unity votes attributable to party pressure appears in panel (b). Figure 8 panel (b) shows that, in 2018, party pressure causes about an extra 10% of roll calls to be votes which pin the majority of one party directly against the other, a substantial quantitative increase in the amount of adversarial behavior in the Senate.

In Figure 9, we report the ideology of the median member in each party and further split the Democratic Party into the Southern Democrats and Northern Democrats, to emphasize this important component of historical heterogeneity within that organization. The well known ideological convergence between Southern Democrats and the Republican party along the first ideological dimension is evident in Figure 9.[46]

In terms of symmetry, the pattern of ideological polarization does not appear to be driven by one party relative to the other. Instead, both Republican and Democratic parties contribute to the ideological divergence highlighted in Figure 9. The extant literature has discussed asymmetries in voting polarization based on DW-Nominate (Grossmann and Hopkins, 2016), but they appear driven by a marginally higher party pressure parameter for the Republican Party in the last part of the sample and not by asymmetric ideological divergence.

To provide a more complete presentation of the distributions of ideological preferences along the two policy dimensions, we report the kernel density estimates for the two parties over time. The first dimension marginal distributions are reported in Figure 10, and the second dimension distributions in Figure 11. We report only the 2D Senate model for brevity. Not only have the first moments of the Democratic and Republican Parties been diverging over time, most visibly from the 95th Congress (started in 1977) in Figure 10, but the variances in the first dimension of each party have also fallen over time. Our model is consistent with the extant literature for these well-established facts.

In summary, our first group of results shows that party pressure has played a significant role over time, particularly in recent Congresses. The data clearly rejects models that omit party pressure. While we confirm standard findings in terms of a recent increase in ideological polarization, existing results of non-monotonic and asymmetric dynamics appear unsupported by the data once we include a role of for parties in the analysis.

4.2 Comparison to DW-Nominate

We now compare our results to those of the DW-Nominate method. Recall that a comparison of our 2D estimates to those of DW-Nominate is appropriate because we analyze our estimates after

[46] We report an analogous figure for the second dimension in Figure 26 of Appendix D.

a Procrustes rotation on to DW-Nominate's space. Nevertheless, we must emphasize that this basis for comparison is not unique – using other rotations would likely produce similar, but not identical results.

Figure 19 in Appendix D provides scatter plots of our first dimension estimates versus those of DW-Nominate. Appendix Figure 20 presents the same comparison for DW-Nominate to a third model, which we called the "misspecified model". Appendix Figures 21 and 22 present the corresponding scatter plots for the second dimension estimates. The misspecified model implements our main model with a constraint of no party pressure. It is therefore an identified version of our two-dimensional model that is directly comparable to DW-Nominate in that it lacks a role for parties. The first dimension estimates of the misspecified model align reasonably to those of DW-Nominate, but in our model with party pressure, a sizable gap opens up between members of the two parties located at the same first-dimensional ideological level. This gap is driven by the fact that our model recognizes that individuals who have the same preferences, but belong to different parties, are often pressured in opposite directions, therefore appearing less moderate. By ignoring party pressure DW-Nominate misattributes the difference in voting behavior exclusively to differences in preferences, as does the misspecified model. This shift is ultimately responsible for the mismeasurement of ideological polarization in DW-Nominate and leads to a different interpretation of the data.

Figure 23 in Appendix D reports the time series of polarization in the first and second dimensions according to DW-Nominate and our main estimates. As shown in this figure, our ideological estimates imply a sharper growth in first dimension polarization. Furthermore, they do not replicate the early sharp decline in liberal-conservative polarization that so typically defines the time series for DW-Nominate over the 20th century in the Senate, although admittedly this may be the result of being limited to the post 1927 period. Figure 23 also shows markedly different dynamics for the second dimension of the model relative to DW-Nominate, a feature that we trace to DW-Nominate's identification issues and discuss further below.

Pairwise rank correlations between model estimates in the first and second dimension are also informative. Notice, however, that these correlations paint a different picture than the location of the marginal densities or consistency of the estimated ideology parameters. Rank correlations simply capture the similarity in rankings of politicians between methodologies. The rank correlation of the first dimension of ideological positions of our baseline model (after imposing the rotation) and DW-Nominate is 0.857. This high correlation means that that our ordering and that of DW-Nominate are quite similar along the first dimension. As the ordering of legislators along the first dimension is probably the most widely-accepted feature of DW-Nominate, we find this correlation reassuring. On the other hand, the rank correlation of second dimension ideological positions across models is much lower, 0.435. This low correlation is most likely due to the fact that the second dimension of ideologies and the cutline parameters appear the most sensitive to the lack of identification issues in DW-Nominate. One plausible explanation may be the short time period over which the second dimension makes up an important feature of the legislative voting data (the 1960s and 1970s), whereas the first dimension appears relevant for the entire sample period. Such results are not driven by cross-party variation: the correlations between our estimates and those of DW-Nominate are also high within parties for the first dimension (0.728 for Democrats and 0.884 for Republicans), but low for the second dimension (0.498 for Democrats and 0.309 for Republicans). The results are also not specific to DW-Nominate: we replicated the Bayesian approach of Clinton et al. (2004) and applied it to their original setting (House of Representatives, Congress 106). We find a very high correlation between our measure and theirs in the aggregate (0.944) and within parties (0.899 for Democrats, 0.762 for Republicans).

Finally, comparing DW-Nominate to the misspecified model produces, as expected by design, similar results. The rank correlation along the first dimension is high at 0.910, while the correlation along the second dimension is substantially lower, at 0.365, again presumably due to lack of identification.

4.3 Model Fit

Assessing the in-sample fit of our empirical model, congressional cycle by congressional cycle, further quantitatively validates our approach. In Figure 25 of Appendix D, we report the time series for the in-sample fraction of correctly predicted roll call votes in each congressional cycle. The share of correctly predicted votes increases over time, with at least 80 percent of all individual choices being correctly predicted in any cycle. The share of correctly predicted votes in 2018 reaches about 95 percent of all votes cast, which is extremely high.

It is important to remark that the ability to predict individual vote choices to a high degree may not necessarily be fully indicative of all aspects of model quality, especially with respect to bias of the ideal point estimates and the location of the distributions of Congress members. High levels of correctly-predicted binary vote choices can be achieved even with very biased and inconsistent estimates of the cardinal locations of the ideal points when using an approximately correct ordinal ranking of politicians. This is the reason why, while DW-Nominate has excellent predictive power, we can show that its estimates of preference parameters are biased by the omission of party pressure, missing an important feature of the data.[47] The misattribution by omission can be substantial: as discussed in Section 4.1, party pressure makes up on average, $65 - 70$ percent of voting polarization from the misspecified model (Figure 7) over the entire period (with the

[47] The same holds with our misspecified model omitting party pressure: it has excellent predictive power, like our baseline model (see Figure 35 in Appendix D for a comparison), but is biased due to the former's omission of party pressure.

remaining $30 - 35$ percent being correctly attributed to ideological polarization).

4.4 Additional Validation of the Ideological Estimates

We can further show that our ideological estimates are consistent with existing qualitative evidence and additional theoretical hypotheses.

First, if party pressure is truly driving polarization in congressional roll call voting as we propose, one should expect our measure of ideological polarization to better match the results of estimators of polarization that are less likely affected by the omission of party influence than DW-Nominate. To test this hypothesis, we compare the distribution of our ideological estimates to the ideological estimates from Ansolabehere et al. (2001a), which used Project Vote Smart's National Political Awareness Test (NPAT), a survey administered to all House candidates. To the extent that politicians' responses to the NPAT survey's questions about policy preferences are less contaminated by party pressure than roll call votes, we expect our ideological estimates to be more similar to those of NPAT than those of DW-Nominate. Figure 24 in Appendix shows the distributions for the three measures for Congresses 104 and 105 (the ones originally used in Ansolabehere et al., 2001a). We can see that the results are in line with the stated hypothesis: the overlap of Democratic and Republican ideologies in our estimates is very similar to that in NPAT, while there is almost no overlap in DW-Nominate.

Second, we can qualititively evaluate our results by discussing individual politician estimates. Consider, for example, the members we identify as moderates: those who sit in the overlap of the ideological distributions of Republicans and Democrats in Figure 10.[48]

The overlapping moderates among Republicans from Congress 104 onwards are (in alphabetical order): Scott Brown, John Chafee, Lincoln Chafee, William Cohen, Susan Collins, Mark Hatfield, James Jeffords, Robert Packwood, Olympia Snowe and Arlen Specter. This list is very much in line with journalistic accounts and with the perception of congressional analysts: it represents a combination of senators who eventually switched to become Democrats/Independents at later dates (e.g., L. Chafee, Jeffords and Specter), and of known moderates (e.g., Susan Collins, Olympia Snowe and William Cohen - the latter a Republican who served in Bill Clinton's administration).

The overlapping Democrats are: Evan Bayh, John Breaux, Joe Donnelly, J. James Exon, Howell Heflin, Mary (Heidi) Heitkamp, Ernest Hollings, Gordon (Doug) Jones, John Johnston, Joe Manchin, Claire McCaskill, Zell Miller, Earl (Ben) Nelson and Samuel Nunn. Again, this list is in line with qualitative views of Congress. It consists of Southern Democrats, known to be socially conservative (e.g., Breaux and Johnston from Louisiana, Heflin and Jones from Alabama, Nunn

[48] For Congress 104 onwards, these are Republicans to the left of 0 and Democrats to the right of -0.1. By focusing on politicians after Congress 104 (the Republican Revolution), we can operationalize this exercise in a context with hundreds of estimates.

from Georgia), known swing Democrats (such as Joe Donnelly, described by Politico as “constantly dogged by Republicans aiming to unseat him” while also facing ”disgruntled Democrats who think he’s far too conservative”; Ben Nelson, called “The Least Reliable Democrat” by the Huffington Post, and Heitkamp, who was spoken of highly by former President Trump[49]), and senators who were known for their bipartisan work (e.g., Zell Miller and Bayh).

5 Robustness and Extensions

In this section, we describe additional exercises that validate our estimates and show their robustness to different identification threats. In Section 5.1, we show robustness of our baseline results to alternative definitions of the party pressure direction, $W_{p,t}$, and to the assumption that party pressure is applied on all votes. We also demonstrate that our estimates align well with those we produced in Canen et al. (2020). In Section 5.2, we provide a discussion of potential mechanisms that could confound the interpretation of $\bar{y}^{max}$as party pressure, and perform several robustness checks of this interpretation. In Section 5.3, we consider the potential roles of presidential and committee pressure, as well as re-election concerns.

5.1 Alternative Specifications of Party Pressure Direction, $W_{p,t}$

In addition to the standard identification assumptions discussed in Section 2.4, our results depend on the way in which we construct the preferred direction of each party, $W_{p,t}$. To assess the reliance of our estimates on this variable’s exact definition, we consider alternatives based on suggestions within the extant literature. We re-estimate our model under five alternative scenarios: (i) assuming no party pressure (i.e. $W_{p,t} = 0$) on lopsided votes (where lopsided is defined as at least 65 percent Yes votes unless the majority party controls more than 62% of seats in which case it is defined as at least 70% of Yes votes),[50] (ii) dropping votes where a party’s Leader and Whip voted differently (approximately 25% of the sample), (iii) using only the Whip’s vote when the Leader and Whip voted differently, (iv) assuming no party pressure on votes where the leaderships

[49]See https://www.politico.com/magazine/story/2017/12/05/the-loneliest-democrat-in-trump-country-216012/ (Politico), https://www.huffpost.com/entry/ben-nelson-vote-democrats_n_804101 (Huffington Post), https://www.politico.com/story/2018/05/30/trump-heitkamp-democrats-midterms-dakota-611563 (Politico), respectively. Accessed June 14th, 2023.

[50]This is a a specification inspired, but different, than the one presented in Snyder and Groseclose (2000). In contrast to their work, identification of this specification does not rely on comparing voting behavior of the same legislators in lopsided and non-lopsided votes, a source of weak identification due to the lack of variation in voting behavior in lopsided votes (McCarty et al. (2001)). Instead, our parameters for party pressure (y_p^{max}) are identified by information on the party leaderships’ preferred directions within non-lopsided votes. As a result, individual ideologies are recovered from average voting behavior conditional on party pressure, using information on both lopsided and non-lopsided votes.

of both parties vote in the same way, and (v) estimating party pressure using only votes in which the leaders disagree (in the last two cases, we can only identify the aggregate amount of party pressure, $y_D^{max} + y_R^{max}$).[51]

The first specification tests whether our results rely on the assumption of party pressure on every vote. It does so by incorporating an idea that has received extensive attention in the literature following Snyder and Groseclose (2000), while still maintaining identification of the party pressure and ideology parameters. The second and third specifications test the robustness of the empirical construction of $W_{p,t}$ itself. The econometrician does not observe the exact direction of party pressure. Instead, in our baseline specification, we proxy it with leadership votes. This proxy might seem less appropriate when leaders within the same party disagree (e.g. the Majority Whip's decision differs from the Majority Leader's). For example, one particular reason for this difference in voting could be the use of a motion to reconsider in the Senate, whereby a senator on the prevailing side or who did not vote can motion for a revote. This may incentivize a leader to vote against his/her preferred policy in order to preserve the possibility of a future revote.[52] The fourth and fifth specifications are similar to the first in that they test whether or not our results depend on the assumption that pressure is applied to every vote.

We present the results for total party pressure $y_D^{max} + y_R^{max}$ across models (i)-(v) in Figure 12, and the results for individual parties for (i), (ii) and (iii) in Figure 13 (i.e. the specifications where the individual parameters are identified). It is clear that our quantitative and qualitative results are remarkably similar across specifications, establishing that our results are robust to a more restrictive construction of $W_{p,t}$ and to a range of assumptions about the bills for which pressure is applied.

We can also compare our benchmark estimates of party pressure to those from Canen et al. (2020). The latter derives identification from information contained in detailed internal party records before floor votes (whip counts, as cataloged by Evans, 2018), and thus does not exclusively rely on assumptions about the direction of party pressure. This comparison is possible only for the short subsample in which both sets of results are available: for both parties in the House of

[51]Estimating using only bills for which the leaders disagree addresses the particular concern that unobserved differences between bills in which leaders agree and disagree (such as bills on which they disagree being noisier, for example) confound our results.

[52]Only a senator on the prevailing side or who did not vote can motion to reconsider. In most cases, this motion is pro-forma: after it gets proposed, another senator who voted alike immediately motions to table it. This dual procedure guarantees that the first vote is final (i.e. it will not be revoted). See Schneider and Koempel (2012) for details. Nevertheless, a Majority Leader may sometimes deviate from his/her preferred vote in order to file a motion to reconsider. For example, when (s)he is about to lose a vote in the Senate, (s)he might prefer to switch sides and vote with the opposition, preserving the possibility of a future revote due to a motion to reconsider. A recent example was Mitch McConnell's vote with the Democrats in the failure to confirm Judy Shelton's nomination to the Federal Reserve Bank (see: https://www.washingtonpost.com/business/2020/11/17/shelton-fed-mcconnell/). This motion is pro-forma in the House of Representatives (Schneider and Koempel, 2012).

Representatives between 1977-1986 (i.e. Congresses 95-99). Figure 30 in Appendix D shows that the estimates of party pressure are remarkably correlated across identification strategies, with a linear correlation of 0.88,[53] and that the different identification strategies produce quantitatively similar estimates for the role of parties.

5.2 Potential Confounds

Party pressure operates across multiple members of the same party concurrently. Hence, certain types of common shocks that affect members in correlated ways may affect our estimates of the pressure parameters. We therefore consider whether or not party-specific shocks may be major drivers of our estimates of party pressure parameters. We argue that this is not the case for several reasons.

First, changes in votes due to omitted common value policy components (Kendall and Matsusaka, 2021) can be immediately ruled out, as they would be common to *all* members. Our estimates of party pressure, instead, are identified off of differences between parties. In fact, to affect our estimates substantively, any common shock would need to be specific to the members of one party only and, furthermore, it would need to, in roughly 60% of the votes in each Congress, affect members of the other party in exactly the opposite way.

Second, any common shock must operate at very high time frequency - the frequency of congressional voting, which numbers in the thousands per cycle. While certain large public opinion or media shocks may affect certain salient roll calls, they are unlikely to materialize at a daily frequency across thousands of bills.

Third, to believe that party-specific shocks are substantially responsible for the results, one would have to explain why the size of such shocks would vary over time in the way that our estimates of party pressure do. In particular, as discussed in Section 4.1, the uptick in pressure that we observe in the data is generally consistent with the consensus among U.S. Congress scholars on how institutions and the role of parties have evolved since the 1980s. It seems less plausible that generic party-specific shocks would accidentally align with changes in internal committee seat allocation procedures, rule changes, and internal party whip system reorganization observed over time – all factors of party influence.

For the above reasons, generic common shocks are unlikely drivers of our results. Nevertheless, we perform two additional checks to probe this possibility. These tests build upon the fact that, to be driving our estimates, any party-specific shocks must realize systematically in the direction of the leader's votes: arbitrary shocks common to party members that do not affect the leadership would not show up as party pressure. In our first check, we re-estimate the model assuming each

[53] To make the results comparable, we scale up the estimates from Canen et al. (2020) by a factor of $\sqrt{2}$ because of differences in the way in which the ideologies and party pressure parameters were scaled in the two models.

party's preferred direction (shocks) is uncorrelated with the leader's vote (equal chance of a shock of size y_p^{max} in either direction for each party). This version of the model is strongly rejected in favor of our actual model when using a Vuong model selection test ($p - value < 0.001$).

In the second test, rather than assuming random shock directions, we sort members in each Congress by how often they vote in line with the party leadership. Then, we re-estimate our model, replacing the actual leader's vote with the votes of members at different ranks on this list (e.g., 50th percentile, 25th percentile, etc.). If generic common shocks other than direct party influence were at play, we would expect our estimates of party pressure to be unchanged as we use different members across the distribution of voting behavior. Instead, if party pressure from the leadership plays a specific role, as we conjecture, we would expect that the party pressure estimates should increase monotonically as we focus on members that vote with the leadership more often. The results of this exercise are shown in Figure 31 in Appendix D. As expected, we estimate stronger party pressure effects for members whose votes are more correlated with the actual leader's (the figure shows averages across time).

In fact, this second exercise provides a lower bound for the amount of our main estimates of party pressure that must be attributed to party leadership. We should not expect (and do not find) estimates of party pressure to be zero when using members far from the leadership as putative leaders.[54] To the extent that even these members are disciplined, their votes will be correlated with party leadership if leaders exert discipline. But, even if we take the extreme stance that the estimate obtained for the least correlated member is due to some form of party pressure not due to the leadership, such as logrolling (trading votes among legislators in the same party), party conformism (a desire to go with the flow in order to 'get along'), or peer pressure, the *difference* between this estimate and the estimate obtained with the actual party leader must be attributed to party discipline. Thus, while our main estimates provide evidence of party pressure which could be due to discipline, peer pressure, etc., the difference across estimates provides a lower bound for the influence of party leaders (about 50% of our original estimates).

5.3 Extensions: Presidential and Committee Influence, and Re-election Concerns

5.3.1 Presidential Influence

We first consider whether or not Presidents are also able to exert pressure on party members. The executive branch is known to occasionally expend significant resources to corral politicians to vote in their preferred direction, above and beyond any party leadership pressure. Indeed, presidential

[54] We thank Professor James Snyder and a reviewer for suggesting variations of this test.

behavior has been found to be significantly associated with changes to roll call voting and other congressional outcomes (see Chiou and Rothenberg 2014; Howell and Rogowski 2013 for recent examples).

To account for this possibility, we extend our baseline model by introducing additional data from VoteView.com which codes presidential positions (based on the President's declared stance on a roll call). Such data is available in the Senate from the 1960's onward. We let W_t^{pres} denote the direction of the President's position when available[55], coded analogously to $W_{p,t}$, and allow the maximum pressure faced by a politician in the President's party to be $W_{p,t}y_p^{max} + W_t^{pres}y_{pres}^{max}$. The first term is the same as in the baseline model (i.e., the party influence), while the second term allows the politician to be affected by presidential influence. The parameter y_{pres}^{max} captures the extent of presidential influence (i.e., how far the President can corral members of his own party, beyond what is done by the party leadership itself). Legislators in the opposing party to the President are deemed to only face party pressure, parameterized as before by $W_{p,t}y_p^{max}$ for roll call t.[56]

The main results for the presidential influence parameters (y_{pres}^{max}) and party pressure parameters (y_p^{max}) are shown in Figure 32 in Appendix D. The ability of Presidents to assert influence seems to vary substantially across administrations. In the cases of President George W. Bush and President Obama and early on with President Eisenhower, presidential influence is positive and substantial. It is much lower during the terms of Democratic presidents in the 1960's and 1970's, as well as at the end of the Nixon administration (Congress 92). These findings appear broadly consistent with other evidence (e.g., Rivers and Rose, 1985).

Importantly for our purposes, allowing U.S. Presidents to exert influence does not substantially change the effects of party leaders – the estimates of party pressure in Figure 32 do not substantially differ from our baseline estimates (see the left-hand panel of Figure 32).

5.3.2 Committee Influence

Our baseline estimates point to strong leadership pressure between 1927 - 1963, which may be surprising to Congressional scholars of this period, who have emphasized that the main source of power in Congress during this time stemmed from committee membership rather than party leadership. After all, party leaders did not control nominations, committee assignments or promotions (which were based on seniority at the time), and struggled to set an agenda due to the presence of a Southern Coalition in the Rules Committee (Jenkins, 2011 for an overview). To the extent that

[55] We observe a President's position for approximately 25% of the sample.

[56] We note that we can separately identify the presidential influence parameter, y_{pres}^{max}, as long as there exist cases in which the presidential position differs from his party's leadership positions (i.e., some t such that $W_{p,t} \neq W_{p,t}^{pres}$). This occurs in the data: across our sample, both Republican and Democrat presidents agree with their party on approximately 2400 roll calls, while differing for approximately 350.

party and committee member votes are correlated, we could be picking up committee pressure as leadership pressure. Disentangling these two possibilities is extremely difficult given that it is possible, and even likely, that party and committee leaders bargain before ever reaching the floor.

However, here, we re-estimate our model replacing party leadership votes with committee member votes to provide some suggestive evidence. Specifically, we re-estimate the model replacing the leader's direction, $W_{p,t}$, with the direction of the vote of the party's highest ranking member in the most salient committees voting on the bill.[57] To do so, we collect committee composition data from three separate sources: Canon et al. (2022); Nelson (2022); Stewart III and Woon (2022) which, when merged together, result in a comprehensive dataset of Congress-by-Congress committee membership and seniority. As mentioned before, the pressure parameters are identified off differences in voting behavior among such senior-ranking committee members across parties.

We conduct this exercise for the two most important and salient committees in the Senate: the Finance Committee (equivalent to the Ways and Means Committee in the House, with authority over taxes, finances, customs and spending in certain federal programs including Medicare and Medicaid) and the Appropriations Committee. We focus on these committees in accordance with both qualitative (i.e. in the attributions and desirability of each committee) and quantitative evidence (both are among the highest scores in the Grosewart measure Stewart III and Groseclose, 1999; Stewart III, 2012, which are based on the committees most Congress members ask to be assigned to). The results are shown in Figure 33 of Appendix D.

The results for each of the two committees are roughly in-line with extant literature. Early on, whether we use leader votes for committee member votes, we find similar estimates of pressure. More recently, on the other hand, pressure is substantially larger when using leadership votes, suggesting that committees were indeed powerful early on, but party leaders appear more powerful today (e.g., through campaign funds, committee assignments, and branding). Again, one should take this evidence with caution – as noted above it is difficult to disentangle the sources of pressure without observing who exactly is handing out the rewards and punishments.

5.3.3 Re-election Concerns

Congress members up for re-election may be less susceptible to party influence as they may be given leeway to vote as their constituents demand. In this extension, we consider how party pressure may vary in the cross-section, allowing the party pressure parameters to differ between those members of the Senate that are up for re-election versus those that are not.[58]

We find only modest evidence in support of the hypothesis that Senators in a class up for re-

[57] If no vote of any committee member is observed, we assume no committee pressure.

[58] Senate seats are divided in three separate Classes. Each class corresponds to 1/3 of the chamber's seats and every two years a different class of Senate seats is up for election.

election face less pressure. On average, y_D^{max} and y_R^{max} are only 3% and 7% lower for members facing re-election, respectively. Figure 34 in Appendix D provides a full comparison of the estimates for each Congress. These moderate effects are perhaps not surprising. Rather than being pressured less, a member facing re-election may be pressured just as often, but in equilibrium be better able to extract concessions from the party.

6 Implications for Theories of Party Organization

Our results allow us to speak to different theories of political party organization. Such theories, for the most part, have remained either purely theoretical or have been guided by less formal quantitative approaches (Sinclair, 2014). We do not aim here for a complete analysis of the historical determinants of party pressure, as this would be beyond the scope of the paper, but include this discussion to demonstrate the potential value of having estimates of party power.

First, we emphasize the compatibility of our approach and results with existing theories of party behavior. For example, extensions of the procedural cartel theory (Cox and McCubbins (1993, 2005)) propose that parties organize themselves and pressure their members for policy purposes. In doing so, they are able to maintain a party's reputation ("brand"), which is of common value. While these authors usually do not explain the origins of party pressure, they share common mechanisms with those we propose in the model and that we quantify empirically.

Our results are particularly in line with predictions from the Conditional Party Government (CPG) theory of Aldrich (1995) and Rohde (1991). This theory states that legislators delegate more agenda-setting power to leaders when the party is more ideologically homogeneous – exactly the pattern that our results indicate. The intuition is that, as party members become more aligned, it is more beneficial to delegate power to leaders who are more likely to advance commonly-desired policies. Indeed, Figure 14 reports evidence of a inverse U-shape time series in the variance of the first dimension of ideologies within each party, in contrast to the U-shape in party pressure of Figure 4. This negative correlation between the time series of party pressure and within party variance along the liberal-conservative dimension is strong and statistically significant for both Republicans and Democrats.[59]

To explain the trends in the data, one could hypothesize a dynamic version of this CPG: increases in party pressure due to more homogeneous parties may induce the exit of moderate members, increasing ideological homogeneity even further. Increasing homogeneity could then lead to a further increase in party pressure, and so on, in a self-reinforcing mechanism.[60]

[59] The estimates from separate regressions of y_p^{max} on the variance of ideology estimates for party p are -9.218 for Democrats and -3.529 for Republicans. Robust standard errors are 2.881 and 1.305, respectively.

[60] It is also partly consistent with other theories of organization, such as party leadership as "enablers" as in Van Houweling (2003). In this argument, the rank-and-file would delegate authority to leadership, who could

We find a high degree of correlation between party pressure across parties (0.515) in our sample. This correlation is high even though there is extensive evidence of technological innovations during this period, including the introduction of focus-group tested languages and coordinated vocabularies by the 1994 Revolution Republicans (see Gentzkow et al., 2019). Because of these innovations, one might have thought that increases in party influence would have come first for the innovating party, followed by the other (as seen by the adoption of these tactics by Democrats). Although still possible, the high correlation in influence across parties suggests that such technological innovations diffuse quickly across the political spectrum.[61]

Indeed, we expect that our approach could prove fruitful in testing other existing theories of party behavior. Our model recovers consistent estimates for y_p^{max} without imposing structure on its explanatory sources (e.g. majority status or divided government). As a result, we can use it as a dependent variable in a regression framework to test such sources. Table 3 in Appendix D reports the estimates of such an exercise. To highlight one result, we find suggestive evidence that unified and divided governments have similar party behavior. This finding is consistent with Krehbiel (1998) and Mayhew (2004), but in contrast to Sundquist (1988), who argue that party behavior differs when the president's party does not coincide with the majority in Congress.

7 Conclusion

Political polarization is currently at an all-time high in the United States and many other Western Democracies. This phenomenon is attributed by many to the election of representatives who express radically more extreme views than their predecessors. Under this reading, without compromising the integrity of the electoral process, there would seem to be little remedy to the current adversarial state of liberal democracies. Voters are purposefully electing extreme types over moderates.

Elected legislators, however, do not act as independent decision-makers. They belong to structured political organizations. These organizations operate with formal systems of leadership and pursue specific party goals by incentivizing their members. Perhaps more encouragingly, party

better coordinate policy outcomes, managing the different policy preferences between politicians and their electorate. This would be consistent with our estimates to the extent that such coordination and selection of bills follows that outlined in Section 2.

[61] In fact, qualitative evidence suggests that this spread may not be constrained to the U.S. alone – other countries often adopt the same American legislative tactics and electoral innovations in their own campaigns and legislative proceedings. For example, in the early 2000s, Silvio Berlusconi in Italy applied similar public relations techniques to the U.S. Republican Revolution. Similarly, in 2017 Emmanuel Macron in France employed some of the campaigning techniques experimented with in the Democratic presidential campaigns of 2008 and 2012. In 2018 Jair Bolsonaro in Brazil explicitly mirrored Republican tactics (see https://apnews.com/article/e6d1ef0d496545dd86d21584253b2312). This international spread of U.S.-born parliamentary innovations could possibly drive similar patterns of political polarization across different political systems.

strategies and the technology of whipping appear more amenable to transformation and policy change than slow-moving secular trends in voters' attitudes.

We show that U.S. party leaders have been important in driving elite polarization, essentially carving out, through stronger control and influence, the moderate middle ground between the two parties. Employing a structural model and a new methodology for the analysis of legislative voting in the U.S., we show that the Democratic and Republican Party leaderships have played a substantial role in driving political polarization over the last century. We estimate that about 65-70 percent of current polarization in congressional voting is due to the ability of U.S. parties to influence and control the votes of their rank and file. Increasing ideological polarization accounts for the remaining portion of the variation.

Virtually all extant methods for the analysis of elite polarization currently attribute no role to party pressure, instead ascribing the entirety of the variation to ideological polarization. Based upon our tests, this assumption is statistically rejected by the data. Correspondingly, within extant models, legislators appear substantially farther from each other than they are in reality, misattributing influence from the party leadership as extreme preferences.

Because our methodology requires only vote data and leadership positions, we are also able to document how the role of party pressure has changed over time. The well known U-shaped profile of political polarization over the last century appears to be the combination of a mainly monotonic increase in ideological separation between median party members' policy preferences and a U-shaped profile of party pressure over time (with a low point in the 1960's-early 1970's). Strategies of "slash and burn", in which parties describe other members disparagingly, are now commonplace, and the timing of their emergence aligns with the inflection points in party pressure estimated in the data.[62]

At the moment, U.S. political parties appear to be at a high point of party influence, with the technological tools and strategic abilities that allow them to direct their members (and to offer incentives to toe the party line) more readily than ever before. We do not study these specific tools and tactics here, but the ability to measure and analyze party control that we offer will hopefully open the path to new research in this area.

Finally, we hope that the methodology that we have developed will be applied in other contexts in order to assess party pressure in the cross-section. Specifically, it can be readily applied to state legislatures and other countries for which vote data is readily available (e.g., the UK and Brazil).

[62] https://www.nytimes.com/1990/09/20/opinion/the-politics-of-slash-and-burn.html

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8 Tables and Figures

Figure 1: Opposing Party Pressure in 2 Dimensions

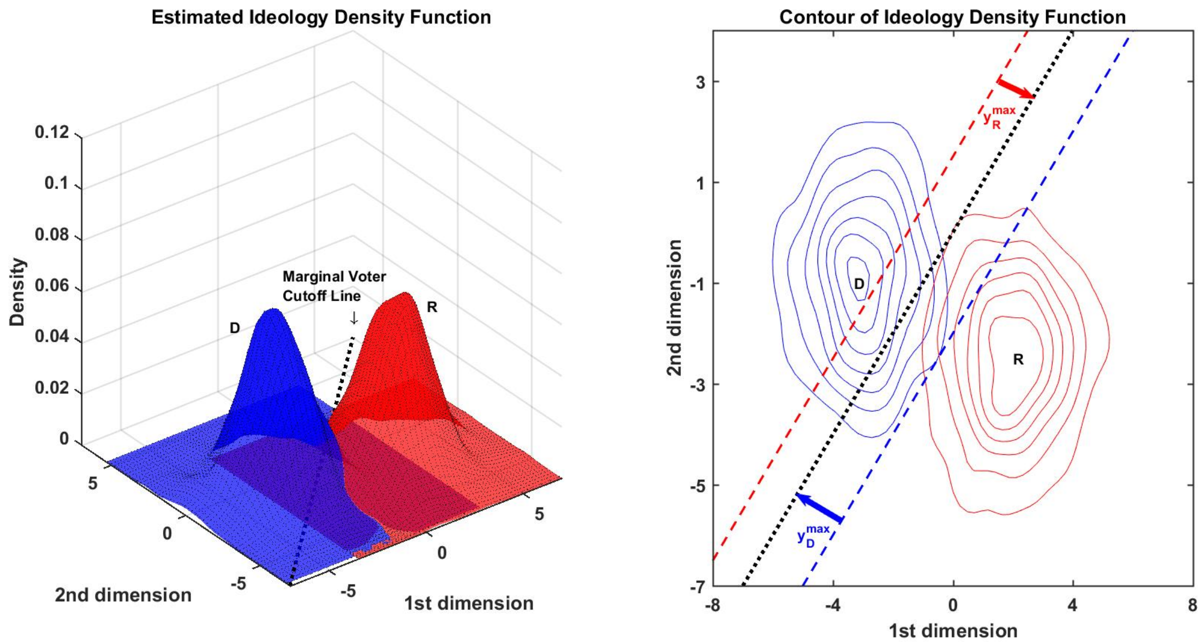


Figure 2: Congruent Party Pressure 2 Dimensions

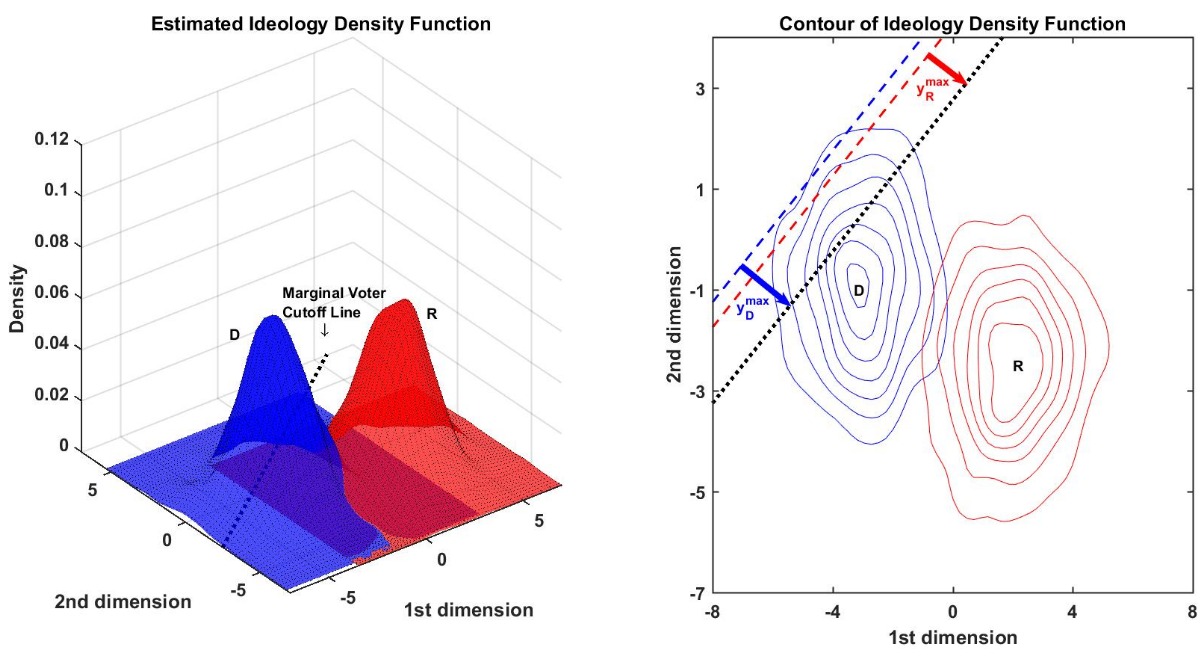
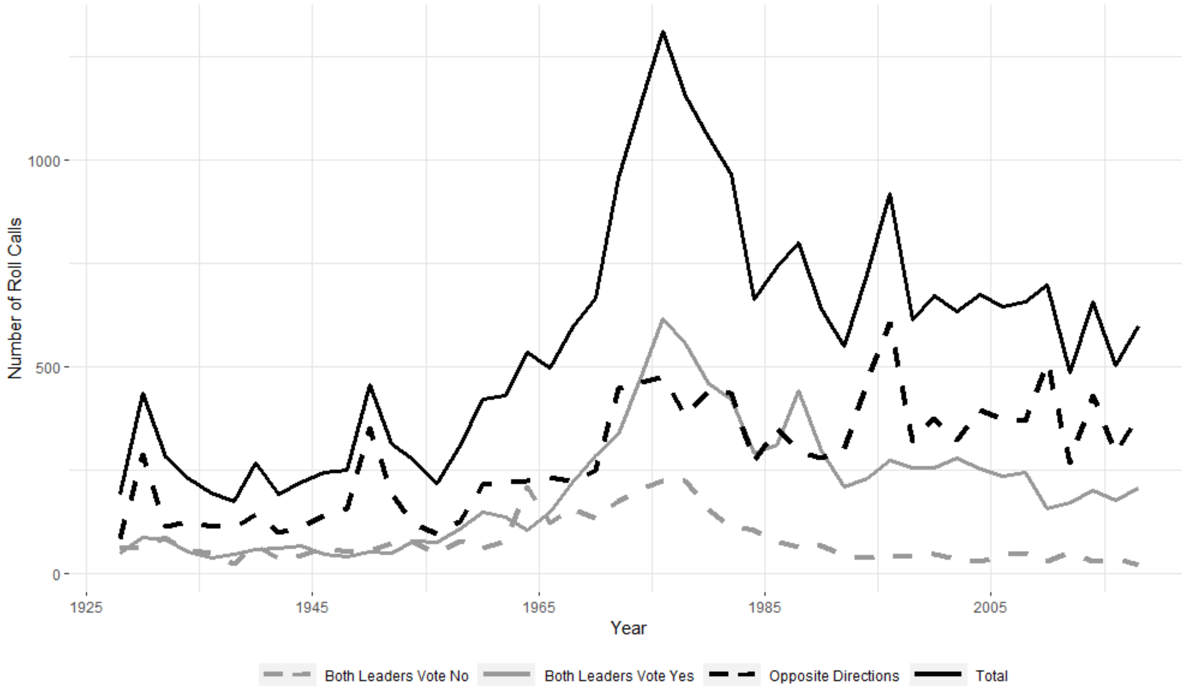
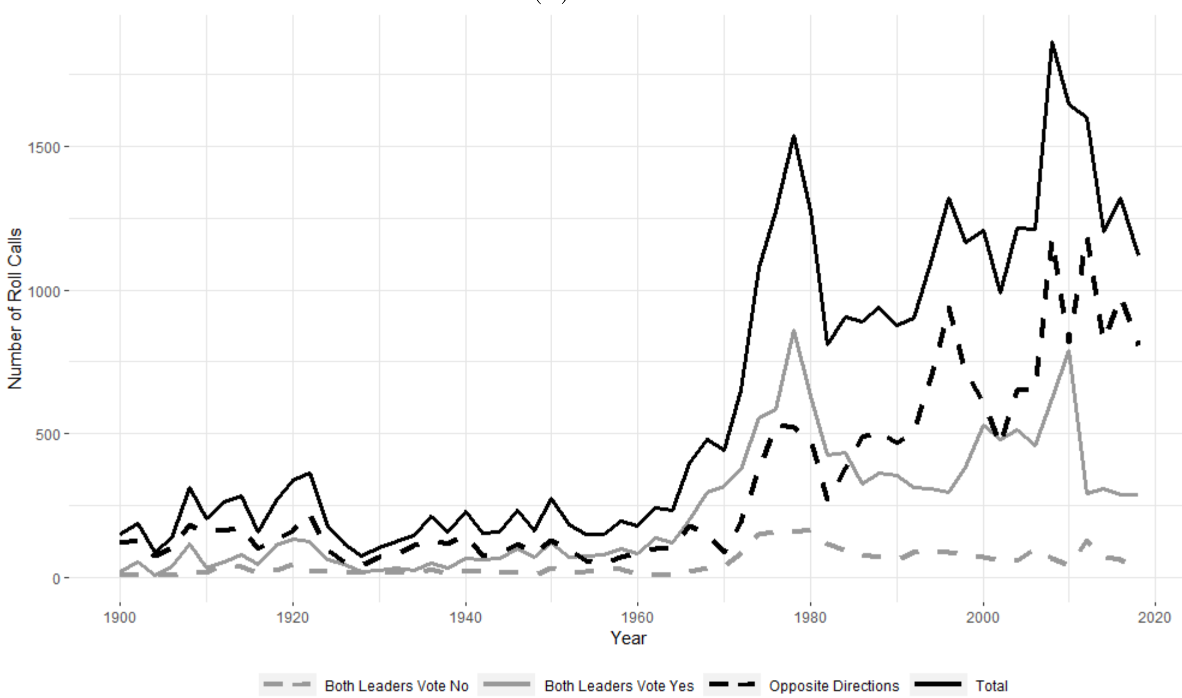


Figure 3: Roll Call Votes Across the Sample

(a) Senate

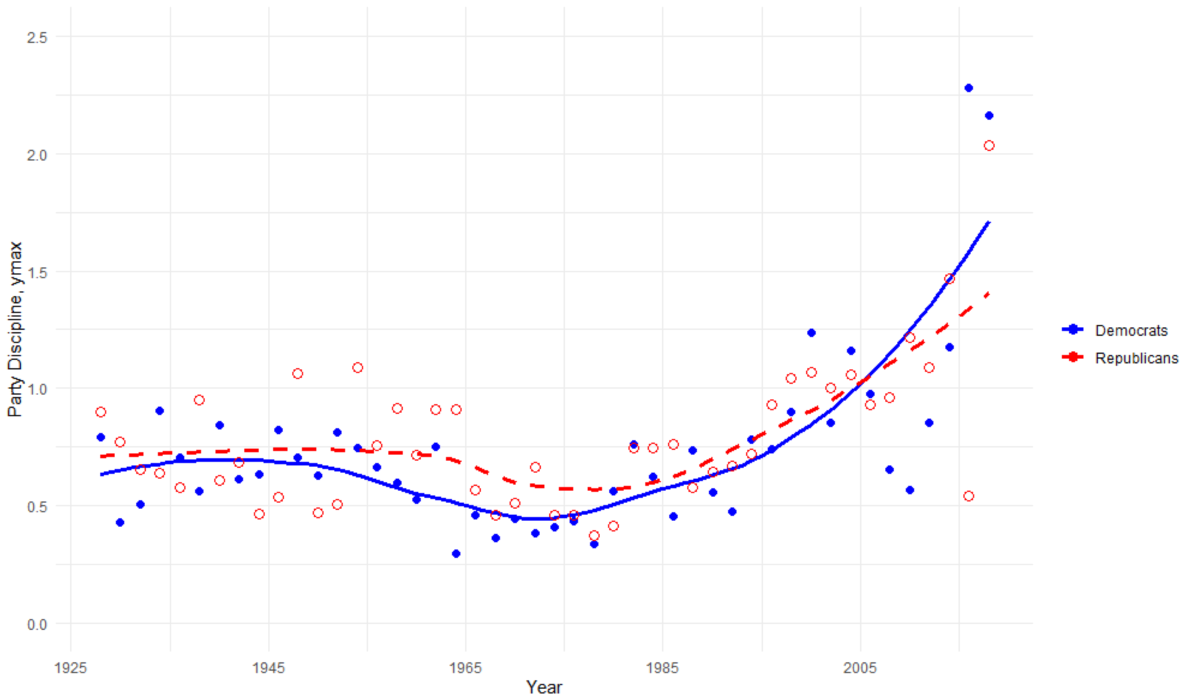


(b) House



Notes: The total number of roll call votes in each Congress by chamber, as well as a decomposition into how these votes are split between roll calls in which both party leaders vote in favor of the new policy, both vote against the policy, and those in which they vote in opposite directions.

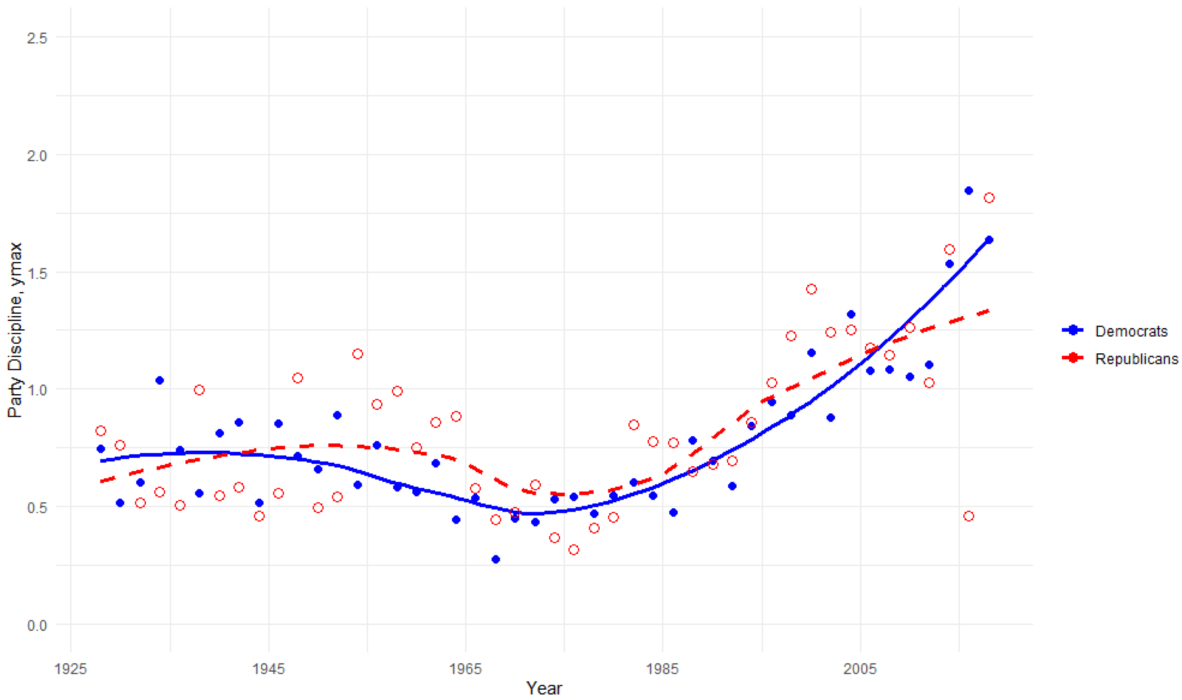
Figure 4: Party Pressure Over Time, 1927-2019 - Senate 2D Model



Notes: Estimates of y_p^{max} shown for each party, Democrats in filled blue, Republicans in unfilled red. Party-specific smoothed fit (Loess) curves are also shown.

Figure 5: Party Pressure in the 1D Model

(a) Senate



(b) House

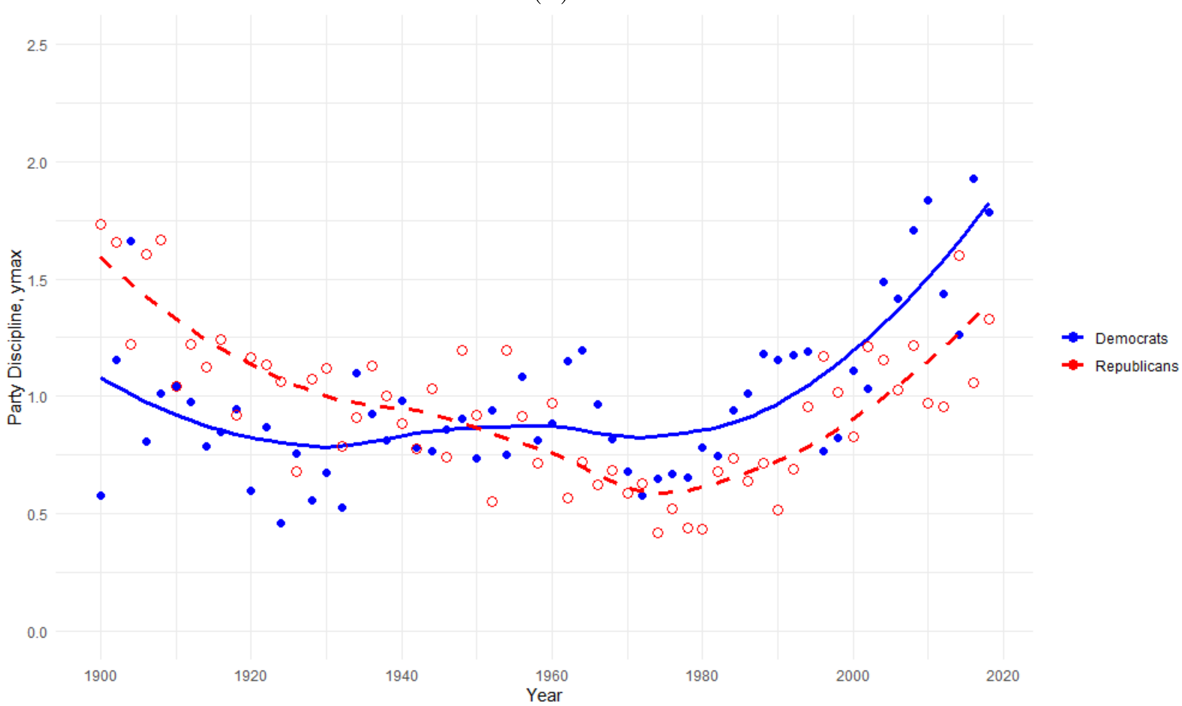
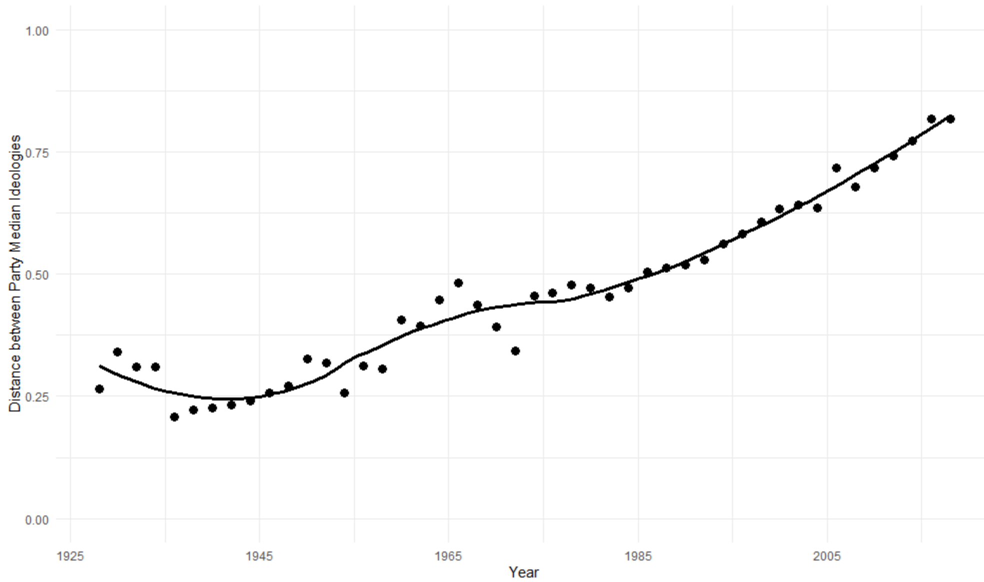
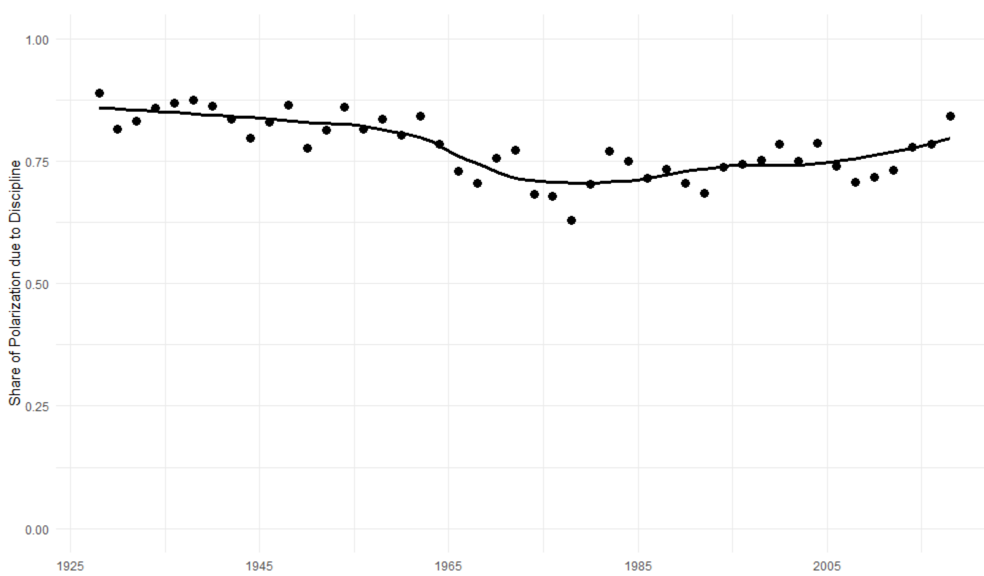


Figure 6: Ideological Polarization Between Senate Members, 1927-2019 (1st Dimension) - Senate 2D Model



Notes: Estimates of the distance between party medians in the 1st dimension for the Senate 2D Model are shown, together with a smoothed fit (Loess) curve.

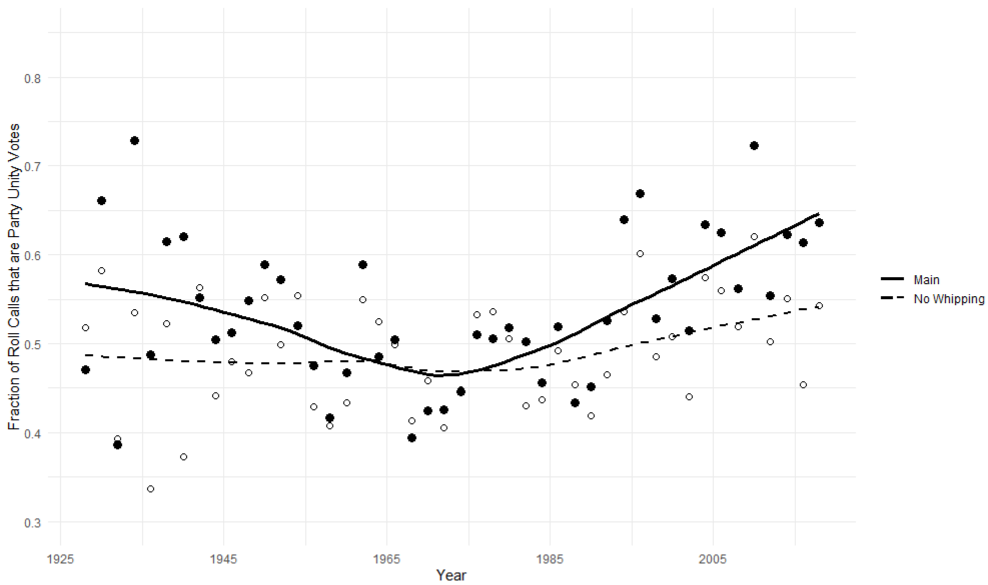
Figure 7: Share of Polarization Attributable to Party Pressure: Comparison to Ideological Distance Between Centroids



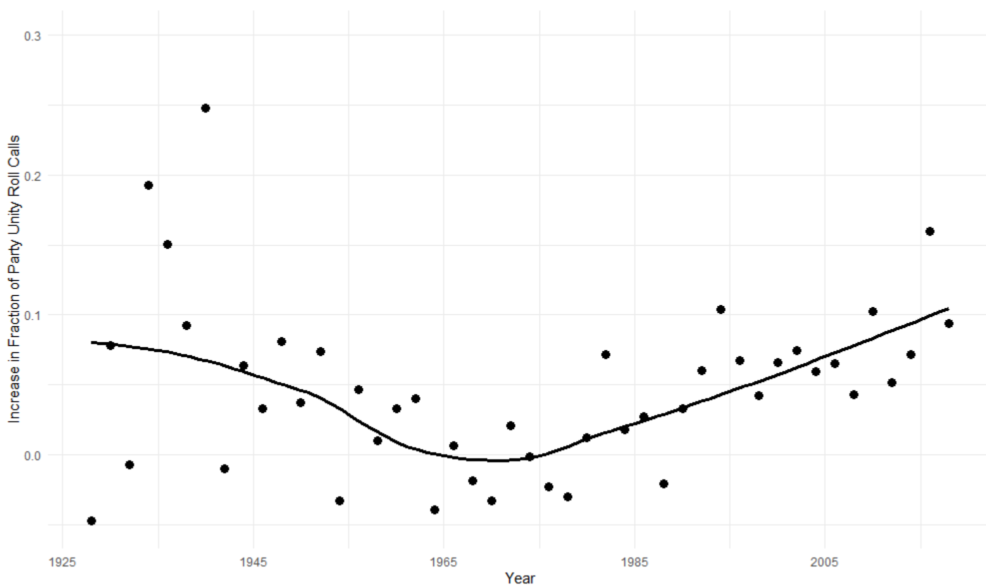
Notes: The estimated share of polarization attributed to party pressure is shown for each Congress for the Senate 2D Model, computed by the total amount of party pressure divided by that amount plus the distance between party centroids, together with a smoothed fit (Loess) curve.

Figure 8: Share of Polarization Attributable to Party Pressure: Party Unity Votes With/Without Pressure

(a) Party Pressure Compared to Ideological Distance Between Party Centroids



(b) Increase in Fraction of Roll Calls that are Party Unity Votes with Pressure



Notes: The first graph shows the fraction of roll calls that are party unity votes (votes that have the majority of one party voting against the majority of the other party) as predicted by our estimates with party pressure (main model) and without (setting $y_P^{max} = 0$ for both parties). The main model is presented as a solid line with filled dots and the no pressure model as a dashed line with hollow dots, each with a smoothed fit (Loess) curve. The bottom graph plots the increase in the fraction of party unity votes due to party pressure (i.e. the difference between the estimates of the first graph) with a smoothed fit (Loess) curve.

Figure 9: Ideological Polarization Over Time (1st dimension), 1927-2019 - Senate 2D Model

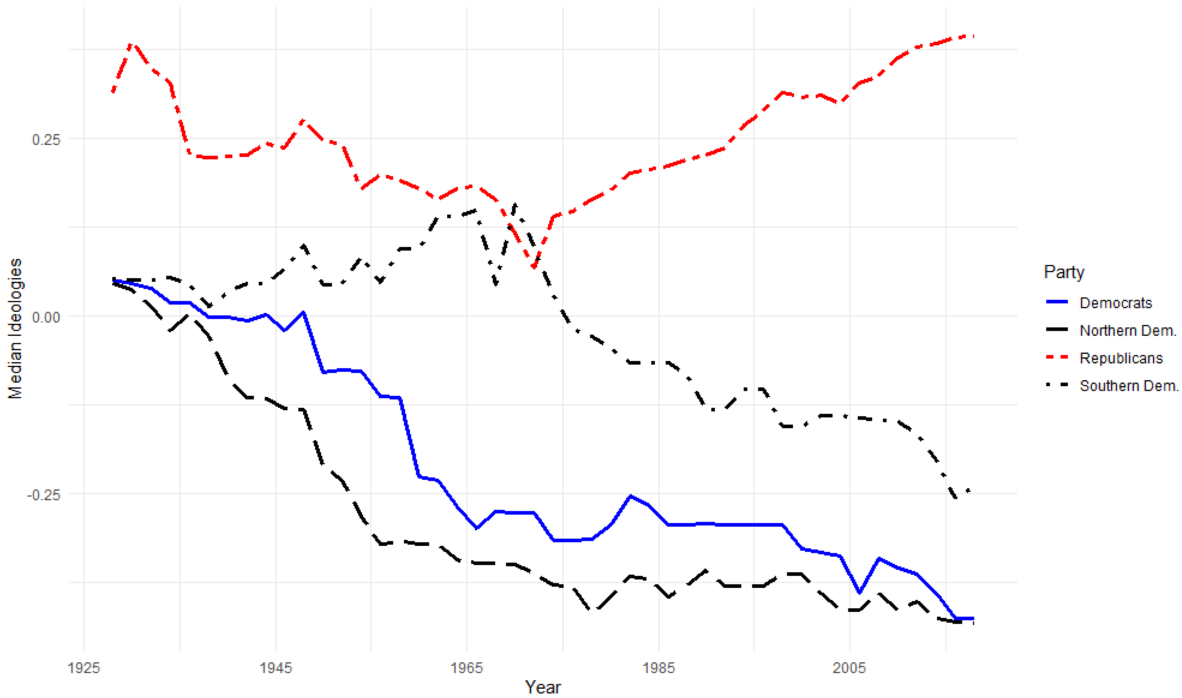
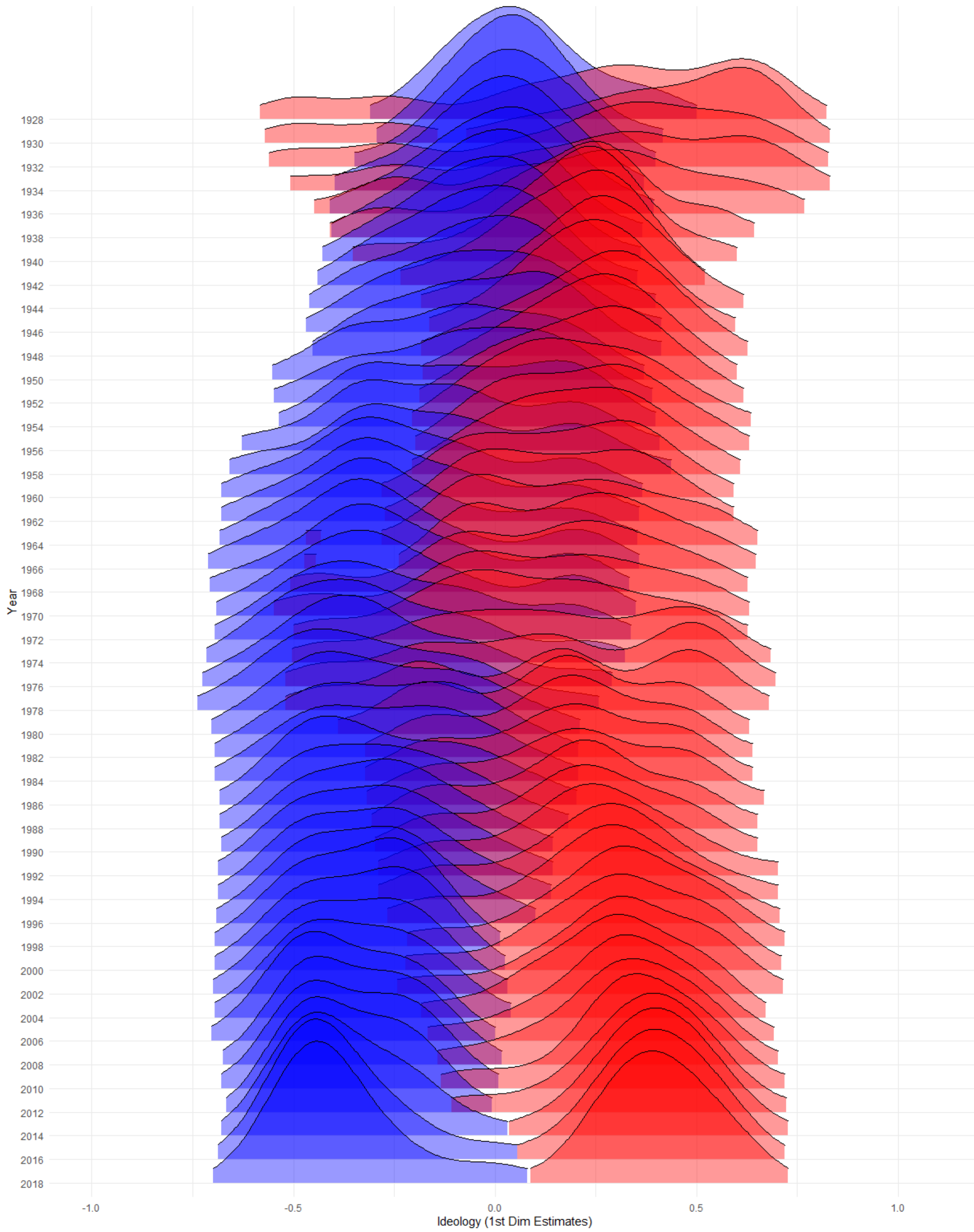
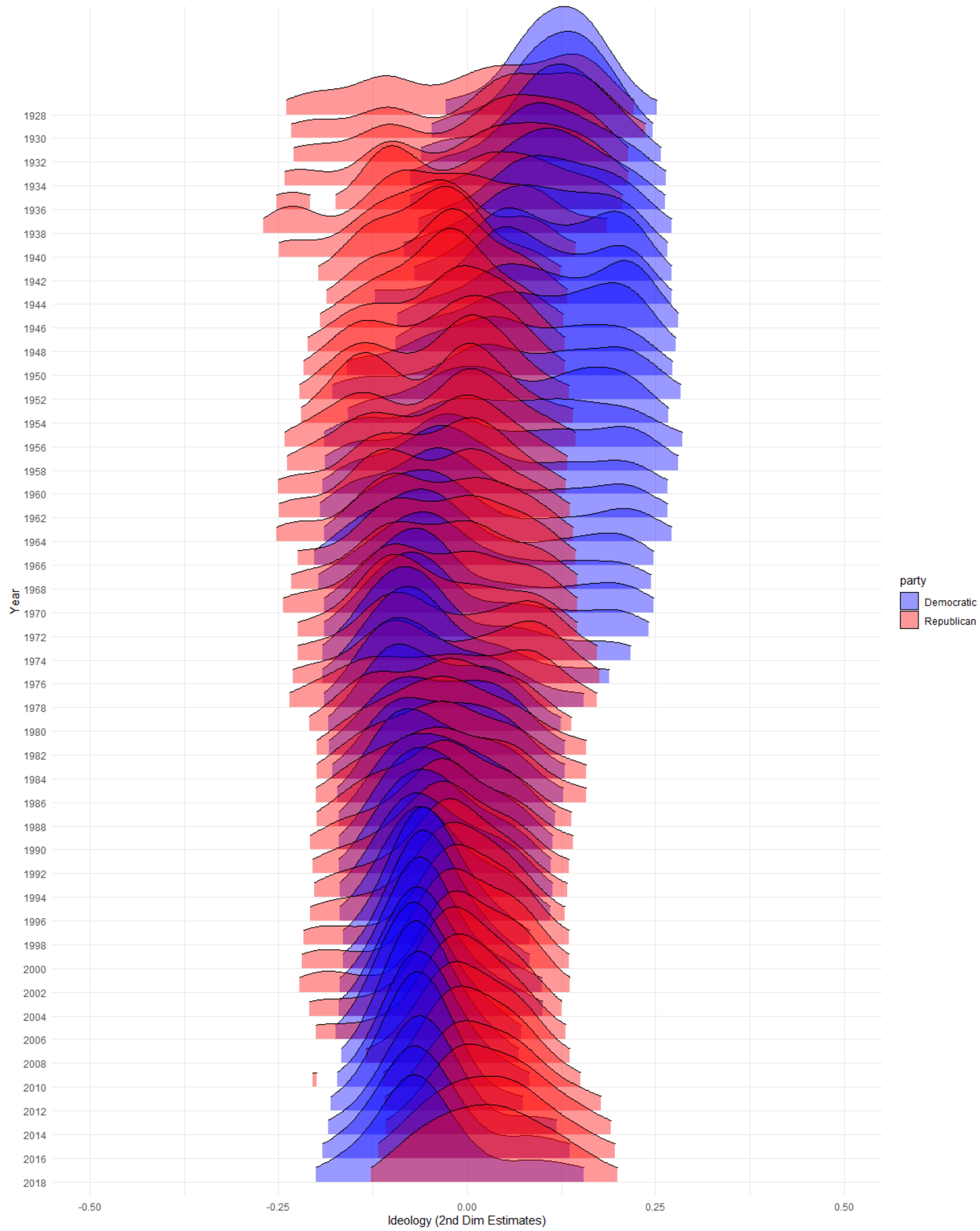


Figure 10: Ideological Polarization Between Senate Members, 1927-2019 - Senate 2D Model



Notes: Kernel density estimates of the ideological parameters for the first dimension from the Senate 2D Model across Congresses.

Figure 11: Ideological Polarization Between Senate Members, 1927-2019 - Senate 2D Model



Notes: Kernel density estimates of the ideological parameters for the second dimension from the Senate 2D Model across Congresses.

Figure 12: Robustness of Total Party Pressure ($y_D^{max} + y_R^{max}$) - Senate 2D Model

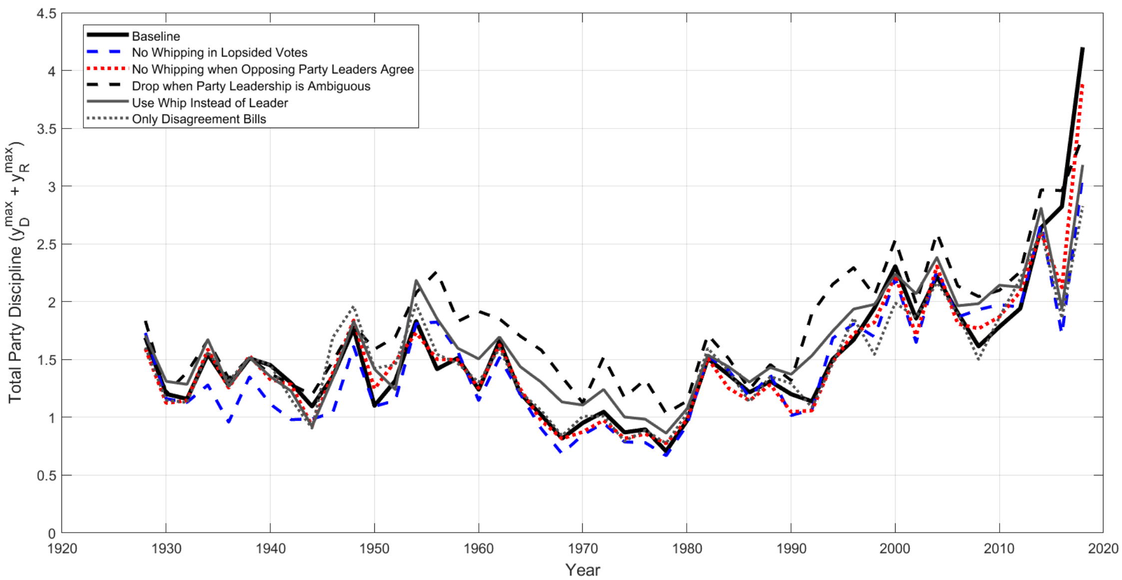


Figure 13: Robustness of the Estimates of Party Pressure - Senate 2D Model

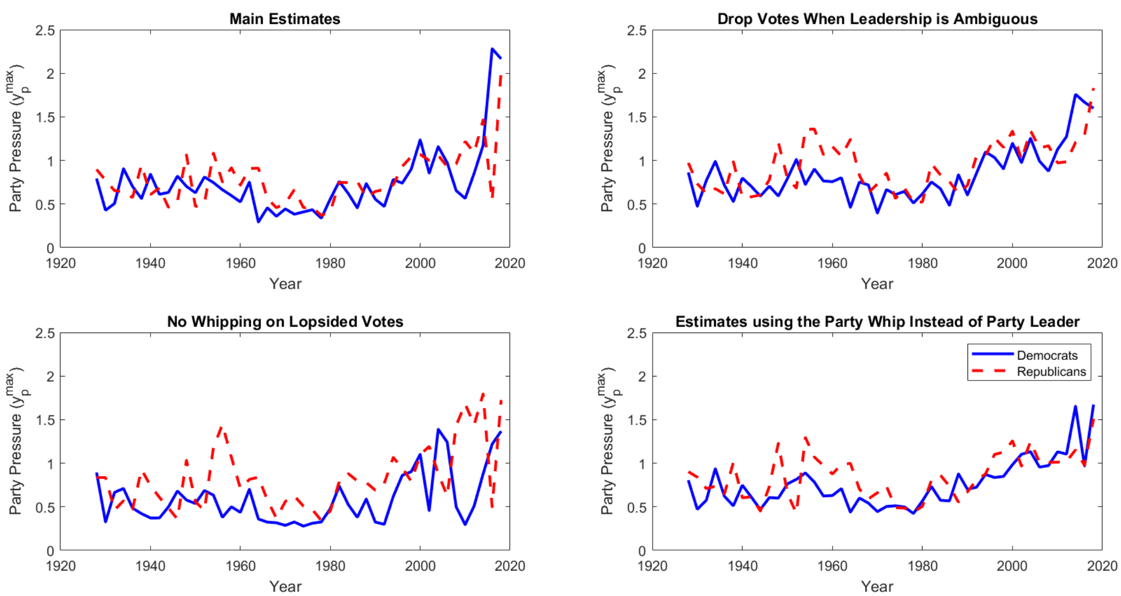
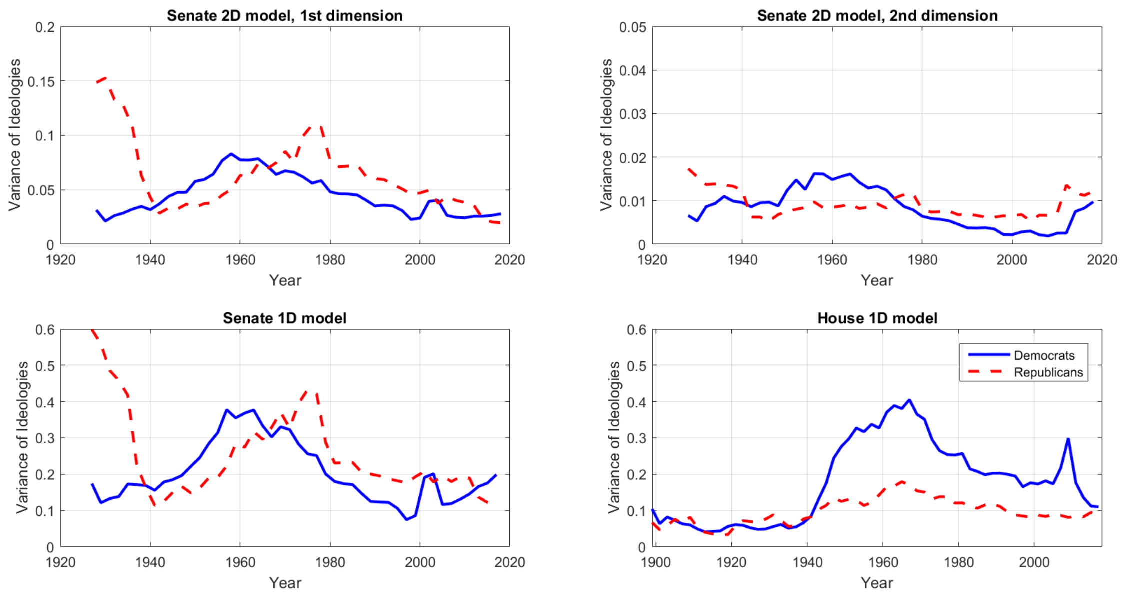


Figure 14: Variance of Estimated Ideologies over Time



Notes: Each panel shows the variance of estimated ideologies within party over time.

Table 1: Number of Parameters Across Specifications

Model	Ideology	Party Pressure	Roll Call	Total
Senate - 1 Dimensional	789	92	25824	26705
House - 1 Dimensional	5316	120	35795	41231
Senate - 2 Dimensional	1568	92	22314	23974

Appendix A: Identification

This Appendix proves the Identification of our model in two dimensions under the following assumptions.

Assumptions ID:

1. The set of ideal points, $\{(\theta_1^i, \theta_2^i)\}_{i=1}^N$, is not perfectly collinear within at least one party.
2. (i) There exists a politician 0 such that $\bar{\theta}^0 = (0, 0)$. (ii) There exists a politician k whose first dimension ideology, θ_1^k, is known.
3. (i) There exists a bill 0 such that $m_0 = 0$. (ii) There exists a bill, s, for which $m_s \neq 0$.
4. The two parties apply pressure in the same direction on at least one bill, and opposite directions on at least one other.

For $\mathcal{I}_t = 1$, we can rewrite (5) as:

$$\Pr\left(Y_{it} = 1 | \bar{q}_t \in Q_p^1, \bar{x}_t; \theta^i, y_p^{max}, m_t\right) = \Phi\left(\sqrt{\frac{1}{1+m_t^2}}\left(\theta_2^i - m_t\theta_1^i - b_t\right) + W_{p,t} \times y_p^{max}\right)$$

Let us use the simplified notation, $\Pr(Y_{it} = 1) = \Pr\left(Y_{it} = 1 | \bar{q}_t \in Q_p^1, \bar{x}_t; \theta^i, y_p^{max}, m_t\right)$. This term is the likelihood component of politician i voting Yes on a bill t if $\mathcal{I}_t = 1$. It is more convenient for us to work with the standardized likelihood:

$$\Phi^{-1}\left(\Pr(Y_{it} = 1)\right) = \sqrt{\frac{1}{1+m_t^2}}\left(\theta_2^i - m_t\theta_1^i - b_t\right) + W_{p,t} \times y_p^{max}, \tag{8}$$

which makes explicit the unique correspondence between data (on the left hand side) and model parameters (on the right hand side).

Using Assumption ID3(i), we begin by comparing the probability of voting Yes on the normalizing bill 0 between any two politicians, i and j, belonging to the same party:

$$\Phi^{-1}\left(\Pr(Y_{i0} = 1)\right) - \Phi^{-1}\left(\Pr(Y_{j0} = 1)\right) = \theta_2^i - \theta_2^j$$

It is immediate that with $j = 0$ (the normalized member in Assumption ID2(i)), we obtain identification of θ_2^i for all members of the party containing member 0, which, in correspondence with our empirical application, we assume is party D (without loss).

For $\mathcal{I}_t = 0$, we have instead

$$\Phi^{-1}\left(1 - \Pr(Y_{it} = 1)\right) = \sqrt{\frac{1}{1+m_t^2}}\left(\theta_2^i - m_t\theta_1^i - b_t\right) + W_{p,t} \times y_p^{max}. \tag{9}$$

One can see immediately that the difference in standardized likelihoods, using (9), for bill 0 will again identify the second dimension ideologies, $\{\theta_2^i\}_{i=1}^N$ for members of party D.

We next show that the cutlines for each party, and directions, $\mathcal{I}_t$, are unique for each bill. Consider the vote decisions of politician 0 and another member of party D, j, on an arbitrary bill, t. The standardized likelihoods are given by:

$$\begin{aligned} \Phi^{-1}\left(\Pr\left(Y_{0t}=1\right)\right) &= \pm\sqrt{\tfrac{1}{1+m_t^2}}\left(\theta_2^0 - m_t\theta_1^0 - b_t\right) \pm W_{D,t}\times y_D^{max} \\ \Phi^{-1}\left(\Pr\left(Y_{jt}=1\right)\right) &= \pm\sqrt{\tfrac{1}{1+m_t^2}}\left(\theta_2^j - m_t\theta_1^j - b_t\right) \pm W_{D,t}\times y_D^{max}, \end{aligned} \tag{10}$$

where the sign of the RHS depends upon $\mathcal{I}_t$.

The set of points in the (θ_1, θ_2) space that are at distance $\Phi^{-1}\left(\Pr\left(Y_{it}=1\right)\right)$ from i's ideal point define a circle centered at $\bar{\theta}^i$. Allowing for both $\mathcal{I}_t = 0$ and $\mathcal{I}_t = 1$, the equations for members 0 and j in (10) define the tangents to each of the two circles for members 0 and j. At most four $(m_t, \hat{b}_t, y_D^{max})$ triplets define cutlines that are tangent to both circles: at most two outer tangents that place members 0 and j on the same side of a cutline, and at most two inner tangents that place the members 0 and j on opposite sides of a cutline. Figure 15 illustrates the possible cutlines.

For an outer tangent for which both members lie on the same side, we have $\theta_2^i < m_t\theta_1^i + \hat{b}_t \mp W_{D,t}\times y_{D,t}$ for $i \in \{0, j\}$, or $\theta_2^i > m_t\theta_1^i + \hat{b}_t \mp W_{D,t}\times y_{D,t}$ for $i \in \{0, j\}$. These inequalities imply $\Pr\left(Y_{it}=1\right) < \frac{1}{2}$ for both members or $\Pr\left(Y_{it}=1\right) > \frac{1}{2}$ for both members, depending on $\mathcal{I}_t$.

For an inner tangent for which one member lies on each side, we instead have either $\Pr\left(Y_{0t}=1\right) < \frac{1}{2}$ and $\Pr\left(Y_{jt}=1\right) > \frac{1}{2}$, or $\Pr\left(Y_{0t}=1\right) > \frac{1}{2}$ and $\Pr\left(Y_{jt}=1\right) < \frac{1}{2}$, again depending on $\mathcal{I}_t$.

Therefore, given knowledge of the voting probabilities, at most two of the four possible cutlines (with an appropriate $\mathcal{I}_t$ associated with that cutline) can simultaneously satisfy the equations for the standardized likelihood of 0 and j: either two cutlines that form outer tangents, or two cutlines that form inner tangents.[63]

Assumption ID1 allows us to show that the cutline and direction of each bill is uniquely determined from the two remaining possibilities by means of contradiction. Suppose, to the contrary, that two cutline/direction pairs satisfy the two standardized likelihood equations for 0 and j. Recall that each associated cutline must be tangent to both of the circles centered on each member's ideal point.

Now consider the possible locations of the other members, i, of party D. To ensure the two cutlines are indistinguishable, the circle centered on $\bar{\theta}^i$ with radius $\Phi^{-1}\left(\Pr\left(Y_{it}=1\right)\right)$ for each member must also be tangent to both potential cutlines. Following the Locus theorem, a generic

[63] In the two limiting cases in which a cutline passes exactly through a member's ideal point, the two possible cutlines are such that they pass on opposite sides of the other member's ideal point. The appropriate cutline is then immediately identified by knowing whether this second member's voting probability is greater or less than one-half.

D member i must then lie on the line, A, passing through $\bar{\theta}^0$ and the intersection of the two potential cutlines, or on the line orthogonal to A, that also passes through the intersection, A'. Points on these two lines are the only points that ensure i is equidistant from both cutlines, so that the circle associated with i is tangent to both.

We can rule out points on the line A'. If the two potential cutlines are outer tangents to the circles of 0 and j, then if a member i is located on A', he lies on the same side as 0 and j for one cutline and on the opposite side for the other. But, we know how each of the three probabilities, $\Pr(Y_{0t} = 1)$, $\Pr(Y_{jt} = 1)$, and $\Pr(Y_{it} = 1)$, compares to one-half. If all are on the same side, all must be greater than one-half or all must be less. If i is on the opposite side, then his probability must be greater than one-half if the other two are less than one-half, or vice versa. Thus, if i lies on A', we can distinguish between the two pairs of solutions, a contradiction. Similarly, if the two potential cutlines are inner tangents to the circles of 0 and j then for one of the cutlines, i is on the same side as 0 (and opposite to j) and for the other i is on the same side as j (and opposite to 0). Knowing which voting probabilities are greater or less than one-half again allows us to tell the solutions apart.

We have then shown that if we have two potential solutions, all members of party D must lie on the line A. But, the same argument applies to party R: taking any two members for party R, we can show that for there to be two potential cutlines for party R (with associated directions), all members of party R must also be collinear. But, if the members of each party are collinear, we violate Assumption ID1. Thus, the cutline for each party, as well as the direction, $\mathcal{I}_t$, is unique for all bills.

Uniqueness of the cutlines immediately guarantees m_t is unique for each bill (but not necessarily b_t or y_D^{max}, because, for each bill, only their sum or difference enters the vote probabilities). Furthermore, given uniqueness of the cutlines and direction of each bill, if the ideological position of a member of either party is known in one dimension, the ideological position in the other dimension is generically unique, because only one possible ideological position for the member at the distance, $\Phi^{-1}(\Pr(Y_{it} = 1))$, from the cutline exists (the vote probabilities in (10) are linear in each dimension). The two exceptions are: (i) the first dimensional ideology is known and the cutline is vertical, or (ii) the second dimensional ideology is known and the cutline is horizontal. But, given that θ_1^k is known for member k (Assumption ID2(ii)), θ_2^k is unique because we have at least one bill that doesn't have a vertical cutline (the normalizing bill). And, given that θ_2^j is known for all members of party D, each θ_1^j is unique because we have at least one cutline that is not horizontal (Assumption ID3(ii)).

We next establish uniqueness of each of b_t, y_D^{max}, and y_R^{max} using only uniqueness of the cutlines, directions, and positions of members 0 and k. In our empirical application, the normalizing member, k, of Assumption ID2(ii) belongs to party R.[64] The difference in the normalized likelihoods of members 0 and k is given by

$$\begin{aligned} & \Phi^{-1}\left(\Pr\left(Y_{0t}=1\right)\right)-\Phi^{-1}\left(\Pr\left(Y_{kt}=1\right)\right) \\ = & \pm\sqrt{\frac{1}{1+m_t^2}}\left(\theta_2^0-\theta_2^k-m_t(\theta_1^0-\theta_1^k)\right)\pm W_{D,t}\times y_D^{max}\mp W_{R,t}\times y_R^{max} \end{aligned} \quad (11)$$

The party pressure directions are known from the data on leadership votes up to the indeterminacy of $\mathcal{I}_t$. From Assumption ID4, we can write the equations corresponding to (11) for two bills, t and r, one in which the two parties exert pressure in the same direction (t) and one in which they exert pressure in opposite directions (r)[65]:

$$\begin{aligned} \Phi^{-1}\left(\Pr\left(Y_{0t}=1\right)\right)-\Phi^{-1}\left(\Pr\left(Y_{kt}=1\right)\right) &= \pm\sqrt{\frac{1}{1+m_t^2}}\left(-\theta_2^k+m_t\theta_1^k\right)\pm y_D^{max}\mp y_R^{max} \\ \Phi^{-1}\left(\Pr\left(Y_{0r}=1\right)\right)-\Phi^{-1}\left(\Pr\left(Y_{kr}=1\right)\right) &= \pm\sqrt{\frac{1}{1+m_r^2}}\left(-\theta_2^k+m_r\theta_1^k\right)\pm y_D^{max}\pm y_R^{max} \end{aligned} \quad (12)$$

Regardless of the directions, $\mathcal{I}_t$, for each bill, the two equations of (12) are linearly independent, because the first equation has the difference of the party pressure parameters on the right-hand side and the second equation has the sum. Thus, given uniqueness of the other parameters in the equations, the pressure parameters are also unique.[66]

Given uniqueness of all of the cutlines, directions, and y_D^{max}, the unique value of each b_t is determined by the equation corresponding to (8) for member 0. Then, to establish uniqueness of members $i \neq k$ of party R, we can take the difference in normalized likelihoods between member i and member 0 on the normalizing bill:

$$\begin{aligned} & \Phi^{-1}\left(\Pr\left(Y_{00}=1\right)\right)-\Phi^{-1}\left(\Pr\left(Y_{it}=1\right)\right) \\ = & \mp\theta_2^i\pm W_{D,t}\times y_D^{max}\mp W_{R,t}\times y_R^{max} \end{aligned}$$

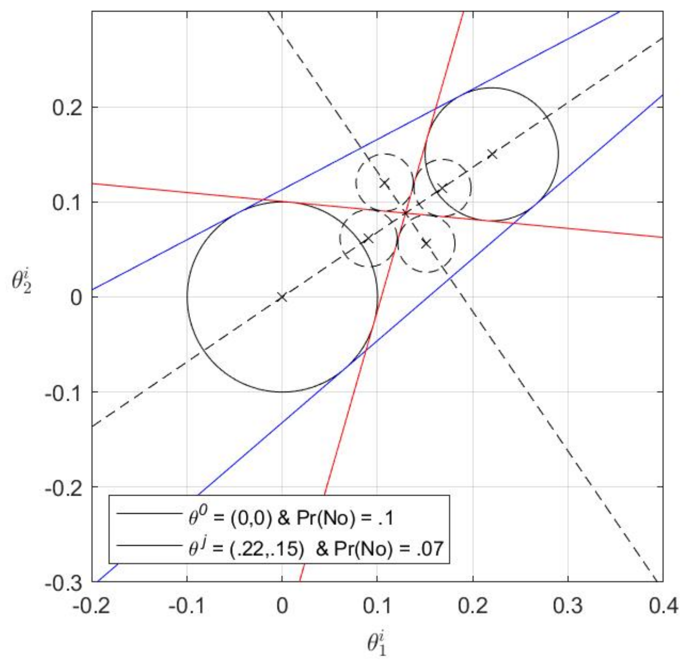
[64]We do not require the two normalizing members of Assumption ID2 to belong to different parties. In fact, the proof is somewhat simpler if they are in the same party.

[65]We take $W_{D,t}=W_{R,t}=1$, $W_{D,r}=1$, and $W_{R,r}=-1$, but the same argument holds for the other possibilities.

[66]In the version of the model in which parties only exert pressure (in opposite directions) when the party leaderships disagree, we cannot separately identify the party pressure parameters. In this case, we have only the second of the two equations in (12) so that only the sum of the pressure parameters, $y_D^{max}+y_R^{max}$, is identified. We can make use of the bills without party pressure to establish uniqueness of the other parameters using similar arguments to those for the main case.

which establishes that each θ_2^i for a member of party R is unique. Finally, given each θ_2^i is unique, each θ_1^i of a member of party R must be unique because we have at least one cutline that is not horizontal (Assumption ID3(ii)).□

Figure 15: Identification Assumptions in a Numerical Example



Appendix B: DW-Nominate's Lack of Identification in Two Dimensions (or higher)

In this section, we provide new insights as to the lack of identification of DW-Nominate (Dynamically Weighted Nominal Three-Step Estimation) in two dimensions. In Section B.1, we formally prove (building on, but correcting the proof in Potthoff (2018)), that W-Nominate is not identified. This result immediately extends to DW-Nominate, as it is a generalization of W-Nominate with dynamically changing ideal points (i.e. preferences linearly changing in time).[67] In Section B.2, we show that, even if the utility weight in W-Nominate were constrained to 1, the Gaussian utility function assumed in Nominate makes it very difficult to determine the number of normalizations necessary for it to be identified. This section builds on the work of Rivers (2003), which is, to

[67]In fact, the parameters that govern the changes in ideology over time are also easily shown to not be identifiable. As the cutline parameters of each Congress are arbitrary, one can simultaneously change both the cutline parameters and the parameter that governs the change in ideology without changing the vote probabilities. To identify changes in ideology, one would either need to assume some reference ideology remains unchanged across Congresses or assume that some bill is identical (has the same cutline parameters) in each Congress.

date, the best formal discussion of identification of multidimensional spatial models. Finally, in Section B.3, we consider the effect of normalizing members' ideologies to lie within a unit circle: the only clearly specified normalization that Nominate imposes.

As background, the current version of DW-Nominate, updates active members' ideologies and estimates the cutline parameters for new bills as they become available (Boche et al., 2018). To do so, it holds constant inactive members' ideologies and the cutlines of previous bills (no "back-propagation"). New ideology and cutline estimates all rely on previous runs of DW-Nominate for identification. To quote Boche et al. (2018), p.24, "*...By effectively locking in place the locations that Poole last estimated for past members, we guarantee that our scores maintain compatibility with the widely used DW-Nominate scores with which scholars are familiar.*" Thus, unfortunately, beyond the unit circle normalization that DW-Nominate imposes, we do not know what other normalizations were initially imposed. As we show, however, no matter what these normalizations were, DW-Nominate is not identified.

B.1: Lack of Identification of W-Nominate

In W-Nominate, the 'W' stands for 'weighted'. It normalizes the utility weight in the first dimension to be one and allows the weight in second dimension, w_2, to be estimated. Here, we prove that this model is not identified by providing a transformation that can change the rank ordering of members in either (or both) dimensions. Importantly, the transformation we provide is not a combination of a rotation, scale, and translation and thus poses a problem even if the rotation, scale, and location of the estimates are constrained via suitable normalization (as in our work).

Consider the likelihood argument in Carroll et al. (2009):

$$\begin{aligned} Pr(Y_{i,t}=1) \quad &= \quad \Phi\left[u(\overline{\theta}_i,\mathbf{x}_t)-u(\overline{\theta}_i,\mathbf{q}_t)\right] = \\ &\quad\ \Phi\left[\beta e^{-\frac{1}{2}\left(\theta_1^i-x_{1,t}\right)^2-\frac{w_2}{2}\left(\theta_2^i-x_{2,t}\right)^2}-\beta e^{-\frac{1}{2}\left(\theta_1^i-q_{1,t}\right)^2-\frac{w_2}{2}\left(\theta_2^i-q_{2,t}\right)^2}\right] \end{aligned}$$

where $\Phi(\cdot)$ is the CDF of the standard normal distribution. The vector of parameters of interest is $\Theta=\{\theta_1^i,x_{1,t},q_{1,t},\theta_2^i,x_{2,t},q_{2,t},w_2\}$.

Consider $s>0$ and $0<r<1$ and define the following candidate (nonlinear) transformation of the parameter vector, which can be proven to not be a rotation (other than in the special case

$w_2 = s = 1$):

$$\begin{aligned}
\tilde{\theta}_1^i &= \theta_1^i\sqrt{r} - \theta_2^i\sqrt{w_2\left(1-r\right)} \\
\tilde{x}_{1,t} &= x_{1,t}\sqrt{r} - x_{2,t}\sqrt{w_2\left(1-r\right)} \\
\tilde{q}_{1,t} &= q_{1,t}\sqrt{r} - q_{2,t}\sqrt{w_2\left(1-r\right)} \\
\tilde{\theta}_2^i &= s \times \left(\theta_1^i\sqrt{(1-r)} + \theta_2^i\sqrt{w_2 r}\right) \\
\tilde{x}_{2,t} &= s \times \left(x_{1,t}\sqrt{(1-r)} + x_{2,t}\sqrt{w_2 r}\right) \\
\tilde{q}_{2,t} &= s \times \left(q_{1,t}\sqrt{(1-r)} + q_{2,t}\sqrt{w_2 r}\right) \\
\tilde{w}_2 &= \frac{1}{s^2}
\end{aligned}$$

To check that within this class of transformations one obtains the same likelihood of the vote data:

$$\Phi\left[\beta e^{-\frac{1}{2}\left(\tilde{\theta}_1^i-\tilde{x}_{1,t}\right)^2-\frac{\tilde{w}_2}{2}\left(\tilde{\theta}_2^i-\tilde{x}_{2,t}\right)^2} - \beta e^{-\frac{1}{2}\left(\tilde{\theta}_1^i-\tilde{q}_{1,t}\right)^2-\frac{\tilde{w}_2}{2}\left(\tilde{\theta}_2^i-\tilde{q}_{2,t}\right)^2}\right] = \\
\Phi\left[\beta e^{-\frac{1}{2}\left(\theta_1^i-x_{1,t}\right)^2-\frac{w_2}{2}\left(\theta_2^i-x_{2,t}\right)^2} - \beta e^{-\frac{1}{2}\left(\theta_1^i-q_{1,t}\right)^2-\frac{w_2}{2}\left(\theta_2^i-q_{2,t}\right)^2}\right]$$

it suffices to show that:

$$\left(\tilde{\theta}_1^i - \tilde{x}_{1,t}\right)^2 + \tilde{w}_2\left(\tilde{\theta}_2^i - \tilde{x}_{2,t}\right)^2 =$$

$$\left(\theta_1^i\sqrt{r} - \theta_2^i\sqrt{w_2\left(1-r\right)} - x_{1,t}\sqrt{r} + x_{2,t}\sqrt{w_2\left(1-r\right)}\right)^2 \\
+\frac{1}{s^2}\left(s\times\left(\theta_1^i\sqrt{(1-r)} + \theta_2^i\sqrt{w_2 r}\right) - s\times\left(x_{1,t}\sqrt{(1-r)} + x_{2,t}\sqrt{w_2 r}\right)\right)^2 =$$

$$\left(\left(\theta_1^i - x_{1,t}\right)\sqrt{r} - \left(\theta_2^i - x_{2,t}\right)\sqrt{w_2\left(1-r\right)}\right)^2 + \left(\left(\theta_1^i - x_{1,t}\right)\sqrt{(1-r)} + \left(\theta_2^i - x_{2,t}\right)\sqrt{w_2 r}\right)^2 =$$

$$\left(\theta_1^i - x_{1,t}\right)^2 r + \left(\theta_2^i - x_{2,t}\right)^2 w_2\left(1-r\right) - 2\left(\theta_1^i - x_{1,t}\right)\sqrt{r}\left(\theta_2^i - x_{2,t}\right)\sqrt{w_2\left(1-r\right)} \\
+\left(\theta_1^i - x_{1,t}\right)^2\left(1-r\right) + \left(\theta_2^i - x_{2,t}\right)^2 w_2 r + 2\left(\theta_1^i - x_{1,t}\right)\sqrt{(1-r)}\left(\theta_2^i - x_{2,t}\right)\sqrt{w_2 r} =$$

$$\left(\theta_1^i - x_{1,t}\right)^2 + w_2\left(\theta_2^i - x_{2,t}\right)^2$$

This proves that W-Nominate in two dimensions is not identified up to this class of transformations, which is broader than than the class of transformation that only rotate, scale, and/or change the location of the ideal points.

To show how this class of transformations is particularly damaging, consider the three individuals, $i = a, b, c$, located at points $\bar{\theta}^a = (-.3, -1), \bar{\theta}^b = (.1, -.3)$, and $\bar{\theta}^c = (.25, -1.2)$ in Figure 16.

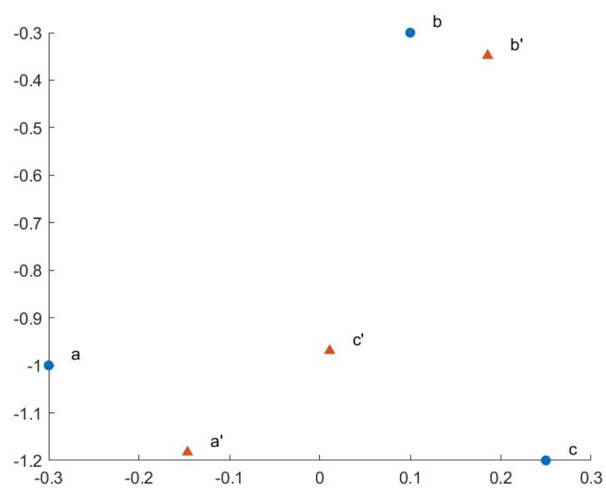
Consider the proposed transformation:

$$\begin{aligned} \tilde{\theta}_1^i &= \theta_1^i \sqrt{r} - \theta_2^i \sqrt{w_2 (1-r)} \\ \tilde{\theta}_2^i &= s \times \left(\theta_1^i \sqrt{(1-r)} + \theta_2^i \sqrt{w_2 r} \right) \end{aligned}$$

for the case of $r = .8; s = 12.5; w_2 = .3$. After applying this transformation (which, with the corresponding transformations for x_t, q_t, and w_2 will not change the vote probabilities) results in individuals a, b, c being located at $(-.0234, -7.8008), (.1629, -1.2781)$, and $(.5175, -5.9509)$, respectively. That is, applying this transformation to each i, rearranges the data cardinally and, more significantly, ordinally. However, so do other types of transformations, including linear transformations such as rotations, and therefore this may appear of no particular concern.

What is damaging is that once the transformation is applied to the original data, it is no longer possible to recover the original ordinal ranking of the true positions. We illustrate this fact by optimally rotating the transformed data back into the original data space.[68] In this example, even after optimally rotating the transformed positions back to the original data space, we observe ordinal changes with respect to the true positions along both dimensions. The new locations are at the points, $\bar{\theta}_{a'} = (-.1464, -1.1828), \bar{\theta}_{b'} = (.1856, -.3481)$, and $\bar{\theta}_{c'} = (.0108, -.9691)$ as illustrated in Figure 16. As can be seen, a', b', c' are now misordered along both dimensions relative to the original ideal points.

Figure 16: Problematic Example for DW-Nominate



[68]In particular, we apply the Procrustes rotation to the transformed data employing optimal shift, scale, and rotation, so as to bring the transformed data back to the original data space.

B.2: Identification of Nominate

The previous section proves lack of identification for nonlinear transformations when, as in W-Nominate and DW-Nominate, the utility weight in the second dimension is estimated. Here, we discuss the identification of Nominate, which constrains all utility weights to be equal to one.[69]

In Section B.2.1, we consider the problem of identifying members' ideologies under the assumption that some of the cutline parameters, $\bar{x}_t$ and $\bar{q}_t$, are known. In Section B.2.2, we discuss the reverse problem: identifying the cutline parameters assuming some of the ideology parameters are known. Sections B.2.1 and B.2.2 are illustrative of the interim steps of the Nominate method (Nominal Three-Step Estimation), where either the cutlines or the ideal points are taken as given and the remaining set of parameters are estimated, iterating until convergence.

B.2.1: Known Bill Parameters

Making use of the Gaussian preferences employed in Nominate, let us start by highlighting that, for known roll call "0"

$$\Phi^{-1}\left[Pr(Y_{i,0}=1)\right] = u(\bar{\theta}^i, \bar{x}_0) - u(\bar{\theta}^i, \bar{q}_0)$$
$$= e^{-\frac{1}{2}\left[\left(\theta_1^i - x_{1,0}\right)^2 + \left(\theta_2^i - x_{2,0}\right)^2\right]} - e^{-\frac{1}{2}\left[\left(\theta_1^i - q_{1,0}\right)^2 + \left(\theta_2^i - q_{2,0}\right)^2\right]}$$

is a highly-nonlinear equation in two unknowns (θ_1^i, θ_2^i). A generalized cubic equation in (θ_1^i, θ_2^i) follows from a second-order Taylor expansion of the difference in the deterministic utilities on the RHS for each vote:

$$\Phi^{-1}\left[Pr(Y_{i,0}=1)\right] =$$
$$e^{-\frac{1}{2}\left[\left(\theta_1^i - x_{1,0}\right)^2 + \left(\theta_2^i - x_{2,0}\right)^2\right]} - e^{-\frac{1}{2}\left[\left(\theta_1^i - q_{1,0}\right)^2 + \left(\theta_2^i - q_{2,0}\right)^2\right]} =$$
$$\textstyle\sum_{n=0}^{\infty} \frac{\left(-\frac{1}{2}\right)^n}{n!} \left[\left[\left(\theta_1^i - x_{1,0}\right)^2 + \left(\theta_2^i - x_{2,0}\right)^2\right]^n - \left[\left(\theta_1^i - q_{1,0}\right)^2 - \left(\theta_2^i - q_{2,0}\right)^2\right]^n\right] \approx$$
$$-\tfrac{1}{2}\left[\textstyle\sum_{j=1}^{2}\left(\theta_j^i - x_{j,0}\right)^2 - \sum_{j=1}^{2}\left(\theta_j^i - q_{j,0}\right)^2\right] + \tfrac{1}{8}\left[\left[\sum_{j=1}^{2}\left(\theta_j^i - x_{j,0}\right)^2\right]^2 - \left[\sum_{j=1}^{2}\left(\theta_j^i - q_{j,0}\right)^2\right]^2\right] =$$
$$-\tfrac{1}{2}\left[\textstyle\sum_{j=1}^{2}\left(x_{j,0} - q_{j,0}\right)\left(x_{j,0} + q_{j,0} - 2\theta_j^i\right)\right] \times \left[1 - \tfrac{1}{4}\sum_{j=1}^{2}\left[\left(x_{j,0}\right)^2 + \left(q_{j,0}\right)^2 - 2\theta_j^i\left(x_{j,0} + q_{j,0} - \theta_j^i\right)\right]\right]$$

It is therefore possible to see that, even using approximations, a single normalization on a "0" bill is insufficient to uniquely pin down the (θ_1^i, θ_2^i) unknowns from the data $\Phi^{-1}\left[Pr(Y_{i,0}=1)\right]$.

Notice further that even for a quadratic loss function, instead of a Gaussian utility function, a

[69]We discuss the difficulties a Gaussian utility function creates even when $\beta = 1$ is assumed (Nominate estimates the parameter β as well, creating a further burden for identification on top of the ones discussed here).

single roll call normalization would still be insufficient for an unique mapping:

$$\begin{gathered}\Phi^{-1}\left[Pr(Y_{i,0}=1)\right]= \\ -\tfrac{1}{2}\left(\left(\theta_1^i-x_{1,0}\right)^2+\left(\theta_2^i-x_{2,0}\right)^2\right)+\tfrac{1}{2}\left(\left(\theta_1^i-q_{1,0}\right)^2+\left(\theta_2^i-q_{2,0}\right)^2\right)= \\ -\tfrac{1}{2}\left[\sum_{j=1}^2\left(\theta_j^i-x_{j,0}\right)^2-\sum_{j=1}^2\left(\theta_j^i-q_{j,0}\right)^2\right]= \\ -\tfrac{1}{2}\sum_{j=1}^2\left(x_{j,0}-q_{j,0}\right)\left(x_{j,0}+q_{j,0}-2\theta_j^i\right)\end{gathered}$$

To see the extent of the normalizations needed for different classes of individual utility functions, consider full knowledge of all policy issues $\bar{x}_t, \bar{q}_t$ for the set of T bill upon which a politician i votes, which can be treated as data. Then we can write the system of polynomials in the unknown ideology parameters, (θ_i^1, θ_i^2):

$$\begin{cases}\Phi^{-1}\left[Pr(Y_{i,0}=1)\right]=\delta_0^0+\delta_1^0\theta_1^i+\delta_2^0\theta_2^i+\delta_3^0\left(\theta_1^i\right)^2+\delta_4^0\left(\theta_2^i\right)^2+\delta_5^0\theta_1^i\theta_2^i+... \\ ... \\ \Phi^{-1}\left[Pr(Y_{i,t}=1)\right]=\delta_0^t+\delta_1^t\theta_1^i+\delta_2^t\theta_2^i+\delta_3^t\left(\theta_1^i\right)^2+\delta_4^t\left(\theta_2^i\right)^2+\delta_5^t\theta_1^i\theta_2^i+... \\ ... \\ \Phi^{-1}\left[Pr(Y_{i,T}=1)\right]=\delta_0^T+\delta_1^T\theta_1^i+\delta_2^T\theta_2^i+\delta_3^T\left(\theta_1^i\right)^2+\delta_4^T\left(\theta_2^i\right)^2+\delta_5^T\theta_1^i\theta_2^i+...\end{cases} \quad (13)$$

Here, full knowledge of all $\bar{x}_t=\left(x_t^1, x_t^2\right), \bar{q}_t=\left(q_t^1, q_t^2\right)$ delivers what essentially amounts to bill-specific data $\{\delta_0^t, \delta_1^t, \delta_2^t, \delta_3^t, \delta_4^t, \delta_5^t, ...\}$, and (13) remains a system of T (typically nonlinear) equations in the two original unknowns (θ_1^i, θ_2^i). Generally, there cannot be any theoretical assurance of a unique exact mapping from the data on the LHS of the equations in the system to a unique $(\theta_1^i, \theta_2^i)^*$ for every i beyond the linear system case. However, operating under the hypothesis that the model is correctly specified the system in (13) will admit a unique solution for T large enough. In fact, (θ_1^i, θ_2^i) may be identifiable given knowledge of only the bill parameters for $\tau < T$ bills. We illustrate a few cases here, but emphasize that a general proof is not available (to the best of our knowledge).

For the quadratic utility case, the number of necessary normalizations is $\tau = 2$ bills (i.e. 8 parameter restrictions for $\bar{x}_0, \bar{x}_1, \bar{q}_0, \bar{q}_1$), given that the polynomials in (13) are of the first order. This implies that two roll calls can uniquely identify a solution (θ_1^i, θ_2^i) to (13), i.e. there is no observationally equivalent $\left(\tilde{\theta}_1^i, \tilde{\theta}_2^i\right) \neq (\theta_1^i, \theta_2^i)$ delivering the same set of values $\Phi^{-1}\left[Pr(Y_{i,t}=1)\right]$.

This result for quadratic utility is conceptually identical to the result in Rivers (2003), which proves that, for $d = 2$, the number of required restrictions is $d(d+1) = 6$. The difference here is that here we are considering as parameters the policy points, and not simply the policy cutlines (the

6 parameter restrictions on $\{\delta_0^0, \delta_1^0, \delta_2^0, \delta_0^1, \delta_1^1, \delta_2^1\}$). This difference does not affect the identification of the set of ideal points, but makes identification of the bill parameters more burdensome.

For utility functions that deliver conic functions in the system (13), the number of required normalizations $\tau = 5$ (i.e. 20 parameter restrictions). To see why, consider first that any system of two conic equations admits at most four solutions. Define these solutions as $\left\{\theta^A, \theta^B, \theta^C, \theta^D\right\}$. All of these solution are observationally equivalent in the sense of exactly satisfying both equations. This system defines the first two roll calls $\{\bar{x}_t, \bar{q}_t\}_{t=0,1}$ that are required for normalization. Let us now add an additional third bill $\bar{x}_2, \bar{q}_2$ introducing another conic equation and under the assumption that such conic equation is non-redundant in the sense of the direction of axes of the associated ellipse are not the same as those of any of the previously normalized conic equations. At most, three of the elements of the set $\left\{\theta^A, \theta^B, \theta^C, \theta^D\right\}$ will satisfy this third equation (if all the elements of $\left\{\theta^A, \theta^B, \theta^C, \theta^D\right\}$ satisfied this third restriction, than that would imply that the third conic equation is, in fact, redundant). Without loss, define the remaining set of candidate solutions as $\left\{\theta^A, \theta^B, \theta^C\right\}$. Adding a fourth bill to the normalization (again assuming non-redundancy), delivers a set of candidate solutions satisfying this fourth constraint of (at most) two elements $\left\{\theta^A, \theta^B\right\}$, and a fifth bill, pins down the ideology vector uniquely to, say, $\left\{\theta^A\right\}$. In summary, normalization of five bills is needed for theoretical identification of the ideology parameters (θ_1^i, θ_2^i) under the assumption that the model is correctly specified.

For utility functions that deliver cubic functions in (13), as in the case of a second-order approximation of the difference in Gaussian utilities used in Nominate, the number of normalizations is higher than $\tau = 5$ bills, as the number of conditions grows. This exercise illustrates that the number of normalizations required for Gaussian utility functions in Nominate is likely much higher than that required for quadratic utility functions, and that it is difficult to determine how many bills must be normalized to uniquely identify the ideal points for N members.

The discussion in this subsection illustrates the inherent difficulty in proving identification within each of Nominate's interim steps (i.e. the algorithm's iteration step where all of the cutline parameters are assumed given and the ideal points are estimated). It is not immediate that each iteration is guaranteed to deliver a unique vector of ideal point estimates.

B.2.2: Known Ideal Points

Concerning the policy choice parameters $\bar{x}_t, \bar{q}_t$, let us focus on the expression

$$Pr(Y_{i,t} = 1) =$$
$$\Phi\left[e^{-\frac{1}{2}\left(\theta_1^i - x_{1,t}\right)^2 - \frac{1}{2}\left(\theta_2^i - x_{2,t}\right)^2} - e^{-\frac{1}{2}\left(\theta_1^i - q_{1,t}\right)^2 - \frac{1}{2}\left(\theta_2^i - q_{2,t}\right)^2}\right]$$

for known ideology parameters. Specifically, under a normalization for $\theta^0 = (\theta_1^0, \theta_2^0)$, we can write:

$$\begin{gathered}\Phi^{-1}\left[Pr(Y_{0,t}=1)\right] = \\ e^{-\frac{1}{2}\left[\left(\theta_1^0 - x_{1,t}\right)^2 + \left(\theta_2^0 - x_{2,t}\right)^2\right]} - e^{-\frac{1}{2}\left[\left(\theta_1^0 - q_{1,t}\right)^2 + \left(\theta_2^0 - q_{2,t}\right)^2\right]} = \\ \sum_{n=0}^{\infty} \frac{\left(-\frac{1}{2}\right)^n}{n!} \left[\left[\left(\theta_1^0 - x_{1,t}\right)^2 + \left(\theta_2^0 - x_{2,t}\right)^2\right]^n - \left[\left(\theta_1^0 - q_{1,t}\right)^2 + \left(\theta_2^0 - q_{2,t}\right)^2\right]^n\right] \approx \\ -\frac{1}{2}\left[\sum_{j=1}^{2} \left(x_{j,t} - q_{j,t}\right)\left(x_{j,t} + q_{j,t} - 2\theta_j^0\right)\right] \times \left[1 - \frac{1}{4}\sum_{j=1}^{2}\left[(x_{j,t})^2 + (q_{j,t})^2 - 2\theta_j^0\left(x_{j,t} + q_{j,t} - \theta_j^0\right)\right]\right]\end{gathered}$$

which, even in second-order approximate form, does not lend to an immediate analysis of the mapping from data to policy points and generally admits multiple solutions.

With a further normalization for $\theta^1 = (\theta_1^1, \theta_2^1)$ one can make more progress focusing on quadratic losses or first-order approximation of the (difference in) Gaussian utilities. In particular, note that with quadratic losses:

$$\begin{aligned}\Phi^{-1}\left[Pr(Y_{0,t}=1)\right] - \Phi^{-1}\left[Pr(Y_{1,t}=1)\right] &= \\ -\frac{1}{2}\sum_{j=1}^{2}\left(x_{j,t} - q_{j,t}\right)\left(x_{j,t} + q_{j,t} - 2\theta_j^0\right) + \frac{1}{2}\sum_{j=1}^{2}\left(x_{j,t} - q_{j,t}\right)\left(x_{j,t} + q_{j,t} - 2\theta_j^1\right) &= \\ \sum_{j=1}^{2}\left(x_{j,t} - q_{j,t}\right)\left(\theta_j^0 - \theta_j^1\right).\end{aligned} \tag{14}$$

Following a similar approach to that laid out in the preceding section, we can observe that for every roll call t, four equations of the type (14) are necessary for the four unknown bill parameters. We require therefore four politicians to be normalized (i.e. 8 parameters) to uniquely identify all parameters $\bar{x}_t, \bar{q}_t$ from the data.

For the case of Gaussian preferences such as those used in Nominate, however, the situation appears more complex. For the case of the second order Taylor expansion, we see that the system of equations of conditions for identification will be composed of generalized quartic equations and so that we know that we need at least 20 restrictions. Again, this fact illustrates that Nominate with Gaussian preferences requires a substantially higher number of identification restrictions than for the quadratic utility case of Rivers (2003). Mirroring the problem with estimating the ideal points holding the cutlines fixed, it is not immediate that the alternative iteration steps in which the ideal points are held fixed and the cutlines estimated will deliver unique cutline estimates.

B.3: A discussion of further normalizations in DW-Nominate

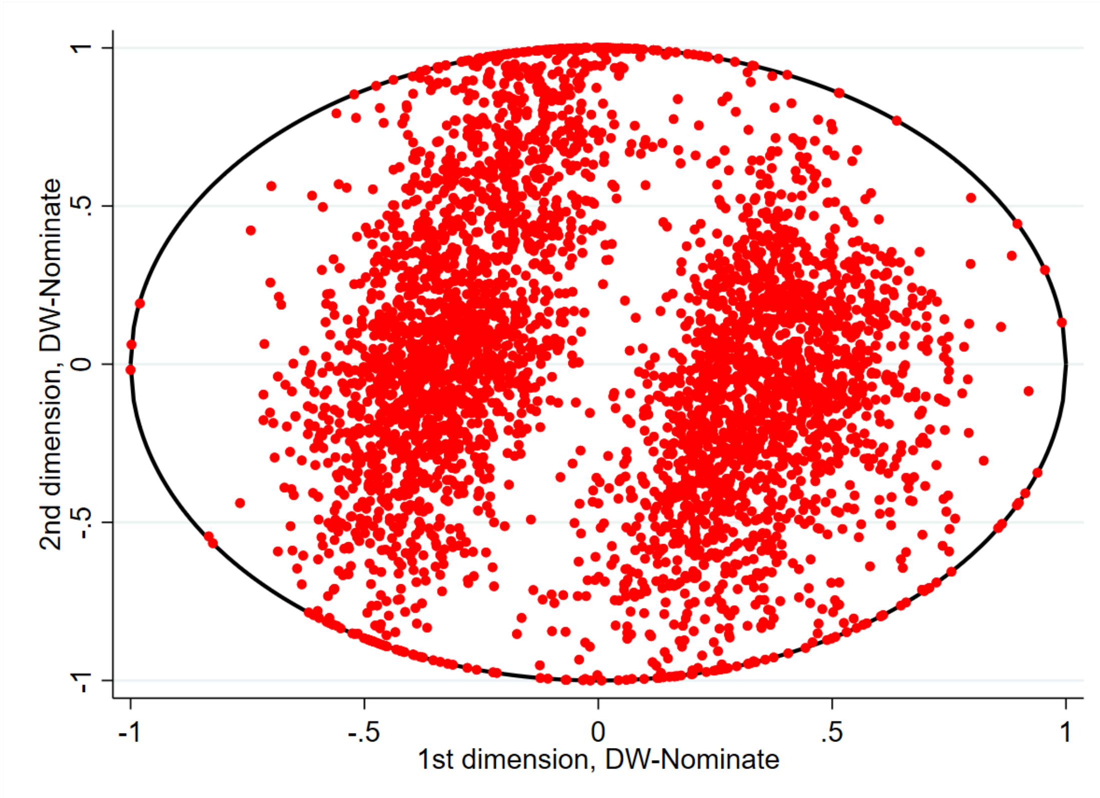
The only normalization that DW-Nominate imposes that is consistently specified (see p.268 of Armstrong et al. 2014) is that all of the ideologies must lie within a unit circle. This normalization may at first appear intuitive, but we point out two difficulties that it creates. Both of the difficulties arise because DW-Nominate does not re-estimate all ideologies and cutline parameters when new roll call data arrives (i.e. no back-propagation). If one were to estimate everything *without* restricting ideologies to the unit circle and then simply rescale them to lie within the unit circle, the normalization would pose no problem. For example, one could take our estimates and simply rescale them all to lie within the unit circle given that the scaling is arbitrary. But, because DW-Nominate imposes the restriction in the estimation process, two complications arise.

The first difficulty is that a unit circle restriction creates an artificial negative correlation between the two dimensions of members' ideological positions. To see this problem most clearly, consider a new member of Congress, i, that is very liberal in the first dimension. Locating this member at $\theta_1^i = -1$ forces him or her to be perfectly moderate in the second dimension (θ_2^i must be 0). In reality, the estimation procedure will be forced to make a compromise: to place a member at an extreme position along the first dimension, it must mechanically moderate the member in the second dimension (and similarly, for placing a member at an extreme position along the second dimension). We do not believe there is any ex ante reason to think that politicians cannot simultaneously hold extreme positions in both dimensions, but DW-Nominate rules out this possibility through the unit circle normalization.

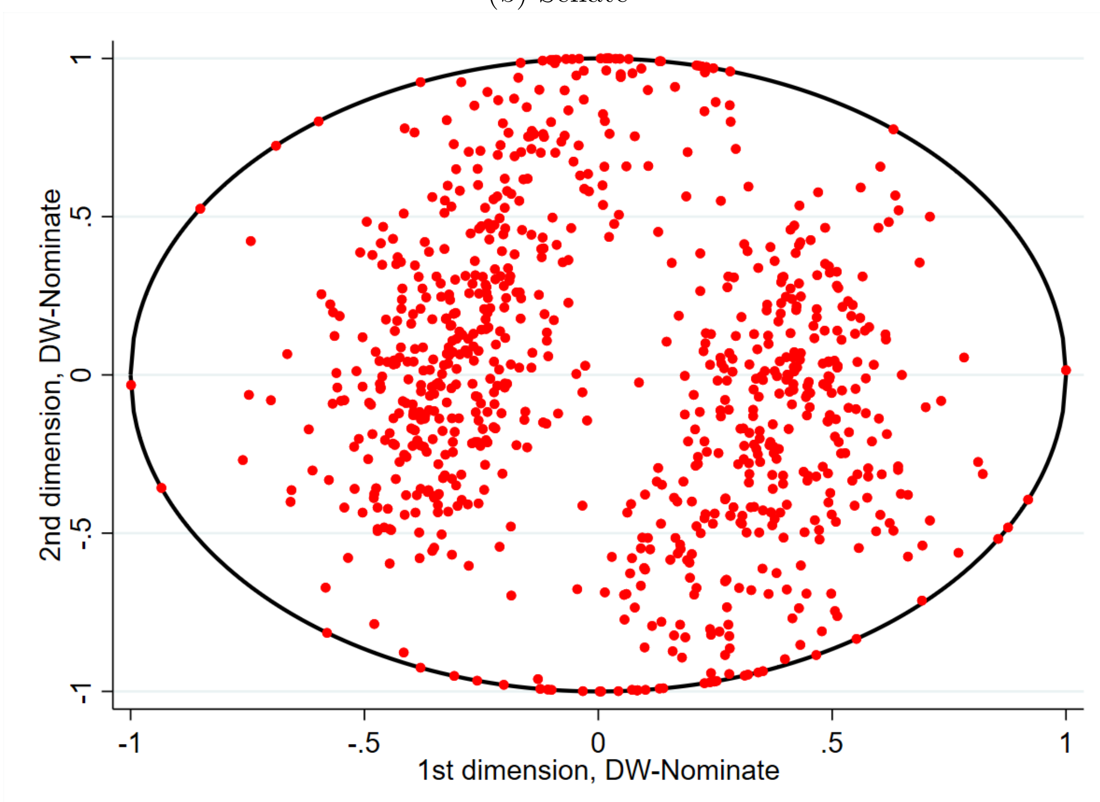
The second difficulty directly stems from the lack of back-propagation. At one point in time, prior to knowing all future members' ideological points, DW-Nominate was scaled such that all members at that time lied within the unit circle. But, unless the constraint was originally 'slack' (no members were located on the unit circle), this scaling implies that any future member that is more extreme than any of those in this initial set will lie on the unit circle boundary artificially. If progressively more extreme politicians are in fact replacing more moderate ones, this normalization starts to progressively become more problematic. To provide suggestive evidence that this artificial constraint is binding, in Figure 17, we plot the unit circle together with all DW-Nominate estimates for each ideology from Congress 70 to Congress 115, both for the House and for the Senate. Since Congress 70, approximately 7% of estimates in the House sit on the boundary of the unit circle, with 8% being on the boundary for the Senate. This evidence suggests that the unit circle boundary is directly and artificially constraining the estimated ideologies for a non-trivial number of legislators. Furthermore, note that this constraint also affects estimates of members away from the boundary, because their ideologies are estimated by incorporating information from those who sit on the boundary.

Figure 17: The Role of the Unit Circle Restriction in DW-Nominate

(a) House of Representatives



(b) Senate



Appendix C: Computational Details of the Estimation Procedure

We maximize the likelihood in (7) via an unconstrained optimization procedure, providing the analytic gradient to the algorithm to greatly improve estimation speed. Rather than using an off-the-shelf quasi-newton algorithm (such as Matlab's fminunc), which proved to perform very poorly given the non-convexity of our likelihood function, we instead use Adam, a version of the steepest descent algorithm. Adaptive Moment Estimation (Adam) is a stochastic optimization algorithm which is also ideal for problems with a large number of parameters like ours (Kingma and Ba, 2014).

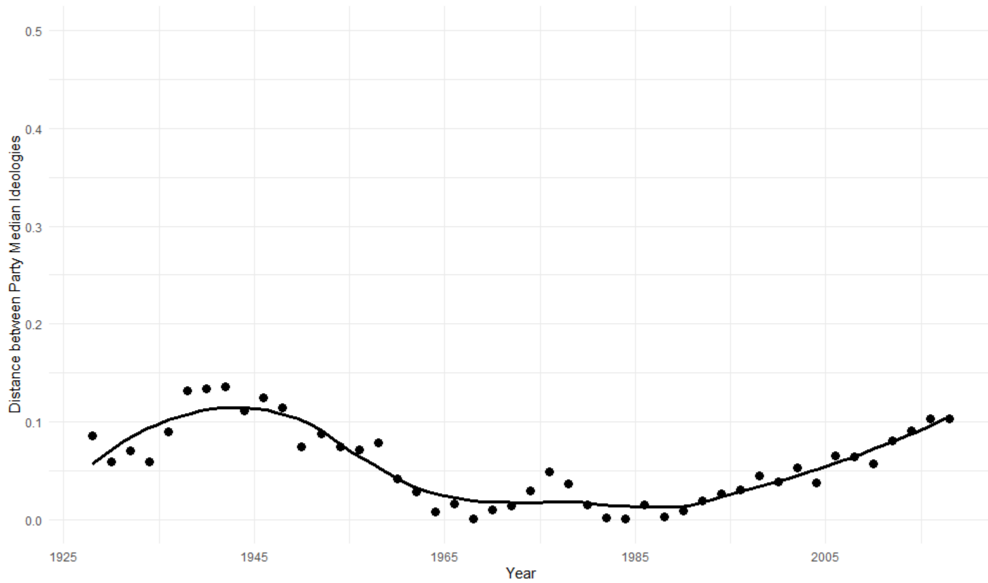
As is standard, we run the estimation procedure until either the stepsize or the gradient is small (for the 2D model, typically the estimation procedure terminated due to the stepsize being small, on the order of 1e-4).

Because for non-convex optimization problems, convergence to a global maximum cannot be guaranteed, we ran the estimation procedure for our main model (Senate 2D) with 60 starting points, with each batch of 12 taking roughly one day when each starting point runs in parallel. For the Senate 2D model, we use the first dimension ideological positions from the Senate 1D model as starting points. For the misspecified Senate 2D model (without party pressure), we use ideology estimates from the full Senate 2D model. Starting points were otherwise randomly chosen (i.e. for the cutlines, party pressure parameters, and ideologies for the 1D models).

We report the estimates for the estimation run that produced the largest likelihood across runs. But, we emphasize that the estimates of the main parameters of interest (namely, the party pressure parameters) were quantitatively very similar (although not identical) across runs.

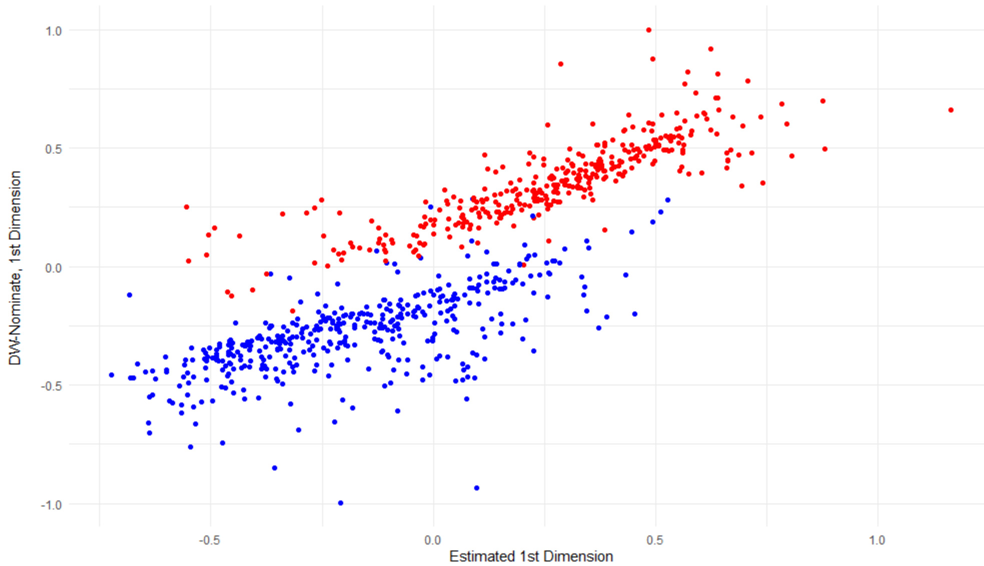
Appendix D: Additional Tables and Figures

Figure 18: Ideological Polarization Between Senate Members, 1927-2019 (2nd Dimension) - Senate 2D Model



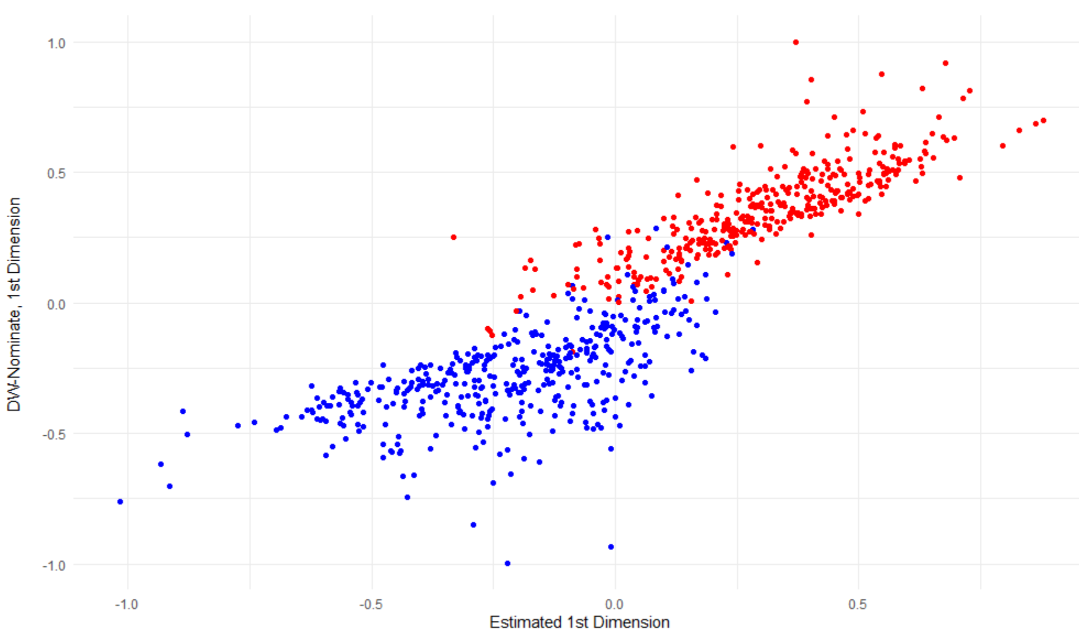
Notes: Estimates of the distance between party medians in the 2nd dimension for the Senate 2D Model are shown, together with a smoothed fit (Loess) curve.

Figure 19: Estimated (Senate 2D) Model vs. DW-Nominate, 1st Dimension



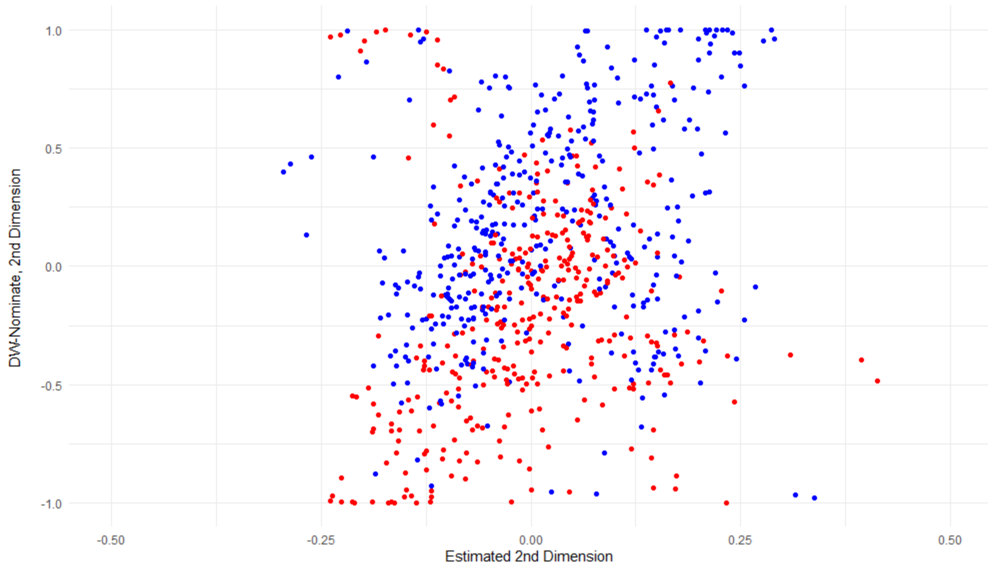
Notes: Scatter plot of first dimension estimated ideologies versus those from DW-Nominate, pooled across all Congresses. Democrats are shown in blue, Republicans are shown in red. The correlation is 0.840. The correlation within Republicans is 0.884, while the one within Democrats is 0.728.

Figure 20: Misspecified (Senate 2D) Model vs. DW-Nominate, 1st Dimension



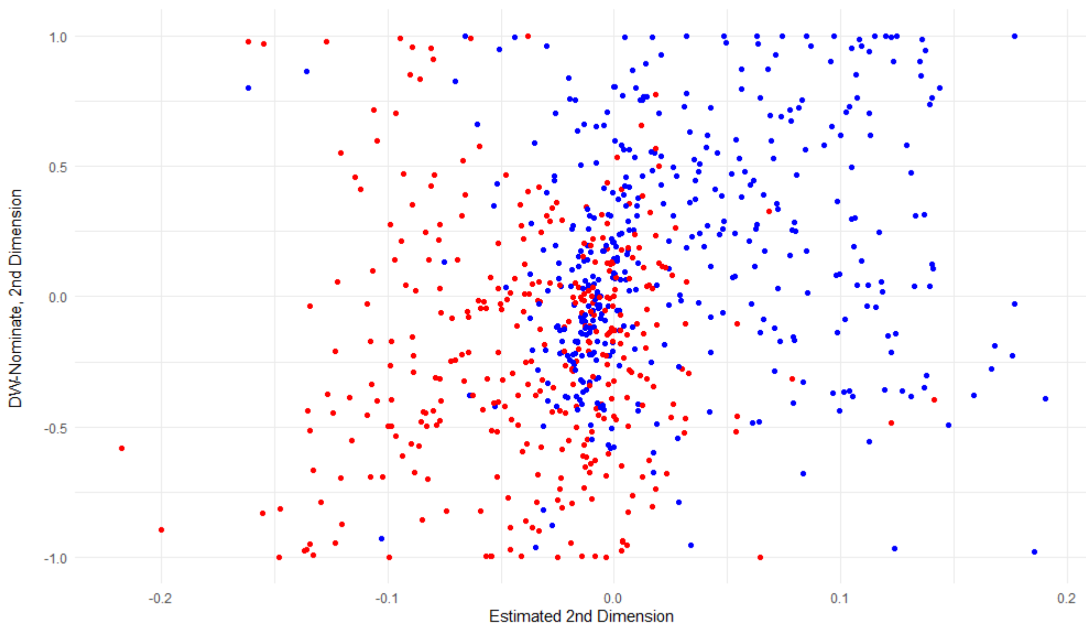
Notes: Scatter plot of the first dimension estimated ideologies of the misspecified model (no party pressure) versus those from DW-Nominate, pooled across all Congresses. Democrats are shown in blue, Republicans are shown in red. The correlation is 0.910.

Figure 21: Estimated (Senate 2D) Model vs. DW-Nominate, 2nd Dimension



Notes: Scatter plot of the second dimension estimated ideologies versus those from DW-Nominate, pooled across all Congresses. Democrats are shown in blue, Republicans are shown in red. The correlation is 0.435. The correlation within Republicans is 0.498, while the one within Democrats is 0.309.

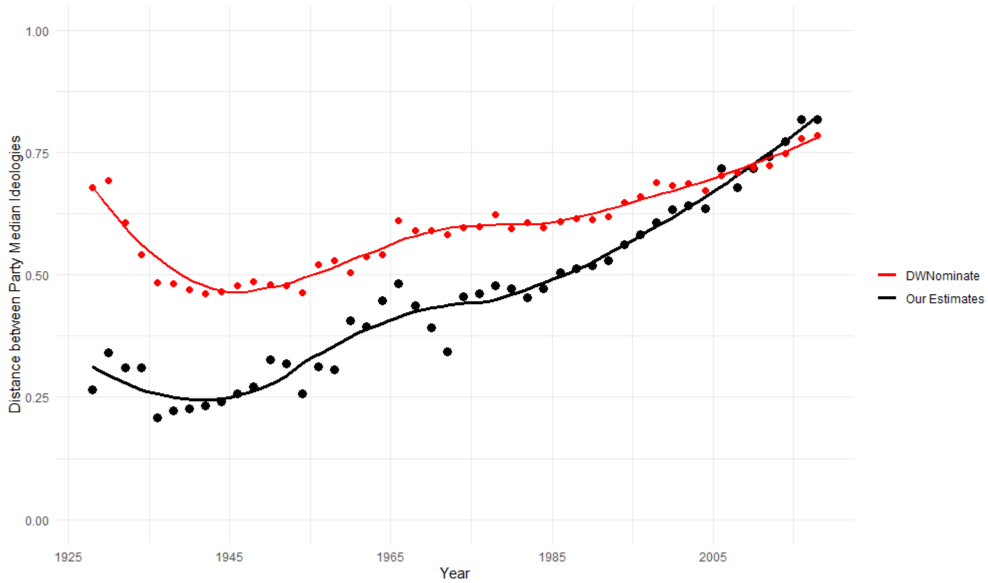
Figure 22: Misspecified (Senate 2D) Model vs. DW-Nominate, 2nd Dimension



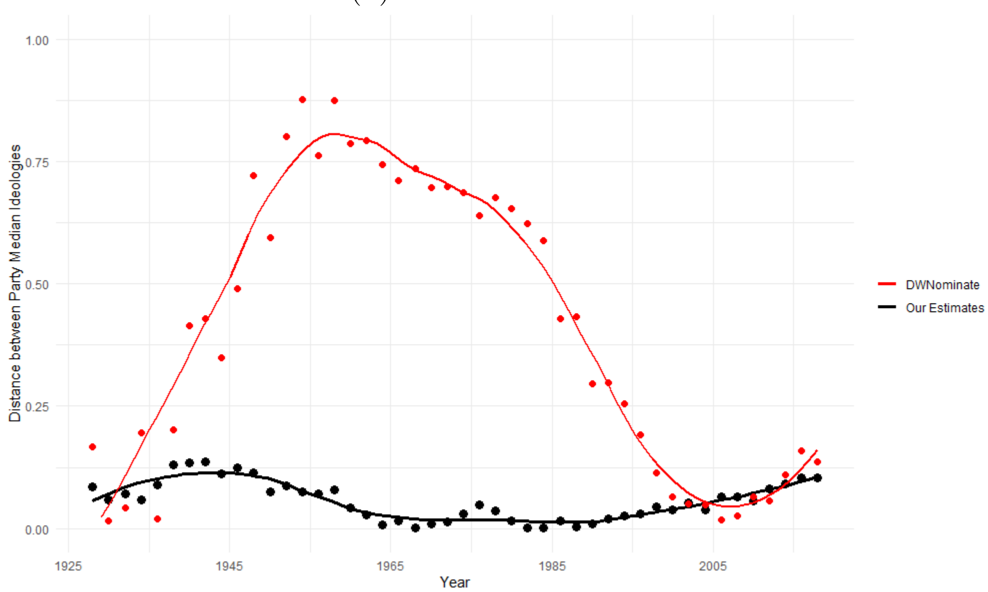
Notes: Scatter plot of the second dimension estimated ideologies of the misspecified model (no party pressure) versus those from DW-Nominate, pooled across all Congresses. Democrats are shown in blue, Republicans are shown in red. The correlation is 0.365.

Figure 23: Trends in Ideological Polarization: Senate 2D Model vs. DW-Nominate

(a) First Dimension



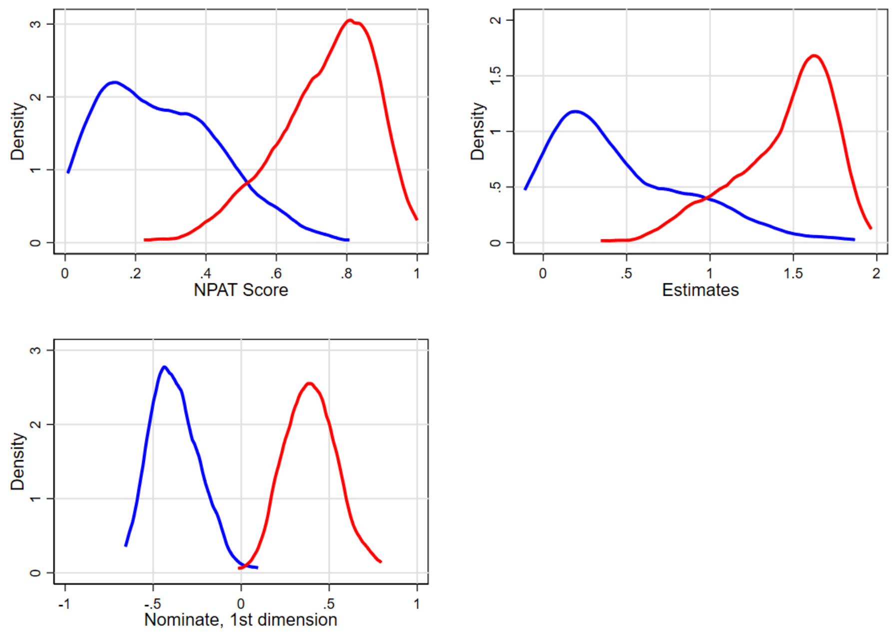
(b) Second Dimension



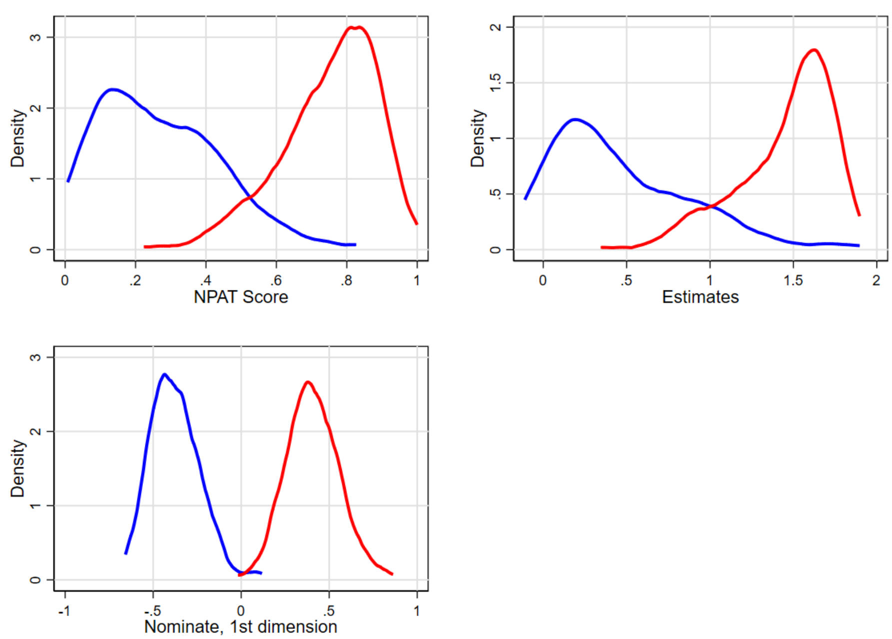
Notes: The two graphs compare the ideological polarization (difference between estimated party medians) across time for the Senate 2D model and DW-Nominate.

Figure 24: Trends in Ideological Polarization: Our Estimates, NPAT and DW-Nominate

(a) Congress 104, House

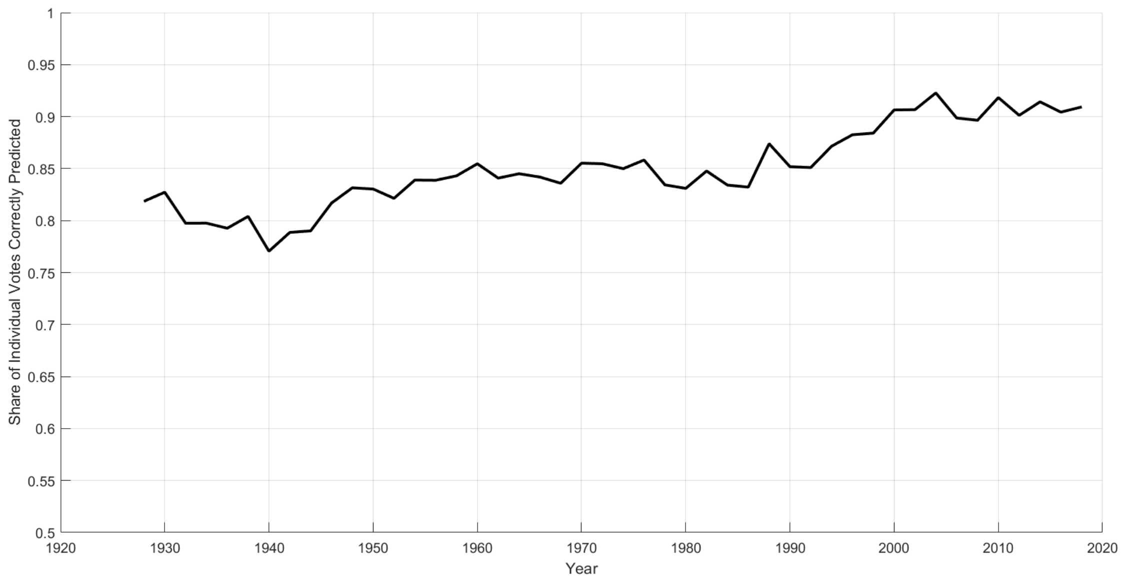


(b) Congress 105, House



Notes: The two graphs compare the distribution of Democrat and Republican ideologies across three different measures: NPAT (derived from House politicians' responses to policy surveys in 1996 and 1998), our estimates and DW-Nominate. We present the results for Congresses 104 and 105, the ones analyzed by Ansolabehere et al. (2001a,b). The figures show the distributions for the same politicians: while NPAT has less estimates than roll-call based methods, we only show the results for the set of politicians with NPAT scores for comparability.

Figure 25: Model Fit: Share of Votes Correctly Predicted in the Senate (2D Model)



Notes: Average share of votes that are correctly predicted in each Congress. A vote is considered to be correctly predicted if, under our estimated parameters, the probability of a congress member voting as observed in the data is larger than 0.5.

Figure 26: Ideological Polarization Over Time (2nd dimension), 1927-2019 - Senate 2D Model

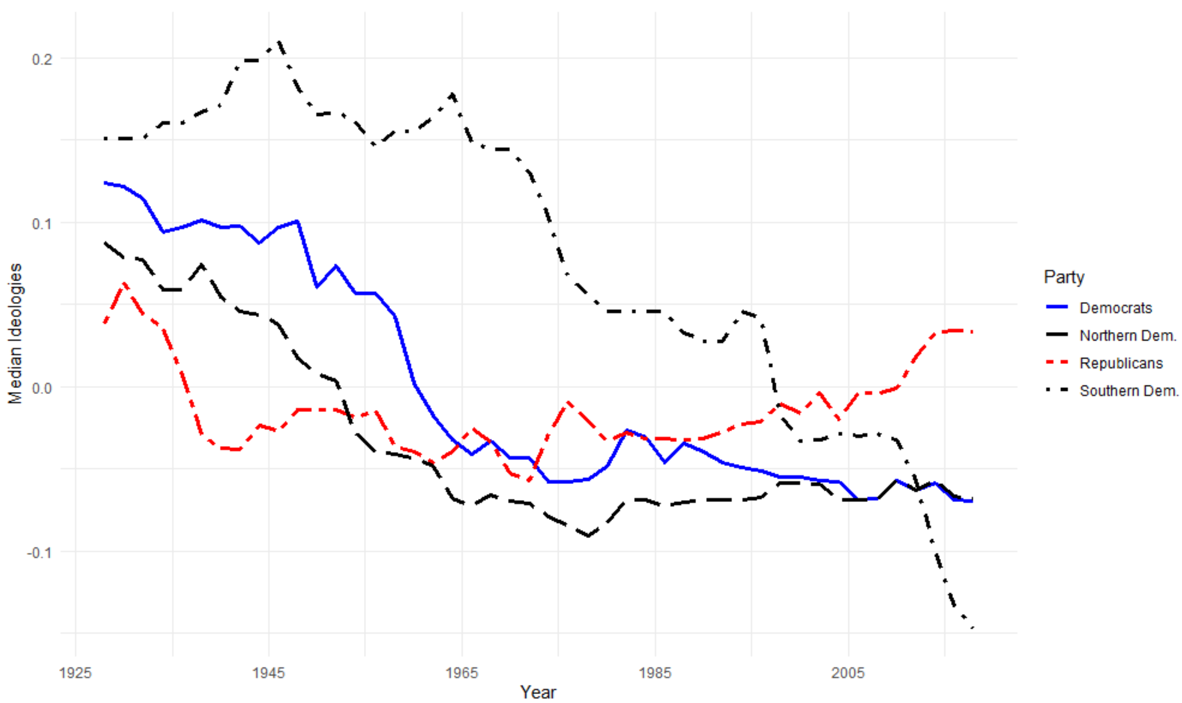
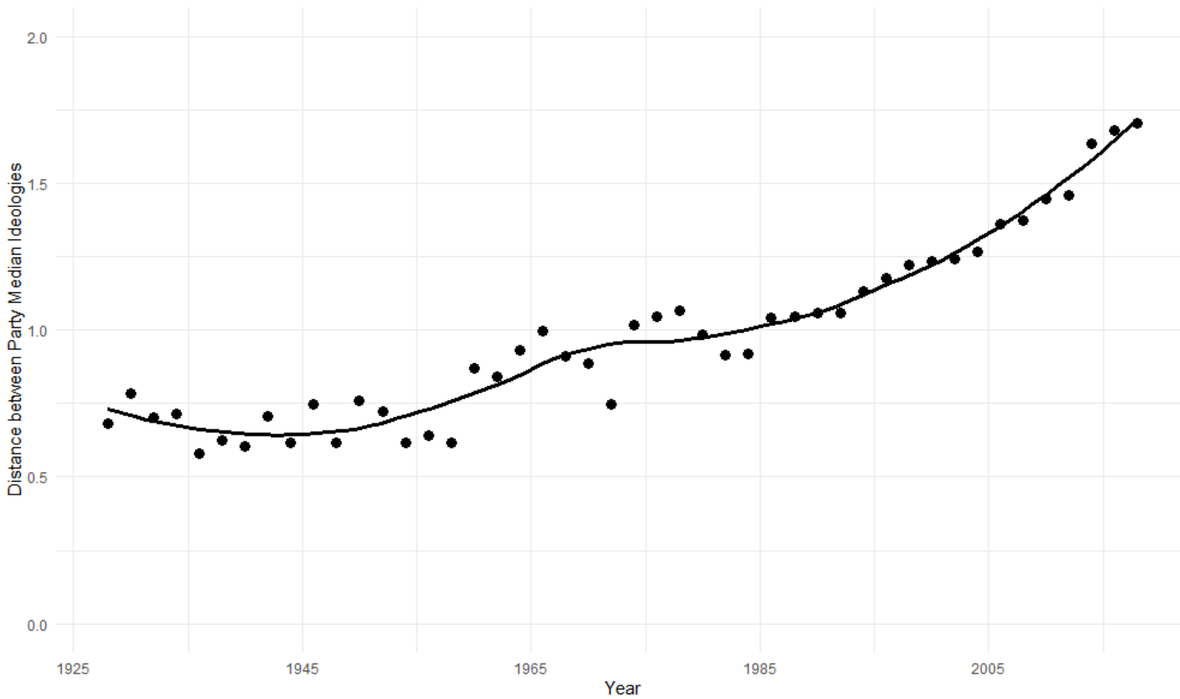


Figure 27: Ideological Polarization in the 1D Model

(a) Senate



(b) House

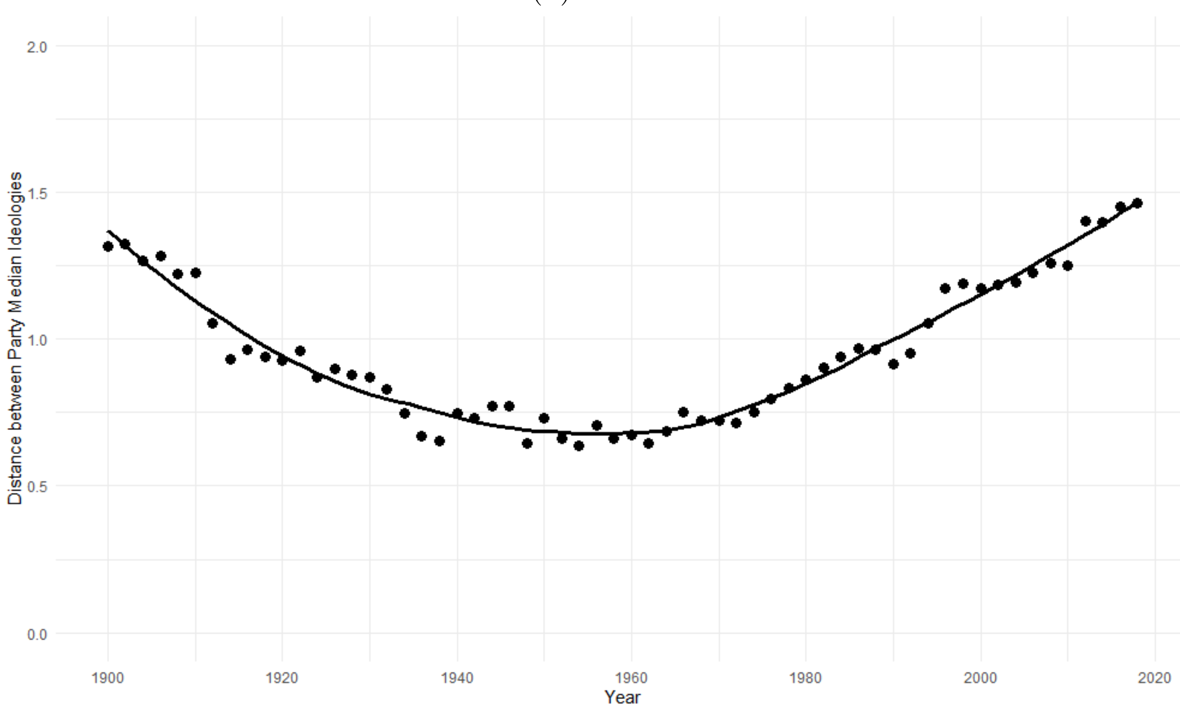
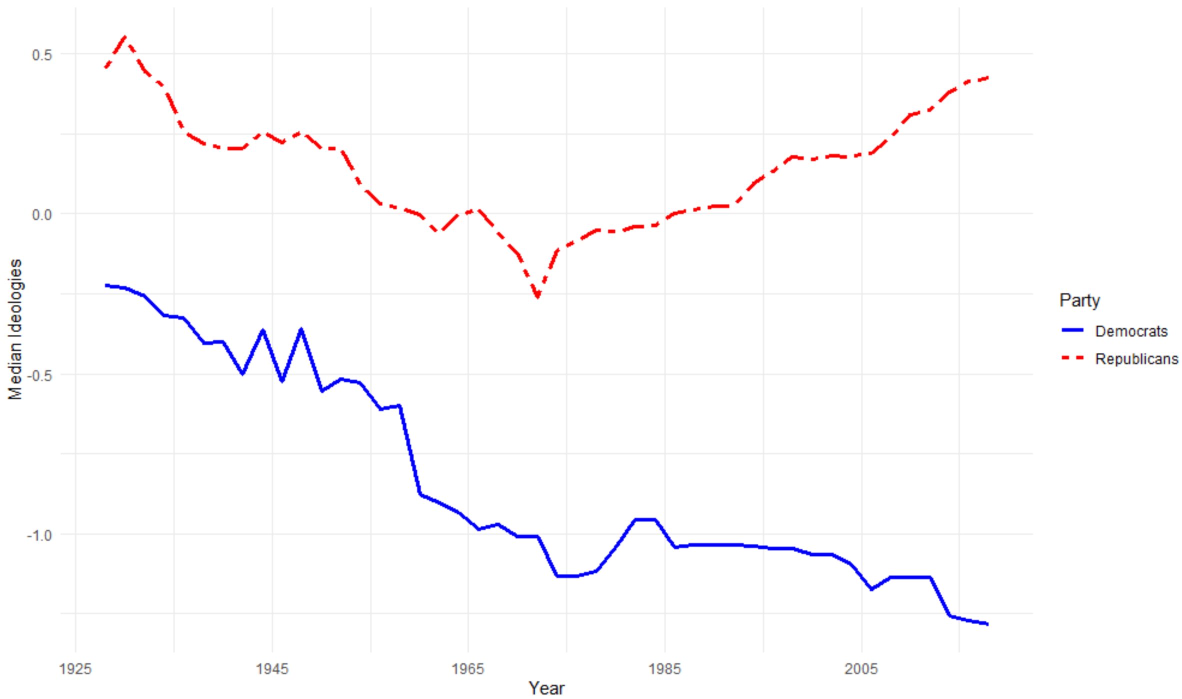


Figure 28: Ideological Polarization over Time, 1927-2019 - 1D Model

(a) Senate



(b) House

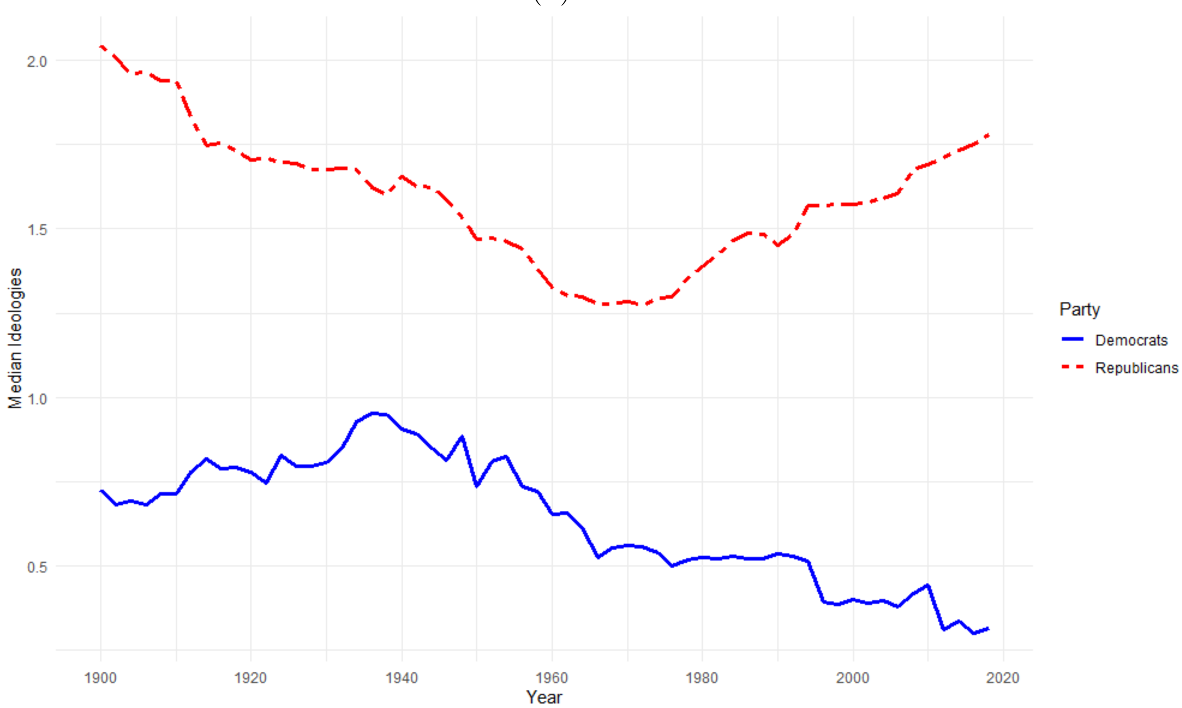
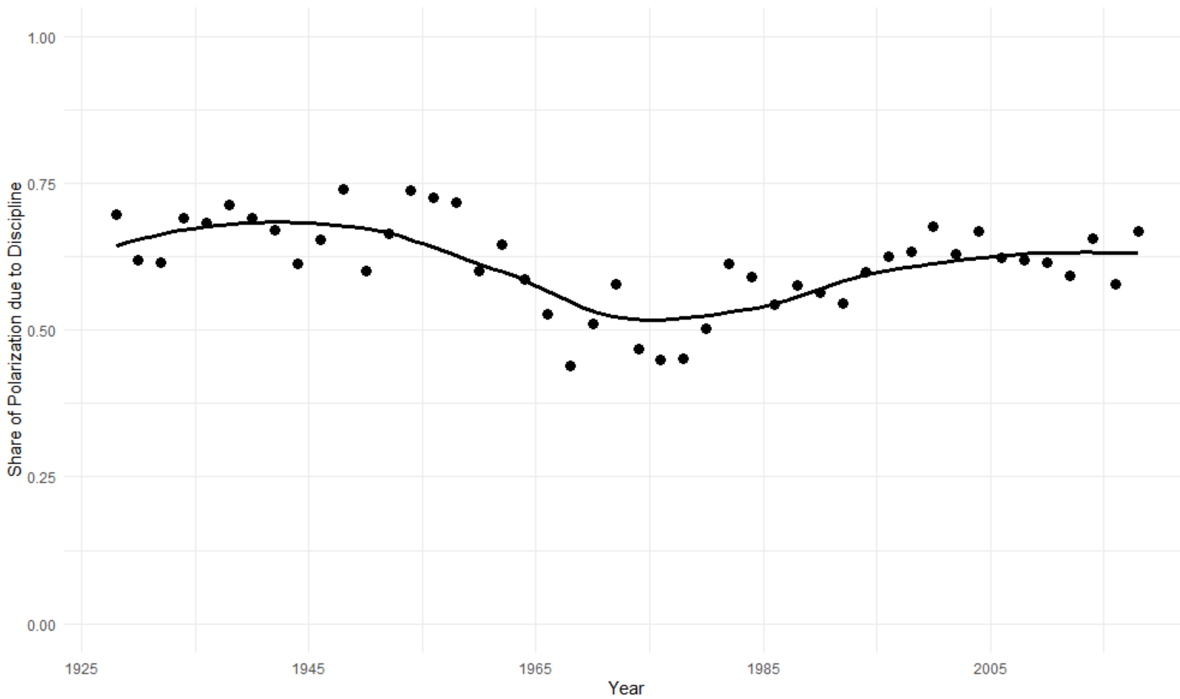


Figure 29: Share of Ideological Polarization Attributable to Party Pressure - 1D Model

(a) Senate



(b) House

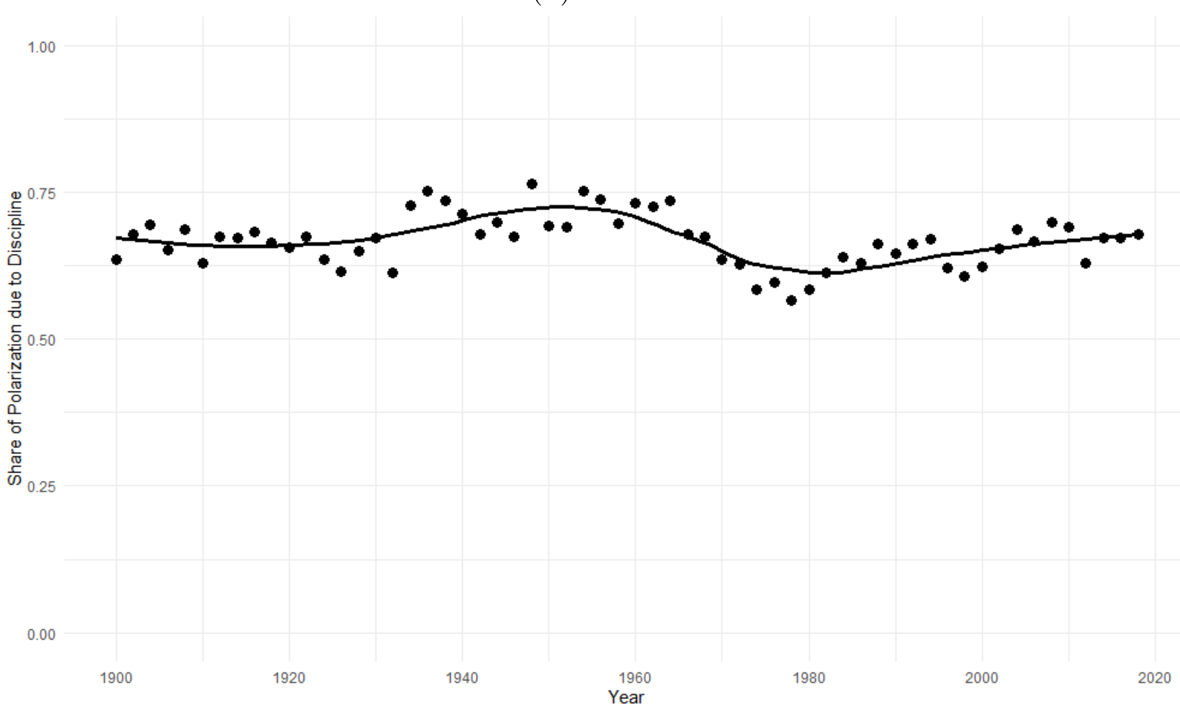
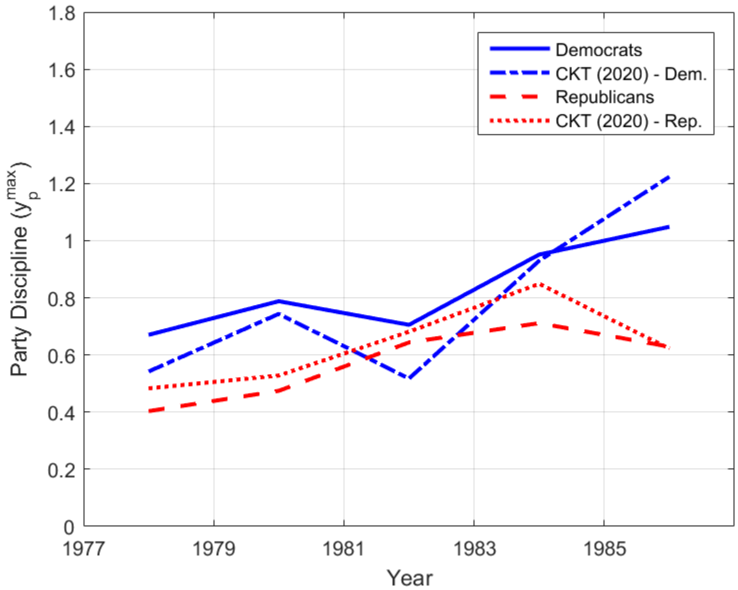
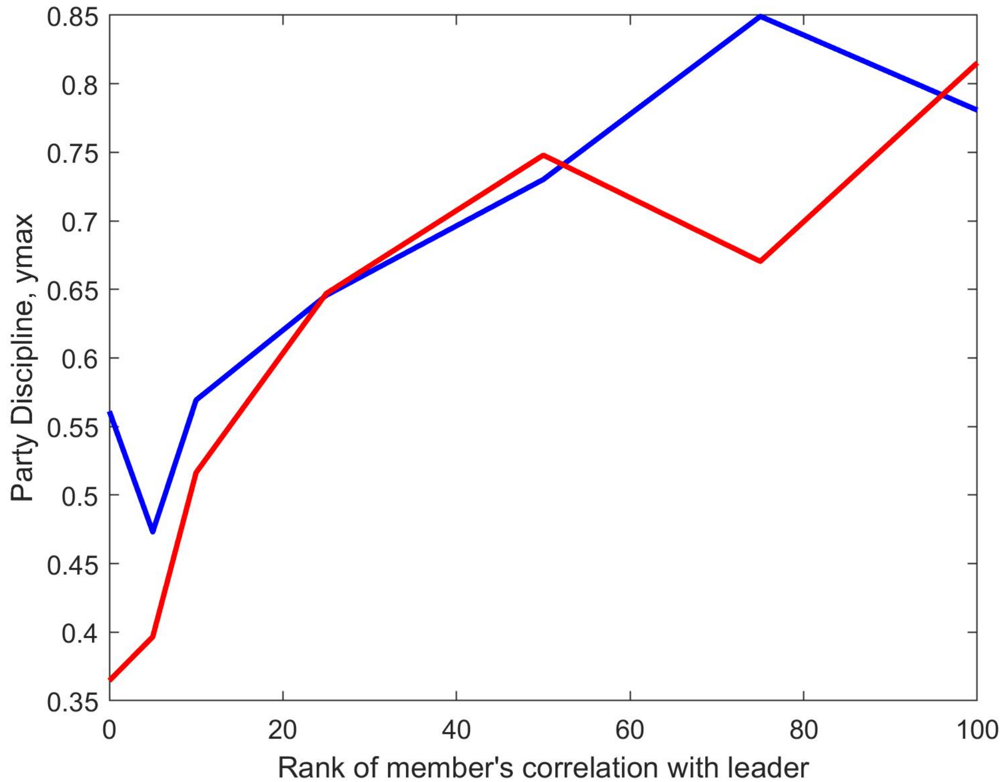


Figure 30: Comparison of Party Pressure Estimates



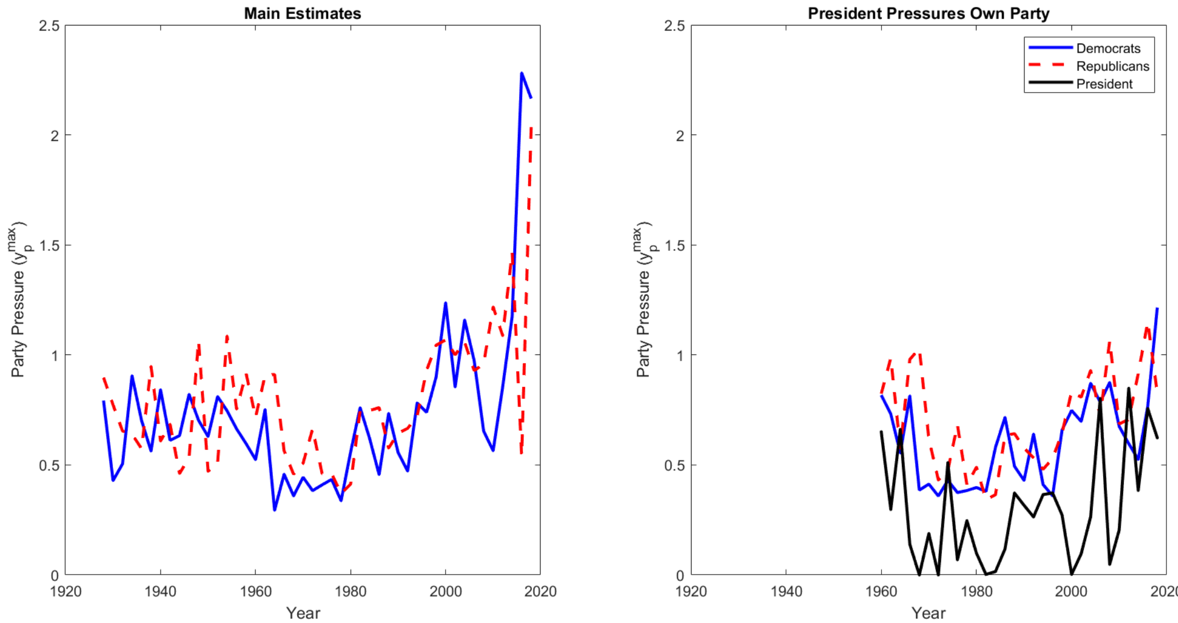
Notes: Estimates of y_p^{max} compared to those from Canen et al. (2020) for 1977-1986 (i.e. Congresses 95-99). Canen et al. (2020) assumed utility shocks have a variance equal to two (instead of one), so the prior estimates are rescaled by $\sqrt{2}$.

Figure 31: Party Pressure Estimates Using Members Other Than the Leader



Notes: Estimates of y_p^{max} when we use different party members to construct the discipline directions, $W_{p,t}$, in place of the true leader. The different party leaders are based on percentile ranks of the members whose votes are most correalted with the leader (100% being the leader). Estimates for Democrats are presented in blue, while estimates for Republicans are in red.

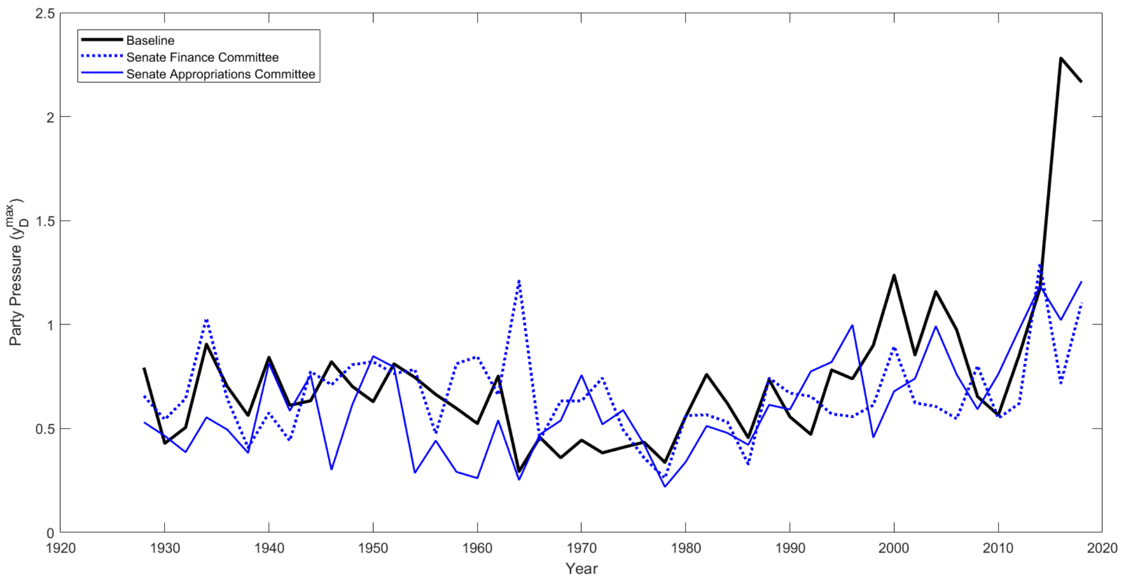
Figure 32: Party Pressure Estimates Allowing for Presidential Influence



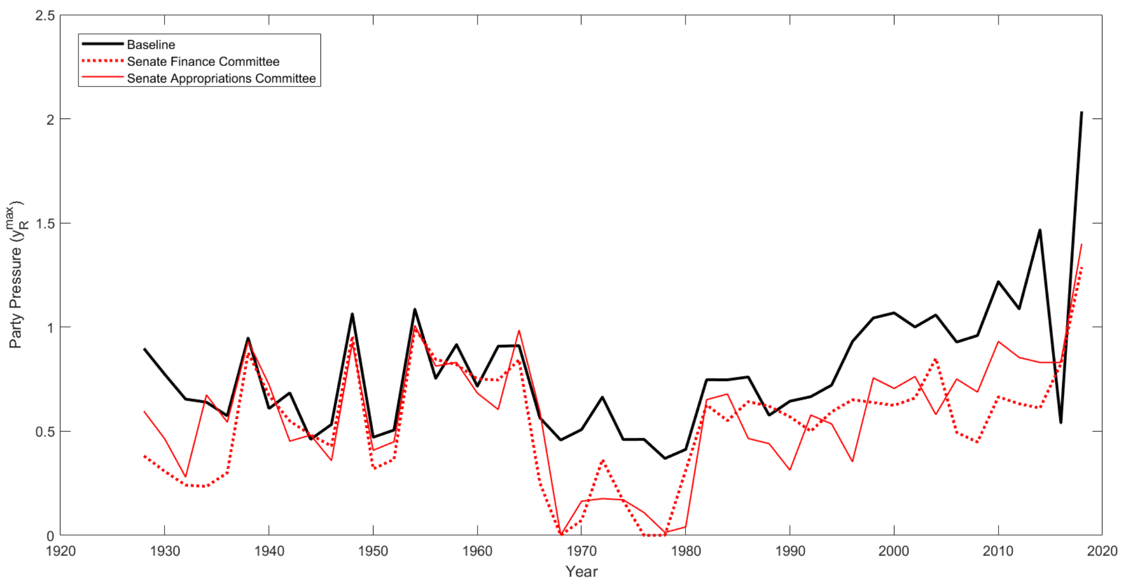
Notes: Estimates of y_p^{max} when we extend the model to allow the incumbent president to also pressure members of his own party. The left figure presents the baseline estimates for comparison purposes. The estimated parameter of the president's influence is shown in a black line in the righthand figure.

Figure 33: Party Pressure Estimates Allowing for Committee Influence

(a)
Democrats



(b) Republicans



Notes: Estimates of y_p^{max} when we replace the direction of party pressure obtained from party leadership, $W_{p,t}$, by a direction of pressure obtained from the most senior ranking member of a salient committee (either from the Senate Finance Committee or from the Senate Appropriations Committee).

Figure 34: Party Pressure Heterogeneity in the Presence of Re-Election Concerns

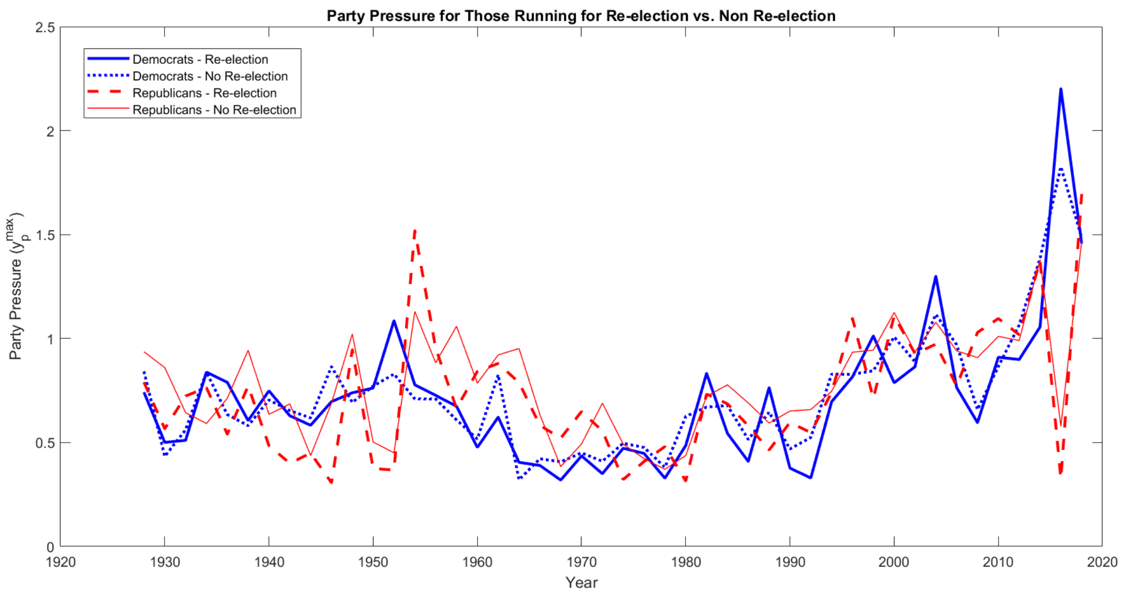
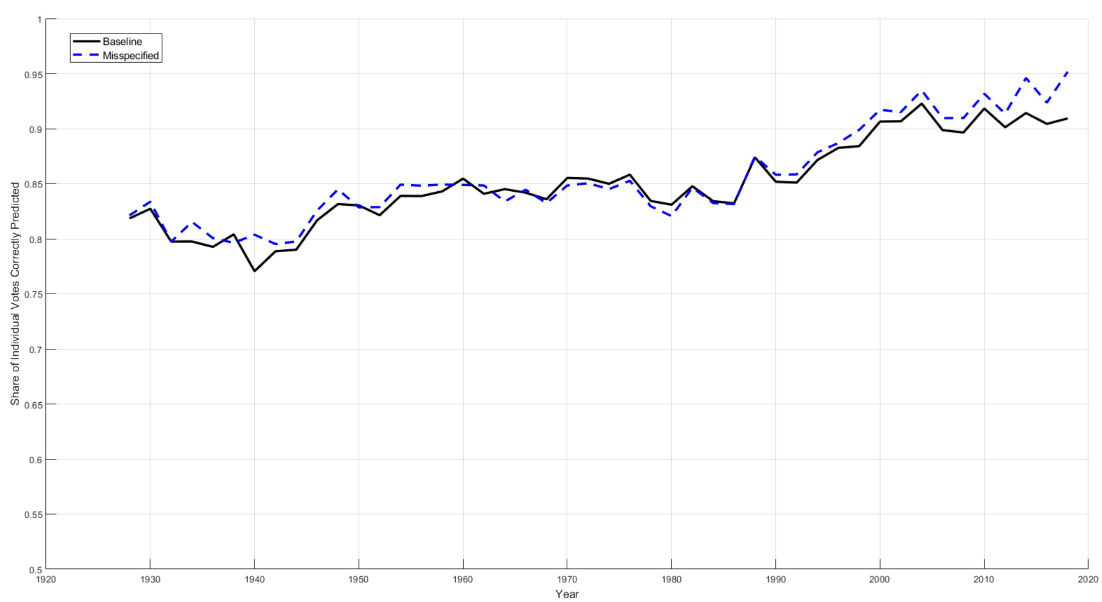


Figure 35: Comparison of Model Fit: Baseline Model and Misspecified Model



Notes: Average share of votes that are correctly predicted in each Congress for the baseline model (already shown in Figure 25) and for the misspecified model omitting party pressure. A vote is considered to be correctly predicted if, under our estimated parameters, the probability of a congress member voting as observed in the data is larger than 0.5.

Table 2: Summary Statistics

Congress	Senate				House			
	Bills introduced	Avg. bills per member	Bills passed	Fraction that pass	Bills introduced	Avg. bills per member	Bills passed	Fraction that pass
80th (1947-1948)	3,186	33.2	1,670	0.524	7,611	17.5	1,739	0.228
81st (1949-1950)	4,486	46.7	2,362	0.527	10,502	24.1	2,482	0.236
82nd (1951-1952)	3,665	38.2	1,849	0.505	9,065	20.8	2,008	0.222
83rd (1953-1954)	4,077	42.5	2,231	0.547	10,875	25.0	2,129	0.196
84th (1955-1956)	4,518	47.1	2,550	0.564	13,169	30.3	2,360	0.179
85th (1957-1958)	4,532	47.2	2,202	0.486	14,580	33.5	2,064	0.142
86th (1959-1960)	4,149	41.5	1,680	0.405	14,112	32.3	1,636	0.116
87th (1961-1962)	4,048	40.5	1,953	0.482	14,328	32.8	1,927	0.134
88th (1963-1964)	3,457	34.6	1,341	0.388	14,022	32.2	1,267	0.090
89th (1965-1966)	4,129	41.3	1,636	0.396	19,874	45.7	1,565	0.079
90th (1967-1968)	4,400	44.0	1,376	0.313	22,060	50.7	1,213	0.055
91st (1969-1971)	4,867	48.7	1,271	0.261	21,436	49.3	1,130	0.053
92nd (1971-1972)	4,408	44.1	1,035	0.235	18,561	42.7	970	0.052
93rd (1973-1974)	4,524	45.2	1,115	0.246	18,872	43.4	923	0.049
94th (1975-1976)	4,115	41.2	1,038	0.252	16,982	39.0	968	0.057
95th (1977-1978)	3,800	38.0	1,070	0.282	15,587	35.8	1,027	0.066
96th (1979-1980)	3,480	34.8	976	0.280	9,103	20.9	929	0.102
97th (1981-1982)	3,396	34.0	786	0.231	8,094	18.6	704	0.087
98th (1983-1984)	3,454	34.5	936	0.271	7,105	16.3	978	0.138
99th (1985-1986)	3,386	33.9	940	0.278	6,499	14.9	973	0.150
100th (1987-1988)	3,325	33.3	1,002	0.301	6,263	14.4	1,061	0.169
101st (1989-1990)	3,669	36.7	980	0.267	6,664	15.3	968	0.145
102nd (1991-1992)	3,738	37.4	947	0.253	6,775	15.6	932	0.138
103rd (1993-1994)	2,805	28.1	682	0.243	5,739	13.2	749	0.131
104th (1995-1996)	2,266	22.7	518	0.229	4,542	10.4	611	0.135
105th (1997-1998)	2,718	27.2	586	0.216	5,014	11.5	710	0.142
106th (1999-2000)	3,343	33.4	819	0.245	5,815	13.4	957	0.165
107th (2001-2002)	3,242	32.4	554	0.171	5,892	13.5	677	0.115
108th (2003-2004)	3,078	30.8	759	0.247	5,547	12.8	801	0.144
109th (2005-2006)	4,163	41.6	684	0.164	6,540	15.0	770	0.118
110th (2007-2008)	3,738	37.4	556	0.149	7,441	17.1	1101	0.148
111th (2009-2010)	4,101	41.0	176	0.043	6,677	15.3	861	0.129
112th (2011-2012)	3,767	37.7	364	0.097	6,845	15.7	561	0.082

Table 3: Regression Results - Sources of Party Pressure

	Estimates of y_p^{max}				
Party (Republican)	0.051 (0.073)	0.036 (0.097)	0.051 (0.073)	0.036 (0.097)	0.036 (0.060)
Majority Status		-0.045 (0.097)		-0.045 (0.097)	-0.045 (0.060)
Divided Government (1 if Divided)			0.032 (0.073)	0.032 (0.074)	0.087 (0.051)
Observations	92	92	92	92	92
Decade Fixed Effect					Yes
R^2	0.005	0.009	0.008	0.011	0.635

Notes: Regressions of the time series of estimates of $\{y_p^{max}\}_{p\in\{D,R\}}$ for the Senate 2D model on a Party level dummy variable (equal to 1 if p is Republican), dummy variable for Majority Status (which equals 1 if party p held the majority of seats in the Senate, and 0 otherwise) and dummy variable for divided government (which is equal to 0 if the president's party is the same as the majority party in the House and in the Senate and 1 otherwise). Robust standard errors in parentheses.

Appendix E: Monte Carlo Simulations

As shown in the main text, we can identify the parameters for individual ideologies, $\{\theta^i\}$, and for party pressure, (y_D^{max}, y_R^{max}), under general forms of agenda-setting within the random utility framework when preference shocks are realized after the agenda is set. Here, we report Monte Carlo experiments to verify that the parameters we recover are independent of the agenda.

We use an analogous set-up to that of (Clinton et al., 2014). First, we set the number of politicians to $n = 100$, with two parties: a majority party (D) with 55 members and a minority party (R) with 45 members. We draw ideologies i.i.d. from the following normal distributions: for party D, $\theta^i \sim N(-\frac{\alpha}{2},1)$ and for party R, $\theta^i \sim N(-\frac{\alpha}{2},1)$. Hence, α parameterizes ideological polarization: the distance between parties' ideological distributions. We vary α across simulations to illustrate unbiased estimates even with polarized ideologies (larger α). We set the party leaders at the median of their respectively drawn distributions.

Preferences follow equation (1) in the main text for the one-dimensional model, with voting decisions being made analogous to equation (4) in Section 2.2.3. Preference shocks are drawn i.i.d. from a standard normal distribution.[70]

Our goal is to illustrate that we can obtain unbiased estimates with general forms of agenda-setting. To do so, we draw cutpoints *at random*: i.i.d., from a Normal distribution with mean

[70]The standard normal assumption on preference shocks is necessary for identification - see the main text.

zero and standard deviation σ_v. The parameter σ_v parameterizes the partisanship in agenda-setting: low values imply most cutpoints pin parties against each other. The ratio $\frac{\alpha}{\sigma_v}$ parameterizes the share of cutpoints between the party medians (i.e., where leaders exert pressure in opposite directions). We draw $T = 750$ cutpoints, which is close to the median value in our sample.

We consider a total set of eight exercises. First, we consider two sets of party pressure parameters: $(y_{D,}^{max} y_R^{max}) = (0.6, 0.4)$ and $(y_{D,}^{max} y_R^{max}) = (0, 0)$. The former are similar to those estimated within our sample, while the latter are used to illustrate that we obtain estimates of no party pressure if it does not exist. Second, we set $\alpha = 0.5$ (parties are not very polarized) and $\alpha = 1$ (parties are polarized, as their medians are 1 standard deviation of preference shocks apart). Finally, we set $\sigma_v = 0.5$ (cutpoints are concentrated between party medians) and $\sigma_v = 1$ (cutpoints are often drawn from extreme agendas). Our exercises consist of all possible combinations of the two different sets of parameters for party pressure, ideological polarization, and agenda-setting.

The results are shown in Table 4 below for $R = 100$ simulations. As we see, our procedure estimates party pressure parameters accurately and consistently across specifications: whether party pressure is zero or positive, whether agenda-setting is extreme or not, and whether ideological polarization is large or small. These results illustrate the robustness of obtaining unbiased estimates of both polarization and party pressure, provided the sample sizes are as large as in our data. By contrast, in small samples we may only rarely observe switching for some politicians. In this case, estimates can be biased as Bateman et al. (2017) demonstrate.

Table 4: Monte Carlo Simulation Results for Estimation of $\bar{y}^{max}$

Specification: $(y^D_{max}, y^R_{max}) = (0.6, 0.4)$

	Low Polarization ($\alpha = 0.5$)	High Polarization ($\alpha = 1$)	Low Polarization ($\alpha = 0.5$)	High Polarization ($\alpha = 1$)
	Divisive Agenda ($\sigma_v = 0.5$)	Divisive Agenda ($\sigma_v = 0.5$)	Extreme Agenda ($\sigma_v = 1$)	Extreme Agenda ($\sigma_v = 1$)
y_D^{max}	0.609	0.613	0.604	0.603
	(0.018)	(0.015)	(0.020)	(0.017)
y_R^{max}	0.405	0.419	0.399	0.394
	(0.016)	(0.020)	(0.022)	(0.020)

Specification: $(y^D_{max}, y^R_{max}) = (0, 0)$

	Low Polarization ($\alpha = 0.5$)	High Polarization ($\alpha = 1$)	Low Polarization ($\alpha = 0.5$)	High Polarization ($\alpha = 1$)
	Divisive Agenda ($\sigma_v = 0.5$)	Divisive Agenda ($\sigma_v = 0.5$)	Extreme Agenda ($\sigma_v = 1$)	Extreme Agenda ($\sigma_v = 1$)
y_D^{max}	0.004	0.007	0.005	0.004
	(0.007)	(0.010)	(0.008)	(0.007)
y_R^{max}	0.005	0.017	0.005	0.003
	(0.008)	(0.013)	(0.007)	(0.006)

Notes: Low ideological polarization refers to a distance between the party medians in the ideological distributions of $\alpha = 0.5$, while high polarization refers to $\alpha = 1$. σ_v refers to the standard deviation in cutpoints, which are drawn at random. This can be low ($\sigma_v = 0.5$) or high ($\sigma_v = 1$), capturing the extent to which most observations are between the party medians or beyond them. The two panels refer to different values of the party pressure parameters: in the first, party pressure exists for both parties at values similar to estimated values. In the second, there is no party pressure. Entries present the average estimates across simulations, while parentheses refer to the standard deviation in estimates across $R = 100$ simulations.