

# A sign of the times? Weak and strong polarization in the U.S. Congress, 1973–2016

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## ABSTRACT

Claims that the United States Congress is (becoming more) polarized are widespread, but what is polarization? In this paper, I draw on notions of intergroup relations to distinguish two forms. Weak polarization occurs when relations between the polarized groups are merely absent, while strong polarization occurs when the relations between the polarized groups are negative. I apply the Stochastic Degree Sequence Model to data on bill cosponsorship in both the U.S. House of Representatives and U.S. Senate, from 1973 (93rd session) to 2016 (114th session) to infer a series of signed networks of political relationships among legislators, which I then use to answer two research questions. First, can the widely reported finding of increasing weak polarization in the U.S. Congress be replicated when using a statistical model to make inferences about when positive political relations exist? Second, is the (increasing) polarization observed in the U.S. Congress only weak polarization, or is it strong polarization? I find that both chambers exhibit both weak and strong polarization, that both forms are increasing, and that they are structured by political party affiliation. However, I also find these trends are unrelated to which party holds the majority in a chamber.

## Introduction

Claims that U.S. politics in general, and the U.S. Congress in particular, are (becoming more) polarized are now standard fare from media outlets (e.g. *The Economist*, 2013; *Ingraham*, 2015; *Drutman*, 2016), and exist alongside a rich literature within political science on polarization and partisanship (e.g. *Layman et al.*, 2006). Increasingly these claims are grounded in the patterns observed in legislators' political networks (*Alemán and Calvo*, 2013; *Andris et al.*, 2015; *Briatte*, 2016; *Cho and Fowler*, 2010; *Desmarais et al.*, 2015; *Fowler*, 2006a, 2006b; *Kirkland*, 2011, 2013, 2014; *Kirkland and Gross*, 2014; *Moody and Mucha*, 2013; *Neal*, 2014; *Porter et al.*, 2005; *Rippere*, 2016; *Waugh et al.*, 2011; *Zhang et al.*, 2008), which highlight that polarization is a relational phenomenon, and in particular a phenomenon rooted in the nature of intergroup relations (*Hewstone et al.*, 2002). But, questions remain about what kind of legislative intergroup relations constitute polarization and about how to measure those relations.

Most prior accounts of legislative polarization as a relational phenomenon have defined it as occurring when legislators can be partitioned into groups such that members of the same group are linked to one another by positive relations (e.g. of ideological alignment, collaboration, or cooperation), and members of different groups are not (e.g. *Moody and Mucha*, 2013; *Waugh et al.*, 2011; *Zhang et al.*, 2008).

Defined in this way, polarization is the political analog to the social psychological case of in-group favoritism *without* out-group derogation (*Brewer*, 1999; *Levin and Sidanius*, 1999; *Hewstone et al.*, 2002), which in this paper I call *weak polarization*. Past research on weak polarization has focused on political networks constructed via bipartite projection, viewing legislators as having a political relation when they engage in co-sponsorship of bills (e.g. *Fowler*, 2006a), co-voting on bills (e.g. *Andris et al.*, 2015), co-membership on committees (e.g. *Porter et al.*, 2005), and co-attendance at press events (e.g. *Desmarais et al.*, 2015). Inferring political relations from such co-behaviors can be promising, but this past work often fails to account for structural distortions present in bipartite projections (e.g. inflated density and clustering), which calls into question past conclusions about polarization. Applying the Stochastic Degree Sequence Model (SDSM; *Neal*, 2014), which is one approach to overcoming these distortions, I ask: *Can the widely reported finding of (increasing) weak polarization in the U.S. Congress be replicated when using a statistical model to make inferences about when positive political relations exist?*

Although most prior studies of legislative networks have considered only positive political relations, legislators can also be linked to one another by negative relations (e.g. of ideological misalignment, opposition, or competition). When both positive and negative relations are known, it is possible to identify what I call *strong polarization*, in which

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the relations between polarized groups are not merely absent but instead are negative. Defined in this way, strong polarization is the political analog to the social psychological case of in-group favoritism with out-group derogation (Brewer, 1999; Levin and Sidanius, 1999; Hewstone et al., 2002). This conception of polarization more explicitly includes the role of opposition, which is intuitively part of polarization but has been absent from past studies of polarization. Because the SDSM allows inferences to be drawn about both positive and negative political relations, I use it to ask: *Is the (increasing) polarization observed in the U.S. Congress only weak polarization, or is it strong polarization?* Although any polarization may be problematic because “it impedes steps necessary to solve mounting national problems” by making compromise more difficult (Pierson, 2015), understanding the specific form of polarization is also important because weak and strong polarization may differ in the severity of impediments to compromise that they create.

I answer these two questions by examining bill co-sponsorship patterns in both the U.S. House of Representatives and U.S. Senate, from 1973 (93rd session) to 2016 (114th session)<sup>1</sup>. By exploring these two questions over such a long period, it is also possible to consider whether these trends in polarization are associated with shifts in the majority political party. The remainder of the paper is organized in four sections. In this first section, I review how networks have been used to understand political polarization and introduce intergroup relations as way to distinguish weak from strong polarization. In the second section, I describe bill co-sponsorship data as a way to measure legislators’ political relations, focusing on the challenges of this approach and discussing methods of making more principled inferences from these data. The third section presents evidence about the presence and growth of positive and negative relations among legislators at the dyad-level, then of both weak and strong polarization in the U.S. Congress. In the concluding section, I summarize these findings, comment on their limitations and directions for future research, and discuss the implications of growth of the previously unstudied strong form of polarization.

## What is polarization?

### Polarization in political networks

Polarization is a broad concept that refers to the existence (or process of formation) of distinguishable groups that differ on one or more characteristics. Political polarization focuses on differentiation by political ideology, which in the United States is often associated with political party affiliation, and thus is often described as partisan polarization or partisanship (Layman et al., 2006). Within political polarization, it is common to distinguish mass polarization, which occurs among the electorate, from elite polarization, which occurs among the elected. In this paper, I focus on a specific form of elite political polarization: polarization among legislators. Legislators are particularly important political actors because they (are supposed to) serve as political representatives of the electorate and are directly responsible for the creation of law. Evidence of legislative polarization has been demonstrated in the U.S. Congress (e.g. Zhang et al., 2008), U.S. states (Kirkland, 2013), and parliaments throughout Europe (Briatte, 2016). In political science, ideological scores such as DW-NOMINATE (McCarty et al., 2006), which place individual legislators on a liberal-conservative continuum based on their voting patterns, have been the

most widely used approach to measuring legislative polarization. By providing a single score for each legislator, this approach is appealing in its simplicity and interpretability, but fails to directly capture the relational nature of polarization. As a result, attention has turned to studying polarization in legislators’ political networks.

A great deal of effort has been devoted to studying the networks among legislators to better understand the legislative process. Because discerning a politician’s true position and political relationships can be challenging (Clayman, 2017), in nearly every case these networks are measured indirectly using legislators’ co-behaviors, including their co-sponsorship of bills (e.g. Fowler, 2006a), their co-voting on bills (e.g. Andris et al., 2015), their co-membership on committees (e.g. Porter et al., 2005), and their co-attendance at press events (e.g. Desmarais et al., 2015). Two legislators’ joint participation in these events is typically interpreted as an indirect indicator of a relation between them. For example, as a public expression of mutual support for a common goal, two legislators’ sponsorship of the same piece of legislation is interpreted as evidence of their collaboration or cooperation in the legislative process of shepherding bills from introduction, through debate, to a vote, and hopefully their passage into law (Kirkland, 2013; Andris et al., 2015). Although the specific type of relationship might depend on the behavior – coordination may be indicated by co-voting (Waugh et al., 2011), while collaboration may be indicated by co-attendance (Desmarais et al., 2015) or co-sponsorship (Kirkland and Gross, 2014) – the relationships inferred from co-behaviors are implicitly positive ones.

These types of implicitly positive-relation legislative networks have been studied at the national level in the United States (Andris et al., 2015; Cho and Fowler, 2010; Fowler, 2006a, 2006b; Kirkland, 2011; Kirkland and Gross, 2014; Moody and Mucha, 2013; Neal, 2014; Porter et al., 2005; Rippere, 2016; Waugh et al., 2011; Zhang et al., 2008), and throughout Europe (e.g. Briatte, 2016) and South America (e.g. Alemán and Calvo, 2013), as well as at the state level in the United States (Kirkland, 2011, 2013, 2014). Across these diverse settings, using different data sources and methods, these studies have consistently found that legislators form distinct groups that are bound together by these positive relations, and distinguished from one another by the relative absence of positive relations between them. This has been interpreted as evidence of, and indeed is often proposed as the very definition of, polarization.

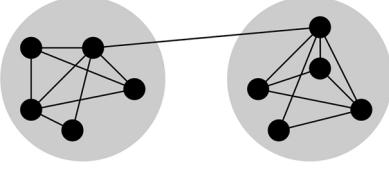
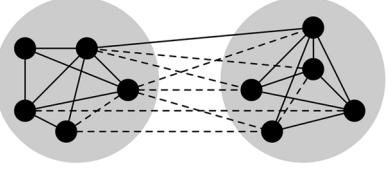
### Intergroup relations and types of polarization

Nearly all studies of polarization in legislative networks seek to identify instances where legislators’ networks resemble the example in the left column of Table 1: groups of legislators are distinguishable by the presence of positive relations within the groups, and by the absence of positive relations between the groups. Such a pattern occurs, for example, in the classic instance of partisan polarization when members of the same party collaborate, but members of different parties do not. This pattern has a direct analog in the more general literature on intergroup relations, corresponding to the case of in-group favoritism without out-group derogation. (Brewer, 1999; Levin and Sidanius, 1999; Hewstone et al., 2002). I call polarization that takes this form *weak polarization*. It is a weak form of polarization not only because this type of structure occurs without any explicitly negative relations, but also because its extent can be reduced by the formation of just a few new positive relations. A few new between-party collaborations on legislation (i.e. bipartisanship) can transform a weakly polarized legislative body into one that is significantly less polarized. Past evidence of weak polarization has rested on indirectly measuring positive relations between legislators using an approach that, for reasons I discuss in the methods section, is potentially problematic. Thus, in the analyses I present below, I ask: *Can the widely reported finding of (increasing) weak polarization in the U.S. Congress be replicated when using a statistical model to make inferences about when positive relations exist?*

<sup>1</sup> Since the 1930s, a session of the U.S. Congress begins on January 3 of an odd-numbered year, and runs until January 3 of the next odd-numbered year (e.g. the 114<sup>th</sup> session ran from 3 January 2015 through 3 January 2017). For the sake of convenience, throughout the paper and in the figures, I refer to the years of a congressional session rather than the session number, and report the years as the starting odd-numbered year and the following even-numbered year (e.g. I report the 114<sup>th</sup> session as 2015–2016).

**Table 1**

Intergroup relations and types of polarization.

Type of polarization	Weak	Strong
Intergroup relations analog	In-group favoritism <i>without</i> out-group derogation	In-group favoritism <i>with</i> out-group derogation
Network Definition	Groups are distinguishable by the presence of (implicitly positive) relations within groups, and by the absence of (implicitly positive) relations between groups.	Groups are distinguishable by the presence of positive relations within groups, and by the presence of negative relations between groups.
Measurement	Modularity in a non-signed graph	Triangle index in a signed graph
Example Network		
Relations		
— Positive		
- - - Negative		

Most social psychological research on intergroup relations focuses on this type of pattern, leading [Hewstone et al. \(2002\)](#) to summarize that “the bias uncovered in social-psychological research predominantly takes the mild form of in-group favoritism, rather than out-group derogation” (p. 579; [Brewer, 1999](#); [Levin and Sidanius, 1999](#)). There are a number of reasons that such a configuration is so frequently observed in intergroup research. For example, [Skvoretz \(2013\)](#) showed that it would emerge from individuals’ attraction to similar others, their repulsion from or avoidance of dissimilar others, or a combination of both processes. Similarly, [Hewstone et al. \(2002\)](#) contend that it could be a methodological artifact, driven by the fact that intergroup research is rarely conducted in contexts sufficiently extreme to contain observable levels of negative relations. However, the reason that this pattern is frequently observed in legislative networks is much simpler (and also methodological): studies of legislative networks rarely attempt to measure negative relations among legislators (e.g. [Moody and Mucha, 2013](#); [Waugh et al., 2011](#); [Zhang et al., 2008](#)).

But, negative relations certainly do exist among legislators. They might occur in instances of political opposition, as is often observed in the rhetoric used by majority and minority congressional leaders when talking about the other’s legislative agenda. For example, Senate majority leader Mitch McConnell and Senate minority leader Chuck Schumer have been described as having “developed virtually no rapport in a body where trust and relationships are essential. To the extent they’ve engaged, it’s mainly been to launch political — and at times, personal — attacks” ([Raju, 2015](#)). Negative relations might also occur in instances of political competition, as is observed between even members of the same party when they advocate for different versions of the same legislation. For example, in an attempt to repeal the Affordable Care Act, “GOP Senate leadership has pinned itself between competing forces... In one corner, you’ve got Republican senators who want changes made that will clearly add to the bill’s bottom line. In the other corner, so-called ‘deficit hawks’ are fretting over the red ink” ([Eleveld, 2017](#)). What might research on legislative networks and polarization be missing by not attending to negative relations?

When negative relations exist and are measured, it becomes possible to observe the pattern shown in the right column of [Table 1](#), which corresponds to the case of in-group favoritism *with* out-group derogation ([Brewer, 1999](#); [Levin and Sidanius, 1999](#); [Hewstone et al., 2002](#)). In this case, the groups are distinguishable not merely by the absence of positive relations between the groups, but by the presence of negative relations between the groups. I call polarization that takes this form *strong polarization*. It is a strong form of polarization not only because its existence explicitly requires negative relations, but also because it is difficult to transform a strongly polarized network into a less polarized one. For example, in a partisan context, the elimination or reduction of strong polarization would require both the dissolution of between-party

negative relations and the formation of between-party positive relations, which the literature on intergroup relations suggests is not easy to do (e.g. [Hewstone et al., 2002](#)). Because to date only positive relations and levels of weak polarization in the U.S. Congress have been investigated, in the analyses I present below, I ask: *Is the (increasing) polarization observed in the U.S. Congress only weak polarization, or is it strong polarization?*

Several theories in the intergroup relations literature exist to explain the emergence of such a configuration. [Hewstone et al. \(2002\)](#) note that “the constraints normally in place, which limit intergroup bias to in-group favoritism, are lifted when out-groups are associated with stronger emotions” (p. 579), as might often be observed in contentious legislative contexts. Similarly, [Brewer \(1999\)](#) suggested that a social system may cross the “fine line between the absence of trust and the presence of active distrust” when there is intolerance for difference driven by factors with clear analogs in the legislative context: perceived threat in the face of competition over resources (e.g. committee agenda setting power), and manipulation by group leaders (e.g. president, majority/minority leaders and whips; p. 435).

Balance theory also provides a potential explanation for the formation of such a configuration, and explicitly links social psychology and network science. As initially formulated by [Heider \(1946\)](#), balance theory holds that in a triad of relations, the system is balanced and thus stable when all three relations are positive (i.e. + + +; they are all friends), or when one relation is positive and two are negative (i.e. + – –; two are friends, and they share a mutual enemy). In contrast, the system is unbalanced and unstable when one (i.e. – + +) or three (i.e. – – –) relations are negative, and will tend over time to resolve this imbalance by changing the valence of one of the relations. For example, an unstable – + + triad in which two of my friends dislike each other could become a balanced + – – triad if I align with one friend to unite against the other as our common enemy. These hypotheses have received support in a range of social settings including a fraternity at the University of Michigan ([Doreian et al., 1996](#)), urban social groups ([Rawlings and Friedkin, 2017](#)), and middle school students ([Rambaran et al., 2015](#)). [Cartwright and Harary \(1956\)](#) formalized Heider’s (1946) ideas using signed graphs. They demonstrated that as unbalanced triads transform into balanced ones, the social system will tend toward the strong polarization configuration shown in [Table 1](#), which at the extreme would include “two mutually exclusive subsets such that each positive line joins two points of the same subset and each negative line joins points from different subsets” (p. 286). Thus, balance theory also implies the formation of groups characterized by positive relations among their members, and negative intergroup relations.

## Methods

### *Bill co-sponsorship*

Politicians are busy, and they may have reasons for concealing or misrepresenting their true political relations, making data on political networks difficult or impossible to collect via direct report (Clayman, 2017; Fowler, 2006b). As a result, networks among politicians are nearly always inferred from indirect, typically archival, sources. Some have focused on legislators' committee co-memberships to infer the existence of political relations between a pair of legislators that serve on the same committees (e.g. Porter et al., 2005). However this may not reveal political relations between individual legislators because committee assignments can also be driven by non-ideological factors including seniority. In other cases, the focus is on similarity in voting, grounded in the assumption that if two legislators vote similarly, they share political views (Andris et al., 2015; Moody and Mucha, 2013; Waugh et al., 2011). This strategy is promising because it relies on legislators' outward expressions of their political views. However this approach risks selection bias because legislators only vote on a small fraction of legislation that is introduced (Carrubba et al., 2008). For example, in the 1973–1974 session, 26,222 bills were introduced but only 2% (562) were voted on, and by the 2015–2016 session, this number had risen only slightly to 5% (661 of 10,334 bills).

The most common strategy for indirectly inferring legislators' relations is through bill co-sponsorship data, which has been examined in both state and federal legislative bodies throughout the world (Alemán and Calvo, 2013; Briatte, 2016; Cho and Fowler, 2010; Fowler, 2006a, 2006b; Kirkland, 2011, 2013, 2014; Kirkland and Gross, 2014; Neal, 2014; Rippere, 2016; Zhang et al., 2008). Although there is some variation across these contexts, the process of bill co-sponsorship closely resembles that used in the U.S. Congress. In both chambers of the U.S. Congress – the U.S. House of Representatives and U.S. Senate – a piece of legislation is introduced for consideration by a legislator who serves as its "sponsor," while other legislators in the same chamber can express their support for the legislation by co-sponsoring it (Wilson and Young, 1997). These data are more useful than committee membership or voting patterns because they exist for all pieces of legislation and are explicit expressions of each legislator's own legislative agenda.

Several nuances of bill co-sponsorship in the U.S. Congress impact how these data can be used. First, which sessions of Congress should be considered? Electronic data on bill co-sponsorship are available for both chambers of the U.S. Congress starting in the 1973–74 session. However, until the 1979–80 session, a single piece of legislation introduced in the House of Representatives could be cosponsored by a maximum of 25 representatives (Thomas and Grofman, 1993). This restriction led to the introduction of uniquely-numbered duplicates of the same legislation to allow more than 25 representatives the opportunity to express support for popular legislation. Therefore, I examine all electronically available co-sponsorship data in the Senate (1973–present), but only examine co-sponsorship data in the House from the 1979–80 session onward.

Second, which types of legislation should be considered? Four types of legislation may be introduced in the U.S. Congress: bills (consecutively numbered S.# in the Senate and H.R.# in the House), joint resolutions (S.J.Res. & H.R.Res.), concurrent resolutions (S.Con.Res. and H.Con.Res), and simple resolutions (S.Res. & H.Res.). Only bills and joint resolutions have the force of law if passed, so I restrict my attention to these types of legislation. Over the sessions examined, an average of 6482 bills were sponsored in each House session (s.d. = 1039), and an average of 3490 bills were sponsored in each Senate session (s.d. = 522).

Third, should sponsors and co-sponsors be distinguished? The sponsor of a piece of legislation is simply the first among potentially many legislators responsible for actually introducing it to the chamber

for consideration. However, the sponsor is not necessarily the person who drafted the legislation, who in practice may be a group of legislative support staff possibly spanning multiple legislators' offices, nor its most significant champion in subsequent deliberation (Wilson and Young, 1997). Therefore, I ignore the distinction between sponsor and co-sponsor, treating all legislators sponsoring or co-sponsoring a piece of legislation equally, and using the term "co-sponsor" for all of them.

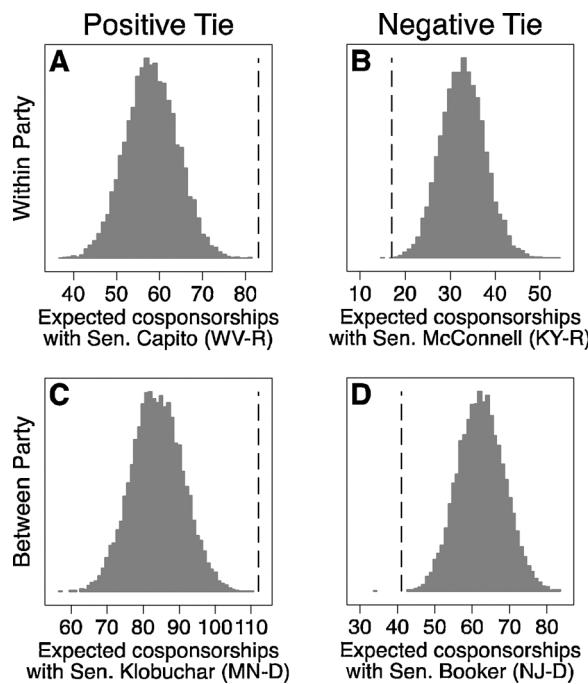
### *Inferring positive and negative political relations*

A final critical question for inferring political relations from bill co-sponsorship data is: how many pieces of legislation must two legislators jointly co-sponsor before an inference that they have a positive (or negative) relation is warranted?

The most common approach involves adopting a universal threshold (typically zero), then defining a pair of legislators as having a relation if their number of joint co-sponsorships exceed the threshold (Cho and Fowler, 2010; Fowler, 2006a, 2006b; Kirkland, 2011, 2013; Kirkland and Gross, 2014; Rippere, 2016). However, this approach yields networks that are necessarily dense and clustered. It also offers a questionable rationale for such inferences because it ignores the number of pieces of legislation co-sponsored by a legislator and the number of co-sponsorships received by a piece of legislation, both of which vary significantly. Serrano et al. (2009) summarized the problem introduced by ignoring such details by noting that "strongly disordered networks with heavy-tailed [degree] distributions cause this simple thresholding algorithm to be very poorly performing since nodes with small [degree] are systematically overlooked" (p. 6486). More concretely, in the legislative context, observing that two legislators engaged in many joint co-sponsorships may not be particularly noteworthy, and thus may not warrant inferring they have a relationship if (a) they both frequently co-sponsored legislation and (b) the legislation they both co-sponsored was non-controversial and widely sponsored by others also. Conversely, observing that two legislators engaged in few joint co-sponsorships may still be noteworthy and warrant inferring they have a relationship if (a) they both rarely co-sponsored legislation and (b) the legislation they co-sponsored was controversial and sponsored by few others.

To avoid these problems, I use the stochastic degree sequence model (SDSM), which was developed as a general framework for making inferences about relations in bipartite projections based on conditional null probability distributions of edge weights (Neal, 2014). Applied in this context, it generates a distribution of the number of bills two legislators might have jointly co-sponsored if the two legislators co-sponsored bills randomly, but (a) the legislators sponsored roughly the same number of bills and (b) the bills received roughly the same number of sponsorships. This distribution represents the expected number of joint co-sponsorships under a chance null hypothesis, that is, the number of joint co-sponsorships that would be observed if legislators randomly sponsored legislation. A pair of legislators' observed number of joint co-sponsorships is then compared to the empirically derived null distribution, with decisions about the statistical significance of an edge made using a two-tailed  $\alpha$ -level of 0.05. A positive relation exists when two legislators jointly co-sponsor significantly more bills than expected under the null hypothesis. Conversely, a negative relation exists when two legislators jointly co-sponsor significantly fewer bills than expected under the null hypothesis.

Fig. 1 uses the example of Sen. Susan Collins (ME-R) in the 2015–2016 session to illustrate the approach. Each plot shows the conditional null distribution of the number of jointly co-sponsored bills for a pair of legislators, while the dashed line marks their observed number of joint co-sponsorships. Fig. 1A shows that Collins jointly co-sponsored many more bills (83) than expected with Sen. Capito (WV-R), which suggests that they have a positive relation. This conclusion is consistent with their similar DW-NOMINATE ideology scores (Collins = 0.106,



**Fig. 1.** Examples of Sen. Susan Collins' (ME-R) positive relations (A & C) and negative relations (B & D) in the 2015–16 session of the U.S. Congress, inferred using the SDSM. Dashed lines identify the observed number of joint co-sponsorships, while the histogram shows the number expected in 10,000 SDSM null model replications.

Capito = 0.255).<sup>2</sup> It is also consistent with reports of their coordination to block the repeal of the Affordable Care Act (ACA; Rubin, 2017). Likewise, Fig. 1B shows that Collins jointly co-sponsored many fewer bills (17) than expected with Sen. McConnell (KY-R), which suggests they have a negative political relation. This is consistent with their dissimilar ideology scores (McConnell = 0.404) and her highly publicized role in blocking McConnell's attempted repeal of the ACA.

Similar patterns can be seen in Collins' relations with Democrats. Her joint co-sponsorship of more bills (112) than expected with Sen. Klobuchar (MN-D) suggests a positive relation, consistent with their similar (for members of opposing parties) ideology scores (Collins = 0.106; Klobuchar = -0.237) and their ongoing collaboration to promote funding for Alzheimer's research (Press Releases 1/29/2016 & 2/6/2017; Fig. 1C). Finally, the smaller than expected number of jointly co-sponsored bills (41) with Sen. Booker (NJ-D) suggests a negative relation, consistent with their dramatically different ideology scores (Booker = -0.498; Fig. 1D). These examples highlight that positive and negative relations identified by this approach are not necessarily linked to party affiliation, and that the number of joint co-sponsorships necessary to infer that a positive or negative relation exists is unique to each pair of legislators.

#### Measuring polarization in political networks

In graph theoretic terms, weak polarization occurs when (implicitly

<sup>2</sup> DW-NOMINATE ideology scores are widely used in political science to measure legislators' ideological positions. They are obtained by applying a multidimensional scaling algorithm to roll call voting data, and range along a single conservative (positive scores) to liberal (negative scores) continuum (McCarty et al., 2006). For example, Sen. Collins score of 0.106, which is near 0, indicates her position as a center-leaning conservative. The scores reported here were computed by Jeff Lewis, Nolan McCarty, Keith Poole, and Howard Rosenthal and available at [http://k7moa.com/Weekly\\_Constant\\_Space\\_DW-NOMINATE\\_Scores.htm](http://k7moa.com/Weekly_Constant_Space_DW-NOMINATE_Scores.htm).

positive) edges in a non-signed graph are located within, but not between, groups. It can therefore be measured using an index of modularity, which quantifies the extent to which a network partition exists that satisfies these properties (Newman and Girvan, 2004), and which has been widely adopted as an indicator of legislative polarization (Baldassarri and Bearman, 2007; Kirkland, 2011, 2013, 2014; Kirkland and Gross, 2014; Moody and Mucha, 2013; Waugh et al., 2011; Zhang et al., 2008). In the analyses reported below, following the approach used by Zhang et al. (2008), modularity is measured using Newman and Girvan's (2004)  $Q$ , with a partition based on political party affiliation. It therefore measures the extent of weak partisan polarization (Table 1, left column).

Strong polarization occurs when positive edges are located within groups, and negative edges are located between groups. Because strong polarization occurs in signed networks composed of both positive and negative edges, it cannot be measured by conventional modularity metrics (Traag and Bruggeman, 2009). However, in the two-party context of the U.S. Congress, strong polarization mirrors what Cartwright and Harary (1956) define as a balanced graph: "all points [i.e. legislators] can be separated into two mutually exclusive subsets [i.e. Republicans and Democrats] such that each positive line joins two points of the same subset and each negative line joins points from different subsets" (p. 286). To measure the extent to which the network satisfies this property (i.e. is balanced), I use what they called the degree of structural 3-balance and what more recently is called the triangle index, which is the proportion of all triangles that are balanced (Aref and Wilson, 2018; Doreian and Mrvar, 2016; Table 1, right column).

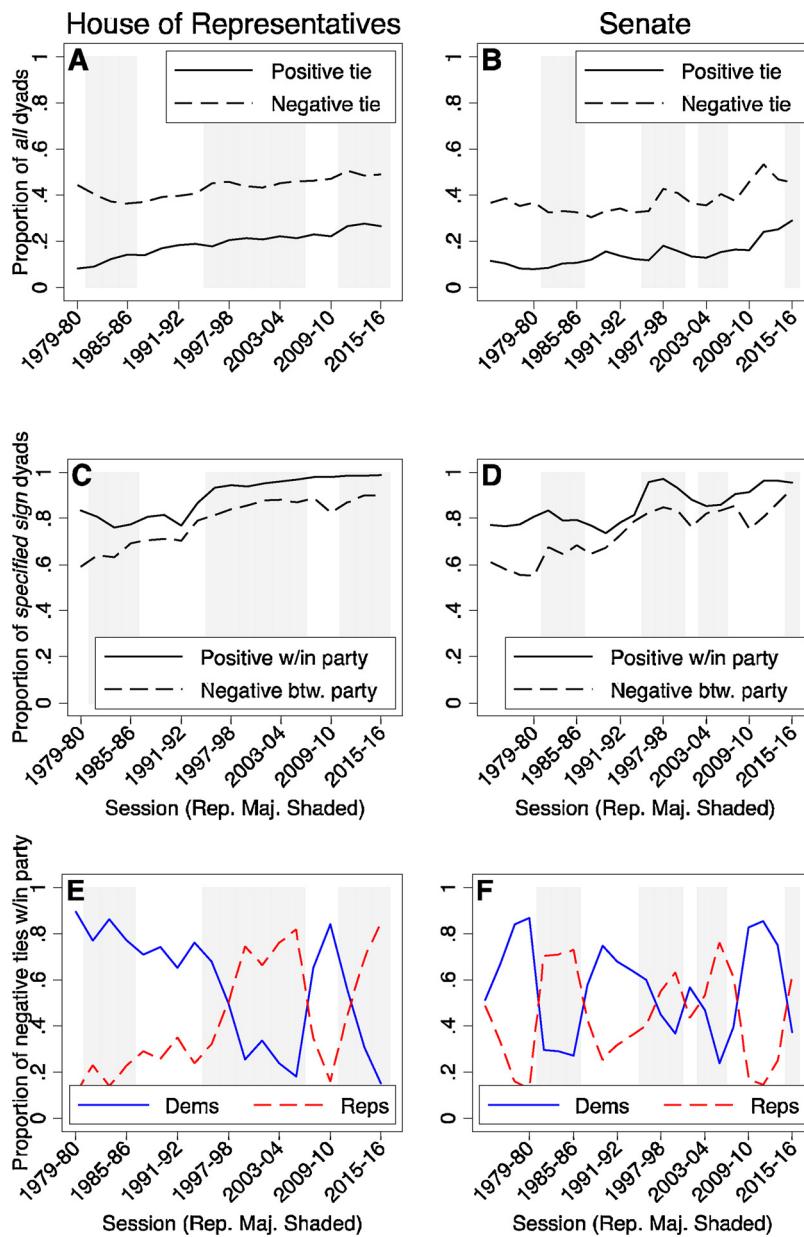
#### How polarized is it?

##### Positive and negative relations

Before turning to polarization, it is helpful to first consider dyad-level trends in positive and negative political relations. Fig. 2A & B show the proportion of dyads linked by a positive relation (solid line) or negative relation (dashed line) in the House and Senate. In this and all figures that follow, the shaded regions identify sessions in each chamber in which Republicans held the majority, while unshaded regions identify sessions in which Democrats held the majority. Two trends are evident in both chambers during this period. First, negative relations are more than twice as common as positive relations, which is surprising because favoritism is observed more often than derogation in most social psychological research (Hewstone et al., 2002). Second, both types of relations are becoming more common, suggesting that legislators are increasingly "choosing sides" by engaging in patterns of bill co-sponsorship that clearly convey legislative agendas. Interestingly, these trends are not associated with which political party holds a majority.

Fig. 2C & D decompose these trends by legislators' party affiliations, illustrating the proportion of positive relations that occur among legislators from the same party (solid line), and the proportion of negative relations that occur among legislators from different parties (dashed line). Perhaps not surprisingly given the purpose of political parties for advancing specific agendas, a majority of positive relations occur within party and a majority of negative relations occur between party. However, the completeness of this pattern is striking. By the 2015–16 session, 98.8% of all positive relations in the House were between legislators of the same party, while only 1.2% of positive relations occurred between a Republican and a Democrat. Similarly, nearly 90% of negative relations were between legislators affiliating with different parties. These patterns illustrate a shift away from bipartisanship, which again is unrelated to which political party controls the chamber.

However, this masks a subtle final trend. Fig. 2E & F further decompose this trend by illustrating the proportion of within-party negative relations that occur between two Democrats (solid line) or



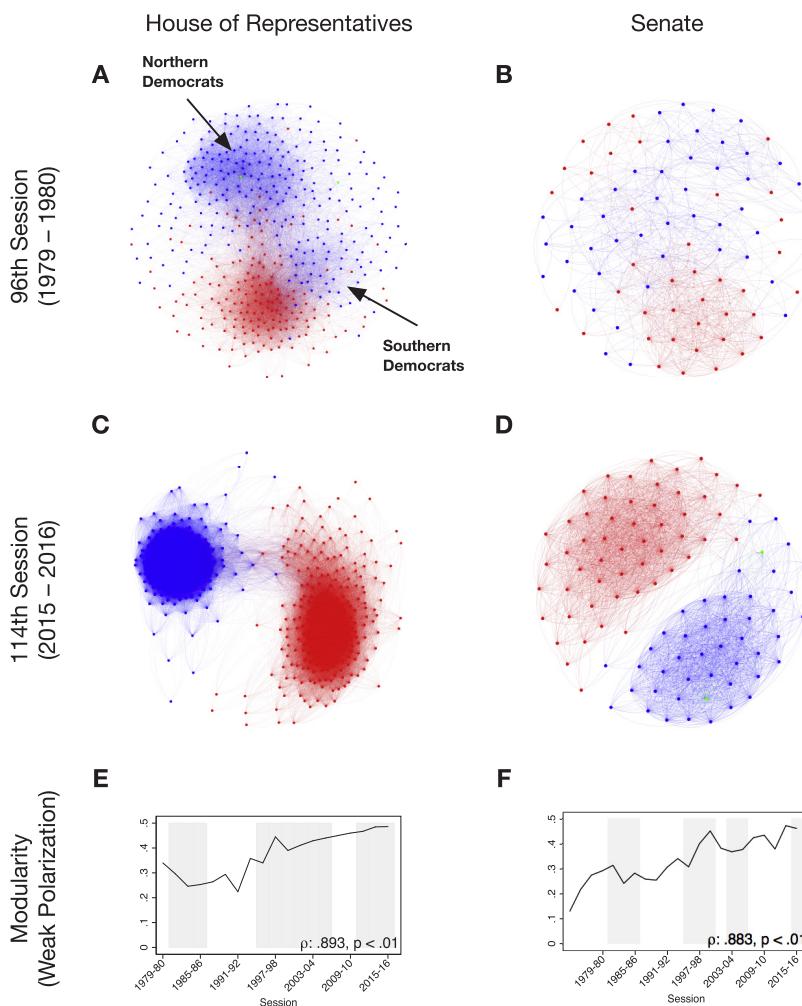
**Fig. 2.** Positive and negative relations in the U.S. Congress, 1973–2016. Positive (negative) relations are defined as occurring between pairs of legislators who jointly co-sponsor more (fewer) bills than expected under a chance null hypothesis using the SDSM. (A & B) Negative relations are more common than positive relations throughout the period in both chambers. (C & D) Positive relations occur primarily and increasingly between legislators from the same party, while negative relations occur primarily and increasingly between legislators from different parties. (E & F) Within-party negative relations occur primarily among legislators in the majority party.

between two Republicans (dashed line). It is here that the effect of a party's majority status emerges. Since the 1993–94 session in the House, and throughout the study period in the Senate, within-party negative relations occur primarily between legislators in the majority party. Minority party legislators close ranks and “stay on message,” while majority party legislators explore opportunities for asserting specific agendas through the formation of within-party factions. This finding mirrors Kirkland and Slapin's (2017) observation that “ideologically extreme legislators become markedly less loyal to their party when it controls the majority” (p. 26). It has important implications for the structure of political networks and the legislative process because, as long as a single party retains majority control, it presents the opportunity for factions within the majority to develop and solidify. Indeed, as Figs. 2E and 3F illustrate, the proportion of negative relations within the majority party typically increase with each session the party holds the majority, and reaches its highest level at the end of this tenure. If a single party held the majority long enough, this could set the stage for the splintering of the party, however in practice this has not occurred, perhaps because during this study period no single party held

the majority long enough. Instead, this type of “strategic disloyalty” (Kirkland and Slapin, 2017) seems to prevent the majority party from advancing its agenda, despite its majority control. For example, the Republican party held the majority in the U.S. House of Representatives from 1995 to 2006, during which time negative relations among Republicans increased to the point that they accounted for the vast majority of the negative relations in the House. The final session of this extended period of Republican control – was widely described by the media as the “do nothing Congress” for its inability to pass legislation (e.g. Schieffer, 2006).

#### Weak polarization

The trends displayed in Fig. 2 show that the dyadic ingredients for polarization are present, but polarization is a whole-network phenomenon. To examine the presence of weak polarization in the U.S. Congress, Fig. 3 provides comparative sociograms of the positive-relation-only network at the beginning (1979–80 session; panels A & B) and end (2015–16 session; panels C & D) of the study period. In the sociograms,



Democrats are shown in blue, Republicans in red, and the few Independents in green. Lines representing positive relations are shown as a combination of the color of the two legislators: positive relations between two Democrats are blue, between two Republicans are red, and the few bipartisan positive relations are purple. In the electronic version of these figures, labels identifying each legislator are visible when zoomed in.

In the 1979–80 session, some evidence of weak polarization is visible in both the House and Senate. Clusters of Republican (red) legislators are clearly visible at the bottom of Fig. 3A and B, while clusters of Democrat (blue) legislators are visible at the top of these figures. However, the amount of separation between these clusters is modest, indicating only modest weak polarization. Additionally, while political party clearly plays a role, weak polarization at this time was not strictly partisan. For example, in the House (Fig. 3A), two factions of Democrats are visible: a group of Northern Democrats appear as a large dense cluster at the top, while a group of Southern Democrats who were more closely aligned with Republicans appear as a smaller cluster at the bottom.

By the 2015–16 session, weak polarization in the House and Senate had grown quite extreme and partisan (Fig. 3C & D). In this session, Republicans primarily maintained positive relations only with other Republicans, and Democrats only with other Democrats. The few nodes that appear between the otherwise disconnected components represent legislators who have elsewhere been identified as among the most bipartisan, including Rep. Frank LoBiondo (R-NJ), Rep. Brad Ashford (D-NE), and Sen. Susan Collins (R-ME; Tumulty and Newton-Small, 2009).

While weak polarization can be observed in these sociograms,

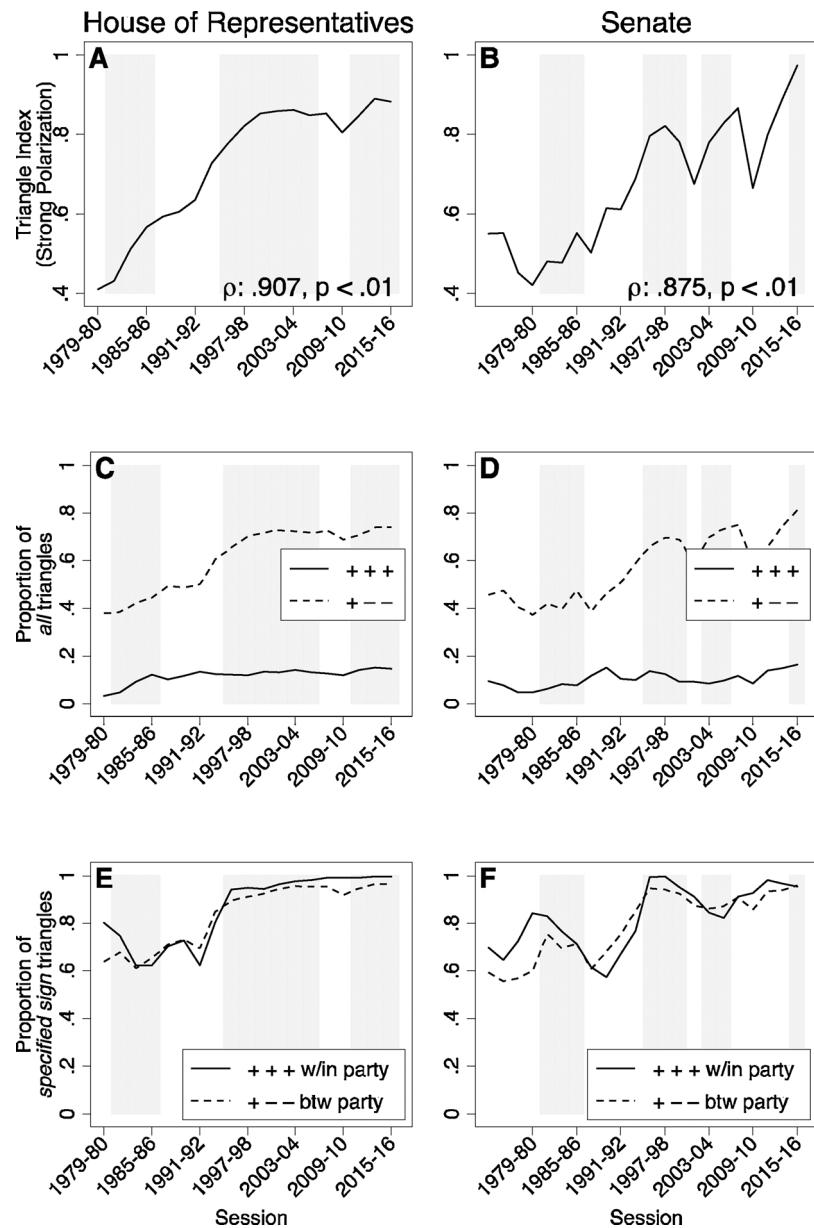
**Fig. 3.** Weak polarization. (A–D) Nodes are legislators, with Republicans in red, democrats in blue, and independents in green. Node labels are visible in the electronic version when zoomed in. Edges are positive relations inferred using the SDSM, and are colored according to their endpoints (e.g. a republican-republican collaboration is red, a republican-democrat collaboration is purple). (E & F) Modularity, computed using a partition based on party membership, measures weak polarization and displays a significant increasing trend in both chambers (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

Fig. 3E & F quantify the extent of weak polarization present in these networks throughout the study period using modularity, which in this case measures the extent to which relationships are present within but not between political parties. (e.g. Moody and Mucha, 2013; Waugh et al., 2011; Zhang et al., 2008). The spearman correlation between modularity and time (House:  $\rho = 0.893$ , Senate  $\rho = 0.883$ ; both  $p < .01$ ) indicates that, consistent with prior studies, both chambers exhibit a statistically significant increasing weak polarization. The maximum value of modularity in a two-community setting is 0.5 (Fortunato and Barthélémy, 2007), so these findings also suggest that both chambers of Congress are approaching maximal weak polarization.

#### Strong polarization

Strong polarization occurs in networks with both positive and negative relations, which are too dense to effectively visualize using sociograms. Thus, Fig. 4A & B quantify the extent of strong polarization present in these networks throughout the study period using the triangle index, which measures the proportion of triangles that are balanced (c.f. Doreian et al., 1996). The spearman correlation between the triangle index and time (House:  $\rho = 0.907$ , Senate  $\rho = 0.875$ ; both  $p < .01$ ) indicates that both chambers exhibit a statistically significant increasing strong polarization, regardless of which party holds the majority.

Why is Congress becoming more strongly polarized? Decomposing the triangle index into the two types of balanced triangles (i.e. + + + and + – –) offers some insight. As Fig. 4C & D illustrate, nearly all of the



**Fig. 4.** Strong polarization. (A & B) Triangle Index, the proportion of triangles that are balanced, measures strong polarization and displays a significant monotonically increasing trend in both chambers. (C & D) Of the two types of balanced triangles, the +-- configuration is more common and shows more growth than the +++ configuration. (E & F) Nearly all +++ triangles occur among legislators of the same party, while nearly all +-- triangles occur among legislators from different parties.

growth in these networks' strong polarization can be attributed to the growth of +-- triangles. Indeed, while the proportion of +++ triangles has remained roughly constant since the 1970s (solid line), the proportion of +-- triangles has increased by more than 50% during this time (dashed line). Moreover, as Fig. 4E & F illustrate, these triangle configurations are closely linked to political party affiliation. An increasing proportion of +++ triangles occur among a set of three legislators who share a common party affiliation (solid line). It is these triangles that solidify within-party cohesion, which mirrors past findings about the ubiquity of in-group favoritism. In contrast, an increasing proportion of +-- triangles occur in cases where two legislators from the same party have a positive relation (i.e. the + leg of the triangle), and both have a negative relation with a third legislator from a different party (i.e. the two – legs of the triangle; dashed line). It is these triangles that solidify the out-group derogation characteristic of strong polarization.

#### A sign of the times?

Political polarization has long been a central issue in political science, frequently with a focus on observing and lamenting its progression. In this paper, I have focused on the nature of intergroup relations among legislators to distinguish, measure, and document two related forms of polarization in the U.S. Congress. *Weak polarization*, which is the form examined in the prior literature (e.g. Andris et al., 2015; Moody and Mucha, 2013; Neal, 2014; Waugh et al., 2011; Zhang et al., 2008), occurs when two or more internally cohesive groups are distinguishable from each other by the relative absence of (implicitly positive) relations between them (Table 1, left column). It mirrors the common finding of in-group favoritism in social psychology (Hewstone et al., 2002) and the construct of communities in the network science literature (Newman and Girvan, 2004). In contrast, *strong polarization* occurs when the internally cohesive groups are distinguishable not by

the absence of positive relations between them, but instead by the presence of negative relations between them (Table 1, right column). It mirrors the increasing recognition in social psychology that “in-group favoritism [can] give way to...antagonism against out-groups” (Hewstone et al., 2002, p. 579), and mirrors the construct of structural balance in the network science literature (Cartwright and Harary, 1956). Given this distinction between polarization’s weak and strong forms, I have aimed to answer two related research questions.

First, can the widely reported finding of (increasing) weak polarization in the U.S. Congress be replicated when using a statistical model to make inferences about when positive relations exist? Using the SDSM, I infer that a positive relation exists when two legislators jointly co-sponsor significantly more bills than expected under a null hypothesis. Defining positive relations in this way, I find that both the House of Representatives ( $\rho = 0.893$ ,  $p < .01$ ) and Senate ( $\rho = 0.883$ ,  $p < .01$ ) display a significant increase in weak polarization that began in the early 1980s and has continued to the present. These findings replicate existing reports of increasing weak polarization (e.g. Andris et al., 2015; Moody and Mucha, 2013; Neal, 2014; Waugh et al., 2011; Zhang et al., 2008), however they also extend this earlier work by examining a much longer timeframe (1973–2016) and using a statistical model for inferring positive relations.

Second, is the (increasing) polarization observed in the U.S. Congress only weak polarization, or is it strong polarization? Again using the SDSM to make inferences about positive and negative relations, I find that the House of Representatives ( $\rho = 0.907$ ,  $p < .01$ ) and Senate ( $\rho = 0.875$ ,  $p < .01$ ) display a significant increase in strong polarization starting in the early 1980s, and reaching their highest levels of strong polarization in the 2015–16 session. That is, although earlier studies have focused only on growing weak polarization in the U.S. Congress, there is evidence that the growing polarization is actually the more problematic strong form. The formation of + + + triads of legislators facilitates within-party cohesion (i.e. in-group favoritism), while the even more rapid formation of + – – triads facilitates between-party opposition (i.e. out-group derogation), where the groups in this case closely mirror to the dominant political parties.

Throughout the study period, the balance of power has shifted between Republicans and Democrats multiple times in both chambers of Congress. However, although both weak and strong polarization in the U.S. Congress are structured around legislators’ party affiliations, its growth is not directly linked to which party holds a majority. That is, these findings suggest that the only thing that is bipartisan is the push toward greater polarization. There is, however, one notable exception that requires further investigation: within-party negative relations are substantially more common in the majority party. In-group derogation is uncommon in the social psychology literature, and with the notable exception of Kirkland and Slapin’s (2017) recent work, has not been extended to the case of legislative networks. These within-majority negative relations could facilitate the splintering of parties if played out over a long period, but the shorter periods of within-majority negative relation formation observed in these data may merely serve to hamper the majority party’s ability to advance its agenda.

These findings are subject to a number of limitations. First, like all prior studies of legislative networks, these analyses rely on an indirect measure of legislators’ positive and negative relations, making inferences from their joint participation in events (here, co-sponsorship of legislation). Using the SDSM as a statistical framework for making these inferences is helpful, but future studies should explore more direct methods of measuring relations in legislative networks, including how legislators talk (or tweet) about one another. Second, although certain patterns provide clues about possible mechanisms for the emergence of polarization (e.g. Fig. 4C–F), these analyses have focused on whole-network patterns over time (i.e. modularity and balance; Doreian et al., 1996) rather than on identifying behavioral mechanisms. A key challenge to analyzing these data using techniques designed to uncover network formation mechanisms (e.g. ERGM, SIENA; Yap and Harrigan,

2015) is the fact that the nodes represent congressional districts or states, not individuals. This is not an arrangement restricted to politics, but occurs in many organizational settings. Thus, this challenge offers another future direction: the development of a network modeling framework that allows nodes to represent durable “containers” with potentially shifting occupants.

Despite these limitations, these findings have implications for, and point to new questions about, the future of Congressional politics in the U.S. The scholarly discussion about whether U.S. politics is becoming more polarized may be nearing an end because, as Figs. 3E and F and 4A and B illustrate, the U.S. Congress is approaching maximal levels of both weak and strong polarization. It would be challenging for legislators to become substantially more polarized than they were in the 2015–16 session. Although more sophisticated network models may be helpful for identifying the mechanisms that lead to polarization, this pattern also suggests it might be time to consider the mechanisms that could also lead to a reduction in polarization (i.e. de-polarization). There is already a robust theoretical and empirical body of literature exploring the conditions under which relationships tend toward balance (e.g. Doreian et al., 1996; Rambaran et al., 2015; Rawlings and Friedkin, 2017; Yap and Harrigan, 2015), but relatively little theory on or examples of the conditions under which relationships might tend toward imbalance. Achieving this might involve making good on the promises of the intergroup contact hypothesis, however if the conditions and processes that favor imbalance and positive intergroup contact are unlikely in legislative contexts, what are the implications of ever-increasing levels of balance and strong polarization for law-making?

This is, of course, a complicated question whose answer goes beyond what an analysis of bill co-sponsorship alone can provide. However, some of the findings presented above suggest a possible answer. There has been a steady progression toward a Congress characterized by strong partisan polarization, which imposes severe constraints on compromise because each party views the other as not merely having a different legislative agenda being pursued in parallel, but rather as an opponent to their own legislative agenda. Moreover, this progression has unfolded despite shifts in which political party holds the majority in each chamber. Although the balance of power occasionally shifts from one party to another, with each shift the new majority party is afforded an opportunity to pursue its legislative agenda not in parallel to, but in opposition to, the other party’s agenda. This pattern may help explain why, in spite of increasingly polarized rhetoric, “there is little evidence that party polarization has promoted ideologically extreme policy outcomes” (Lee, 2015, p. 261; emphasis added). Strong polarization reduces the likelihood of bipartisan compromise and collaboration, so the legislative and policy outcomes that occur are likely to be partisan ones, which can then be reversed at the next shift in majority party control. Indeed, such a pattern has played out around the passage of the Affordable Care Act in the highly polarized 2009–10 session, and its attempted repeal in the (presumably) highly polarized 2017–18 session. Accordingly, under a two-party system, the threat that strong polarization poses to lawmaking may not be the implementation of extreme policy, but rather may be dramatic swings from one partisan extreme to another that prevent the long-term implementation of any policy.

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