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The Punctuated Origins of Senate Polarization

This article uses a new dynamic ideal-point estimation method that incorporates smoothing techniques to construct a more detailed account of Senate polarization. The results reveal that the Senate polarized in two distinct phases. Member replacement accounts for nearly all of the increase from the early 1970s through the mid-1990s after which ideological adaptation emerges as the dominant force behind polarization. In addition, I find that a few brief periods of intensified partisanship account for most of the increase in polarization since the mid-1990s, suggesting that these episodes have had significant and lasting effects.

The rise in Congressional polarization is among the defining features of contemporary American politics. Many of the maladies of Congress go hand-in-hand with polarization, from legislative gridlock to increased partisan rancor and incivility. The widening rift between the parties is also thought to affect the quality of representation. As the parties move to the ideological extremes and the ranks of moderates dwindle, the sizable portion of the electorate that resides nearer the political center becomes alienated (Fiorina, Abrams, and Pope 2005). These relationships are so evident that measures of polarization routinely double as a proxy for the health of our legislative institutions.

An open question in the literature on Congressional polarization concerns its origins. The increase in polarization since the early 1970s is well documented, but its causes are not fully understood. While scholars generally agree that no one factor can explain the recent rise in polarization, there is an ongoing debate over the relative importance of competing accounts. Some scholars emphasize factors external to Congress, such as shifting electoral coalitions (Carmines and Stimson 1989; Poole and Rosenthal 1997), partisan sorting among the electorate (Abramowitz and Saunders 1998; Bishop and Cushing 2009) and changing preferences of voters and partisan activists (Layman and Carsey 2002; Theriault 2008; Abramowitz 2010). Others highlight the importance of factors endogenous to Congress, such as institutional arrangements, procedural rules,

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and the changing strategies of party leaders (Aldrich 1995; Cox and McCubbins 2005, 1993; Roberts and Smith 2003; Rhode 1991; Sinclair 1995).

In testing these competing accounts, special attention has been paid to the mechanism by which the parties have polarized. The standard measure of partisan polarization is calculated as the distance between the mean ideal points of the parties in Congress. Based on this metric, Congress can polarize via two distinct mechanisms. The first mechanism is member replacement. Member replacement increases polarization when incoming legislators are more ideologically extreme than the outgoing senators they replace. The second mechanism is movement in legislator ideal points across time, referred to here as ideological migration. Ideological migration increases polarization when sitting legislators drift away from the ideological center as their careers progress.

Measuring the relative contributions of these mechanisms is essential to understanding polarization's underlying causes. Poole and Rosenthal (1997) among others (Brady and Han 2004; Price 2002) emphasize the importance of member replacement. According to Poole "once elected to Congress, members adopt a consistent ideological position and maintain it over time. There may be changing minds, but they are not in Congress" (2007, 435). This claim has strong implications for the origins of partisan polarization in Congress. Jacobson notes that "if Poole is right, then not only have the bitter partisan fights within Congress contributed nothing (at least directly) to partisan polarization but the changing electoral environment is reflected only in the replacement of moderates by more extreme partisans, not by continuing members that adapt to new electoral realities" (2007, 91).

I weigh in on this debate with results from a new dynamic ideal-point-estimation method that adapts Poole's Optimal Classification (OC) to smooth legislator ideal points across time. In contrast to the only widely used estimation technique that allows for intertemporal movement of ideal points, McCarty, Poole, and Rosenthal's DW-NOMINATE, the method measures time by the exact date of the roll call rather than by a single integer value for each two-year Congress.

Smoothing legislator ideal points makes it possible to track changes in polarization within and across legislative periods, which leads to more refined measures of the relative contributions of member replacement and ideological migration. The method also reveals localized features in the data that would otherwise be overlooked. This enables us to explore questions about who adapts, why, when, and in response to what. Although dynamic OC can be applied to any voting body applicable to OC, here I focus on the Senate rather than the House due to greatly increased computational costs of fitting the model.[1] While the scaling includes all roll-call votes cast during the 1st through the 111th Senates, thus permitting more extensive historical analyses, I focus on the contemporary era. Following Theriault (2006, 2008), I begin the analysis in 1972, generally viewed as a turning point in Congressional polarization.[2]

I apply these new measures to the following questions about the origins of Senate polarization. First, what proportion of the increase in Senate polarization since 1972 is attributable to member replacement versus ideological migration? Second, has the Senate polarized gradually or is the process intermittent? Third, have partisan fights and Senate rules changes contributed to polarization?

I find that replacement and migration account for comparable portions of the increase in polarization since 1972. However, their relative effects are not uniform over the period under study. I find that the Senate polarized in two distinct phases. The first phase is dominated by member replacement, followed by a second phase dominated by ideological migration. Replacement drives Senate polarization from 1972 to 1996, a period that corresponds with the southern partisan realignment. Ideological migration, on the other hand, has little effect on Senate polarization before the 101st Congress but emerges as the primary driver of polarization starting in the 105th Congress.

After establishing that ideological migration has contributed much to Senate polarization, I examine the manner in which these changes occurred. I distinguish two types of migration-driven polarization, each lending support to a different theory of polarization. The first is a smooth, well-behaved trend whereby senators gradually change their policy positions over time, which is consistent with individual senators adapting to their gradually changing constituencies. The second is a trend in which sudden jumps or periods of accelerated polarization punctuate an otherwise stable polarization trend, suggesting that ideological migration occurs in waves and is better understood as a group-level phenomenon.[3]

I find that a punctuated migration trend better characterizes the evolution of Senate polarization. A change-point model applied to the migration identifies a few widely spaced jumps that account for the lion's share of increase in polarization since the mid-1990s. The timing of these jumps suggests that they are linked to legislative battles and other periods of heightened partisan tension. Three of the largest jumps occur in response to the budget crisis and subsequent government shutdowns of 1995, the invasion of Iraq in 2003, and the debates over health care reform in 2010. This represents the first empirical evidence that periods of heightened partisan conflict have had significant and lasting effects on Congressional polarization.

The remainder of the article is organized as follows. The following section overviews the measurement of Congressional polarization. The next section introduces a new dynamic ideal-point-estimation method that allows for a far more detailed characterization of how Senate polarization evolved over time. The following sections report the results and weigh in on the migration versus replacement debate. The final sections assess the effects of divisive legislative battles and Senate rules changes on polarization.

Measuring Partisan Polarization in Congress

The growing gap between the parties in Congress is now widely recognized. Poole and Rosenthal (1984) were the first to detect that the parties in both houses were moving apart. Since then, they have shown in each successive update of their roll-call measures continued growth in this polarizing trend (McCarty, Poole, and Rosenthal 2006; Poole and Rosenthal 1997). Their finding is not specific to their measures of legislator ideology. The widening gap between the parties shows up in voting behavior as revealed by roll-call party-loyalty votes (Aldrich 1995; Rhode 1991; Roberts and Smith 2003), presidential support scores (Fleisher and Bond 2004), and interest-group ratings (Levitt, Groseclose, and Snyder Jr. 1999).

Scholars provide consistent evidence of a polarizing Congress but have produced inconsistent findings about what drives the trend. Fleisher and Bond (2004) analyze the frequency of party votes since 1970 and find that member replacement accounts for around 90% of the total reduction of moderates in Congress. Poole (2007) examines whether legislator ideal points are fixed or subject to change during the course of a legislator's career. He interprets the total increase in classification when moving from static ideal points to period-specific ideal points as the percentage of roll-call voting that ideological migration can at most explain. He demonstrates that period-specific legislator ideal points only slightly increase correct classification over a model that holds ideal points fixed and concludes that member replacement must account for the vast majority of polarization in both the House and Senate.

Other studies find that migration had a significant effect. Roberts and Smith (2003) find that migration accounts for between 50 and 82% of the increase in Congressional polarization during the 98th–100th and 103rd–104th Congresses, periods they identify as polarization phases. They uncover evidence that party strategies played a role in polarizing Congress and conclude that the bulk of the increase in polarization during the last generation occurred during very limited periods. Jacobson (2007) produces similar results by regressing members current DW-NOMINATE scores on their initial score, a trend term, and a count for the number of terms served. He finds that, on average, Democratic senators have trended to the left, and Republican senators have trended to the right.

Theriault (2006, 2008) develops a simple but effective methodology to distinguish the contributions of replacement and migration. He first matches each entering senator with the senator being replaced and attributes to member replacement any change in the distance between the parties that results. He then measures the effect of ideological migration by summing changes in DW-NOMINATE scores for all members that continue on to serve in the following Congress. In a comprehensive microlevel analysis of congressional polarization, he finds that ideological migration accounts for 35% of the increase in House polarization and 38% of the increase in Senate polarization during the 92nd through 108th Congresses.

Although informative, Theriault's reliance on DW-NOMINATE scores limits his approach. DW-NOMINATE allows for detailed characterizations of how member replacement has affected polarization by categorizing instances of member replacement into types—for example, cross-party or within-party replacement. However, DW-NOMINATE models movement in legislator ideology with linear trends, precluding a similarly detailed exploration of how ideological migration has contributed to polarization. Theriault's analysis offers evidence that ideological migration is an important component of Senate polarization but stops there. It tells us nothing about the manner in which those changes took place. Such an analysis calls for a new approach to modeling intertemporal movement of legislator ideology.

In the following section, I develop a dynamic version of Keith Poole's (Poole 2000) Optimal Classification (OC) scaling algorithm that utilizes kernel methods (i.e., localized estimates) to smooth legislator positions over time. The method combines two existing technologies, roll-call scaling and nonparametric smoothing techniques. It recovers legislator estimates from kernels applied to localized subsets of the data, hence smoothing legislator estimates within and across periods. As opposed to existing roll-call scaling methods, which generally estimate a single ideal point per legislative period, this method tracks legislator movement from one day to the next.

Dynamic Optimal Classification

Existing methods for dynamic ideal-point estimation specify time by grouping roll calls into contiguous legislative periods (McCarty and

Rothenberg 1996; McCarty, Poole, and Rosenthal 1997; Martin and Quinn 2002). For example, legislative periods in the U.S. Congress are two years, one for each Congress. This reduces time into a sequence of integer values that take on the familiar form of longitudinal data. DW-NOMINATE uses Legendre polynomials to model intertemporal movement. This permits legislator movement but does so in a highly structured fashion. The rate and direction of each legislator's trend is held constant across periods.

Nokken and Poole (2004) develop a technique that further relaxes constraints on legislator movement by recovering period-specific legislator estimates from DW-NOMINATE. They first estimate a static W-NOMINATE scaling that recovers a single ideal point for each legislator held constant over time. Using the roll-call parameters (i.e., the normal vectors and cutting points) recovered from the static W-NOMINATE scaling, they then recover period-specific legislator estimates. This is done by treating each period for a given legislator as an independent observation when running the legislator recovery procedure. While this procedure allows for greater versatility, it assumes that ideal points remain stable during legislative periods and change only after elections. As a result, it will overlook local features in the data that occur within the course of a two-year legislative period.

Rather than organizing votes into distinct legislative periods, I develop a method that recovers a legislator estimate for each roll call as though it were a single period. Time is modeled as a function of the frequency of observed events rather than the linear passage of time.[4] This is accomplished with nearest-neighborhood smoothing methods. Following Nokken and Poole, I first scale the legislature using OC-assuming static ideal points. Using the recovered roll-call parameters, the method recovers a time-series of ideal points for each legislator from localized subsets of roll-call votes. The method recovers localized ideal-point estimates from the set of the h temporally adjacent data points, where h is the window width. For instance, assuming a window width of $h = 200$, the method recovers one ideal-point estimate for roll calls 1 through 200, then another estimate for roll calls 2 through 201, then another for roll calls 3 through 202 and so on. This is analogous to taking snapshots of a legislator's voting record from a "moving window" that summarize the legislator's movement through time.

The procedure first recovers starting estimates with OC holding legislator ideal points constant over time. It then estimates a smoothed trend using kernel estimators for every legislator who votes on at least h roll calls. This is done by applying a moving window to Poole's legislator-recovery algorithm $L(.)$, a sophisticated dimension by dimension grid search that locates the point along a line that minimizes voting errors for each legislator.[5] For the purposes here, it suffices to think of $L(.)$ as no different from any other optimization algorithm that uses a grid search. It may be helpful to think of $L(.)$ as a nonparametric estimator that identifies an optimal set of legislator ideal points, such that the maximum number of vote choices is on the correct side of their respective cutting lines. A more detailed formal description of the nonparametric kernel estimators can be found in the appendix.[6]

I report model testing and fit statistics in the appendix. The appropriate comparison between DW-NOMINATE and dynamic OC is the increase in the aggregate proportional reduction in error (APRE)[7] moving from a constant model to a dynamic model. By incorporating linear trends, DW-NOMINATE increases the APRE by 1.5% over static W-NOMINATE. In comparison, smoothing legislator trends with dynamic OC (h = 200)[8] results in a 4.4% increase over static OC. To provide another point of comparison, an unconstrained period-specific OC scaling (i.e., scaling each Congress separately and aggregating results) increases the APRE by 2.7% over the pooled static-OC scaling, only about half of the increase associated with dynamic OC. This suggests that senators shift positions both within and across periods.

Uncertainty Estimates

Lewis and Poole (2004) develop a method to recover bootstrapped uncertainty measures for W-NOMINATE. They implement a parametric bootstrap scheme that first draws N samples from the likelihood density for the true values and then computes for each sample the parameters of interest.[9] An important feature of their choice of bootstrapping scheme is that it samples directly from the cells of vote matrix, which differs from nonparametric bootstrapping techniques that implement block sampling schemes. This modeling choice reflects that sampling from rows or columns would violate assumptions of independence.

Although OC similarly requires a resampling scheme that draws from cells rather than from blocks, the parametric bootstrap cannot be applied to nonparametric methods. Fortunately, OC's robustness to missing data makes it well suited for jackknifing schemes. I use a generalized jackknife sampling scheme that measures uncertainty by repeatedly drawing random subsets from the data, each time reestimating the model.[10] I introduce error by randomly dropping 20% of yea and nay votes (i.e., setting their values to missing), which is akin to "shooting holes" in the voting matrix at random.[11] The technique successfully pervades the estimates with uncertainty and produces results that closely resemble uncertainty measures derived from Lewis and Poole's parametric bootstrapping method.

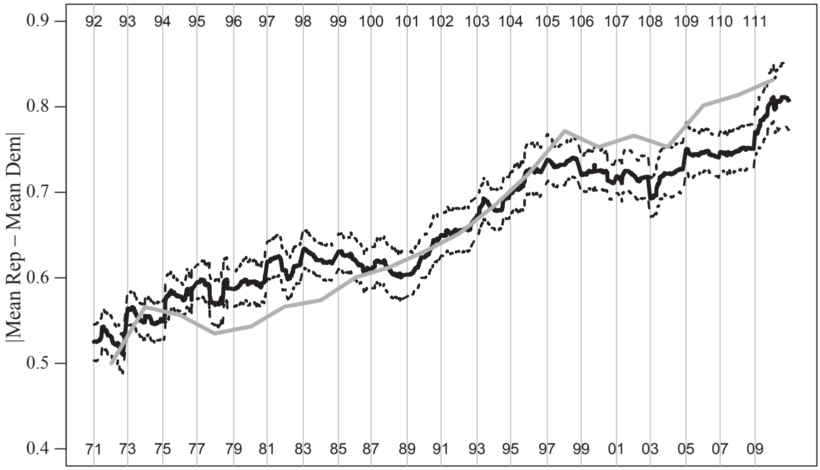
Replacement or Migration?

I distinguish between member replacement and ideological migration in a manner similar to Theriault (2006, 2008). I calculate the replacement effects for each group of entering/exiting senators by measuring the change in the positions of the party means and attribute to member replacement any resulting increase in the distance between the parties.[12] I then subtract these replacement effects from the initial polarization trend to isolate a date-specific trend of polarization attributable to ideological migration. To illustrate, suppose a replacement shock of 0.1 occurs on date x. I subtract 0.1 from the initial polarization trend for all dates including and following x. The resulting trend will reflect polarization from ideological migration, since whatever portion of the increase in polarization not accounted for by replacement is attributable to movement in legislator ideal points.

This methodology applied to DW-NOMINATE provides generalized measures of the proportion of polarization resulting from ideological migration but is minimally informative about its rate and timing. In contrast, the smoothed polarization trends allow for more powerful and nuanced inferences by revealing localized features in the data, as shown in Figure 1. Figure 2 deconstructs the polarization trend into the cumulative effects of replacement and migration. Overall, replacement accounts for 55% and migration accounts for 45% of the total increase since the 92nd Congress. Replacement increases polarization a total of 0.167, with a 95% jackknife-confidence bounds at 0.117 and 0.218; migration increases polarization a total of 0.116, with a 95% jackknife-confidence bounds at 0.048 and 0.184. The cumulative effect of migration is greater than the 38% found by Theriault. However, this discrepancy results not from different methods but rather from the inclusion of the 109th–111th Congresses. When I restrict the analysis to the 92nd–108th Senates, the identical period analyzed by Theriault, I find that migration accounts for 38.6% of the increase in polarization.

Senate polarization evolved in two phases. Member replacement was responsible for most of the increase in polarization from the early 1970s through the mid-1990s. This corresponds to the Southern Realignment, a period during which southern districts that had traditionally elected moderate Democrats (aka Dixiecrats) began electing conservative Republicans. During this period, southern senators account for 56%

FIGURE 1
Senate Polarization Trend from 1971 to 2010



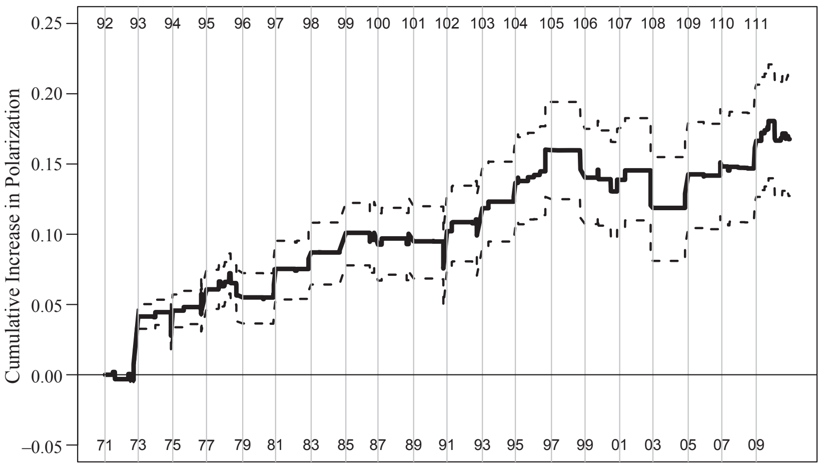
Note: Political polarization measured by the distance between party means. The gray line is the DW-NOMINATE MPR measure. The solid black line is the median value from the jackknifed dynamic OC scalings. The dotted lines represent the 2.5 and 97.5 percentiles for the jackknifed confidence intervals.

of the increase in polarization due to replacement. Ideological migration has little effect on Senate polarization until the 101st Congress but accounts for nearly the entire increase in polarization since the 105th Congress.

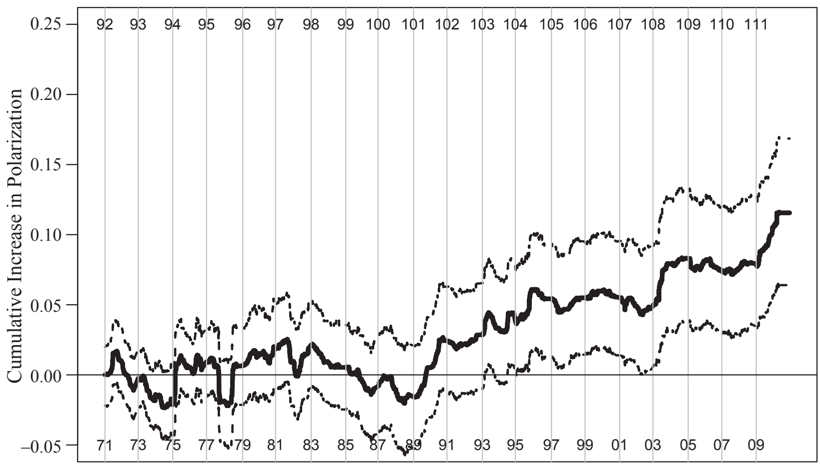
Interestingly, this finding is consistent with claims made in the late 1990s and early 2000s that member replacement had been the driving force behind Congressional polarization, as the emergence of migration-driven polarization is a recent phenomenon. The story of Senate polarization appears to have entered a new chapter during the mid-1990s. The hollowing out of the political center that began in the 1970s was primarily a consequence of partisan sorting, driven largely by the disappearance of conservative Democrats in the South. By the turn of the century, ideological overlap between parties in the Senate had all but disappeared, and only a handful of moderates remained. Continued growth in Senate polarization could no longer simply be a story of vanishing moderates. In the following section, I show that much of the increase in Senate polarization since the 105th Congress originates from a few brief periods of heightened partisan strife.

FIGURE 2
Cumulative Increases in Polarization
from Replacement and Ideological Migration

Cumulative Increase in Polarization from Member Replacement



Cumulative Increase in Polarization from Ideological Migration



Note: The solid line is the median value from the jackknifed runs and the dotted lines are the .025 and .975 confidence intervals.

Moving Apart

Jacobson argues that developments internal to Congress may have also increased polarization. In his words,

> Congressional insiders and others who observe the House and Senate on a day-to-day basis, attuned to the personalities, tactics, and moods of members, point to events and developments internal to Congress as forces driving the parties apart: disputed elections, personal scraps between leaders, fights over judicial appointments, partisan scandal mongering, rules altered or manipulated to partisan ends, slash-and-burn tactics of disgruntled minorities. These episodes are obviously manifestations of intensified partisan conflict; but they may also contribute to it in a self-reinforcing spiral, magnifying party divisions beyond those explainable by electoral forces or the issue agenda. (Jacobson 2004, 3)

If member migration accounts for much of the increase in polarization in recent decades, how has this process evolved? Did senators gradually drift toward the extremes during the course of their careers? Or does polarization occur in relatively short bursts in response to the adoption of new procedural rules, bitter partisan policy battles, or the sudden emergence of new political movements?

I distinguish two types of polarization resulting from migration. Each points to a different conclusion about the underlying causes of polarization. The first is a smooth, well-behaved trend that suggests a process whereby senators gradually change their policy positions. This would be consistent with Senators slowly responding to changing constituencies. The second is an intermittent process whereby migration shocks (i.e., sudden periods of accelerated polarization) punctuate an otherwise stable polarization trend.

One way to approach this question is to identify a list of political events that scholars have identified as fanning the flames of partisanship and test whether they correspond to increases in polarization. A list of events would likely include the budget crisis of 1995, the Clinton impeachment trial, the run-up to the Iraq War, and the debate over the Affordable Health Care Act. However, beyond a few key events, it is difficult to compile a definitive list of polarizing events that is not prone to highly subjective assessment. It also precludes the possibility of observing jumps in polarization that result from reasons other than legislative battles—for instance, a rise in polarization in response to the sudden emergence of a new political movement.

I instead adopt an approach that allows the data to speak directly to the question at hand. I do so by applying a Bayesian change-point model to the migration trend to detect jumps in the polarization trend (Barry and Hartigan 1993).[13] The advantage of this approach is that it does not

TABLE 1
Months with the Highest Posterior Probability of Observing a Change Point Averaged over all Jackknifed Iterations

Month	Mean Posterior Probability	Effect on Polarization	Legislative Environment/Notable Events
March 1975	0.787	+	Filibuster Reform
September 1977	0.756	−	
July 1978	0.720	+	Panama Canal Debate/ New Right Emerges
November 1981	0.373	−	
April 1993	0.494	+	Omnibus Budget Reconciliation Act of 1993
October 1995	0.379	+	Budget Crisis
March/May 2003	0.460/0.403	+	Two-jumps detected: one during the run-up to the Iraq War and a second in the months after the invasion
July 2003	0.363	+	Run-up to Iraq War
March 2005	0.349	+	"Nuclear Option" over filibuster/Schiavo's Law
March 2010	0.411	+	Final passage of Affordable Health Care Act

require the researcher to identify a priori a set of political events associated with partisan fights. It instead uses statistical methods to identify points in time during which sharp and significant increases/decreases in polarization occur. The model treats change points in a time series as parameters to be estimated. The change points are thus discovered from the data and are accompanied by uncertainty estimates of the probability that a change point actually occurred at the specified point in time. Nonetheless, face validity can be established insofar as the detected change points align with some notable events mentioned above. After identifying the change points, I test whether polarization increased/decreased during the specified periods.

For each jackknife run, I construct a trend line of polarization resulting from migration and run the change-point model to search for sudden jumps. Rather than search through the polarization trend for each date, I instead take the value for the first date of each month. Table 1 lists the 10 months associated with the highest mean posterior probability of observing a jump across all jackknifed iterations. The first column shows the month in which the jump occurs. The second column indicates whether polarization increased or decreased in response. The third column lists the corresponding political event. This column is left blank if there is ambiguity with respect to the associated event.

The timing of the migration shocks lends support to Jacobson's claim. Six out of the 10 most probable change points can be traced back to legislative battles. One of the largest jumps occurred in October of

1995, corresponding with the federal government shutdowns following the Republican-controlled Congress' failure to pass a budget bill. An earlier jump occurred in the spring of 1993 as Congress debated the Omnibus Budget Reconciliation Act, which sought to close the deficit by raising revenue through a series of tax increases on corporations, wealthy individuals, and entitlement benefits while simultaneously expanding aid to low-income households received through the Earned Income Tax Credit. After extended debate, the legislation narrowly passed despite unified Republican opposition. The legislation's failure to include commensurate spending cuts alongside the tax increases fueled Republicans opposition and helped set the stage for the Clinton Health Care debate and later budget battles. Two more jumps occurred during the winter and spring of 2003, corresponding with the early months of the Iraq War. Another jump occurred in March 2010 as Senate Democrats invoked reconciliation rules to pass the controversial Affordable Health Care Act. The final jump occurred in March of 2005, corresponding to the majority Republicans' threat to invoke the "nuclear option" in response to Democratic use of the judicial filibuster.

The connections between the remaining migration shocks and specific legislative battles are less clear. In lieu of drawing a direct link to a specific event for these jumps, overviews of legislative activity at the time can still aid in interpreting the results by providing additional context. The jumps in September of 1977 and July 1978 both occur during the 95th Senate. Prior to the 111th Congress, the 95th Congress was the last in which a single party controlled the Presidency and Congress with a filibuster-proof supermajority in the Senate. The 95th Senate is also remembered for its bitter and extended political debate over the ratification of the Panama Canal Treaty. Although the treaty was eventually ratified in April of 1978, the debate galvanized the conservative movement, setting the stage for the emergence of the New Right (Smith 2006).

Lastly, the jump that occurred in March 1975, the largest in the sample, is among the more difficult to link a specific legislative event. On the one hand, it may reflect corresponding changes to filibuster rules. Having increased their majority to 61 in the 1974 elections, Senate Democrats adopted a new rule that weakened the supermajority requirement for invoking cloture from a two-thirds majority to 60 votes. On the other hand, it is not obvious why lowering the cloture requirements would lead to increased polarization. The reform passed with strong bipartisan support and partisanship on cloture votes was not appreciably higher than in the previous Congress (Binder and Smith 1997). Moreover, almost any plausible mechanism to link the rules change to increased polarization would seem to differ in nature from the heightened partisan acrimony

TABLE 2
Dates of Change Points and Corresponding Events
(standard errors in parentheses)

Date	Legislative Event	Mean Increase in Polarization from Migration	% Iterations in Which Change Point Detected
03/1975–04/1975	Filibuster Reform	.027 (.0004)	88.3
06/1978–10/1978	New Right Emerges	.026 (.0004)	90.9
09/2009–03/2010	Affordable Health Care Act	.024 (.0007)	89.8
02/2003–06/2003	Invasion of Iraq	.024 (.0006)	84.9
09/1995–02/1996	Budget Showdown	.016 (.0007)	77.3

that characterizes many of the legislative events discussed above. An alternative explanation more in line with those above is that the Senate spent much of that spring debating a major tax reform bill.

The change-point model is useful for identifying periods of abrupt change but is less useful in measuring the effect these policy debates had on polarization. The change-point model, which searches for jumps from one month to the next, is biased against identifying change points in consecutive months. Yet the Senate spent months crafting and deliberating the legislation in question. To measure the effect of each debate, I identify the months that correspond with the beginning and ending of each legislative battle and measure the mean increase and jackknifed standard error for the period. I also calculate the percentage of jackknife samples that detect jump points during the period. I then take the first and last dates in the period and calculate the increase in the migration trend. Table 2 reports the dates of each period, the mean increase in polarization resulting from the migration and the percentage of jackknife samples that detect at least one change point during the period.

The magnitudes provide compelling evidence that migration increases polarization in quick, widely spaced bursts rather than as a gradual process. In fact, the average net increase in polarization during these events, which encompass just 22 out of 938 months, is 0.09, accounting for three-quarters of the total increase in polarization resulting from migration. Nearly the entire increase in polarization observed since 2000 resulted from just two migration shocks.

Discussion

In interpreting the findings, it is important to recognize the limitations of using roll-call scaling methods to study Congressional polarization. Ultimately, legislative voting behavior is a product of an induced utility function, in which the personal preferences of legislators are the dominant but not sole input. As such, the recovered ideal points are best understood as measures of ideological voting, not the idealized form of ideology, per se. Likewise, the polarization trends analyzed above are best understood as measuring changes in patterns of ideological voting.

Similar to other roll-call scaling methods, dynamic OC does not model the processes determining which bills come before the floor for a vote. This makes it difficult to disentangle the extent to which the findings regarding ideological migration might also reflect changes in the agenda and rightly raises concerns that migration shocks are partly explained by temporary changes in the agenda as the issues in contention are voted on with greater frequency. But if the objective of the measure is to track changes in partisan polarization in roll-call voting, then there is a strong case to be made in favor of having the primary dimensions of political conflict adjust as issues emerge, realign, and fade away. From this perspective, an advantage of the dynamic-scaling methodology is that it offers localized estimates of how issues map onto the primary dimensions of ideological conflict as reflected in voting patterns.

Nevertheless, there is evidence that the migration shocks are more than temporary blips in response to agenda change. In particular, none of the jumps is followed by a sudden drop returning polarization to previous levels, as might be expected after the legislation in contention has been resolved. In fact, the migration shocks generally appear to have lasting influence. Rather than a spike in polarization that quickly returns to its previous level, the trend typically remains at its heightened level.

Regardless of the extent to which agenda change or the strategic machinations of party leaders have contributed to this trend, it is clear that Senate voting patterns have polarized. What this study offers is a better read on how the trend evolved with time and new insights about its underlying causes that suggests a path forward for future research on this important topic.

Conclusion

Improving our understanding of Congressional polarization entails tracking its progress and documenting the patterns and forces driving the parties apart. I challenge Poole's claims about ideological constancy and member replacement using the same nonparametric scaling methodology upon which he bases his findings. Of course, one need not interpret Poole's finding of ideological constancy in such a stringent manner. In its stronger form, it states that for the duration of their careers members maintain a single position along an unchanging liberal-conservative dimension. A weaker form holds that full-out ideological conversions are rare but would allow for legislators to adapt to changing policy evidence, legislative issue agendas, constituencies, and electoral landscapes. The results presented here confirm that senators seldom experience ideological conversions but also reveal senators to be subject to meaningful ideological change.

The above findings contrast with accounts of Congressional polarization that view member replacement and ideological migration as opposing explanations. They have both contributed to Senate polarization, but their effects were not felt simultaneously. Ideological migration has in recent years eclipsed member replacement as the driving force behind Senate polarization. This should encourage researchers to continue to look beyond member replacement as the dominant force underlying polarization since the mid-1990s.

Perhaps the most important finding is that ideological shocks rather than ideological drift better account for migration's effect on Senate polarization. It tells us that the "electoral connection" is at best an incomplete explanation of how ideological migration contributed to Senate polarization. If senators were adapting to electoral change brought about by constituency sorting, we would expect a gradual migration trend. Yet the recovered trend reveals that ideological migration in the Senate is not characterized by gradual change. It instead suggests that rule changes and bitter partisan fights have contributed more than their fair share to the historic rise in Senate polarization.

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APPENDIX A

Dynamic OC-Scaling Methodology

A formal description of the nonparametric kernel as applied to Poole's legislator recovery algorithm $L(.)$ is as follows. For legislator i on roll call j, let $\theta_{ij} = \hat{L}\left(\boldsymbol{y}_{i[j-h/2,j+h/2]}; \boldsymbol{\delta}_{[j-h/2,j+h/2]}\right)$ where θ_{ij} is the ideal-point estimate for legislator i at roll call j; $\boldsymbol{y}_{i[j-h/2,j+h/2]}$ is a vector of vote outcomes for legislator i within the fixed window width h; and $\boldsymbol{\delta}_{[j-h/2,j+h/2]}$ is a matrix of roll-call parameters (normal vectors, cutting lines, roll-call directions).

In order to guarantee strict convergence, two rejection criteria are imposed on newly estimated smoothed legislator ideal points. The first simply requires that newly estimated trends reduce the total number of classification errors. The second criterion requires that the new trends reduce the "signal-to-noise" ratio, which is defined as the ratio of classification rate to total movement. It is calculated using the equation, $\nabla = \sum_{i=1}^{I} \sum_{j=2}^{J} \left|\theta_{sij} - \theta_{si(j-1)}\right|$. In most cases, a trend that is substantially more erratic and only slightly increases classification will be rejected. Newly estimated trends must satisfy both criteria. Any legislator trend that fails to pass the rejection criteria reverts to the estimates from the previous round. This ensures that each legislator's trend climbs uphill in each iteration. The algorithm to perform the scaling is as follows:

Algorithm for dynamic OC:

1. Get starting values for each period from the eigenvectors of the double-centered legislator agreement-score matrix and scale each period separately using OC.
2. Apply Poole's common-space bridging algorithm to bridge across periods (Poole 1998). This is performed using the *basic space* package in R.
3. Run OC until convergence with legislator estimates held constant across periods.
4. Recover legislator trends with kernel estimators for all individuals with at least h votes.
5. Replace newly estimated trends that do not meet the rejection criterion with the trends from the previous round.
6. Rerun the cutting plane procedure conditional on legislator trends estimated in step 4.
7. Go to step 3. Repeat until convergence.

Specifying the model involves a choice of kernel. A uniform kernel is the simplest but provides poor estimates at the tails. This is because there are fewer than h votes available to fit the local estimates. Rather than break uniformity of window width, when specifying a uniform kernel I set the estimates for $j < h/2$ to $\theta_{is(h/2)}$ and the estimates for $j > J - h/2$ to $\theta_{is(J-h/2)}$. This means that the legislator's trend is held constant for the first $h/2$ votes and again for the final $h/2$ votes.

One way to improve estimates at the tails is to distance-weight errors. Tri-Cube Weighted kernel estimators use the same set of observations per window as the uniform kernel but penalize errors such that temporally distant votes receive less weight. Modified for $\hat{L}(.)$ the weight is given by,

$$w(v_x) = \begin{cases} \left(1 - \left|\dfrac{v_x - v_j}{m}\right|^3\right)^3 I(x) & \text{for } \left|\dfrac{x-j}{m}\right| < 1 \\ 0 & \text{for } \left|\dfrac{x-j}{m}\right| \geq 1 \end{cases},$$

where v_j is the date of the vote at the center of the window; v_x is the date of the vote being weighted; $I(x)$ is an indicator function that takes on the value 1 if x is a voting error and 0 otherwise; and m is the maximum distance of votes included in the window, such that $m = max(|v_j - v_{(j-h/2)}|, |v_j - v_{(j+h/2)}|)$. An error that occurs on the date of the roll call receives full weight, an error on the furthest date in the window receives no weight, and errors on all other dates receive weights in the range (0, 1).

I report the classification statistics for both the uniform and tri-cube kernels in Appendix B. Although tri-cube weighted kernels produce better estimates at the tails, the downside is that legislator trends become much more dynamic, roughly tripling values of ∇ over uniform kernels with the same window width. For this reason, all I use is a uniform kernel.

APPENDIX B

Classification Results from the U.S. Senate

Table A1 lists the correct classification rate, total errors, and total movement of the legislators for DW-NOMINATE, constant OC, and dynamic OC for four values of *h*. The

TABLE A1
1st through 111th U.S. Senates

	Correct Classification	APRE	Errors	∇_1	∇_2
WNOMINATE(constant)	85.2	56.3	435429		
DW-NOMINATE	85.7	57.8	420622		
Constant OC	88.4	65.7	330691		
Constrained period-Specific OC	89.0	67.6	312942		
Unconstrained period-Specific OC	89.3	68.4	304905		
Dynamic OC					
Uniform Kernel					
h = 100	90.9	73.1	259120	3364	6200
h = 150	90.4	71.5	274489	1713	3379
h = 200	90.0	70.1	284031	993	2007
h = 250	89.9	70.0	289104	644	1300
h = 300	89.6	69.3	296282	459	921
h = 350	89.5	68.8	301034	326	688
Tri-Cube Weighted Kernel					
h = 100	91.7	75.6	235499	8606	15623
h = 150	91.1	73.6	254455	4599	9130
h = 200	90.6	72.3	266854	2769	5740
h = 250	90.3	71.4	276301	1873	3855
h = 300	90.1	70.6	283240	1306	2752
h = 350	89.9	70.1	288142	949	2055

Note: The Constant-OC model pools all roll calls and legislators by estimating a single ideal point for the entirety of a legislator's career. The Constrained period-specific OC model uses the roll-call estimates from the Constant-OC scaling to estimate Congress-specific estimates for each legislator, as discussed in the second section. In contrast, the Unconstrained Congress-specific model estimates each Congress individually and does not produce estimates that can be compared over time. All results are from two-dimensional scalings. The congressional voting records are from Poole and Rosenthal's voteview.com.

TABLE A2
Correlations of Legislator Estimates from Two-Dimensional Scalings of the 1st–110th U.S. Senates with Uniform Kernels Across Varying Window Widths

	$h = 100$	$h = 150$	$h = 200$	$h = 250$	$h = 300$	$h = 350$
Dimension 1						
$h = 100$	1.000					
$h = 150$	0.964	1.000				
$h = 200$	0.960	0.975	1.000			
$h = 250$	0.957	0.973	0.983	1.000		
$h = 300$	0.955	0.971	0.981	0.987	1.000	
$h = 350$	0.954	0.969	0.980	0.986	0.989	1.000
Dimension 2						
$h = 100$	1.000					
$h = 150$	0.895	1.000				
$h = 200$	0.883	0.929	1.000			
$h = 250$	0.876	0.922	0.949	1.000		
$h = 300$	0.870	0.915	0.945	0.958	1.000	
$h = 350$	0.862	0.907	0.939	0.955	0.965	1.000

increase in classification that accompanies allowing for within-period movement is evidence that senators shift positions within, not just across, periods in a nonrandom fashion. The fourth and fifth columns provide a general measure of how constrained legislator estimates are from one roll call to the next. Selecting a value of h comes with an inherent trade-off between correct classification and trend stability. The larger the window size, the more confident we are that the trends reflect actual changes in voting behavior, as estimates become increasingly robust to the data-generating process. On the other hand, larger window widths decrease the sensitivity of the results. Reducing the window width relaxes the level of constraint—i.e., the "glue" that holds the ideological space together. As a result, the estimates become more localized, in turn causing legislator trends to become more dynamic. Smaller window sizes can be useful in detecting temporary changes in voting patterns but tend to decrease the signal-to-noise ratio.

Table A2 displays the correlation coefficients of legislator estimates from scalings specified with different window widths. The directly off-diagonal cells are the most informative. The correlations are increasing with h, indicating that trends become more consistent with larger window widths. For any two values of $h \geq 200$, the two sets of converged estimates correlate at or above .98 on the first dimension and .934 on the second dimension. The uniform and weighted kernel estimates are also highly correlated. The correlation between the uniform and weighted kernel estimates each with a window width of 250 is 0.976 for the first dimension and 0.930 for the second dimension.

NOTES

1. It takes approximately five hours for the model to converge when scaling the 1st–111th Senates on a current CPU core. It takes over a day for scaling the 1st–111th Houses to converge.

2. Focusing the analysis on the Senate also bestows other advantages. Unlike the House, Senate seats are not subject to redistricting and the sometimes sudden changes in constituencies that accompany it. In addition, the influence of party leaders is attenuated as compared to the House.

3. Of course, it is possible for either pattern to result from changes in party strategies. While worth noting, determining the extent to which shifting party strategies or any other specific explanations have contributed to polarization is not the focus of this article. Instead, the analysis is designed to speak very generally to whether Congress has polarized in response to its internal dealings and affairs or has simply been swept along by the tides of member replacement and shifting constituencies.

4. An alternative approach is to treat each day as a period. This reduces the total number of parameters to be estimated by grouping together all votes cast by a legislator on a given day.

5. For a complete treatment of this algorithm, see (Poole 2005).

6. See Bonica (2011) for a complete treatment of the dynamic OC method.

7. The APRE is the total sum of PRE over the total number of roll calls included in the scaling. The equation for proportional reduction in error (PRE) for each roll call is, $\frac{\text{votes in the minority} - \text{errors}}{(\text{vote in the minority})}$. It reports the marginal increase in the number of votes correctly predicted by the cutting plane over the null prediction of assuming everyone votes in the majority.

8. A cross-validation test identified as optimal a window size of between 200 and 250 votes.

9. Their sampling process can be broken down into three steps. They first run W-NOMINATE to convergence and calculate the probabilities for each observed vote choice. They then draw for each nonmissing cell in the vote matrix a value from the uniform distribution over 0 to 1. If the random draw is greater than the estimated probability for observing the vote choice, they flip the direction of the observed vote from yes to no or vice versa. If the random draw is less than the estimated probability, the observed value is used. They repeat this process a thousand times to recover standard errors.

10. This differs from the bootstrap which draws random samples with replacement.

11. I thank Howard Rosenthal for both the uncertainty jackknifing scheme and the analogy.

12. To elaborate on calculating the replacement effects, assume the Senate is evenly divided with 50 members from each party and that the party means for Democrats and Republicans are at −0.5 and 0.5, respectively. Now suppose an exiting Democrat with an ideal point of −0.1 is replaced by an incoming Republican with an ideal point of 0.9. The resulting replacement effect is calculated as the overall change in the distance between party means. Given the initial distance between party means of $\left|\overline{Rep_1} - \overline{Dem_1}\right| = |0.5 - -0.5| = 1.0$ and the postreplacement of $\left|\overline{Rep_2} - \overline{Dem_2}\right| = |0.5078 - -0.5081| = 1.0160$, the resulting replacement effect is 0.016.

13. The Bayesian change-point analysis was performed using the *bcp* package in R with 20,000 iterations following 5,000 burn-in iterations (Erdman and Emerson 2007). The prior probability of observing a change point during a given month is set to 0.05.

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