DIVISION OF THE HUMANITIES AND SOCIAL SCIENCES
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA 91125

GERRYMANDERING ROLL-CALLS: VOTES, DECISIONS, AND PARTISAN BIAS IN CONGRESS, 1879-2000

Gary W. Cox
University of California, San Diego

Jonathan N. Katz
California Institute of Technology

SOCIAL SCIENCE WORKING PAPER 1158

September 2003

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Gary W. Cox* Jonathan N. Katz†

Abstract

We argue that the standard toolbox used in electoral studies to assess the bias and responsiveness of electoral systems can also be used to assess the bias and responsiveness of legislative systems. We consider which items in the toolbox are the most appropriate for use in the legislative setting, then apply them to estimate levels of bias in the U.S. House from 1879 to 2000. Our results indicate a systematic bias in favor of the majority party over this period, with the strongest bias arising during the period of "Czar rule" (51^{st}-60^{th} Congresses, 1889-1910) and during the post-packing era (87^{th}-106^{th} Congresses, 1961-2000). This finding is consistent with the majority party possessing a significant advantage in setting the agenda.

"The definition of alternatives is the supreme instrument of power."
–E. E. Schattschneider (1960, p. 86).

The U.S. House of Representatives, like other legislatures, takes official actions pursuant to formal motions proposed by its members. Each motion is voted upon, either implicitly (e.g., an appeal for unanimous consent) or explicitly (e.g., a voice vote). Votes on the most important motions are usually *roll call votes* in which each member's decision is a matter of public record.

Congressional parties can affect legislative decisions on the floor in two basic ways. First, they can influence how members vote on the various motions put to the House. Second, they can influence what motions are offered for the House's consideration to begin with. In this paper, we focus on the latter issue — and particularly on the agenda power of the majority party.

*Department of Political Science, University of California, San Diego, La Jolla, CA 92093-0521; gcox@weber.ucsd.edu

†Division of the Humanities and Social Sciences, California Institute of Technology, Pasadena, CA 91125; jkatz@caltech.edu, (626) 395-4077.

The paper begins, in the next section, by elaborating an analogy between voting to choose between candidates in an election and voting to choose between alternatives in a roll call. The literature on gerrymandering suggests that the party controlling redistricting in a particular state has both the motive and the opportunity to rig the translation of votes into seats in its own favor, producing what is technically called partisan bias. The literature on agenda power suggests that the party controlling the agenda in a particular Congress has both the motive and the opportunity to rig the translation of votes into decisions in its own favor — again producing partisan bias.

After setting up the basic analogy, we argue that the standard toolbox used in electoral studies to assess the bias and responsiveness of electoral systems can also be used to assess the bias and responsiveness of legislative systems. We consider which items in the toolbox are the most appropriate for use in the legislative setting, then apply them to estimate levels of bias in the U.S. House from 1879 to 2000. Our results indicate a systematic bias in favor of the majority party over this period, with the strongest bias arising during the period of "Czar rule" (51^{st}-60^{th} Congresses, 1889-1910) and during the post-packing era (87^{th}-106^{th} Congresses, 1961-2000).

1. VOTES AND DECISIONS

In a typical U.S. congressional election, a set of voters is presented with a choice between two candidates, one Republican and one Democrat. In a typical congressional roll call vote, a set of legislators is presented with a choice between two alternatives, the state that would obtain were the motion accepted and the state that would obtain were the motion rejected. In both the electoral and legislative example, each chooser has just one vote to cast and the alternative receiving the most votes wins (we exclude from analysis votes on veto overrides and other motions in the U.S. House that require a $\frac{2}{3}$ approval to pass).[1]

The consequence of winning in an election is that one party gets a seat in the House and the other fails to get this seat. The consequence of winning in a legislative vote is more complex. If the two parties take the same position (either for or against) a motion, then both win.[2] If the two parties take opposite positions then, as in the election, one wins and one loses. In what follows, we focus on the cases of party disagreement.

[1] In the legislative setting, ties are broken in favor of the "no" position. Ties in the electoral arena are broken in various ways.

[2] In the electoral arena, this would be like a fusion candidate (a nominee of both major parties) running unopposed (something we ignore).

1.1. *Responsiveness and bias in electoral voting processes*

Students of elections have a long-standing interest in how votes map into seats. Within a single district, the answer is transparent: a party's seat share is zero, if it secures less than 50% of the two-party vote; and one, if it secures more than 50% (we ignore ties). Aggregating across all the districts in a legislature, the votes-to-seats mapping becomes more complex and is usually described in terms of two key parameters: responsiveness and bias.

Responsiveness refers to how much a party's aggregate seat share responds to changes in its aggregate vote share. To be concrete, let s denote the share of all seats that a party wins in a given state legislature (elected in single-member districts by plurality rule); and v denote the average vote share garnered by the party's candidates in the various districts within the state.[3] If all the districts in a state are "safe" for one party or the other, then the statewide vote share may change (moderately) yet produce no change in the statewide seat share. This would be an example of low responsiveness. In contrast, if all the districts in a state are closely contested by the two parties, then a small statewide vote swing may produce a very large change in the parties' seat shares — an example of large responsiveness.

Bias refers to an advantage for one party in the efficiency with which its votes translate into seats. For example, if a state legislature has been gerrymandered by the Republicans, there may be a few extremely safe Democratic districts and a large number of just-winnable Republican districts. In this state, the Democrats "pay" a lot in votes for each seat they win, while the Republicans "pay" substantially less per seat won. Put another way, the Republicans have arranged the districts so that they win by a little and lose by a lot, thereby increasing the number of seats they can eke out of a given expected vote.

The standard equation used to represent (and to estimate) the levels of responsiveness and bias, given statewide vote (v) and seat (s) shares, is the seats-vote curve:

$$\frac{s}{1-s} = \exp(\lambda)\left(\frac{v}{1-v}\right)^{\rho} \tag{1}$$

where the parameter ρ represents responsiveness, and λ represents bias.[4] This specific functional form generalizes the classic cube law (Kendall and Stuart 1950), which emerges when $\lambda = 0$ and $\rho = 3$.

Examples of seats-vote curves can be found in Figure 1. To see the effect of responsiveness, ρ, it is simplest to assume no bias ($\lambda = 0$). In this case, $\rho = 1$ corresponds to "proportional representation": a party can expect to get a statewide seat share equal to

[3] An alternative is to define v as the total number of votes received statewide, expressed as a share of the two-party statewide vote total.

[4] For discussions of bias and responsiveness in elections using this equation, see King and Browning (1987), King (1990), and Campagna and Grofman (1990).

its statewide vote share. Values of ρ larger than one imply larger seat bonuses for the party winning more votes statewide; that is, the vote-richer party's seat share exceeds its vote share.[5] Positive values of ρ smaller than one imply larger and larger seat bonuses for the party winning fewer votes statewide; that is, the vote-poorer party's seat share exceeds its vote share. Finally, if $\rho = 0$, then seat shares are completely unrelated to vote shares.

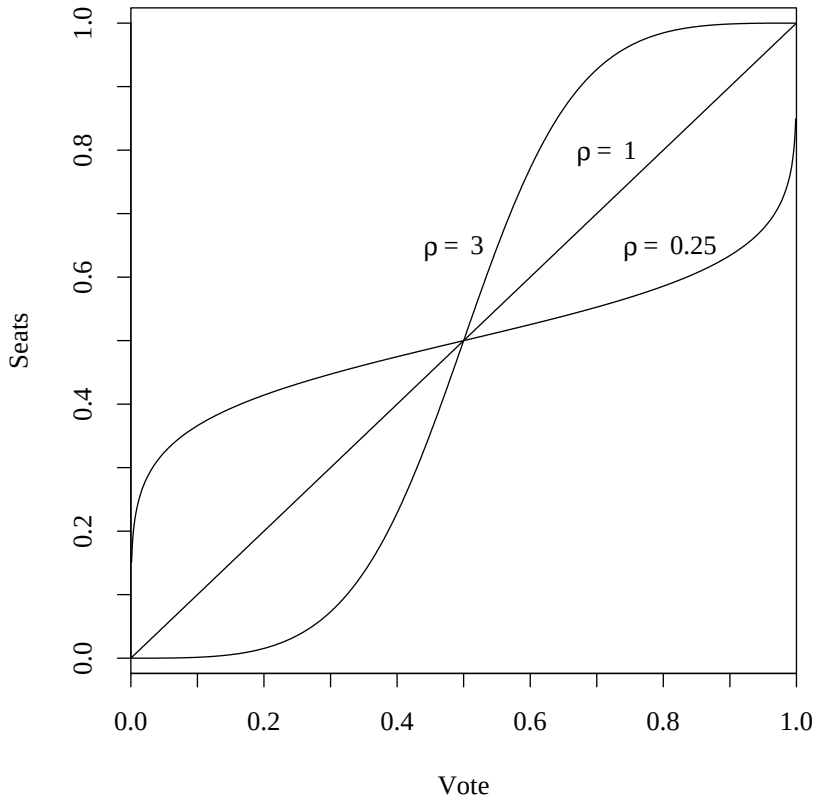

Figure 1: *Examples of Seats-Votes Curves with varying values of ρ and $\lambda = 0$*

The effect of bias, λ, is simpler. As λ increases, the favored party's seat share increases, as long as $v > 0$. In terms of the Figure 1, λ causes the curve to shift right for positive values and left for negative ones. That is, non-zero values of λ cause the electoral system to favor one of the parties in the translation of votes into seats.

[5] A larger bonus for the vote-richer party also implies a larger slope near $v = 0.5$ — that is, greater responsiveness of seat shares to vote shares.

1.2. *Responsiveness and bias in legislative voting processes*

Both responsiveness and bias can be defined in the legislative setting as well. To see how, first consider how to define the variables, seats (s) and votes (v) in the seats-votes equation above.

In the electoral context, the variable v is the average, across all the districts of a given state, of the vote share garnered by the Democratic candidate. In the legislative context, v is the average, across all "party" votes occurring in a given Congress, of the vote share garnered by the "Democratic position." A "party" vote is one that pits majorities of the two parties against one another (one favoring the motion, one opposing) and the "Democratic position" is whichever side of the question a majority of Democrats favor.

In the electoral context, the variable s is the share of times that Democratic candidates in a given state win. In the legislative context, s is the share of times that Democratic positions in a given Congress win (where the denominator is restricted to "party" votes).[6]

Having defined the variables in the legislative arena, one is in a position to estimate the votes-to-seats equation by one of the several techniques on offer in the electoral studies literature. We consider the best estimation option later, simply noting now that it is possible to estimate both responsiveness (ρ) and bias (λ) for legislative binary vote data.

2. WHY WE SHOULD EXPECT MAJORITY-PARTY BIAS IN ELECTORAL VOTES

Many scholars argue that the party in control of redistricting in a state will engineer bias in its own favor. Cox and Katz (2002), for example, view responsiveness and bias as properties of state districting laws. Each such law has the potential to recombine the voters in a state into different districts, thereby affecting the number of marginal and safe districts and their distribution between the two parties. Districting plans that create more safe districts across the board will exhibit lower responsiveness. Districting plans that give one party a markedly higher safe-seat-to-marginal-seat ratio than the other will exhibit bias.

The usual method by which partisan effects in redistricting are detected is to allow bias (λ) to be a function of which party controls the redistricting. States in which the Republicans control both houses of the state assembly and the governorship, and hence control the redistricting process, are expected to exhibit pro-Republican bias, with just the opposite expectation for states in which the Democrats are in control. Empirically,

[6]Note that the seats won in the electoral context are plausibly equally valuable but the victories won in the legislative context can vary widely in importance. Nonetheless, lacking any way to systematically assess importance, we count all victories equally here — and compute a simple victory share.

Cox and Katz (2002) and Engstrom (2003) find considerable support for this line of reasoning over most of U.S. electoral history.[7]

3. WHY WE SHOULD EXPECT MAJORITY-PARTY BIAS IN LEGISLATIVE VOTES

We highlight two arguments in the literature that, although not framed explicitly in terms of bias, nonetheless lead one to predict bias in favor of the party that sets up the agenda process in the U.S. House — i.e., the majority party. Each is somewhat similar to the argument that the party controlling the redistricting process will benefit from electoral bias in its favor.

3.1. *Agenda manipulation*

First, Cox and McCubbins (2002) argue that the majority party always has the power to block the consideration of issues on the House floor, while the minority sometimes does not (depending mostly on the membership of the Rules Committee in a particular Congress).[8] This differential power to block, when it arises, will produce pro-majority party bias.

To see how, consider a simple spatial model. We will assume that the legislators possess single peaked preferences with ideal points along N left-right issue dimensions. Along these N issue dimensions there are pre-defined status quo points, which we will denote $q_1, \ldots, q_n$. These are the policies that will be implemented if no new bill is passed on the given dimension. Assuming that members have additively separable preferences across the dimensions, we can consider each in isolation. Denote the median majority-party member on the jth issue by M_j, the median House member by H_j, and the median minority-party member by m_j. Given a Democratic Congress, one can assume that $M_j < H_j < m_j$. Now suppose that q_j lies between M_j and H_j. The majority-party leaders can foresee that bringing a bill to the floor to change q_j can only lead to a rightward policy change (to H_j) that will displease a majority of Democrats. Thus, if they can prevent the consideration of this particular issue dimension, they will. A similar point holds for the minority and issue dimensions on which q_j lies between H_j and m_j: the minority will, if it can, block consideration of such issues.[9]

[7]For broader reviews of literature on redistricting, see Butler and Cain (1992), McDonald (1999) and Cox and Katz (2002).

[8]Other scholars who emphasize the agenda power of the majority party include Aldrich and Rohde (2000) and Sinclair (2002).

[9]To be more precise, a party will block a bill that will foreseeably defeat it on the floor from being brought up as a stand-alone measure. Possibly, the bill can be packaged in an omnibus proposal that is acceptable to the blocking party. We assume, however, that a simple log-roll — a *sequence* of votes on which promises are made to trade votes — is not credible.

Now consider a Congress in which *only* the majority has a reliable power to block. In such a Congress, all dimensions with status quo points, q_j, between M_j and H_j will be blocked—because, as noted above, dealing with such issues can only lead to rightward policy moves.[10] Dimensions with status quo points, q_j, between $2M_j - H_j$ and M_j may be considered, if the majority can secure a closed rule, but will otherwise be blocked. All other issues will be considered and actual policy changes will be voted through. *The effect of this pattern of agenda manipulation is to prevent narrow defeats of the majority party.* In the same Congress, since the minority cannot (by assumption) block, issues with status quo points between H_j and m_j will be considered and will produce narrow defeats of the minority party. This asymmetry in narrow defeats produces pro-majority bias, varying in size depending on how many issues with status quo points in the censored $[M_j, H_j]$ and uncensored $[H_j, m_j]$ regions there are.

Now consider a Congress — perhaps in the period 1937-1960, during which the Rules Committee has been characterized as controlled by a conservative coalition—in which both the majority and minority party have some power to block.[11] In this Congress, status quo points in both the region $[M_j, H_j]$ and the region $[H_j, m_j]$ will be blocked (and possibly others as well, depending on the ability of various actors to commit to closed rules). This will prevent narrow defeats for both the majority and the minority party, so that no systematic effect on bias is predicted.

Bias in favor of a given party arises when that party wins by a little and loses by a lot, relative to the other party. Thus, bias is a joint product of the ability to block—avoiding narrow defeats of one's party; and the ability to push—forcing through legislation in the teeth of the minority's strenuous opposition (and hence producing narrow victories).[12] We thus expect pro-majority bias to arise in those Congresses in which the majority possessed both the ability to block what would have become narrow defeats and the ability to push through to sometimes narrow victories. In other words, pro-majority bias should arise when there is both an agenda cartel (per Cox and McCubbins 2002) and conditional party government is more visible (Aldrich and Rohde 2000). The Congresses that best fit this description are the czar-rule Congresses at the turn of the twentieth century; and the post-packing Congresses (1961 – present). In the empirical work below, we will test whether these periods stand out in terms of detectable bias.

[10]Note that an issue with q_j between M_j and H_j will, if voted on under an open rule, produce a bill at H_j which passes when pitted against q_j. However, all members to the left of $(\frac{(H_j+q_j)}{2} > M_j$ will vote against the bill. The bill will nonetheless pass, producing a narrow defeat of the majority party, at least half of whose members vote against the bill. If the issue comes up with a bill proposing a leftward policy move, and a special rule preventing rightward amendments, then it will simply fail to pass.

[11]We imagine that the majority's power to block derives from its possession of key posts, such as committee chairs, while the minority's power to block depends on forming alliances with some majority members.

[12]Equivalently, bias is a joint product of asymmetric blocking power (one party having it, one party lacking it).

3.2. *Vote options*

A second argument that leads to a similar conclusion begins with the supposition that the majority party, when it chooses bills to put on the agenda, anticipates that it will need to "buy" some votes on the margin—and then buys just enough to win. More specifically, King and Zeckhauser (2001) argue that the majority party will typically not buy *votes* but instead will buy *vote options*. That is, the Speaker will line up members who are willing to sell their votes to the majority, if necessary to produce victory. When the majority can eke out a victory by exercising its options, it does so and produces a close victory. When the majority is too far short of votes, then there is no point in exercising any of its options; it thus loses by a lot.

If both the majority and minority party were equally able to line up vote options, then there would be no reason to expect bias. However, it is the majority party leadership, not the minority leadership, that is typically credited in the literature with the ability to win close votes. Bauer, Pool and Dexter (1963, 432), for example, put it this way: "The [majority] leadership usually has enough of a reservoir of political credit to have a few votes switched if it would otherwise lose by a narrow margin." To the extent that such claims are correct, one should expect a pro-majority bias in congressional votes.

3.3. *Ideological drift*

A third way in which pro-majority bias might arise does not relate to any procedural advantage possessed by that party. Suppose that the Democrats become the majority party after a narrow electoral victory. Thereafter, the House drifts steadily leftward and the Democrats maintain their majority. In this scenario of "ideological drift," most of the status quo points that each House faces will be to the right of the current House median (because they are near the old House median which is by hypothesis to the right of the current median). The majority Democrats will consequently win a lot in each House. The reason, however, is the continually favorable location of the status quo points, not any agenda-setting advantages. Such a pattern does not appear to characterize the modern House but we control for this possibility in the analysis below in any event.

4. ESTIMATING THE VOTES-TO-DECISIONS EQUATION IN THE HOUSE

Our data consist of all recorded votes from the U.S. House of Representatives in the $46^{th} - -106^{th}$ Congresses (1879–2000). We exclude votes that require a $\frac{2}{3}$ majority for passage (such as suspension of the rules). We also exclude the vote on election of the Speaker and all votes on which the two parties were in agreement (i.e., majorities of both parties voted in the same manner). For the remaining votes—votes on motions requiring a simple majority for passage and on which the two parties were opposed—we

calculate the percentage of the total vote cast for the "Democratic" position and whether the Democratic position prevailed. Averaging across each Congress, we then compute the average vote share garnered by the "Democratic" position, DV; the number of all motions that the Democrats won; and the total number of motions voted on (meeting our criteria). [13]

We use these data to estimate the parameters, ρ and λ, defined in Equation 1. This is done by solving for s in terms of v, yielding

$$s(v|\rho,\lambda) = \left[1 + \exp\left(-\lambda - \rho \ln\left(\frac{v}{1-v}\right)\right)\right]^{-1}. \tag{2}$$

This is the standard grouped logit model with a single independent variable, $\ln(v/(1-v))$, the natural logarithm of the ratio of the average vote share. We actually will allow the bias to differ between Democratic and Republican controlled congresses. In order to account for possible un-modeled heterogeneity we use the extended beta binomial model that generalized the grouped loget model (cf. Palmquist 1999). Complete details of the estimation can be found in Appendix A. From our analysis, we can compute the bias in favor of the majority party (which we shall take as positively signed, with negative values indicating pro-minority bias).[14]

We have analyzed bias in the entire time period from 1879–2000 and in four sub-periods: (1) the pre-Reed Congresses (1879–1890);[15] (2) the Czar-rule Congresses (1889–1910); (3) the post-Cannon Congresses (1911–1961); and (4) the post-packing Congresses (1961-2000). The four sub-periods were chosen to correspond to major organizational watersheds identified in the previous literature. In particular, we use the following landmarks to define our periods: the adoption of Reed's Rules in 1890; the revolt against Speaker Cannon in 1910; and the packing of the Rules Committee in 1961.

The landmarks we have chosen as demarcating our periods stand out in the previous literature as the logical choices. This is obvious enough for the first two, Reed's Rules and the revolt against Cannon (see, e.g., Galloway and Wise 1976), but let us say a few words about the last. Before the Rules Committee was packed with additional liberal members after the 1960 election, standard sources view it as independent of the majority party (and, indeed, dominated by a conservative coalition of Southern Democrats and

[13] It has been suggested that part of the change we document below maybe due to a shift in the composition of the votes we include in our analysis. In particular, in the recent congresses include votes on amendment and procedural motions. However, we note that the set of recorded votes are endogenous under the maintained hypothesis of majority party agenda control and therefore does not pose a problem for our analysis.

[14] We do not discuss the overdispersion parameter estimated in the extended beta binomial model below. One interpretation of it in our context is that there are positive correlations between formally different roll call votes, as when the House votes on essentially the same issue in slightly different guise (e.g., previous question, rule adoption, tabling motion, final passage).

[15]. Ideally, we would include more pre-Reed Congresses. However, including Congresses before the 46^{th} enters a much different congressional world, in which the southern representatives are largely or wholly absent.

Republicans). Afterwards, the majority's control was improved but standard accounts stress that Rules continued to be largely independent of the majority party until further reforms in 1975 (see Rohde 1991, p. 25; Peabody 1963; Oppenheimer 1977). Nonetheless, Cox and Poole (2001) find that party pressures on procedural (and especially special rule adoption) votes increased after 1961, while Cox and McCubbins (2003) find that, relative to other procedural motions, the majority party became abruptly more likely to win on special rule adoption votes after 1961, and the minority party abruptly more likely to lose. We have thus chosen to pool the 1961-73 period with the post-reform period, rather than with the previous period.

5. RESULTS FOR THE U.S. HOUSE, 1879–2000

Our numerical results can be found in Table 1. A graph of the "victories-votes" curve — i.e., the seats-votes curve with the legislative data—estimated for the full time period, 1879-2000, is displayed in Figure 2. The solid line is for Democratic Congresses and the dashed line is for Republican ones. We have also included the actual data points used to estimate the curves. As can be seen, the estimated responsiveness nearly follows the classic cube law since the curves are nearly perfectly S-shaped, with a value of 3.45; while estimated bias in favor of the majority party is 6.5, statistically significant at the.01 level. A bias of this size means that, were the majority party to average 50% of the vote in a series of roll calls, it would expect to win 56.5% of them. Somehow, the majority is getting more bang for its buck: more legislative victories for its legislative votes.

Table 1: Bias and Responsiveness in U.S. House of Representatives Roll Call Voting, 1879–2000

Period	Bias	Responsiveness
1879–1888	0.06	2.59
	(3.33)	(0.51)
1889–1910	35.55	0.01
	(2.95)	(0.45)
1911–1960	2.91	3.76
	(2.42)	(0.37)
1961–2000	6.48	3.45
	(2.11)	(0.33)

Note: Standard errors are in parenthesis below the estimate.

Breaking the analysis into the four sub-periods noted above we find some stark differences. Responsiveness is relatively high in the first, third and fourth periods — 2.59, 3.76 and 3.45, respectively. However, in the second period, it falls to virtually nil (0.01). Bias, meanwhile, is positive (pro-majority-party) in all periods but small and insignificant prior

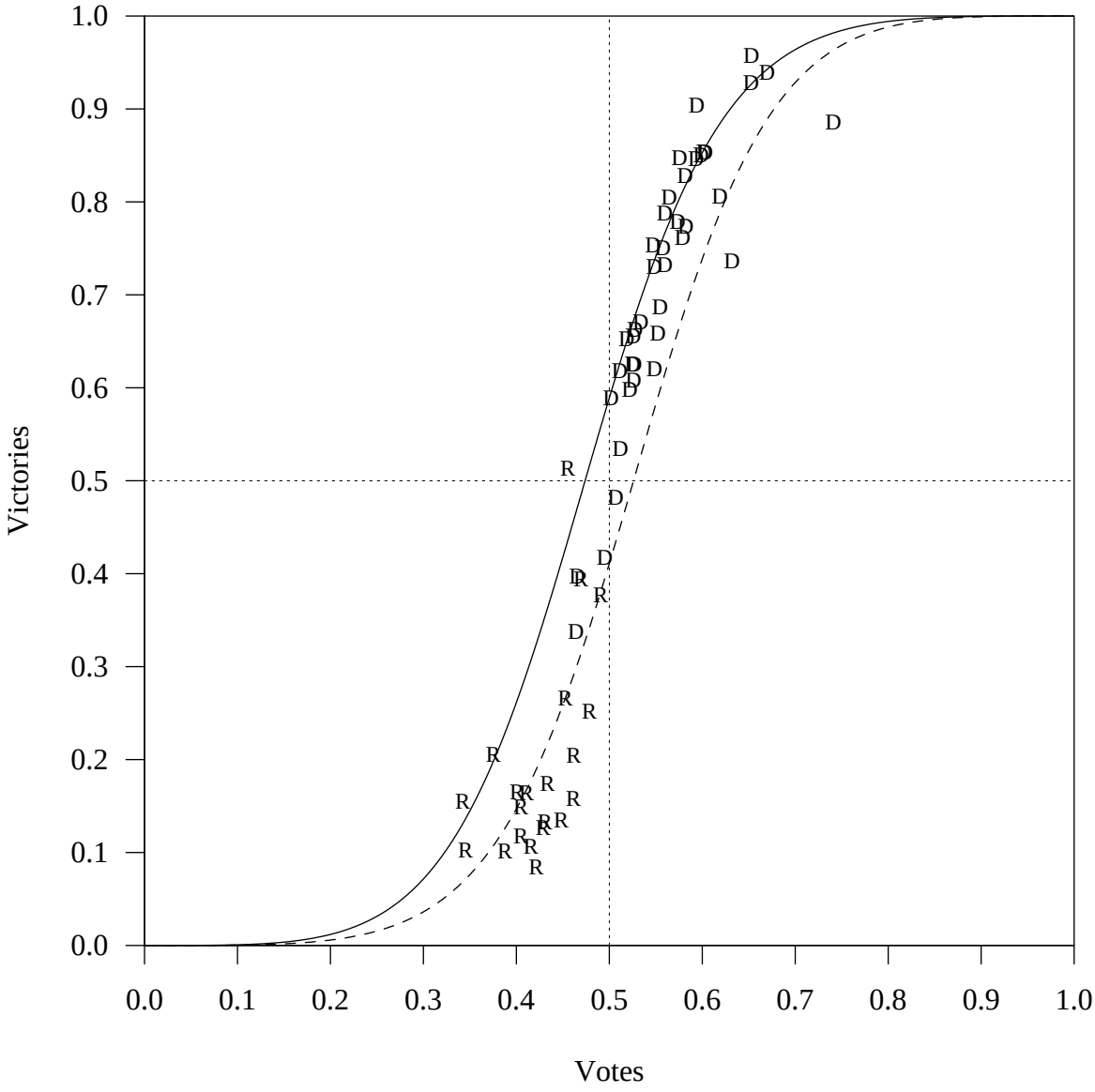

Figure 2: *Victories-Vote Curve for Congressional Roll Calls from 1877 to 2000. The solid line is the curve for Democratic Congress and the dashed line is for Republican Congresses. The data points used to estimate the curves are denoted by the points marked "D" and "R".*

to Reed's rules (0.06)[16]; very large in the czar-rule Congresses (35.55)[17]; moderate in the

[16]The pre-Reed Congresses appear to have been level playing fields with no pro-majority bias to speak of. Cf. Den Hartog (2003).

[17]The czar-rule Congresses appear to have been very tilted playing fields in which the majority won

post-Cannon Congresses (2.91); and very near the overall level of bias (noted in Table 1) in the post-packing Congresses (6.48). By and large, these results fit with conventional accounts of these Congresses. More importantly, they gibe with what one would expect from Cox and McCubbins' cartel model: bias is insignificant when the minority's procedural hand is good (pre-Reed and post-Cannon); but it is significant when the minority's procedural hand is poor (in the czar-rule and post-packing Congresses).

As a check on the robustness of our results, we added an additional control variable, tapping changes in the location of the House median. The rationale for this variable (which simply subtracts the $t-1$ House median from the t House median) is that the status quo policies should be near the lagged House median. Suppose that the House moves rightward between $t-1$ and t. This will mean that the House at time t will face a fair number of left-of-median status quo policies. Dealing with them should produce rightist victories and may increase pro-right bias. Thus, for example, when the Republicans took over the House in 1994, one might attribute the observed pro-Republican bias to the fact that there were many leftist status quo policies to change, rather than to the majority party's ability to manipulate the agenda or buy votes on the margin to secure victory.

Including a variable equal to the change in the House median from $t-1$ to t does not change any of the results reported above. Thus, one can more confidently attribute pro-majority bias to something the majority does, rather than to a consistent pattern of change in the House median that favors the majority party.

6. CONCLUSION

Parties, whether electoral or legislative, seek to win enough votes to attain "victory." *Electoral* victories produce control over legislative seats (and other offices). *Legislative* victories can be as small as fending off a dilatory motion or as large as passing a major piece of legislation. In both arenas, attracting more support in one vote expends resources that could otherwise be used to attract more support in another vote. Thus, in both arenas, parties wish to use their votes efficiently, winning victories at the cheapest possible price in manufactured votes. One can use standard statistical analyses, such as those employed in this paper, to detect any partisan bias — which will arise if one party is systematically more efficient in its translation of votes into victories.

In this paper, we have estimated the bias in congressional votes over the period 1879–2000. What we find is consistent with the cartel theory of how majority parties in the U.S. House operate (Cox and McCubbins 1993; 2002; 2003). When the majority party is both able to block bills it does not like (virtually always) and to push bills it does like

significantly more victories than one would expect based on its vote share alone. Indeed, the low estimated responsiveness suggests that majorities were winning at a constant rate, regardless of their size and average vote share.

against the minority's opposition (in the czar-rule and post-packing Congresses), then it is able to both avoid narrow defeats and generate narrow victories. This means bias in its favor in the translation of votes into victories.

The primary weakness of our method for detecting majority-party agenda-setting advantages is its reliance on highly aggregated data, as is also the case in electoral studies using this method. Other techniques for detecting majority-party advantages rely on a more disaggregated analysis of roll call voting data than we provide here. For example, Sinclair (2002) focuses on how members' votes change between the adoption of a special rule for consideration of a particular bill, and the final passage of that bill. Lawrence, Maltzmann and Smith (2003) and Cox and McCubbins (2002; 2003) similarly rely on features of roll call voting that can be analyzed within a given Congress. In contrast to these more disaggregated approaches, our method focuses more clearly on changes in the main independent variable: majority status. (The other studies necessarily hold this constant when applied to a single Congress, although pooling across Congresses does allow majority status to vary and hence the effects of such variation to be explored.)

Our technique is general and could in principle be applied to any legislature. However, we note that it will yield indeterminate results in some cases of very strong party government. In the U.K., for example, the majority party will typically win a very high percentage of all votes, regardless of its share of the seats; and it will hold most of its members on every vote. The consequence of this is a pattern of data that can be "fit" by a statistical model in either of two ways: zero responsiveness and high pro-majority bias; or high responsiveness and zero bias.

A. ESTIMATION

In this appendix we consider estimation of Equation (1). As written the equation is deterministic and can not directly be used to estimate the parameters of interest from observed data. However, if we assume a stochastic model — following King and Browning (1987; see also King 1990) — then Equation (1) defines the expected portion of Democratic victories in Congress t:

$$\begin{aligned} \mathrm{E}[s_t] &= \left[1 + e^{\lambda}\left(\frac{v_t}{1-v_t}\right)^{\rho}\right]^{-1} \\ &= \left[1 + \exp\left(-\lambda - \rho \ln\left(\frac{v_{i,t}}{1-v_{i,t}}\right)\right)\right]^{-1}. \end{aligned} \tag{3}$$

The second expression for the expected seat proportion is same as the mean function for the standard logit model for grouped data with a constant, λ, and a single independent variable, $ln(\frac{v_t}{1-v_t})$. If we were to further assume that the probability of the Democrats winning a district were independently and identically distributed, we could model the process with a binomial distribution. The binomial assumption and Equation (3) then set up a standard grouped logit model that we could estimate either via maximum likelihood

(as in King and Browning 1987) or two-step minimum Chi-Square methods (see Greene 1993:653–657 or Maddala 1983:28–34).

However, we suspect that there is still some un-modeled heterogeneity — beyond that being picked up by the logistic of the vote shares — and possibly some correlation in the probabilities across districts. In fact, an optimal partisan gerrymander would require such heterogeneity across districts. Assuming that there were not enough partisan voters for the dominant party to win every district, there would be two types of districts in the state: a handful that the minority party wins overwhelmingly and the remaining districts in which the dominant party wins but not by huge margins. In order to handle this we assume that the seat shares follow an extended beta-binomial, instead of a standard binomial distribution. The extended beta-binomial is generated by assuming that the probability (from a binomial model) that a district is won by the democrats varies according to a beta distribution.[18] Let S_t be the number of roll-calls the Democrats win in Congress t and N_t the total number of party votes in t. The extended beta-binomial can then be written as

$$f(S_t|\pi_i,\gamma) = \frac{N_t!}{S_t!(N_t-S_t)!}\frac{\prod_{j=0}^{S_t-1}(\pi_i+\gamma j)\prod_{j=0}^{N_t-S_t-1}(1-\pi_i+\gamma j)}{\prod_{j=0}^{N_t-1}(1+\gamma j),}$$

where we assume the convention that if any of the constituent products are negative, then the term is set to 1. Note that since we are explicitly conditioning on N_t, the model incorporates the heteroskedastity caused by the varying number of votes across years in our sample.

The parameter π_t is the average probability that a given roll-call in Congress t is won by the Democrats. Thus,

$$\pi_i = \frac{\mathrm{E}[S_{i,t}]}{N_i} = \mathrm{E}[s_{i,t}].$$

So we can use Equation 3 to model the systematic variation in the underlying probability. The parameter γ captures the amount that π_t varies over the Congresses or the correlation between roll-calls. If γ is zero, then the extended-binomial is just the binomial and roll-calls are identically and independently distributed. If $\gamma > 0$, there is positive correlation between roll-calls and when $\gamma < 0$ there is negative correlation between roll-calls.

The log likelihood is straight-forward to derive assuming independence across Congresses. The contribution of each Congress t, ignoring terms that do not depend on the parameters, is

$$\mathcal{L}_t(\pi_t,\gamma|S_t,N_t) \propto \sum_{j=0}^{S_t-1}(\pi_t+\gamma j) + \sum_{j=0}^{N_t-S_t-1}(1-\pi_t+\gamma j) - \sum_{j=0}^{N_t-1}(1+\gamma j).$$

We then substitute Equation 3 for π_t to get $L_t(\lambda,\rho,\gamma|S_t,N_t,v_t)$. The likelihood for the entire sample is found by summing the L_t across the Congresses.

[18] See King 1989:45–48 for a complete derivation of the extended beta-binomial distribution.

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