Optimal Supermajority Requirements in a Two-Party System

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Legislative governance in the United States is characterized by a system of checks and balances. On the one hand, agenda-setting power is concentrated. The majority party has significant control over the agenda. Such power is tempered by supermajority requirements (such as the 60-vote requirement for invoking cloture), bicameralism, and the presidential veto. I develop a theory of legislative outcomes which incorporates supermajority requirements. I argue that supermajority requirements can, in fact, serve an important purpose in balancing concentrated agenda-setting power. I find that substantial supermajority requirements are optimal for legislation, if the aim is to enact policies preferred by the median voter.

Legislative governance in the United States is characterized by a system of checks and balances. On the one hand, agenda-setting power is concentrated. The majority party has significant control over the agenda in both the Senate and the House of Representatives, and the President has exclusive proposal power for treaties and nominations. Such concentrated power is tempered by supermajority requirements (such as the filibuster and the two-thirds requirement for international treaties), bicameralism, and the presidential veto.

Of these checks and balances, the filibuster has received a great deal of scrutiny. Its' scope has been gradually reduced throughout the twentieth century, and hundreds of newspaper editorials have called for its elimination. The filibuster is argued to lead to excessive gridlock and frustrate popular majorities. I develop a theory of legislative outcomes which incorporates supermajority requirements. This theory will then allow critical evaluation of their effect on legislative outcomes. I argue that supermajority requirements can, in fact, serve an important purpose in balancing concentrated agenda-setting power. In these circumstances, supermajority requirements will often lead to more moderate policy outcomes than would occur under bare-majority requirements.

Origin and Evolution of the Filibuster

According to Binder (1997), the elimination of the previous question from the Senate rules in 1806 made the modern Senate filibuster possible. Since the cloture rule was not yet established, any one Senator could prevent a vote simply through delay, although this possibility was not taken advantage of until years later. In the later part of the nineteenth century, the Senate's workload increased dramatically. Consequently, the filibuster became a more effective tactic and was employed with increased frequency. In 1917, Rule 22 was adopted, which allowed two-thirds of the Senators present and voting to invoke cloture. In 1975, Rule 22 was amended to require only 60 votes to invoke cloture, although two-thirds of the Senate was still required to invoke cloture on changes to the Senate rules.

Throughout the twentieth century, there have been a number of failed attempts to eliminate the filibuster by allowing 51 Senators to invoke cloture. More recently, the minority party Democrats blocked many of George W. Bush's appellate court nominees using the filibuster. Republican Majority Leader Bill Frist, in turn, threatened to eliminate the filibuster through a parliamentary tactic know as the "Nuclear

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Option" (Klotz 2004). This possibility was postponed due to an agreement struck between 14 moderate Democrats and Republicans which would require the signatories to oppose a change to the Senate rules and allow votes for judicial nominees in all but the most extreme circumstances.[1] Nonetheless, there is a real possibility that we could witness the end of the judicial filibuster in the near future.

If the judicial filibuster is eliminated, there is no reason why the legislative filibuster could not also be eliminated, using the same parliamentary tactic. Wawro and Schickler (2006) argue that majorities have successfully acted against obstruction in the Senate. Moreover, the threat of establishing new rules in the Senate is a credible one, and this fact limits the extent by which minorities can frustrate popular majorities.

The Effect of the Filibuster on Policy Outcomes

The filibuster retains a number of defenders. Some stress the importance of preserving minority rights in the Senate (Henderson and Moore 2005). Others mention the desirability of preserving the differences among the chambers of congress, of which the filibuster is an important component. The filibuster is argued to asymmetrically benefit those who prefer small government (Yglesias 2005) and supermajority requirements are argued to be useful in preventing majority rule from resulting in chaos (Buchanan and Tullock 1962; Caplin and Nalebuff 1988; Hammond and Miller 1987; Levmore 1992; Miller and Hammond 1989).

Binder and Smith (1997) argue that the Senate rules should be changed to allow a bare majority of Senators to invoke cloture.[2] They claim that supermajority requirements and unlimited debate were not features that the framers of the constitution would have wanted, as the conventional wisdom would suggest. Most of the Senate leaders of the nineteenth century favored making it easier to limit debate, but were often thwarted by minorities. Furthermore, they argue that partisan motives are the most important factor in explaining votes on cloture and cloture reform. Finally, they argue that "... there is no necessary theoretical connection between supermajority requirements and policy moderation" (Binder and Smith 1997, 203). It is this point that I will study in detail in this paper.

If control of the agenda were perfectly distributed within the legislature, then we would expect moderate outcomes under bare majority requirements, and we would expect that supermajority requirements would prevent moderate policies from being realized. Concentrated agenda control, however, leads to a friction which prevents policy outcomes from following the median voter. For example, the majority party has significant influence over the agenda, the president has the power to veto legislation, and the president has exclusive proposal power for treaties and nominations. In the presence of concentrated agenda control, supermajority requirements can lead to policy outcomes that actually follow the median voter more closely. This holds for both positive and negative forms of agenda control. Consequently, Binder and Smith's claim of a lack of theoretical connection between supermajority requirements and policy moderation hinges on a strong assumption, and one that many would find unrealistic—that the majority party does not enjoy agenda-setting power.

Evidence on Agenda Control

Assessing the effects of supermajority requirements requires accurately characterizing legislator behavior in the House and the Senate. Perhaps the most convincing evidence of majority power agenda control comes from leadership selection in the House and Senate. As the Speaker of the House has substantial power, nonpartisan theories predict that the median House member should be selected as the speaker. Selection of the Speaker proceeds almost completely along party lines (Carr 2004), and the Speaker typically represents the center of the majority party rather than the center of the chamber (Kiewiet and McCubbins 1991). The same holds for other leadership positions in the House and Senate. The committees in each chamber are stacked in the majority party's favor. Each committee, with the exception of the Ethics committee in the House, has a majority of members from the majority party, and the majority party has a substantial majority on the Rules committee in the House.

Furthermore, there is direct evidence of majority party agenda control. Crespin, Rhode, and Vander Wielen (2002) and Crespin (2005) present evidence that the majority party is more cohesive on procedural votes. Cox and McCubbins (2005) find that the

[1]The determination of what constitutes "extreme circumstances" was left to the discretion of the signatories of the "Memorandum of Understanding on Judicial Nominations."

[2]Binder and Smith propose gradually reducing the supermajority requirement for invoking cloture over a series of cloture votes, eventually to a bare majority. This proposal allows for extended debate while eventually allowing a majority to act.

majority party is less likely to be "rolled" than the minority party. Den Hartog (2005) finds that as a consequence of Jim Jeffords party switch (which handed control of the Senate to the Democratic Party), the Democratic Party became more successful and the Republican Party became less successful. Lawrence, Maltzman, and Smith (2006) compare different models of legislative voting and find that a model with majority party agenda control fits the data best.[3]

Outline of the Paper

In this paper, I develop a model of legislative outcomes, which incorporates majority party agenda control and supermajority requirements. The important thing to realize is that (to the extent that the evidence is viewed as convincing) majority party agenda control exists in *both* the House and the Senate. For example, the leadership represents the median of the majority party in both the House and Senate, and the majority party is less likely to be rolled in both the House and the Senate.[4] As a result I argue that we should consider a model where the majority party retains agenda control in both the House and the Senate. Nonetheless (given that this is still a hotly debated issue), I can also address a popular alternative viewpoint—that the majority party's agenda power is limited to the House of Representatives.

The prevailing evidence fails to distinguish between positive and negative forms of agenda control, e.g., Cox and McCubbins' (2005) finding that the majority party is less likely to be rolled is consistent with both forms of majority party agenda power. Because the evidence does not point me in one direction, I consider both negative and positive forms of agenda control. Under the Gatekeeping model, the majority party will be able to block legislation if it thinks the floor outcome will not be to its liking. Under the Setter model, the majority party will be able to present the floor with a take-it-or-leave-it offer. For comparison purposes, I also consider the Majoritarian model, where the median legislator effectively controls the agenda. By considering these three models, I will be able to demonstrate that while bare majority requirements are optimal when agenda-setting power is distributed throughout the chamber, bare-majority requirements may not be optimal when the majority party controls the agenda.[5]

I show that in a static framework, bare majority requirements are optimal under the Majoritarian and Gatekeeping models, while supermajority requirements are optimal under the Setter model. While these results are instructive, there are two limitations to this analysis. First, the analysis takes the distribution of status quo points as fixed. The distribution of status quo points is clearly not fixed—today's policy outcomes will largely determine tomorrow's status quo points. Hence, the choice of supermajority requirement will affect not only the current policy outcomes, but also the resulting distribution of status quo points. Second, while the theoretical analysis can demonstrate that supermajority requirements are optimal in certain cases, the optimal supermajority requirement will depend on the configuration of preferences within the legislature.

I address both of these limitations in a dynamic analysis of supermajority requirements, which directly models the link between policy outcomes and future status quo points. I assume that today's policy outcome becomes tomorrow's status quo, subject to some random fluctuations (Cox and McCubbins 2005). The theory will take as inputs the preferences of legislators. In order to derive implications of these models for real-world institutions, we must be able to obtain these inputs. In order to represent the preferences of the legislators, I use the time series of DW-Nominate scores (Poole and Rosenthal 1991, 1997).

The results from the dynamic framework suggest that small changes in the composition of the legislature can lead to large fluctuations in policy under majority rule—a phenomenon I will refer to as "overresponsiveness." Supermajority requirements can be effective in reducing overresponsiveness. Of course, excessive supermajority requirements are also undesirable, as they lead to underresponsiveness. I find, however, that substantial supermajority requirements

[3]Crombez, Groseclose, and Krehbiel (2006) argue that the majority party is powerful in neither chamber. They argue that the discharge petition prevents majority party agenda control in the House while the possibility of nongermane amendments prevents majority party agenda control in the Senate. Crespin and Monroe (2005) argue that the majority party is able to exercise control of the legislative agenda in the Senate through the nondebatable motion to table and the ability of the majority leader to use the right of first recognition.

[4]Cox and McCubbins (2005) argue that majority party roll rates are higher and more variable in the Senate, but these differences are not dramatic and the Senate features many sessions where the majority party is rolled on less than 1% of party votes.

[5]The models are similar to some that have been considered in the literature. For example, the Majoritarian model follows work by Krehbiel (1996, 1998). The Gatekeeping model follows work by Denzau and MacKay (1983) and Cox and McCubbins (1993). The Setter model follows work by Romer and Rosenthal (1978). In contrast to the papers mentioned above, I allow for flexibility regarding supermajority requirements, as this feature will be central to the analysis.

are optimal, if the aim is to select policies preferred by the median voter.

A Model of Legislative Outcomes

Throughout, I will model policy outcomes using the one-dimensional spatial model. The legislature will consist of N members, where N is odd. I assume that the legislators never abstain from voting. Member n has a utility function given by,

$$u_n(x;\alpha_n) = -|x - \alpha_n|$$

Here, $x \in \mathbb{R}$ is the policy outcome and $\alpha_n \in \mathbb{R}$ is the ideal point of legislator n. Without loss of generality, I assume that the legislator ideal points are ordered such that,

$$\alpha_1 < \alpha_2 < \ldots < \alpha_N$$

In order for a bill to defeat the status quo, it must receive at least M votes, where $M > \frac{1}{2}N$. In order for a bill to be amended from b to b', b' must receive at least $\frac{N+1}{2}$ votes. In other words, a supermajority of M is needed to pass legislation while only a bare majority of votes is needed to amend legislation prior to passage.[6] For notational convenience, let $l = N + 1 - M$, $m = \frac{N+1}{2}$, and $u = M$. Thus, α_l, α_m, and α_u will denote the ideal points of the lower-pivotal, median, and upper-pivotal legislators (Krehbiel 1998).

The legislature's activity will be described by a multistage game, although the exact form of the game will depend on the allocation of agenda-setting power. I consider three different models—the Majoritarian model, the Gatekeeping model, and the Setter model. I let s denote the location of the status quo and I let F_s denote the cdf of status quo points. I assume that nature draws a single status quo from F_s, though this is equivalent to assuming that a finite number or even a continuum of status quos are drawn from F_s.

The final policy outcome is $x(s;M)$, indicating the dependence of the policy outcome on the status quo and the supermajority requirement. I will evaluate legislative institutions in terms of whether they promote policy outcomes that are close to the median legislator's position.[7] In this sense, I am assuming that the median legislator is a good proxy for the median voter in the electorate, and thus reflects "moderate" policy outcomes.[8]

I evaluate the discrepancy between the policy outcome and the median legislator's position using, $\Delta(s;M) = (x(s;M) - \alpha_m)^2$. I characterize the policy loss using $L(M) = \int_s \Delta(s;M)dF_s(s)$. Each legislative institution induces a different form for $L(M)$. The goal then is to find the optimal supermajority requirement, $M^\star = \underset{\frac{N+1}{2} \leq M \leq N}{\arg\min}\ L(M)$. I will characterize the optimal supermajority requirement under the three legislative institutions described below.

The Majoritarian Model

Under the Majoritarian model, there are two stages to consider. In the first stage, a bill b is selected. In the second stage, the legislature chooses between the bill b and the status quo s. This game can be analyzed using backwards induction, starting from the second stage.

Since the second stage is the final stage in the game, and the legislators are choosing between two alternatives, they have weakly dominant strategies of voting sincerely. To avoid open-set problems in the previous stages, assume that legislators who are indifferent between the bill and the status quo vote

[6]In the U.S. Senate, amendments are subject to filibuster. If amendments are subject to a supermajority requirement, then the set of amendment-proof bills is no longer a singleton, and thus we must assign initial proposer power to some individual in order to complete the model. If the initial agenda setter is the median member of the majority party and the same supermajority requirement applies for amendments and final passage, this actually yields a model which is equivalent to the Gatekeeping model we study. If we assign this power to the median member of the chamber, we simply replicate the Majoritarian model.

[7]Chapter 7 of Powell (2000) offers a defense of using the distance between policy outcomes and the median voter, as a way evaluating the quality of political institutions. While I argue that the median voter better captures policy moderation than the mean voter, this choice does not matter in this application. I use Poole and Rosenthal's DW-Nominate scores as my measure of ideology, and these measures indicate that the median and mean legislators are nearly identical.

[8]This assumption is unlikely to hold exactly, but Bafumi and Herron (2008) find that the median voter and median legislator are close to each other in the 110th House and Senate. Note that whether the median legislator is a good proxy for the median voter depends on the quality of electoral institutions rather than the quality of legislative institutions. Hence, I argue that even if this assumption were to fail, my results would still be informative. My results would suggest that better representation could be achieved by improving electoral institutions and instituting supermajority requirements for the passage of legislation. How to improve electoral institutions is, of course, a topic for another paper.

for the bill.[9] The set of all bills that defeat the status quo will be referred to as the Winset. The Winset is given by,

$$W(s) = \{b : \#\{n : u_n(b;\alpha_n) \geq u_n(s;\alpha_n)\} \geq M\}^{10}$$

In words, the Winset is the set of bills such that the requisite number of voters prefers the bill to the status quo. The following proposition characterizes the Winset.

Proposition 1: The Winset is given by,

$$W(s) = \begin{cases} [s, 2\alpha_l - s], & s \leq \alpha_l \\ s, & \alpha_l < s < \alpha_u \\ [2\alpha_u - s, s], & s \geq \alpha_u \end{cases}$$

Proposition 1 fully characterizes the outcome of the final stage—the bill b will pass if and only if $b \in W(s)$. Notice that when $\alpha_l < s < \alpha_u$, $W(s) = s$, indicating that no alternative bill can defeat the status quo.

Continuing to the first stage, let $v_n(b)$ be the utility legislator n receives from the bill b being chosen to be pitted against the status quo. Using backwards induction,

$$v_n(b) = \begin{cases} -|b - \alpha_n|, & b \in W(s) \\ -|s - \alpha_n|, & b \notin W(s) \end{cases}$$

Thus, the utility a legislator receives from bill b being chosen is $-|b - \alpha_n|$ if the bill would defeat the status quo and $-|s - \alpha_n|$ otherwise.

Assume that legislators keep amending the bill until there are no further amendments that will be approved by the legislature.

Definition: The bill b is *Amendment-Proof* if there does not exist another bill b' such that,

$$\#\{n : v_n(b') > v_n(b)\} \geq \tfrac{N+1}{2}.$$

Thus, a bill is Amendment-Proof if there does not exist an alternative bill that is preferred to the current bill by a majority of the legislature. The following proposition shows that a bill is Amendment-Proof if and only if it is preferred by the median legislator to all bills in the Winset.[11]

[9]See Duggan (2006) for a discussion of open set problems. As Krehbiel (1998) points out, such an assumption is not even technically necessary since the case where indifferent voters vote against the bill cannot comprise a subgame perfect Nash Equilibrium.

[10]Here, $\#A$ refers to the cardinality of set A.

[11]Krehbiel (1996) takes this as his starting point and assigns proposing power to the median legislator.

Proposition 2: The bill $b \in W(s)$ is Amendment-Proof if and only if $|b' - \alpha_m| \geq |b - \alpha_m|$ for all $b' \in W(s)$.

Let $B(s)$ represent the set of Amendment-Proof bills. Proposition 2 shows that this set is characterized by,

$$B(s) = \{b \in W(s) : |b' - \alpha_m| \geq |b - \alpha_m| \text{ for all } b' \in W(s)\}$$

Proposition 3 will more fully characterize this set.

Proposition 3: The set of Amendment-Proof bills is given by,

$$B(s) = \begin{cases} \alpha_m, & s \leq 2\alpha_l - \alpha_m \\ 2\alpha_l - s, & 2\alpha_l - \alpha_m \leq s \leq \alpha_l \\ \mathbb{R}, & \alpha_l \leq s \leq \alpha_u \\ 2\alpha_u - s, & \alpha_u \leq s \leq 2\alpha_u - \alpha_m \\ \alpha_m, & s \geq 2\alpha_u - \alpha_m \end{cases}.$$

Notice that when $\alpha_l \leq s \leq \alpha_u$, every bill $b \in \mathbb{R}$ is Amendment Proof. This occurs because there does not exist a bill that defeats the status quo, and thus no one in the legislature cares which bill is selected in this case.

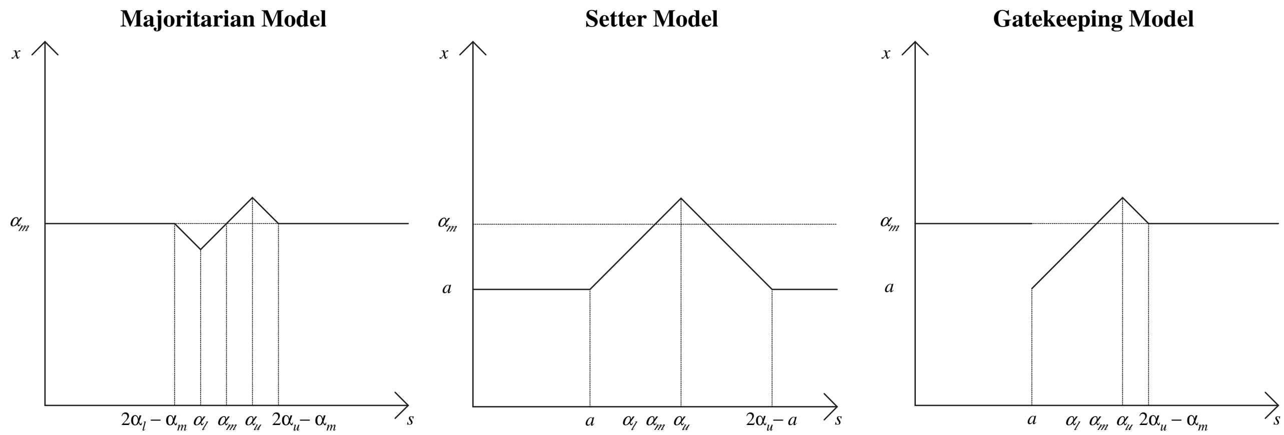
Using Proposition 3, it is immediately apparent that the policy outcome will be characterized by,

$$x(s;M) = \begin{cases} \alpha_m, & s < 2\alpha_l - \alpha_m \\ 2\alpha_l - s, & 2\alpha_l - \alpha_m \leq s \leq \alpha_l \\ s, & \alpha_l < s < \alpha_u \\ 2\alpha_u - s, & \alpha_u \leq s \leq 2\alpha_u - \alpha_m \\ \alpha_m, & s > 2\alpha_u - \alpha_m \end{cases}$$

This is depicted graphically in Figure 1. I will refer to the interval $\alpha_l < s < \alpha_u$ as the gridlock interval, since the policy outcome is equal to the status quo. In this range, there does not exist a bill distinct from the status quo that would garner M votes when pitted against the status quo. If the status quo is relatively extreme, $s < 2\alpha_l - \alpha_m$ or $s > 2\alpha_u - \alpha_m$, then the policy outcome will move all the way to the median legislator's ideal point. Here, the status quo is so extreme that the lower-pivotal and upper-pivotal voters have no incentive to block the legislation from passing. If $2\alpha_l - \alpha_m \leq s \leq \alpha_l$ or $\alpha_u \leq s \leq 2\alpha_u - \alpha_m$, the policy outcome will move only part of the way from the status quo towards the median legislator's position.

A key thing to notice is that when $M = \frac{N+1}{2}$, the policy outcome always equals the median legislator's ideal point while when $M > \frac{N+1}{2}$, this is no longer the case. This implies that as long as the distribution of status quo points places some mass near the median

Figure 1 Majoritarian Model



Note: Figure 1 graphs the policy outcome x as a function of the status quo s for the Majoritarian, Setter, and Gatekeeping Models. Here, α_l refers to the ideal point of the lower-pivotal voter, α_m to the ideal point of the median voter, α_u to the ideal point of the upper-pivotal voter, and a to the ideal point of the agenda setter.

legislator's ideal point, the optimal supermajority requirement must be a bare-majority requirement, a fact formalized below.

Proposition 4: If $\Pr(s : s \in [\alpha_{m-1}, \alpha_m) \cup (\alpha_m, \alpha_{m+1}]) > 0$, then $M^* = \frac{N+1}{2}$.

The intuition behind the result is simple. Under the Majoritarian model, the policy loss associated with a bare majority requirement is zero. Under any larger supermajority requirement $M > \frac{N+1}{2}$, the policy outcome will differ from α_m everywhere in the interval $[\alpha_{m-1}, \alpha_{m+1}]$ except at $s = \alpha_m$. So as long as F_s places some mass in this region (i.e., $[\alpha_{m-1}, \alpha_m) \cup (\alpha_m, \alpha_{m+1}]$), the policy loss will be strictly greater than zero, and $M > \frac{N+1}{2}$ will not be optimal.

The Setter Model

The Setter model involves a two-stage game. In the first stage, the agenda setter selects the bill b. In the second stage, the legislature chooses between the bill and the status quo. Since the bill b will pass if and only if the bill is in the Winset $W(s)$, I can characterize the agenda setter's utility from choosing the bill b as,

$$v_a(b) = \begin{cases} -|b-a|, & b \in W(s) \\ -|s-a|, & b \notin W(s) \end{cases}$$

Assuming that the agenda setter chooses b to maximize $v_a(b)$, I can show the following policy outcome will result,

$$x(s;M) = \begin{cases} a, & s < 2\min\{\alpha_l, a\} - a \\ 2\min\{\alpha_l, a\} - s, & 2\min\{\alpha_l, a\} - a \le s \le \min\{\alpha_l, a\} \\ s, & \min\{\alpha_l, a\} < s < \max\{\alpha_u, a\} \\ 2\max\{\alpha_u, a\} - s, & \max\{\alpha_u, a\} \le s \le 2\max\{\alpha_u, a\} - a \\ a, & s > 2\max\{\alpha_u, a\} - a \end{cases}$$

The case where $a < \alpha_l$ is depicted graphically in Figure 1. Here, the gridlock interval is $a < s < \alpha_u$. When the status quo is very extreme ($s < a$ or $s > 2\alpha_u - a$), the agenda setter will be able to move the policy outcome all the way to his ideal point. When the status quo is in a moderate range ($\alpha_u \le s \le 2\alpha_u - a$), the agenda setter will be able to move the policy outcome part way towards his ideal point. The setter model differs from the Majoritarian model in two ways. First, the gridlock interval is strictly bigger for the Setter model since the agenda setter can block legislation, in addition to the lower-pivotal and upper-pivotal voters. Second, when the status quo is extreme, the agenda setter now gets to select the policy outcome rather than the median legislator.

Under the Setter model, a bare-majority requirement cannot be optimal. The only exception to this rule occurs when the ideal point of the agenda setter is located between α_{m-1} and α_{m+1}, an unlikely situation which is in conflict with available evidence (Kiewiet and McCubbins 1991).

Proposition 5: Under the Setter model, if $a < \alpha_{m-1}$ and F_s places positive mass in the interval $(\alpha_{m+1}, 2\alpha_{m+1} - a)$, then $M^\star > \frac{N+1}{2}$. If $a > \alpha_{m+1}$ and F_s places positive mass in the interval $(2\alpha_{m-1} - a, \alpha_{m-1})$, then $M^\star > \frac{N+1}{2}$.

$$x(s;M) = \begin{cases} \alpha_m, & s \leq 2\min\{\alpha_l, a\} - \alpha_m \\ 2\alpha_l - s, & 2\min\{\alpha_l, a\} - \alpha_m \leq s \leq \min\{\alpha_l, 2a - \alpha_m\} \\ s, & \min\{\alpha_l, 2a - \alpha_m\} \leq s \leq \max\{\alpha_u, 2a - \alpha_m\} \\ 2\alpha_u - s, & \max\{\alpha_u, 2a - \alpha_m\} \leq s \leq 2\max\{\alpha_u, a\} - \alpha_m \\ \alpha_m, & s \geq 2\max\{\alpha_u, a\} - \alpha_m \end{cases}$$

The above result is striking in that it does not depend heavily on the distribution of the status quo points or the ideal point of the agenda setter. As long as there is at least one legislator separating the median legislator and the agenda setter, and there is some probability that the status quo point is located in a region to the right of this legislator, the result obtains.

The Gatekeeping Model

The Gatekeeping model is described by a three-stage game. In the first stage, the agenda setter chooses whether to block legislation. If the agenda setter blocks, the status quo becomes the policy outcome. Otherwise, the game proceeds to the second stage. In the second stage, the floor chooses an amendment-proof bill b to pit against the status quo s. In the third stage, the legislature chooses between the bill and the status quo.

Let a represent the ideal point of the agenda setter. Notice that the last two stages of the Gatekeeping model resemble the Majoritarian model, so that if the agenda setter chooses not to gatekeep, the outcome will be identical to the Majoritarian model. Let f represent the outcome if the bill is allowed to go to the floor. The analysis for the Majoritarian model shows that,

$$f(s;M) = \begin{cases} \alpha_m, & s < 2\alpha_l - \alpha_m \\ 2\alpha_l - s, & 2\alpha_l - \alpha_m \leq s \leq \alpha_l \\ s, & \alpha_l < s < \alpha_u \\ 2\alpha_u - s, & \alpha_u \leq s \leq 2\alpha_u - \alpha_m \\ \alpha_m, & s > 2\alpha_u - \alpha_m \end{cases}$$

The agenda setter will choose to gatekeep if $|s - a| < |f(s;M) - a|$, i.e. if the agenda setter prefers the status quo to the potential floor outcome. We can determine that,

The case where $a < \alpha_l$ is depicted graphically in Figure 1. Like the other models, the Gatekeeping model will contain a gridlock interval, which is equal to $[a, \alpha_u]$. This will be larger than the gridlock intervals for the Majoritarian model and Setter model. When the status quo is extreme enough, the policy outcome will move all the way towards the median legislator's ideal point.

The optimal supermajority requirement under the Gatekeeping model is a bare majority requirement.

Proposition 6: Under the Gatekeeping model, if $a < \alpha_{m-1}$ and F_s places positive mass in the interval $(\alpha_m, 2\alpha_{m+1} - \alpha_m)$, then $M^\star > \frac{N+1}{2}$. If $a > \alpha_{m+1}$ and F_s places positive mass in the interval $(2\alpha_{m-1} - \alpha_m, \alpha_m)$, then $M^\star > \frac{N+1}{2}$.

The intuition behind this result is that outside the gridlock interval, a bare majority requirement leads to a policy outcome equal to the median legislator's ideal point (which cannot be improved upon). Furthermore, increasing the supermajority requirement has the effect of enlarging the gridlock interval. Since instituting a supermajority requirement does not lead to a lower policy loss, either inside or outside the gridlock interval, a bare majority requirement must be weakly optimal.

Evaluating Checks and Balances

The previous section described a model which predicts likely policy outcomes based on the preferences of the legislators and the status quo. The analysis is conditional on the allocation of agenda-setting power as well as the supermajority required for the passage of legislation. This model allows us to gauge the effects of supermajority requirements on political outcomes.

I showed that for a *fixed* distribution of status quo points, bare majority requirements are optimal under the Majoritarian and Gatekeeping models.[12] Under the Setter model, a bare majority requirement cannot be optimal. This analysis leaves open two questions. First, the distribution of status quo points is clearly not fixed. If today's status quo points are determined by yesterday's policy outcomes, the choice of supermajority requirement will determine not only the current policy loss, $L(M)$, but also the future distribution of status quo points. Hence, the results of the third section are not sufficient for characterizing optimal supermajority requirements once we consider the feedback between legislative institutions and the distribution of status quo points.

Second, while I determined that bare majority requirements were not optimal under the Setter model, we would also like to know if the size of the optimal supermajority requirement is much different from $M = \frac{N+1}{2}$. The optimal supermajority requirement will depend on the preferences of the legislature and the distribution of status quo points. Hence, we must determine reasonable values for these before we can fully evaluate the implications of the model. I address both of these points in this section.

Dynamic Structure

Let x_t represent the policy outcome in period t and let α_m^t denote the ideal point of the median legislator in period t. I measure the closeness of policy outcomes to the median legislator using Average Squared Error,[13]

$$ASE = \frac{1}{T}\sum_{t=1}^{T}(x_t - \alpha_m^t)^2.$$

This measure captures the average dispersion of the policy outcome from the median legislator's position.[14]

Consider first the Majoritarian model. When a bare-majority requirement is used, it is clear that $x_t = \alpha_m^t$ for all t, which implies $ASE = 0$. When a supermajority is required, we will not have $x_t = \alpha_m^t$ for all t, which implies that $ASE > 0$. Thus, a bare-majority requirement is optimal under the Majoritarian Model.

Consider, alternatively, the Setter model and assume that the status quo is to the far right of the median legislator. Suppose a temporary change in the electoral environment leads the Democratic Party to gain a small majority in the legislature. Under a bare-majority requirement, the Democratic agenda setter will be able to propose a fairly substantial move to the left. This bill will pass because the median legislator, though a very moderate liberal, still prefers a policy outcome far to the left of the status quo to a policy which is far to the right.

The above example shows that under a bare-majority requirement, a small change in the composition of the legislature can lead to a very substantial change in the policy outcome, if such a change involves a switch in majority party status. I refer to this tendency as "overresponsiveness." A supermajority requirement would lead the Democratic agenda setter to propose a more moderate policy because a larger coalition is necessary to pass legislation. This would result in a less extreme policy outcome. Consequently, for the Setter model, it is possible that supermajority requirements will increase responsiveness to the median legislator.[15]

Though it is not immediately obvious, supermajority requirements can lead to increased policy moderation under the Gatekeeping model as well. Suppose that a temporary increase in the Republican's electoral fortune leads the policy outcome to move to the far right. Suppose that circumstances then return back to a more normal state in which the Republicans hold a small majority in the legislature. If legislation were allowed to go to the floor, the policy outcome would move back towards the center since the median legislator is now a very moderate Republican. However, the Republican agenda setter would have a strong incentive to exercise his gatekeeping power and prevent this from happening.

Employing supermajority requirements cannot prevent him from exercising his gatekeeping power,

[12]As before, a supermajority requirement is optimal if it minimizes the expected squared deviation between the median legislator's ideal point and the policy outcome.

[13]Another equally valid measure is Average Deviation Error given by $ADE = \frac{1}{T}\sum_{t=1}^{T}|x_t - \alpha_m^t|$. I found that this measure led to comparable results, so I only report results based on Average Squared Error.

[14]In the online Appendix A.1, I show that average squared error can be interpreted as an approximation to the long-run average policy loss, $L(M)$.

[15]The results of the Setter model differ from Baron (1996). He assumes that policy in each period is selected under a closed rule and that the agenda setter is randomly selected. Under these assumptions, the policy outcome eventually converges to the median legislator. In my case, policy outcomes fail to converge in the same way because I allow the position of the median legislator to change over time.

but it can greatly decrease the likelihood that the status quo moves to the far right (or left) in the first place. The negative side of supermajority requirements is that they prevent the policy outcome from tracking the median legislator when the median legislator moves to the far right (or left). The advantage is that supermajority requirements reduce the likelihood that the policy outcome will get "trapped" on the far right (or left).

The optimal supermajority requirement is theoretically ambiguous and will depend on the dynamics of legislator preferences and the evolution of the status quo. Hence, these inputs must be specified in order to determine optimal supermajority requirements. For the preferences of the legislature, I use DW-Nominate scores (Poole and Rosenthal 1991, 1997), which provide ideal point estimates for both the Senate and the House of Representatives which are comparable over time. I use data for the 60th to the 108th Congress.[16] Hence, my approach will investigate optimal supermajority requirements in legislative institutions that resemble the U.S. House and Senate in their dynamics. To specify the ideal point of the agenda setter, I use the median member of the Majority party (Cox and McCubbins 1993).[17]

Today's status quo outcome will be influenced by the previous policy outcome, but I allow for a relationship that is not completely deterministic. Specifically,

$$s_t = x_{t-1} + \delta\varepsilon_t$$

where ε_t represents a policy shock (which I assume is normally distributed with mean zero and variance one), and δ represents the magnitude of the shock. Low values of δ mean that the status quo is strongly related to previous policy outcomes while high values of δ indicate that the status quo is essentially random.[18] Since there is no obvious procedure for selecting a single most appropriate value for δ, I consider a number of different values— $\delta \in \{0.0, 0.05, 0.2\}$.[19] Computing the ASE will involve integrating over various realizations of $\varepsilon = (\varepsilon_{60}, \varepsilon_{69}, \ldots, \varepsilon_{108})$ where $t = 60, 61, \ldots, 108$ indicates the set of congresses considered. I take random draws for the stream of disturbance terms, $\varepsilon^r_{61}, \varepsilon^r_{62}, \ldots, \varepsilon^r_{108}$ for $r = 1, 2, \ldots, R$.[20] I simulate a chain of policies $x^r_{60}, x^r_{61}, \ldots, x^r_{108}$ for each choice of r. To simulate this chain of policies, I use the recursion, $s^r_t = x^r_{t-1} + \delta\varepsilon^r_t$, where $x^r_{t-1} = x(s^r_{s-1}; M)$ and $x(s; M)$ refers to one of the functional forms derived in the previous section.[21] I start the chain by assuming that $s^r_{60} = 0$ for all r.[22] I compute the ASE using,

$$ASE \approx \tfrac{1}{TR}\textstyle\sum_{t=1}^{T}\sum_{r=1}^{R}(x^r_t - \alpha^t_m)^2$$

Here, I am simply integrating over realizations of ε using simulation methods. Since the policy outcomes x^r_t depend on the supermajority requirement, the ASE will itself be dependent on M. Denote the optimal supermajority requirement using $M^\star = \underset{\frac{N+1}{2} \le M \le N}{\arg\min} \{ASE(M)\}$. Here, $M^\star$ indicates the supermajority requirement that leads policy outcomes to be close to the median legislator on average.

Table 1 Optimal Supermajority Requirements (Senate)

Delta	Majoritarian Model	Gatekeeping Model	Setter Model
0.00	51	53	60
	50.50%	*52.48%*	*59.41%*
0.05	51	53	60
	50.50%	*52.48%*	*59.41%*
0.20	51	55	60
	50.50%	*54.46%*	*59.41%*

Note: Table 1 reports the optimal supermajority requirements for the Senate, out of a total of 101 voting members. Results are reported for the Majoritarian, Gatekeeping, and Setter models.

Results

Results for the optimal supermajority requirement in the Senate are given in Table 1. As expected, the optimal supermajority requirement under the Majoritarian model is a bare-majority requirement. For the

[16]Prior to this congress, the number of Senators was rapidly increasing due to the admission of new states to the union.

[17]This assumption is conservative, as Kiewiet and McCubbins (1991) show that members of the House and Senate leadership are often more extreme than the median member of their party.

[18]Note that my results continue to hold when $\delta = 0$.

[19]The standard deviation of mean DW-nominate scores is 0.3. A value of $\delta = 0.2$ means that the year-to-year shock to the status quo is of about the same magnitude as the year-to-year shock to the median voter. A value of $\delta = 0.05$ means that the year-to-year shock in the status quo is of a smaller magnitude than the year-to-year shock to the median legislator.

[20]I use $R = 100$ replications in my analysis. One can think of this process as representing a legislature that considers 100 issues in each term, and where these status quos for each of these issues evolve independently.

[21]Here, the functional form $x(s; M)$ also depends on the vector of ideal points in period t, but I drop this from the notation.

[22]The results are robust to the choice of the initial status quo.

Table 2 Optimal Supermajority Requirements (House)

Delta	Majoritarian Model	Gatekeeping Model	Setter Model
0.00	218	234	234
	50.11%	*53.79%*	*53.79%*
0.05	218	233	237
	50.11%	*53.56%*	*54.48%*
0.20	218	224	238
	50.11%	*51.49%*	*54.71%*

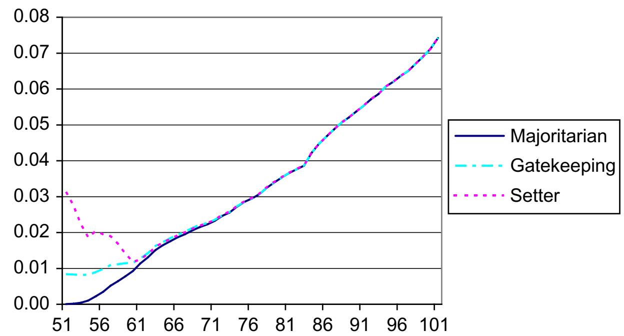
Note: Table 2 reports the optimal supermajority requirements for the House, out of a total of 435 voting members. Results are reported for the Majoritarian, Gatekeeping, and Setter models.

Gatekeeping model, the optimal supermajority requirement ranges between 53 and 55 (depending on the value of δ), and for the Setter model, the optimal supermajority requirement is 60. I report similar results for the House of Representatives in Table 2. Once again, a bare-majority requirement is optimal under the Majoritarian model. The optimal supermajority requirement ranges between 224 (52%) and 234 (54%) for the Gatekeeping model and between 234 (54%) and 238 (55%) for the Setter model.[23]

The results indicate that when control over the agenda is concentrated, substantial supermajority requirements are preferable to bare majority requirements. The case is stronger when the agenda setter has positive agenda control (the Setter model) than when the agenda setter has negative control (the Gatekeeping model).

To get a better sense for the gains or losses in employing supermajority requirements, Figure 2 plots average policy loss for the Senate when $\delta = 0.05$. For the Majoritarian model, the average policy loss increases as the supermajority requirement increases. For the Gatekeeping model, the average policy loss is essentially flat in the 51 to 61 range, although it does contain a small dip around 55. In this sense, under the Gatekeeping model, moderate supermajority requirements are neither helpful nor harmful. For the Setter model, the average policy loss contains a substantial dip around 60. In fact, a bare majority requirement is as bad as a 77 vote supermajority requirement.[24] These results indicate that there may

Figure 2 Average Squared Error



Note: Figure 2 plots the Average Squared Error as a function of the supermajority requirement in the Senate, for the Majoritarian, Gatekeeping, and Setter models. The supermajority requirement is varied between M=51 and M=101, out of a total of N =101 voting members.

in fact be substantial gains from employing supermajority requirements, although once again, the case is stronger when the agenda setter has positive power.

To demonstrate the properties of the model more thoroughly, Figure 3 and Figure 4 plot a single realization of the time series of policy outcomes. Figure 3 covers the Majoritarian model for supermajority requirements of 51, 56, 61, and 66. We know that bare-majority requirements are optimal for the Majoritarian model, and as we would expect, the policy outcome follows the median legislator's position exactly with a bare majority requirement. The policy outcome tracks the median legislator's position less closely when the requisite supermajority is increased.

Contrast this with the Setter model, depicted in Figure 4.[25] With a bare majority requirement, we can clearly observe overresponsiveness. The policy outcome seems to swing back and forth between extremes, with a small change in the median legislator's position leading to drastic changes in the policy outcome from period to period. As the supermajority requirement is increased to 56 and 61, this effect diminishes greatly. Essentially, this occurs because the agenda setter is forced to moderate his proposal in order to ensure that his proposal will receive the requisite supermajority.

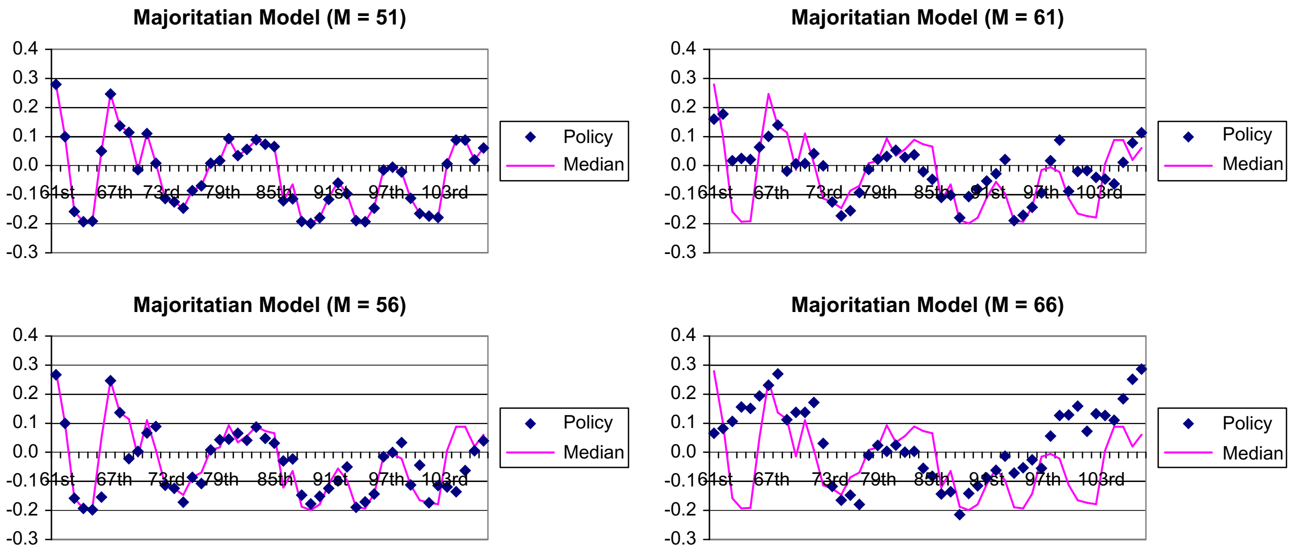
Recall that the optimal supermajority requirement was higher in the Senate in percentage terms. Under the Setter model, a supermajority of 60%

[23] I found similar optimal supermajority requirements for the Setter model when s was drawn from a static distribution. The optimally of supermajority requirements in the Gatekeeping model depends on dynamic status quos, as Proposition 5 makes clear.

[24] The average policy loss from the three models converges as the supermajority requirement gets large because legislation almost never passes when the supermajority requirement is large.

[25] I omit the corresponding figure for the Gatekeeping model because it is largely uninformative. As Figure 4 demonstrates, the ASE varies little with the supermajority requirement in the 51 through 61 range. Hence, all four plots would look roughly the same.

FIGURE 3 Simulated Policy Outcomes (Majoritarian Model)

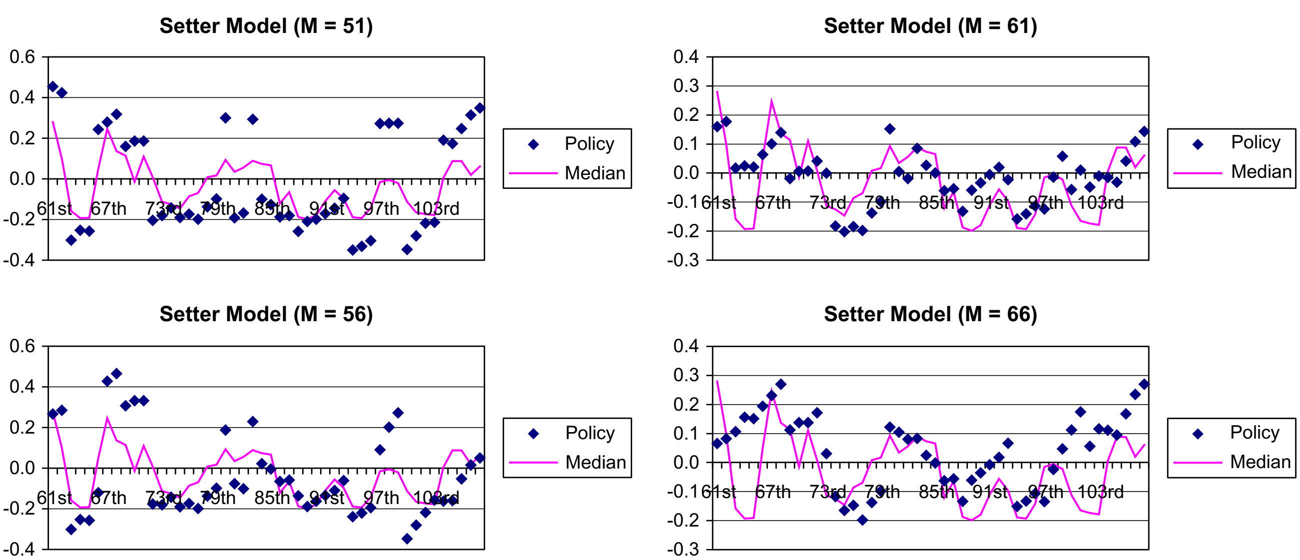


Note: Figure 3 plots one realization of the simulated policy outcomes along with the median legislator for the Majoritarian model, for various supermajority requirements. In this case, the optimal supermajority requirement in 51. The graphs indicate that as the supermajority requirement increases from 51 to 66, the policy outcome follows the median legislator less closely.

(nine additional votes) is optimal in Senate and a supermajority of 54% (19 additional votes) is optimal in the House. The optimal supermajority requirement will be influenced by the size of the chamber and the dynamics of the legislators' ideal points and party membership. We would like to know which of these are responsible for the finding that the optimal supermajority requirement is larger in the Senate.

To isolate why the Senate requires a higher supermajority requirement, I performed the following two experiments. First, I drew a random chamber of 435 Senators (with replacement) for each year in the analysis and replicated the experiments performed earlier. This allows us to gauge what the optimal supermajority requirement would be in a chamber whose ideal point dynamics resemble the

FIGURE 4 Simulated Policy Outcomes (Setter Model)



Note: Figure 4 plots one realization of the simulated policy outcomes along with the median legislator for the Setter model, for various supermajority requirements. In this case, the optimal supermajority requirement is 60. The graphs indicate that as the supermajority requirement increases from 51 to 61, the policy outcomes begin to track the median legislator more closely. When the supermajority requirement increases to 66, the trend reverses.

Senate, but which was as large are the House.[26] I found that the optimal supermajority requirements were now 218 (50.1%), 231 (53.1%), and 260 (60.0%), for the Majoritarian model, the Gatekeeping model, and the Setter model, respectively. In the second experiment, I randomly drew 101 House members and determined that the optimal supermajority requirements where 51, 53, and 57.

My results therefore indicate that finding higher supermajority requirements in the Senate is primarily driven by the dynamics of legislator preferences rather than the size of the chamber. The most important factor influencing the difference between the chambers was that the Senate experienced more changes in leadership. The Senate changed hands 11 times during the period of analysis, while the House only changed hands eight times. As changes in leadership lead to over-responsiveness and the Senate experienced more changes in leadership, there is a greater need for supermajority requirements in the Senate.

Finally, I note that my results are predicated on the assumption that legislators are not forward looking in their voting or agenda-setting behavior. One may wonder whether forward looking agenda setting behavior reduces the overresponsiveness that occurs under bare-majority requirements. In practice, electoral concerns will greatly restrict a legislator's ability to be forward looking. Furthermore, existing evidence suggests that politicians discount the future heavily (Merlo 1997) indicating that myopic behavior by politicians is a reasonable assumption. Nonetheless, in the online Appendix A.2, I show that the main result of this paper continues to hold when the agenda setter is forward looking.

Conclusions

In recent years, the filibuster has been used with increasing frequency. Changes to Rule 22 made over the past century have gradually made it easier to invoke cloture and limit post cloture debate. Many have argued for eliminating the 60 vote supermajority requirement inherent in the filibuster, allowing cloture to be invoked by a bare-majority of Senators. Binder and Smith present a number of arguments for eliminating this supermajority requirement. Among their claims is that "... there is no necessary theoretical connection between supermajority requirements and policy moderation" (1997, 203). I have shown that this needs a qualification—the claim holds only in legislatures where the majority party is not able to control the agenda. Increasing evidence of majority party agenda control means that there is a theoretical reason to believe that representation can be helped by supermajority requirements.

I argued that supermajority requirements lead to increased policy moderation if control over the agenda is concentrated. This can occur if the majority party has either positive or negative control of the agenda. More specifically, concentrated control over the agenda leads to over-responsiveness, where small changes in the composition of the legislature can lead to large changes in policy outcomes. Supermajority requirements can successfully mitigate overresponsiveness, leading policy outcomes to track the preferences of the electorate more closely. For the Senate, supermajority requirements around 60% are optimal for passing legislation. Smaller supermajority requirements are optimal for the House.

I argued earlier that models with majority party agenda control are appropriate for both the House and Senate. From the perspective of constitutional design, my results suggest that the filibuster in the Senate should be left in tact (or perhaps replaced by a true supermajority requirement) and that a small percentage supermajority requirement should be instituted in the House, if the Setter model is viewed as appropriate. If the Gatekeeping model is appropriate, than moderate supermajority requirements are neither harmful nor helpful (and consequently, nothing needs to be changed).

An alternative view exists—that the majority party is powerful in the House, but not the Senate. In this case, the implications of the theory are quite different. If the majority party is not powerful in the Senate, this suggests that the filibuster in the Senate should be abolished in order to increase responsiveness. If the majority party is strong in the House, a moderate supermajority requirement should be instituted there. Under this view, while supermajority requirements do not always harm representation, they have been instituted in the wrong chamber.

My results suggest that responsiveness to the median voter could be further improved by eliminating majority party agenda control. The view I take in this paper is that majority party agenda control is simply not a lever one can pull. This is consistent

[26]By drawing from the distribution of Senate ideal points in each Congress, I approximately replicate the quantiles of the distribution of Senate ideal points in each congress, while changing the chamber size. The quantiles, in turn, determine the pivotal legislators in the chamber, for different values of M. Hence, the experiment changes the chamber size while leaving the dynamics of legislator preferences in tact.

with the view taken in Cox and McCubbins (1993 2005), where political parties yield election-related benefits to members of those parties, such that partisan procedural cartels may form even if majority party agenda control is not institutionalized in the Senate rules. If this view is incorrect and we can take steps to lessen majority party agenda control, then my results have a different interpretation. Binder and Smith's (1997) prescription of allowing a bare majority of Senators to eventually invoke cloture is only likely to improve representation if coupled with reforms aimed at reducing majority party agenda control.

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Appendix

Proof of Propositions

Proof of Proposition 1: The Winset can be characterized by,

$$W(s) = \{b : |\{n : |b - \alpha_n| \leq |s - \alpha_n|\}| \geq M\}.$$

I first show that $b \in W(s)$ if an only if $|b - \alpha_l| \leq |s - \alpha_l|$ and $|b - \alpha_u| \leq |s - \alpha_u|$. Suppose that $|b - \alpha_l| > |s - \alpha_l|$. Then all voters with $n \leq l$ must also have $|b - \alpha_n| > |s - \alpha_n|$. Since there are $N + 1 - M$ such voters, there cannot be M voters with $|b - \alpha_n| \leq |s - \alpha_n|$, so that $b \notin W(s)$. A similar argument holds if $|b - \alpha_u| > |s - \alpha_u|$, so that $b \notin W(s)$.

Now suppose that $|b - \alpha_l| \leq |s - \alpha_l|$ and $|b - \alpha_l| \leq |s - \alpha_l|$. If $b \leq s$, then $|b - \alpha_u| \leq |s - \alpha_u|$ implies that all legislators with $n \leq M$ have $|b - \alpha_n| \leq |s - \alpha_n|$, so at least M legislators have $|b - \alpha_n| \leq |s - \alpha_n|$ and $b \in W(s)$. If $b \geq s$, then $|b - \alpha_l| \leq |s - \alpha_l|$ implies that all legislators with $n \geq N + 1 - M$ have $|b - \alpha_n| \leq |s - \alpha_n|$ so at least M legislators have $|b - \alpha_n| \leq |s - \alpha_n|$ and $b \in W(s)$. Combining these gives,

$$W(s) = \{b : |b - \alpha_l| \geq |s - \alpha_l|, |b - \alpha_u| \geq |s - \alpha_u|\}.$$

Now consider 3 cases. If $s \leq \alpha_l \leq \alpha_u$, then $W(s) = [s, 2\alpha_l - s]$, if $\alpha_l \leq \alpha_u \leq s$, then $W(s) = [2\alpha_u - s, s]$, and if $\alpha_l < s < \alpha_u$, then $W(s) = s$.

Proof of Proposition 2: To show necessity, suppose that $|b' - \alpha_m| \leq |b - \alpha_m|$ for all $b' \in W(s)$. For all $b' \leq b$, it must be the case that $|b' - \alpha_n| \leq |b - \alpha_n|$ for all $n \geq m$, so that a majority weakly prefer to select b over b'. For all $b' \geq b$, it must be the case that $|b' - \alpha_m| \leq |b - \alpha_m|$ for all $n \leq m$, so again a majority weakly prefer to select b over b'. Thus, b is Amendment Proof. I show sufficiency using the contra-positive. Suppose that there exists $b' \in W(s)$ such that $|b' - \alpha_m| > |b - \alpha_m|$. If $b' \leq b$, then $|b' - \alpha_n| > |b - \alpha_n|$ must hold for all $n \leq m$. Similarly, if $b' \geq b$, then $|b' - \alpha_n| > |b - \alpha_n|$ must hold for all $n \geq m$. In both cases, a majority of legislators strictly prefer b' to b, so that b cannot be Amendment Proof.

Proof of Proposition 3: Consider first the case where $s \leq 2\alpha_l - \alpha_m$. In this case, $s \leq \alpha_m \leq 2\alpha_l - s$ so that $\alpha_m \in W(s)$. Since $|b - \alpha_m| = 0$ when $b = \alpha_m$, it follows that $\alpha_m \in B(s)$. Furthermore, we cannot have $b \in B(s)$ for $b \neq \alpha_m$ since $b' = \alpha_m$ would imply $|b' - \alpha_m| < |b - \alpha_m|$. Thus, $B(s) = \alpha_m$ when $s \leq 2\alpha_l - \alpha_m$. Similarly, we can show that when $s \geq 2\alpha_u - \alpha_m$, then $B(s) = \alpha_m$. Now consider the case where $2\alpha_l - \alpha_m \leq s \leq \alpha_l$. Clearly $b = 2\alpha_l - s$ implies that $b \in W(s)$. Notice that $|b' - \alpha_m| \geq |b - \alpha_m|$ implies that $b' > b = 2\alpha_l - s$, but this implies that $b' \notin W(s)$, so $2\alpha_l - s \in B(s)$. Notice that $b > 2\alpha_l - s$ implies that $b \notin W(s)$, so that $b \notin B(s)$. If $b < 2\alpha_l - s$, then $b' = 2\alpha_l - s$ implies that $b' \in W(s)$ and $|b' - \alpha_m| < |b - \alpha_m|$. Thus, $B(s) = 2\alpha_l - s$ when $2\alpha_l - \alpha_m \leq s \leq \alpha_l$. Similar logic shows that $B(s) = 2\alpha_u - s$ when $\alpha_u \leq s \leq 2\alpha_u - \alpha_m$. Finally, when $\alpha_l \leq s \leq \alpha_u$, $W(s) = \phi$, so clearly $B(s) = \mathbb{R}$.

Proof of Proposition 4: Notice that,

$$\Delta(s; \tfrac{N+1}{2}) = 0,$$

$$\Delta(s; M) = \begin{cases} 0, & s < 2\alpha_l - \alpha_m \\ (2\alpha_l - s - \alpha_m)^2, & 2\alpha_l - \alpha_m \leq s \leq \alpha_l \\ (s - \alpha_m)^2, & \alpha_l < s < \alpha_u \\ (2\alpha_u - s - \alpha_m)^2, & \alpha_u \leq s \leq 2\alpha_u - \alpha_m \\ 0, & s > 2\alpha_u - \alpha_m \end{cases}.$$

Hence, for $M > \frac{N+1}{2}$, we have,

$$\int_s \Delta(s;M)dF_s(s) - \int_s \Delta(s;\tfrac{N+1}{2})dF_s(s) = \int_s \Delta(s;M)dF_s(s) \geq \int_{s\in[\alpha_{m-1},\alpha_{m+1}]} \Delta(s;M)dF_s(s).$$

The inequality follows from the fact that $\Delta(s;M) \geq 0$. Define $\bar{s} = \int_{s\in[\alpha_{m-1},\alpha_{m+1}]} sdF_s(s)$. Then,

$$\int_{s\in[\alpha_{m-1},\alpha_{m+1}]} \Delta(s;M)dF_s(s) = \int_{s\in[\alpha_{m-1},\alpha_{m+1}]} (s-\alpha_m)^2 dF_s(s)$$

$$= \int_{s\in[\alpha_{m-1},\alpha_{m+1}]} (s-\bar{s})^2 dF_s(s) + \int_{s\in[\alpha_{m-1},\alpha_{m+1}]} (\bar{s}-\alpha_m)^2 dF_s(s)$$

$$= \Pr(s : s\in[\alpha_{m-1},\alpha_{m+1}])\{(\bar{s}-\alpha_m)^2 + Var(s|\alpha_{m-1} \leq s \leq \alpha_{m+1})\}.$$

If $\bar{s} \neq \alpha_m$, then $\int_{s\in[\alpha_{m-1},\alpha_{m+1}]} \Delta(s;M)dF_s(s) > 0$ and the result follows. Alternatively, if $\bar{s} = \alpha_m$, then,

$$\int_{s\in[\alpha_{m-1},\alpha_{m+1}]} \Delta(s;M)dF_s(s) = \Pr(s : s\in[\alpha_{m-1},{}_{m+1}])Var(s|\alpha_{m-1} \leq s \leq \alpha_{m+1}).$$

Since $\bar{s} = \alpha_m$ and $\Pr(s : s\in[\alpha_{m-1},\alpha_m) \cup (\alpha_m,\alpha_{m+1}]) > 0$, we have $Var(s|\alpha_{m-1} \leq s \leq \alpha_{m+1}) > 0$ and the result follows.

Proof of Proposition 5: I prove the case where $a < \alpha_{m-1}$ (the other case follows by symmetry). I begin by characterizing $(x(s;\frac{N+1}{2}) - \alpha_m)^2 - (x(s;\frac{N+1}{2}+1) - \alpha_m)^2$. Notice that,

$$x(s;\tfrac{N+1}{2}) = \begin{cases} a, & s \leq a \\ s, & a \leq s \leq \alpha_m \\ 2\alpha_m - s, & \alpha_m \leq s \leq 2\alpha_m - a \\ a, & s \geq 2\alpha_m - a \end{cases}$$

$$x(s;\tfrac{N+1}{2}+1) = \begin{cases} a, & s \leq 2a \\ s, & a \leq s \leq \alpha_{m+1} \\ 2\alpha_{m+1} - s, & \alpha_{m+1} \leq s \leq 2\alpha_{m+1} - a \\ a, & s \geq 2\alpha_{m+1} - a \end{cases}.$$

Define $\nu(s;M) = (x(s;\frac{N+1}{2}) - \alpha_m)^2 - (x(s;M) - \alpha_m)^2$. We can determine that,

$$\nu(s;\tfrac{N+1}{2}+1) = \begin{cases} 0, & s < \alpha_{m+1} \\ 4(\alpha_{m+1}-\alpha_m)(s-\alpha_{m+1}), & \alpha_{m+1} < s < 2\alpha_m - a \\ (a-\alpha_m)^2 - (2\alpha_{m+1} - s - \alpha_m)^2, & 2\alpha_m - a < s < 2\alpha_{m+1} - a \\ 0, & s > 2\alpha_{m+1} - a \end{cases}.$$

Clearly, $4(\alpha_{m+1}-\alpha_m)(s-\alpha_{m+1}) > 0$ where $s \in (\alpha_{m+1}, 2\alpha_m - a]$. Next, I show that $(a-\alpha_m)^2 - (2\alpha_{m+1} - s - \alpha_m)^2 > 0$ when $s \in [2\alpha_m - a, 2\alpha_{m+1} - a)$. Since $a < \alpha_m$ and $2\alpha_{m+1} - s - \alpha_m < \alpha_m - s < 0$, it is sufficient to show that $a - \alpha_m < 2\alpha_{m+1} - s - \alpha_m$. Notice that,

$$2\alpha_{m+1} - s - \alpha_m > 2\alpha_{m+1} - a + a - s - \alpha_m > s + a - s - \alpha_m = a - \alpha_m$$

I have shown that $\nu(s;\frac{N+1}{2}+1) = 0$ when $s \notin (\alpha_{m+1}, 2\alpha_{m+1} - a)$ and $\nu(s;\frac{N+1}{2}+1) > 0$ when $s \in (\alpha_{m+1}, 2\alpha_{m+1} - a)$. We have,

$$L(\tfrac{N+1}{2}) - L(\tfrac{N+1}{2}+1) = \int_{s\in(\alpha_{m+1},\,2\alpha_{m+1}-a)} \nu(s;M)dF_s(s)$$

Since F_s places positive mass on $(\alpha_{m+1}, 2\alpha_{m+1} - a)$, we have $L(\frac{N+1}{2}) > L(\frac{N+1}{2}+1)$, proving that $M^* \neq \frac{N+1}{2}$.

Proof of Proposition 6: I prove the case where $a < \alpha_{m-1}$ (the other case follows by symmetry). Since,

$$[2a - \alpha_m, \alpha_m] \subset [\min\{\alpha_l, 2a - \alpha_m\}, \max\{\alpha_u, 2a - \alpha_m\}],$$

for any M, $x(s;M) = s$ when $2a - \alpha_m \leq s \leq \alpha_m$ and $x(s;M) = \alpha_m$ otherwise. Define $\nu(s;M) = (x(s;\frac{N+1}{2}) - \alpha_m)^2 - (x(s;M) - \alpha_m)^2$ and consider $M > \frac{N+1}{2}$. We have,

$$\nu(s;M) = \begin{cases} 0, & s \in [2a - \alpha_m, \alpha_m] \\ -(x(s;M) - \alpha_m)^2, & s \notin [2a - \alpha_m, \alpha_m] \end{cases}$$

It follows that $\nu(s;M) \leq 0$, proving that $L(\frac{N+1}{2}) \leq L(M)$.

We further have $\nu(s;M) = -(s - \alpha_m)^2 < 0$ when $s \in (\alpha_m, \alpha_u]$ and $\nu(s;M) = -(2\alpha_u - s - \alpha_m)^2 < 0$ when $s \in [\alpha_u, 2\alpha_u - \alpha_m)$. Hence, $\nu(s;M) < 0$ when $s \in (\alpha_m, 2\alpha_{m+1} - \alpha_m)$. Since F_s places positive mass on the interval $(\alpha_m, 2\alpha_{m+1} - \alpha_m)$, it follows that $L(\frac{N+1}{2}) - L(M) \leq \int_{s \in (\alpha_m, 2\alpha_{m+1} - \alpha_m)} \nu(s;M) dF_s(s) < 0$. Hence, we have $L(M) > L(\frac{N+1}{2})$ for $M > \frac{N+1}{2}$, proving the result.

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