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Author(s): James H. Fowler

Source: *Political Analysis*, Autumn 2006, Vol. 14, No. 4 (Autumn 2006), pp. 456-487

Published by: Cambridge University Press on behalf of the Society for Political Methodology

Stable URL: https://www.jstor.org/stable/25791871

Advance Access publication June 30, 2006

Political Analysis (2006) 14:456–487
doi:10.1093/pan/mpl002

Connecting the Congress: A Study of Cosponsorship Networks

James H. Fowler
Department of Political Science, University of California, Davis, One Shields Avenue, Davis, CA 95616
e-mail: jhfowler@ucdavis.edu

Using large-scale network analysis I map the cosponsorship networks of all 280,000 pieces of legislation proposed in the U.S. House and Senate from 1973 to 2004. In these networks, a directional link can be drawn from each cosponsor of a piece of legislation to its sponsor. I use a number of statistics to describe these networks such as the quantity of legislation sponsored and cosponsored by each legislator, the number of legislators cosponsoring each piece of legislation, the total number of legislators who have cosponsored bills written by a given legislator, and network measures of closeness, betweenness, and eigenvector centrality. I then introduce a new measure I call "connectedness" which uses information about the frequency of cosponsorship and the number of cosponsors on each bill to make inferences about the social distance between legislators. Connectedness predicts which members will pass more amendments on the floor, a measure that is commonly used as a proxy for legislative influence. It also predicts roll call vote choice even after controlling for ideology and partisanship.

1 Introduction

In the wake of the U.S. Congressional influence-peddling scandal that erupted in late 2005, Jack Abramoff was widely described by the press as the "best-connected" lobbyist on Capitol Hill (e.g., Birnbaum and Balz 2006). Legislators feared the extent to which they could be "connected" to Abramoff, prompting them to return campaign donations and deny having spent time with the lobbyist. In fact, they even curtailed legal contacts with other lobbyists to avoid the appearance that they were in some way connected to lobbyists and legislators who had been tainted by the scandal (Birnbaum and Balz 2006). These events demonstrate that there is a popular perception that being connected is an important part of legislative life, but what exactly does it mean to be connected? And how can we measure it to determine in what sense a legislator is "well connected?"

In the literature on social networks, a social connection is usually defined as a specific relation between two individuals. These relations can be characterized by the existence

Author's note: I would like to thank Tracy Burkett, Diane Felmlee, Jeff Gill, Ben Highton, Bob Huckfeldt, Jonathan Kaplan, Mark Lubell, Mark Newman, Mason Porter, Brian Sala, and Walt Stone for helpful comments and Skyler Cranmer for research assistance. This paper was originally prepared for presentation at the 2005 Midwest Political Science Association and American Political Science Association annual conferences. A copy of the most recent version can be found at http://jhfowler.ucdavis.edu.

of friendship, support, acquaintanceship, contact, communication, presence at a common event, or membership in a common organization. Some of the earliest attempts to analyze the connections between legislators defined a connection as frequency of agreement on roll call votes (Rice 1927; Truman 1959). However, analysis of roll call votes is now thought to describe legislators' ideology more than a social relationship between them (Poole and Rosenthal 1991). Since then, scholars have studied other kinds of social connections to show that friendship, family, and acquaintanceship relations have an important effect on political behavior and outcomes, influencing the flow of political information (Huckfeldt et al. 1995), voter turnout behavior (Straits 1990; Highton 2000; Fowler 2005), and vote choice (Beck et al. 2002). Although these studies have focused almost exclusively on voters, they suggest that personal connections like these may also have an important effect on legislators. For example, we might expect legislators with more friends to be more influential with their peers and better able to influence policy. But testing this hypothesis poses an interesting challenge. How do we observe the network of social connections between legislators? Many of these friendships and support relations are conducted in private and may be difficult to discern since they are based on a complex combination of partisan, ideological, institutional, geographic, demographic, and personal affiliations.

Typical social network studies rely on participant interviews and questionnaires (Rapoport and Horvath 1961; Fararo and Sunshine 1964; Mariolis 1975; Galaskiewicz and Marsden 1978; Bernard et al. 1988; Moody 2001). These data are valuable but suffer from two problems. First, they provide very little information about a very small subset of people. Second, interviews and questionnaire data are based on subjective evaluations of what constitutes a social connection. In studies of friendship networks among children, some respondents will report only one or two friends, whereas others will name hundreds (Rapoport and Horvath 1961; Fararo and Sunshine 1964; Moody 2001). Although legislators are not children, we might be skeptical about the individuals they name as friends since they have a strategic incentive to seem well connected to the "right" people.

Recently, there have been efforts to collect data about networks for which we have a large amount of objective information. For example, Hindman, Tsioutsiouliklisz, and Johnson (2003) study the hyperlink network between political interest groups on the web; Ebel, Mielsch, and Bornholdt (2002) analyze the structure of e-mail networks; Newman (2001a, 2001b) studies scientific collaboration networks; and Porter et al. (2005) analyze the network of committee assignments in the U.S. Congress. Building on these efforts, I study a network that provides substantial information about how legislators are connected to one another: the network of legislative cosponsorships.

In this article, I argue that cosponsorships provide a rich source of information about the social network between legislators. Using large-scale network analysis, I map the cosponsorship networks of all 280,000 pieces of legislation proposed in the U.S. House and Senate from 1973 to 2004. In these networks, a directional link can be drawn from each cosponsor of a piece of legislation to its sponsor since it represents *support* for the sponsor's legislative efforts. I use a number of statistics to describe these networks such as the quantity of legislation sponsored and cosponsored by each legislator, the number of legislators cosponsoring each piece of legislation, the total number of legislators who have cosponsored bills written by a given legislator, and network measures of closeness, betweenness, and eigenvector centrality. I then introduce a new measure I call connectedness that uses information about the frequency of cosponsorship and the number of cosponsors on each bill to make inferences about the social support relationship between legislators. All measures generate facially valid measures of the degree to which legislators are connected, but connectedness outperforms traditional social network measures in predicting a commonly used measure of legislative influence. It also helps to explain legislators' roll call votes, even when controlling for the ideology and party of each legislator. Thus, connectedness may be the best way to characterize the extent to which legislators are well connected to one another in the U.S. Congress.

2 Cosponsorship and Social Connectedness

Since 1967 in the House and the mid-1930s in the Senate, legislators have had an opportunity to express support for a piece of legislation by signing it as a cosponsor (Campbell 1982). Several scholars have studied *individual* motivations for cosponsorship. Mayhew (1974), Campbell (1982), and other scholars who focus on electoral incentives suggest that legislators engage in cosponsorship in order to send low-cost signals to their constituents about their policy stance. Alternatively, Kessler and Krehbiel (1996) suggest that legislators use cosponsorship to signal their preferences to the median voter in the legislature. A variety of empirical studies have addressed these theories, showing that cosponsorship is higher among junior members, liberals, active sponsors, members of the minority party, and legislators who are electorally vulnerable (Campbell 1982; Wilson and Young 1997; Koger 2003).

In contrast, there have also been a number of studies that seek to understand *aggregate* cosponsorship behavior. Panning (1982) uses block-modeling techniques on a cosponsorship network to identify clusters of U.S. legislators who tend to cosponsor the same legislation. Pellegrini and Grant (1999) analyze these clusters and find that ideological preferences and geography explain patterns in the clustering. Talbert and Potoski (2002) use the NOMINATE technique of Poole and Rosenthal (1985) to study the dimensional structure of cosponsorship. They find that cosponsorship is a high-dimensional activity, suggesting that the two ideological dimensions identified in similar analyses of roll call voting are not sufficient to explain cosponsorship behavior.

Prior research on cosponsorship has clearly focused on which *bills* individuals and groups of legislators will support. However, it rarely considers which *legislators* receive the most and least support from their colleagues.[1] This oversight is somewhat puzzling since several scholars have argued that bill sponsorship is a form of leadership (Hall 1992; Caldeira, Clark, and Patterson 1993; Krehbiel 1995; Schiller 1995; Kessler and Krehbiel 1996). For example, Campbell (1982) notes that legislators expend considerable effort recruiting cosponsors with personal contacts and "Dear Colleague" letters. Moreover, Senators and members of the House frequently refer to the cosponsorships they have received in floor debate, public discussion, letters to constituents, and campaigns.

In this article, I posit that cosponsorship contains important information about the *social support network* between legislators. For purposes of illustration, consider two different kinds of cosponsorship, *active* and *passive*. An active cosponsor actually helps write or promote legislation but cannot be considered a sponsor since the rules in both the House and the Senate dictate that only one legislator can claim sponsorship. Thus, some cosponsorship relations will result from a joint effort between legislators to create legislation that is clearly a sign that they have spent time together and established a working relationship. In this case, the cosponsor actively supports the legislative goals of the sponsor.

[1]One notable exception is Wawro (2001) who uses cosponsorship as a proxy for coalition-building skills.

At the other end of the extreme, a passive cosponsor will merely sign on to legislation she supports. Although it is possible that this can happen even when there is no personal connection between the sponsor and the cosponsor, it is likely that legislators make their cosponsorship decisions at least in part based on the personal relationships they have with the sponsoring legislators. The closer the relationship between a sponsor and a cosponsor, the more likely it is that the sponsor has directly petitioned the cosponsor for support. It is also more likely that the cosponsor will trust the sponsor or owe the sponsor a favor, both of which increase the likelihood of cosponsorship. Thus, the push and pull of the sponsor-cosponsor relationship suggest that even passive cosponsorship patterns may be a good way to measure the connections between legislators.

Only two studies have treated the cosponsorship network as a social network. Burkett (1997) analyzes the Senate and finds that party affiliation and similar ideology increase the probability of mutual cosponsorship. She also hypothesizes that seniority will increase the number of cosponsorships received, but she does not find a significant effect. Faust and Skvoretz (2002) utilize Burkett's data to compare the Senate cosponsorship network with social networks from other species. They find that it most resembles the network of mutual licking between cows!

3 Cosponsorship Data

Data for the legislative cosponsorship network is available in the Library of Congress Thomas legislative database. This database includes more than 280,000 pieces of legislation proposed in the U.S. House and Senate from 1973 to 2004 (the 93rd–108th Congresses) with over 2.1 million cosponsorship signatures. Thus, even if cosponsorship is only a noisy indicator of the personal connections between legislators, we have a very large sample to work with that should allow us to derive measures of connectedness that are reliable and valid.

Some scholars have expressed concern that legislative cosponsorships are not very informative since they are a form of "cheap talk" (Kessler and Krehbiel 1996; Wilson and Young 1997). Most bills do not pass, and cosponsors need not invest time and resources crafting legislation; so cosponsorship is a relatively costless way to signal one's position on issues important to constituents and fellow legislators. On the other hand, there may be substantial search cost involved in deciding which bills to cosponsor. From 1973 to 2004, the average House member cosponsored only 3.4% of all proposed bills and the average Senator only cosponsored 2.4%. Thus, although each legislator cosponsors numerous bills, this represents only a tiny fraction of the bills they might have chosen to support.

For the purposes of this study, I include cosponsorship ties for all forms of legislation including all available resolutions, public and private bills, and amendments (I will use the term "bills" generically to refer to any piece of legislation). Although private bills and amendments are only infrequently cosponsored, I include them because each document that has a sponsor and a cosponsor contains information about the degree to which legislators are socially connected. A more refined approach might weigh the social information by a piece of legislation's importance, but it is not immediately obvious what makes one piece of legislation more important than another. One might use bill type to indicate importance—for example, bills may be more important than amendments—but some amendments are more critical than the bills they amend. One might also use length of legislation to denote importance, but sometimes very short bills turn out to be much more important than very long ones. In general, the observation that a piece of legislation of any type has a cosponsor is in and of itself a latent indicator of its importance, so I include all cosponsorship ties observed in the Thomas database.[2]

4 Summary of Network Statistics

Biennial elections cause the membership of the U.S. House and Senate to change every two years, but it remains relatively stable between elections. To ensure that the networks analyzed are relatively static, I partition the data by chamber and Congress to create 32 separate cosponsorship networks. This will allow us to detect differences over time and between the House and the Senate and will help us to understand how institutional rules or artifacts in the data may drive some of the network measures. Table 1 presents some statistics about these networks. Notice that the number of sponsors varies only slightly (less than 2%) from Congress to Congress due to deaths and retirements that occur between Congresses and in some cases inactivity by a particular member. However, there are two fairly large and systematic changes in the total number of bills sponsored that are worth noting.

First, prior to the 96th Congress, there was a 25-cosponsor limit on all legislation in the House, and bills could only be cosponsored when they were introduced. As a result, the number of bills sponsored in the 93rd–95th Houses is about double the number of bills sponsored in later years. These numbers are inflated because of the incidence of identical bills during this period. However, this rule did not deter legislators who sought more support—it was not uncommon for several identical versions of the same bill to be submitted, each with a different set of 25 cosponsors. In 1978 the House voted to remove the limit. Second, the Library of Congress Thomas database provides complete data for all bills and resolutions since the 93rd Congress, but complete data for amendments is not available until the 97th Congress. The number of amendments sometimes exceeds the number of bills and resolutions in the Senate, helping to explain the substantial jump in total bills in the 97th Senate. It is unlikely that either of these systematic features of the data will greatly affect comparability of the cosponsorship networks between Congresses since legislators found a way around the institutional limit on cosponsors in the House, and amendments in both the House and Senate are only rarely cosponsored.

Table 1 also shows that Senators tend to produce more legislation on average than members of the House. This finding is consistent with Schiller's (1995) study of sponsorship in the Senate. She notes that the number of bills Senators sponsor tends to increase in their seniority, the size of their state economy, the number of their personal staff, and the number of committee assignments and chairmanships. Compared to members of the House, Senators tend to have been in politics longer, come from larger districts with bigger economies, have two to three times more personal staff than House members, and sit on and chair more committees since there are many fewer members to conduct business. In contrast, the number of bills *cosponsored* by each legislator does not differ systematically by chamber—the mean House member cosponsored 129–370 bills,

[2]The main difficulty in parsing the Thomas database is the variation in names used by each legislator. Names may appear with or without first initials and names, middle initials and names, and nicknames, and even last names may change for some legislators who change marital status. Moreover, the Thomas database frequently refers to the same person with two or more permutations of his or her name. Fortunately, the names used in Thomas typically remain consistent within a Congress, but they frequently change between Congresses. To be sure I am correctly identifying the sponsor and cosponsor of each bill, I manually create a lookup table that matches each permutation of each name found in Thomas to each legislator's ICPSR code provided by Poole and Rosenthal (http://www.voteview.com/icpsr.htm). This list excludes legislators who never participated in a roll call vote, such as delegates from U.S. territories or the District of Columbia. I then use this table to assign an ICPSR code for each sponsor and cosponsor found to each of the 280,000 bill summary files on Thomas. This permits easy merging with other databases that use these codes.

Table 1 Characteristics of cosponsorship networks, 1973–2004

Congress	*Years*	*Total sponsors*	*Total "bills"*	*Mean "bills" sponsored by each legislator*	*Mean "bills" cosponsored by each legislator*	*Mean cosponsors per "bill"*	*Cosponsors per legislator*	*Mean distance*
House								
93rd	1973–1974	442	20,994	48	129	3	70	1.95
94th	1975–1976	439	19,275	44	151	3	79	1.89
95th	1977–1978	437	18,578	42	170	4	93	1.83
96th	1979–1980	436	10,478	24	187	8	111	1.76
97th	1981–1982	435	10,062	23	223	10	132	1.72
98th	1983–1984	435	9095	21	297	14	157	1.65
99th	1985–1986	432	8606	20	329	17	171	1.61
100th	1987–1988	436	8093	18	341	18	174	1.60
101st	1989–1990	438	8423	19	370	19	184	1.58
102nd	1991–1992	436	8551	19	339	17	172	1.61
103rd	1993–1994	437	7464	17	259	15	144	1.67
104th	1995–1996	433	6558	15	168	11	105	1.77
105th	1997–1998	439	6780	15	219	14	127	1.73
106th	1999–2000	437	7894	18	278	15	151	1.67
107th	2001–2002	441	7541	17	273	16	143	1.68
108th	2003–2004	438	7636	17	276	16	147	1.67
Senate								
93rd	1973–1974	101	5123	51	153	3	54	1.46
94th	1975–1976	100	4913	49	137	3	52	1.48
95th	1977–1978	102	4722	45	121	3	49	1.51
96th	1979–1980	99	4188	41	135	3	54	1.46
97th	1981–1982	101	9674	96	219	2	68	1.31
98th	1983–1984	101	11,228	111	294	3	77	1.24
99th	1985–1986	101	7596	75	324	4	75	1.24
100th	1987–1988	101	7782	77	361	5	83	1.17
101st	1989–1990	100	7370	74	376	5	82	1.17
102nd	1991–1992	101	7686	75	335	4	79	1.21
103rd	1993–1994	101	5824	58	232	4	70	1.30
104th	1995–1996	102	8101	79	176	2	59	1.41
105th	1997–1998	100	7001	70	212	3	67	1.33
106th	1999–2000	102	8265	81	290	4	76	1.24
107th	2001–2002	101	8745	87	261	3	71	1.30
108th	2003–2004	100	7804	78	285	4	72	1.27

Note. "Bills" include any bill, resolution, or amendment offered in the House or Senate. Complete data for amendments starts in the 97th Congress.

whereas the mean Senator cosponsored between 121 and 360 bills. Since there are more members of the House than the Senate, House bills tend to receive more cosponsorships than Senate bills, but as a percent of the chamber the ranges are quite similar.

Using Cosponsorships to Connect Legislators

The cosponsorship networks do not merely yield insights into aggregate patterns of legislator activity—they also contain a wealth of information about connections between individual legislators. In the jargon of social network theory, each legislator represents a *node* in the cosponsorship network, and we can draw a *tie* from each legislator who cosponsors a bill to the sponsor of that bill. These ties are *directed* (asymmetric) because they reflect the cosponsoring legislator's support of the sponsoring legislator's proposed legislation. Although below we will see that there is a significant amount of reciprocal support between legislators, it is important to emphasize here that the direction of each tie provides information about the direction in which support between legislators tends to flow.

There are many ways to measure how much total support a legislator receives in this network. Perhaps the simplest is to identify the total number of bills sponsored by a given legislator and then count all the legislators who have cosponsored at least one of these bills. Table 1 shows that the average number of unique cosponsors per legislator varies from 70 to 184 in the House and from 52 to 83 in the Senate. Notice that although the absolute numbers of cosponsors per legislator tend to be higher in the House, Senators tend to receive support from a much larger fraction of the total members in their chamber. There are also some important changes over time. The average number of cosponsors per legislator reflects in part the degree to which the average member is integrated into the network—when legislators have more cosponsors, it may indicate they are operating in an environment in which it is easier to obtain broad support. Thus, it is particularly interesting that this value falls sharply for the 104th Congress when the "Republican Revolution" caused a dramatic change in the partisan and seniority compositions of both chambers.

Counting unique cosponsors is an important first step in understanding how connected a given legislator is to the network. However, this method neglects information about the legislators who are offering their support. Are the cosponsors themselves well connected? If so, it might indicate that the sponsor is more closely connected to the network than she would be if she was receiving cosponsorships from less connected individuals. One way to incorporate this information is to calculate the shortest cosponsorship distance, or *geodesic*, between each pair of legislators. A given sponsor has a distance of 1 between herself and all her cosponsors. She has a distance of 2 between herself and the set of all legislators who cosponsored a bill that was sponsored by one of her cosponsors. One can repeat this process for distances of 3, 4, and so on until the shortest paths are drawn for all legislators in the network. The average distance from one legislator to all others thus gives us an idea of not only how much direct support she receives but how much support her supporters receive.

Figure 1 shows two examples of these distance calculations for the 108th House. Interestingly, the representative who received the most unique cosponsorships was Representative Randy "Duke" Cunningham, who was forced to resign when it was discovered that he had been taking payments to influence other legislators in order to get defense contracts approved. Cunningham received cosponsorships from 421 legislators and thus had a distance of 1 to each of them. The remaining 16 legislators to whom he had no direct connection were cosponsors on bills sponsored by one of the 421 legislators to whom he did have a direct connection. These legislators had a distance of 2. Thus, the average distance between Cunningham and the other legislators in the network was 1.04. At the other extreme, Harold Rogers received a direct cosponsorship by a single individual—Representative Zach Wamp. Wamp received support from three other individuals, who in turn received support from 319 representatives. The remaining 114 individuals cosponsored at least one bill by someone in the group of 319. Thus, Rogers had a distance of 1 to 1 legislator, 2 to 3 legislators, 3 to 319 legislators, and 4 to 114, for an average distance of 3.25.

Table 1 shows that the mean average distances for each chamber and Congress are quite short, suggesting that legislative networks are very densely connected. In the Senate the

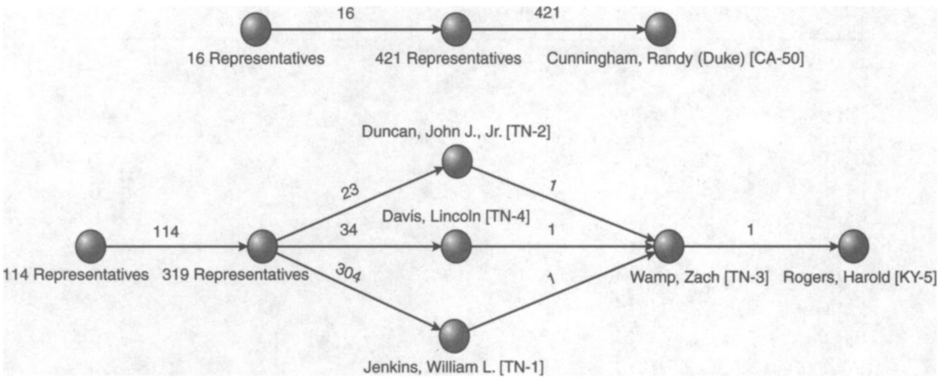

Fig. 1 Example of cosponsorship distance between legislators.

mean average distance ranges from 1.17 to 1.51, whereas in the House it ranges from 1.58 to 1.95. In other words, in the Senate the average member is *directly* connected to nearly all the other Senators, whereas in the House the average member tends to be *indirectly* connected through at most a single intermediary to all the other Representatives. As suggested by studies of the legislative committee assignment network (Porter et al. 2005), the smaller Senate appears to be more densely connected than the House.

5 Mutual Cosponsorship

The data clearly show that the average legislator is supported directly or indirectly by the vast majority of her peers. But to what extent do legislators reciprocate by supporting one another's bills? To answer this question, it will be useful to introduce some notation for describing individual relationships within it. Let A be an $n \times n$ *adjacency matrix* representing all the cosponsorship ties in a network for a given Congress and chamber such that $a_{ij} = 1$ if the ith legislator cosponsors a bill by the jth legislator and 0 otherwise. This network represents the set of unique cosponsorships and contains no information about how often legislators cosponsor each other. To include this information, let Q be an $n \times n$ adjacency matrix representing all the cosponsorship ties in a network such that q_{ij} is the total quantity of bills sponsored by the jth legislator that are cosponsored by the ith legislator.

As noted earlier, cosponsorship is a *directed* relationship. The cosponsor of a bill is assumed to be expressing support for the sponsor's legislation, not the other way around. However, consistent with earlier work (Burkett 1997), there appears to be a significant amount of mutual cosponsorship in the network. Table 2 shows that legislators are more likely to cosponsor bills that are sponsored by those who return the favor. The first two columns are simple correlations between a_{ij} and a_{ji}, $\forall\ i \neq j$ for the House and Senate. In other words, how likely is it that legislator i has cosponsored at least one bill by legislator j if legislator j has cosponsored at least one bill by legislator i? The next two columns are simple correlations between q_{ij} and q_{ji}, $\forall\ i \neq j$ for the House and Senate. In other words, how correlated are the quantity of bills sponsored by legislator i and cosponsored by legislator j with the quantity of bills sponsored by legislator j and cosponsored by legislator i?

In both chambers and across all years, there appears to be significant tendency to engage in mutual cosponsorship. Senators are somewhat more likely to reciprocate than members of the House. Moreover, the higher correlations that result when we include

Table 2 Mutual cosponsorship relationships

	Any bill		*Total number of bills*	
Congress	*House*	*Senate*	*House*	*Senate*
93rd	0.17	0.23	0.23	0.39
94th	0.17	0.25	0.20	0.34
95th	0.17	0.21	0.19	0.33
96th	0.12	0.12	0.15	0.26
97th	0.14	0.17	0.22	0.27
98th	0.15	0.16	0.23	0.36
99th	0.14	0.19	0.21	0.34
100th	0.18	0.18	0.25	0.39
101st	0.15	0.17	0.24	0.39
102nd	0.15	0.26	0.14	0.30
103rd	0.17	0.19	0.23	0.34
104th	0.16	0.20	0.21	0.29
105th	0.16	0.19	0.24	0.36
106th	0.16	0.17	0.25	0.37
107th	0.17	0.17	0.29	0.47
108th	0.18	0.18	0.34	0.43

Note. Pearson product moment correlations.

information about the quantity of bills cosponsored suggest that legislators who cosponsor a lot of bills by one legislator are likely to receive many cosponsorships from the same legislator. The narrow range of variation in these correlations indicates that norms of mutual cosponsorship have remained relatively stable over time in both bodies, though some of the variation may carry implications for how these bodies function. For example, there appears to be an increase in mutual cosponsorship in the 107th and 108th Congresses. It is not clear whether this is due to an increase in cosponsorship activity between members with shared interests or the strategic trading of support on different bills (log-rolling). Either way, the significant and persistent tendency to reciprocate suggests that cosponsorship is a way to build relationships with other legislators (Burkett 1997) and thus provides relevant information about their social network. But how can we use this information to determine which legislators are best connected to the network?

6 Traditional Measures of Centrality

Social network theorists have described a variety of ways to use information about social ties to make inferences about the relative importance of group members. Since we are interested in how connected legislators are to other legislators in the cosponsorship network, I will focus on measures of *centrality*. There are a number of ways to calculate centrality, and each has been shown to perform well in identifying important individuals in social (Freeman, Borgatti, and White 1991) and epidemiological networks (Rothenberg, Potterat, and Woodhouse 1995). The first and most obvious of these has already been discussed—the total number of directed ties to an individual node reflects the *degree* to which that node is supported by other nodes. *Degree centrality* (Proctor and Loomis 1951) or *prestige* scores, then, are simply the total number of unique cosponsors that support each legislator: $x_j = a_{1j} + a_{2j} + \cdots + a_{nj}$. Burkett (1997) utilizes this measure to show that there is no relationship between seniority and prestige in the Senate.

Other measures of centrality look beyond direct cosponsorship ties. As noted above, it is possible to measure the social distance between any pair of individuals in the network by finding one's cosponsors, the cosponsors of one's cosponsors, and so on. *Closeness centrality* (Sabidussi 1966) is the inverse of the average distance from one legislator to all other legislators. If we let δ_{ij} denote the shortest distance from i to j, then $x_j = (n-1)/(\delta_{1j} + \delta_{2j} + \cdots + \delta_{nj})$.

A third measure, *betweenness centrality* (Freeman 1977), identifies the extent to which an individual in the network is critical for passing support from one individual to another. Some legislators may, for example, receive support from several legislators and give it to several other legislators, acting as a bridge between them. Once we identify each of the shortest paths in the network, we can count the number of these paths that pass through each legislator. The higher this number the greater the effect would be on the total average distance for the network if this person were removed (Wasserman and Faust 1994). If we let σ_{ik} represent the number of paths from legislator i to legislator k and σ_{ijk} represent the number of paths from legislator i to legislator k that pass through legislator j, then $x_j = \sum_{i \neq j \neq k} \frac{\sigma_{ijk}}{\sigma_{ik}}$.

A fourth measure, *eigenvector centrality* (Bonacich 1972), assumes that the centrality of a given individual is an increasing function of the centralities of all the individuals that support her. Although this is an intuitive way to think about which legislators might be better connected, it yields a practical problem—how do we simultaneously estimate the centrality of a given legislator and the centralities of the legislators who cosponsor her? Let x be a vector of centrality scores so that each legislator's centrality x_j is the sum of the centralities of the legislators who cosponsor her legislation: $x_j = a_{1j}x_1 + a_{2j}x_2 + \cdots + a_{nj}x_n$. This yields n equations that we can represent in matrix format as $x = A^{\mathrm{T}}x$. It is unlikely that these equations have a nonzero solution, so Bonacich (1972) suggests an important modification. Suppose the centrality of a legislator is *proportional* to instead of *equal* to the centrality of the legislators who cosponsor one of her bills. Then $\lambda x_i = a_{1i}x_1 + a_{2i}x_2 + \cdots + a_{ni}x_n$, which can be represented as $\lambda x = A^{\mathrm{T}}x$. The vector of centralities x can now be computed since it is an eigenvector of the eigenvalue λ. Although there are n nonzero solutions to this set of equations, in practice the eigenvector corresponding to the principal eigenvalue is used because it maximizes the accuracy with which the associated eigenvector can reproduce the adjacency matrix (Bonacich 1987).

Who is the most central legislator? Table 3 presents the scores and names of the top performers on each of these traditional measures of importance by chamber and Congress. The first two columns show the total number of bills sponsored and the total number of unique cosponsors (degree centrality), respectively. These values should have a strong relationship with other measures of centrality since they reflect the total number of opportunities for cosponsorship and the breadth of direct support an individual receives from other legislators. Column two also presents closeness centrality scores. Although degree centrality and closeness centrality scores do not perfectly correlate, they are similar enough in these networks that they generate the exact same set of names for the highest score in each chamber and Congress. This is because legislators are so densely connected in these networks that direct support makes up a very large part of the closeness centrality score, which is based on both direct and indirect support.

Columns three and four of Table 3 show the top legislators based on betweenness and eigenvector centrality scores. Notice that there is a strong correspondence between the names in the eigenvector centrality list and the closeness centrality list, but the betweenness list is quite different. All of the centrality scores produce names that are familiar to students of American politics. They include majority and minority leaders (O'Neill, Byrd,

Table 3 Highest scoring legislator in each chamber and Congress

Congress	Most bills sponsored	Most unique cosponsors/ highest closeness centrality	Highest betweenness centrality	Highest eigenvector centrality
House				
93rd	286 Roe, Robert A. [D-NJ-8]	354/0.84 O'Neill Thomas [D-MA-8]	3349 Wolff, Lester [D-NY-6]	0.157 O'Neill Thomas [D-MA-8]
94th	309 Pepper, Claude [D-FL-14]	434/0.99 O'Neill Thomas [D-MA-8]	2975 Murphy, John [D-NY-17]	0.168 O'Neill Thomas [D-MA-8]
95th	325 Roe, Robert A. [D-NJ-8]	396/0.91 Burton, John L. [D-CA-5]	2917 Nolan, Richard [D-MN-6]	0.141 Burton, John L. [D-CA-5]
96th	122 Roe, Robert A. [D-NJ-8]	386/0.89 Anderson, Glenn [D-CA-32]	2660 Whitehurst, Goerge [R-VA-2]	0.126 Anderson, Glenn [D-CA-32]
97th	150 Michel, Robert [R-IL-18]	408/0.93 Conte, Silvio [R-MA-3]	1949 Whitehurst, Goerge [R-VA-2]	0.115 Conte, Silvio [R-MA-3]
98th	122 Biaggi, Mario [D-NY-19]	406/0.93 Downey, Thomas [D-NY-2]	1457 Simon, Paul [D-IL-22]	0.096 Simon, Paul [D-IL-22]
99th	112 Biaggi, Mario [D-NY-19]	391/0.90 Pepper, Claude [D-FL-14]	1432 Kaptur, Marcia [D-OH-9]	0.091 Pepper, Claude [D-FL-14]
100th	104 Michel, Robert [R-IL-18]	400/0.92 Hughes, William [D-NJ-2]	1378 Kolter, Joseph [D-PA-4]	0.089 Panetta, Leon [D-CA-16]
101st	106 Solomon, Gerald [R-NY-24]	414/0.95 Bilirakis, Michael [R-FL-9]	1192 Roe, Robert A. [D-NJ-8]	0.088 Oakar, Mary Rose [D-OH-20]
102nd	107 Fawell, Harris W. [R-IL-13]	415/0.95 Kennelly, Barbara B. [D-CT-1]	2077 Towns, Edolphus [D-NY-11]	0.092 Kennelly, Barbara B. [D-CT-1]
103rd	102 Traficant, James [D-OH-17]	406/0.93 Moran, James P. [D-VA-8]	1934 Jacobs, Andrew [D-IN-10]	0.105 Moran, James P. [D-VA-8]
104th	144 Solomon, Gerald [R-NY-22]	405/0.93 Johnson, Nancy L. [R-CT-6]	2687 Traficant, James [D-OH-17]	0.135 Bliley, Tom [R-VA-7]
105th	158 Solomon, Gerald [R-NY-22]	387/0.89 Thomas, William [R-CA-21]	2282 Evans, Lane [D-IL-17]	0.115 Thomas, William [R-CA-21]
106th	115 Andrews, Robert E. [D-NJ-1]	416/0.96 Johnson, Nancy L. [R-CT-6]	2075 Shows, Ronnie [D-MS-4]	0.109 Johnson, Nancy L. [R-CT-6]
107th	110 Andrews, Robert E. [D-NJ-1]	432/0.98 Bilirakis, Michael [R-FL-9]	2507 English, Phil [R-PA-21]	0.115 Bilirakis, Michael [R-FL-9]
108th	120 Andrews, Robert E. [D-NJ-1]	421/0.96 Cunningham, Randy [R-CA-50]	1688 English, Phil [R-PA-3]	0.110 Cunningham, Randy [R-CA-50]
Senate				
93rd	161 Inouye, Daniel [D-HI]	99/0.99 Allen, James [D-AL]	181 Humphrey, Hubert [D-MN]	0.157 Allen, James [D-AL]
94th	207 Jackson, Henry [D-WA]	98/0.99 Byrd, Robert C. [D-WV]	175 Dole, Robert J. [R-KS]	0.161 Byrd, Robert C. [D-WV]
95th	138 Inouye, Daniel [D-HI]	103/1.00 Dole, Robert J. [R-KS]	272 Dole, Robert J. [R-KS]	0.175 Dole, Robert J. [R-KS]
96th	126 Inouye, Daniel [D-HI]	100/1.00 Byrd, Robert C. [D-WV]	133 Cohen, William [R-ME]	0.164 Byrd, Robert C. [D-WV]

Continued

Table 3 (continued)

Congress	*Most bills sponsored*	*Most unique cosponsors/ highest closeness centrality*	*Highest betweenness centrality*	*Highest eigenvector centrality*
97th	1495 Metzenbaum, Howard [D-OH]	100/1.00 Thurmond, Strom [R-SC]	104 Moynihan, Patrick [D-NY]	0.135 Thurmond, Strom [R-SC]
98th	2942 Hatch, Orrin G. [R-UT]	100/1.00 Percy, Charles H. [R-IL]	105 Laxalt, Paul [R-NV]	0.124 Percy, Charles H. [R-IL]
99th	360 Metzenbaum, Howard [D-OH]	100/1.00 Thurmond, Strom [R-SC]	126 Cochran, Thad [R-MS]	0.124 Thurmond, Strom [R-SC]
100th	470 Hatch, Orrin G. [R-UT]	100/1.00 Burdick, Quentin N. [D-ND]	37 D'Amato, Alfonse [R-NY]	0.116 Burdick, Quentin N. [D-ND]
101st	231 Hatch, Orrin G. [R-UT]	99/1.00 Inouye, Daniel K. [D-HI]	58 Boschwitz, Rudy [R-MN]	0.117 Inouye, Daniel K. [D-HI]
102nd	355 Mitchell, George J. [D-ME]	100/0.99 Thurmond, Strom [R-SC]	48 Simon, Paul [D-IL]	0.119 Thurmond, Strom [R-SC]
103rd	185 Helms, Jesse [R-NC]	100/1.00 Simon, Paul [D-IL]	87 Brown, Hank [R-CO]	0.133 Simon, Paul [D-IL]
104th	323 D'Amato, Alfonse [R-NY]	100/0.99 Byrd, Robert C. [D-WV]	117 Daschle, Thomas A. [D-SD]	0.155 Dole, Robert J. [R-KS]
105th	224 McCain, John [R-AZ]	99/1.00 Lott, Trent [R-MS]	75 D'Amato, Alfonse [R-NY]	0.141 Lott, Trent [R-MS]
106th	332 Fitzgerald, Peter [R-IL]	101/1.00 Brownback, Sam [R-KS]	50 Robb, Charles S. [D-VA]	0.126 Lott, Trent [R-MS]
107th	254 Feingold, Russell D. [D-WI]	100/1.00 Hatch, Orrin G. [R-UT]	119 Hatch, Orrin G. [R-UT]	0.134 Hatch, Orrin G. [R-UT]
108th	207 Bingaman, Jeff [D-NM]	99/1.00 Biden Jr., Joseph R. [D-DE]	70 Collins, Susan M. [R-ME]	0.131 Biden Jr., Joseph R. [D-DE]

Dole, Daschle, and Lott), numerous committee chairs, and individuals who would later run for higher office or otherwise be involved in presidential politics.

7 Connectedness: An Alternative Measure

None of the traditional measures of centrality takes advantage of two other pieces of information that might be helpful for determining the *strength* of social relationships that exist in the network. First, we have information about the total number of cosponsors c_ℓ on each bill ℓ. The binary indicator a_{ij} assigns a connection from legislator i to j, regardless of whether a bill has 1 cosponsor or 100. However, legislators probably recruit first those legislators to whom they are most closely connected. Moreover, as the total number of cosponsors increases, it becomes more likely that the cosponsor is recruited by an intermediary other than the sponsor, increasing the possibility that there is no direct connection at all. Thus, bills with fewer total cosponsors probably provide more reliable information about the real social connections between two legislators than bills with many cosponsors (Burkett 1997). This relationship might take several different functional forms, but I assume a simple one: the strength of the connection between i and j on a given bill ℓ is posited to be $1/c_\ell$.

Second, we have information about the total number of bills sponsored by j that are cosponsored by i. Legislators who frequently cosponsor bills by the same sponsor are more likely to have a real social relationship with that sponsor than those who cosponsor only a few times. We have already seen that the quantity of bills cosponsored q_{ij} is a better predictor of mutual cosponsorship than the simple binary indicator a_{ij}. This suggests that we might use information about the quantity of bills to denote the strength of the tie between i and j. To incorporate this information with the assumption about the effect of the number of cosponsors into a measure of connectedness, let a_{ij}^{ℓ} be a binary indicator that is 1 if legislator i cosponsors a given bill ℓ that is sponsored by legislator j and 0 otherwise. Then the *weighted* quantity of bills cosponsored w_{ij}will be the sum $w_{ij} = \sum_\ell a_{ij\ell}/c_\ell$.

This measure is closely related to the weighted measure used by Newman (2001b) to find the best-connected scientist in the scientific coauthorship network, which assumes that tie strength is proportional to the number of papers two scholars coauthor together and inversely proportional to the number of other coauthors on each paper. However, ties in the cosponsorship network are directed. This means that unlike the scientific coauthorship network that has symmetric weights $w_{ij} = w_{ji}$, the weights in the cosponsorship network are not symmetric: $w_{ij} \neq w_{ji}$.

Figure 2 shows an example of how these weights are calculated. In the 108th Congress, Representative Edward Schrock cosponsored three bills that were sponsored by Todd Akin. Two of these had very large numbers of cosponsors, so their net contribution to the weighted cosponsorship measure is quite small (1/92 and 1/225). However, Schrock was the sole cosponsor on H.R. 1772, the Small Business Advocacy Improvement Act of 2003, which increases the weighted measure by 1. Schrock and Akin were both chairs of subcommittees under the House Committee on Small Business, and according to their press releases, they worked closely together on the legislation. Thus, the weighted cosponsorship measure successfully identifies a social connection between these two legislators.

We can now use these weights to create a measure of *legislative connectedness*. Suppose the direct distance from legislator j to legislator i is the simple inverse of the cosponsorship weights: $d_{ij} = 1/w_{ij}$. We can use these distances to calculate the shortest distance between any two legislators. It is not possible to use the same procedure as we did for closeness centrality because the distances between each pair of legislators are not

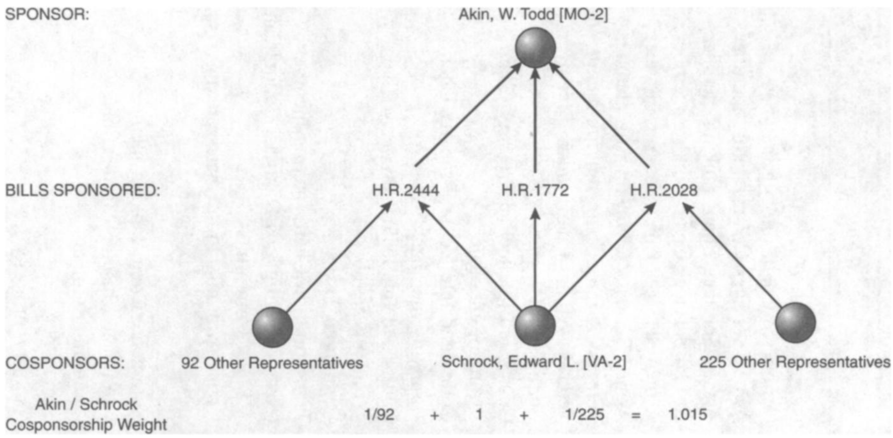

Fig. 2 Weighted cosponsorship distance calculation example.

uniform—sometimes the shortest distance will be through several legislators who are closely connected instead of fewer legislators who are only distantly connected. Dijkstra's algorithm (Cormen et al. 2001) allows us to find the shortest distance between each pair of legislators using the following steps: (1) starting with legislator j, identify from a list of all other legislators the closest legislator i, (2) replace each of the distances d_{kj} with $\min(d_{kj}, d_{ki} + d_{ij})$, and (3) remove legislator i from the list and repeat until there are no more legislators on the list. Once we repeat this procedure for each legislator, the result is a matrix of shortest distances between each pair of legislators in the whole network. Connectedness is the inverse of the average of these distances from all other legislators to legislator j: $(n-1)/(d_{1j} + d_{2j} + \cdots + d_{nj})$.

Table 4 shows a list of the best-connected legislators in each chamber and Congress. Just like the centrality measures, the connectedness measure identifies several majority and minority leaders and committee chairs. To illustrate some of the relationships behind these rankings, column two shows the strongest sponsor/cosponsor weight identified within each chamber and Congress and column three identifies the specific relationship between these two individuals. The sources of these relationships can be divided into four categories: *institutional*, *regional*, *issue based*, and *personal*.

Institutional relationships dominate both chambers. Most of the strongest relationships in the House are between committee chairs and ranking members, whereas in the Senate, they are between majority and minority leaders. Intuitively, it makes sense that party leaders in each committee (including the "committee of the whole" in the Senate) would be strongly connected since they spend a great deal of time together and probably expend a lot of effort negotiating for each others' support. Consistent with prior work (Pellegrini and Grant 1999), regional relationships also appear to be important despite partisan differences. Not only are many of the most strongly connected legislators from the same state but in the House they are also often from contiguous districts. This suggests that politicians may belong to regional or state organizations or may have roots in local politics that cause them to be more likely to have made prior social contacts with one another. Alternatively, they may share similar interests because their constituents have similar geographic characteristics. Either way, being from the same place seems to increase the likelihood that legislators will cosponsor one another's legislation.

Table 4 Best-connected legislator and strongest sponsor/cosponsor relationship in each chamber and Congress

Congress	*Best-connected legislator*	*Strongest sponsor/cosponsor relation*	*Relationship*
House			
93rd	0.44 Koch, Edward [D-NY-18]	69 Staggers, Harley [D-WV-2]/Devine, Samuel [R-OH-12]	Commerce Chair, ranking member
94th	0.57 Pepper, Claude [D-FL-14]	72 Price, Melvin [D-IL-21]/Wilson, Robert [R-CA-41]	Armed Services Chair, ranking member
95th	0.60 Pepper, Claude [D-FL-14]	51 Price, Melvin [D-IL-21]/Wilson, Robert [R-CA-41]	Armed Services Chair, ranking member
96th	0.31 Pepper, Claude [D-FL-14]	58 Price, Melvin [D-IL-21]/Wilson, Robert [R-CA-41]	Armed Services Chair, ranking member
97th	0.27 Montgomery, G. [D-MS-3]	29 Price, Melvin [D-IL-21]/Dickinson, William [R-AL-2]	Armed Services Chair, ranking member
98th	0.27 Roe, Robert A. [D-NJ-8]	30 Price, Melvin [D-IL-21]/Dickinson, William [R-AL-2]	Armed Services Chair, ranking member
99th	0.26 Breaux, John [D-LA-7]	16 Montgomery, G. [D-MS-3]/Hammerschmidt, J. [R-AR-3]	Veterans Affairs Chair, ranking member
100th	0.25 Waxman, Henry A. [D-CA-29]	57 Montgomery, G. [D-MS-3]/Solomon, Gerald [R-NY-24]	Veterans Affairs Chair, ranking member
101st	0.28 Stark, Fortney Pete [D-CA-9]	23 Schulze, Richard T. [R-PA-5]/Yatron, Gus [D-PA-6]	Contiguous Districts
102nd	0.27 Fawell, Harris W. [R-IL-13]	14 Hughes, William [D-NJ-2]/Moorhead, Carlos [R-CA-22]	Courts and Intellectual Property Chair, ranking member
103rd	0.22 Waxman, Henry A. [D-CA-29]	8 Hughes, William [D-NJ-2]/Moorhead, Carlos [R-CA-27]	Courts and Intellectual Property Chair, ranking member
104th	0.24 Traficant, James [D-OH-17]	7 Moorhead, Carlos [R-CA-27]/Schroeder, Pat [D-CO-1]	Courts and Intellectual Property Chair, ranking member
105th	0.22 Gilman, Benjamin [R-NY-20]	7 Ensign, John E. [R-NV-1]/Gibbons, Jim [R-NV-2]	Contiguous Districts
106th	0.28 McCollum, Bill [R-FL-8]	10 Shuster, Bud [R-PA-9]/Oberstar, James L. [D-MN-8]	Transportation Chair, ranking member
107th	0.24 Young, Don [R-AK]	11 DeMint, Jim [R-SC-4]/Myrick, Sue [R-NC-9]	(Nearly) Contiguous Districts, Republican Study Committee
108th	0.28 Saxton, Jim [R-NJ-3]	14 Ney, Robert W. [R-OH-18]/Larson, John B. [D-CT-1]	House Administration Chair, ranking
Senate			
93rd	0.94 Jackson, Henry [D-WA]	65 Magnuson, Warren [D-WA]/Cotton, Norris [R-NH]	Commerce Chair, ranking member
94th	1.12 Moss, Frank [D-UT]	139 Jackson, Henry [D-WA]/Fannin, Paul [R-AZ]	Interior and Insular Affairs Chair, ranking member
95th	0.90 Dole, Robert J. [R-KS]	33 Inouye, Daniel [D-HI]/Matsunaga, Spark [D-HI]	Same state
96th	0.84 Dole, Robert J. [R-KS]	24 Byrd, Robert [D-WV]/Baker, Howard [R-TN]	Majority, minority leader

Continued

Table 4 (continued)

Congress	*Best-connected legislator*	*Strongest sponsor/cosponsor relation*	*Relationship*
97th	0.91 Heinz, Henry [R-PA]	34 Inouye, Daniel [D-HI]/Matsunaga, Spark [D-HI]	Same State
98th	1.28 Hatch, Orrin G. [R-UT]	63 Baker, Howard [R-TN]/Byrd, Robert [D-WV]	Majority, minority leader
99th	1.37 Thurmond, Strom [R-SC]	109 Cranston, Alan [D-CA]/Wilson, Pete [R-CA]	Same state
100th	1.46 Cranston, Alan [D-CA]	70 Byrd, Robert [D-WV]/Dole, Robert J. [R-KS]	Majority, minority leader
101st	1.39 Kennedy, Edward M. [D-MA]	77 Mitchell, George J. [D-ME]/Dole, Robert J. [R-KS]	Majority, minority leader
102nd	1.23 Mitchell, George J. [D-ME]	179 Mitchell, George J. [D-ME]/Sasser, Jim [D-TN]	Federal Housing Reform
103rd	1.20 Mitchell, George J. [D-ME]	59 Mitchell, George J. [D-ME]/Dole, Robert J. [R-KS]	Majority, minority leader
104th	1.58 Dole, Robert J. [R-KS]	38 Dole, Robert J. [R-KS]/Daschle, Thomas A. [D-SD]	Majority, minority leader
105th	1.36 McCain, John [R-AZ]	40 Lott, Trent [R-MS]/Daschle, Thomas A. [D-SD]	Majority, minority leader
106th	1.36 Hatch, Orrin G. [R-UT]	104 Hutchison, Kay Bailey [R-TX]/Brownback, Sam [R-KS]	Marriage Penalty Relief and Bankruptcy Reform
107th	1.61 Feingold, Russell D. [D-WI]	53 McCain, John [R-AZ]/Gramm, Phil [R-TX]	Personal
108th	1.43 McCain, John [R-AZ]	50 Frist, Bill [R-TN]/Daschle, Thomas A. [D-SD]	Majority, minority leader

Some pairs of legislators work closely together because they are drawn to the same issues. For example, Representatives Jim DeMint and Sue Myrick both belong to the Republican Study Committee; Senators George Mitchell and Jim Sasser worked together on Federal Housing Reform and Senators Kay Bailey Hutchison and Sam Brownback worked together extensively on marriage penalty relief and bankruptcy reform. This finding is consistent with prior work that suggests that ideological similarity increases the probability of mutual cosponsorship (Burkett 1997). Finally, some relationships might be best described as personal. For example, Senator John McCain chaired Senator Phil Gramm's 1996 presidential campaign, but McCain has told the media that they have been friends since 1982 when they served together in the House (McGrory 1995). It is possible that friendship is at the core of some of these other relationships, but this may be difficult to evaluate if politicians choose to keep this information private.

8 Connectedness in the 108th Congress

What are the legislative characteristics of the legislators who receive high connectedness scores? Table 5 provides a list of the top 20 most connected legislators for the 108th House and Senate and shows how many bills each of them sponsored and the total number of legislators who cosponsored at least one of their bills. Notice that these general indicators of legislative activity are very important—all but five legislators sponsored more bills than average and received more cosponsorships than average.

Representative Ron Paul is ranked second, but he was cosponsored by only 123 other legislators compared to an average of 147 in the House. Although he clearly had difficulty soliciting broad support, he made up for it with legislative productivity—he is ranked third in the House for the number of bills sponsored. Representative Jeb Bradley who is ranked 15th for connectedness scored below average on both sponsorships and cosponsorships. However, the cosponsors who supported him are themselves ranked very highly—four of his eight closest supporters (Sensenbrenner, Paul, English, and Evans) are ranked in the top 20 for connectedness. Similarly, Representative Dennis Kucinich had a below-average number of cosponsors but managed to gain close support from Representatives Charles Rangel, Steve LaTourette (ranked 21st), Luis Guttierez (ranked 25th), Jerold Nadler (ranked 26th), and John Conyers (ranked 34th). On the Senate side, Russell Feingold and John Voinovich were both ranked in the top 20 but had a below-average number of cosponsors. Voinovich's two closest supporters are both in the top 20 (DeWine and Collins), as are three of Feingold's four closest supporters (Leahy, Collins, and Durbin).

Thus, connectedness is not just about sponsoring a lot of bills and writing a lot of "Dear Colleague" letters—it also matters who one convinces to sign on to the legislation. Figures 3 and 4 illustrate graphically the difference in the strength of ties between the 20 most connected and 20 least connected legislators in each branch. Each arrow shows a cosponsorship relation pointing to the sponsor, and to simplify the graph, relationships to members outside the top or bottom 20 are not shown. Darker arrows indicate stronger connections (higher values of w_{ij}). The Kamada-Kawai algorithm used to draw these graphs assumes that ties between nodes are connected by "springs" with a given rest length and then it moves nodes around trying to minimize the energy in the system. The solution is dependent on the node starting positions, so different graphs can result from the same data. However, this visual interpretation of the data makes clear the dramatic difference in cosponsorship activity between the most and least connected legislators. It also helps illustrate how much more densely connected the Senate cosponsorship network is than the House.

Table 5 Best-connected legislators in 108th Senate and House

Rank	*Best-connected representatives*	*"Bills" sponsored*	*Unique cosponsors*	*Best-connected senators*	*"Bills" sponsored*	*Unique cosponsors*
1	Saxton, Jim [R-NJ-3]	40	258	McCain, John [R-AZ]	189	80
2	Paul, Ron [R-TX-14]	76	**123**	Hatch, Orrin G. [R-UT]	133	97
3	Smith, Christopher H. [R-NJ-4]	57	336	Bingaman, Jeff [D-NM]	207	89
4	Millender-McDonald, Juanita [D-CA-37]	50	205	Grassley, Charles E. [R-IA]	156	97
5	Rangel, Charles B. [D-NY-15]	77	219	Feingold, Russell D. [R-WI]	121	**64**
6	Sensenbrenner, F. James, Jr. [R-WI-5]	45	339	Kyl, Jon [R-AZ]	114	99
7	Maloney, Carolyn B. [D-NY-14]	66	225	Kennedy, Edward [D-MA]	130	78
8	Andrews, Robert E. [D-NJ-1]	120	194	Leahy, Patrick J. [D-VT]	132	85
9	King, Peter T. [R-NY-3]	40	376	Schumer, Charles [D-NY]	166	99
10	Young, Don [R-AK]	60	251	Domenici, Pete V. [R-NM]	108	97
11	Houghton, Amo [R-NY-29]	35	384	Feinstein, Dianne [D-CA]	145	95
12	Camp, Dave [R-MI-4]	36	355	Snowe, Olympia J. [R-ME]	137	94
13	DeLay, Tom [R-TX-22]	35	190	Clinton, Hillary [D-NY]	138	90
14	Filner, Bob [D-CA-51]	44	269	Frist, Bill [R-TN]	157	99
15	Bradley, Jeb [R-NH-1]	**15**	**81**	Collins, Susan M. [R-ME]	104	92
16	English, Phil [R-PA-3]	61	402	Voinovich, George [R-OH]	96	**65**
17	Simmons, Rob [R-CT-2]	26	187	Boxer, Barbara [D-CA]	137	93
18	Evans, Lane [D-IL-17]	27	216	Daschle, Thomas A. [D-SD]	125	77
19	Kucinich, Dennis J. [D-OH-10]	32	**88**	DeWine, Michael [R-OH]	90	94
20	Tancredo, Thomas G. [R-CO-6]	38	192	Durbin, Richard J. [D-IL]	122	79
	House average	17	147	Senate average	78	72

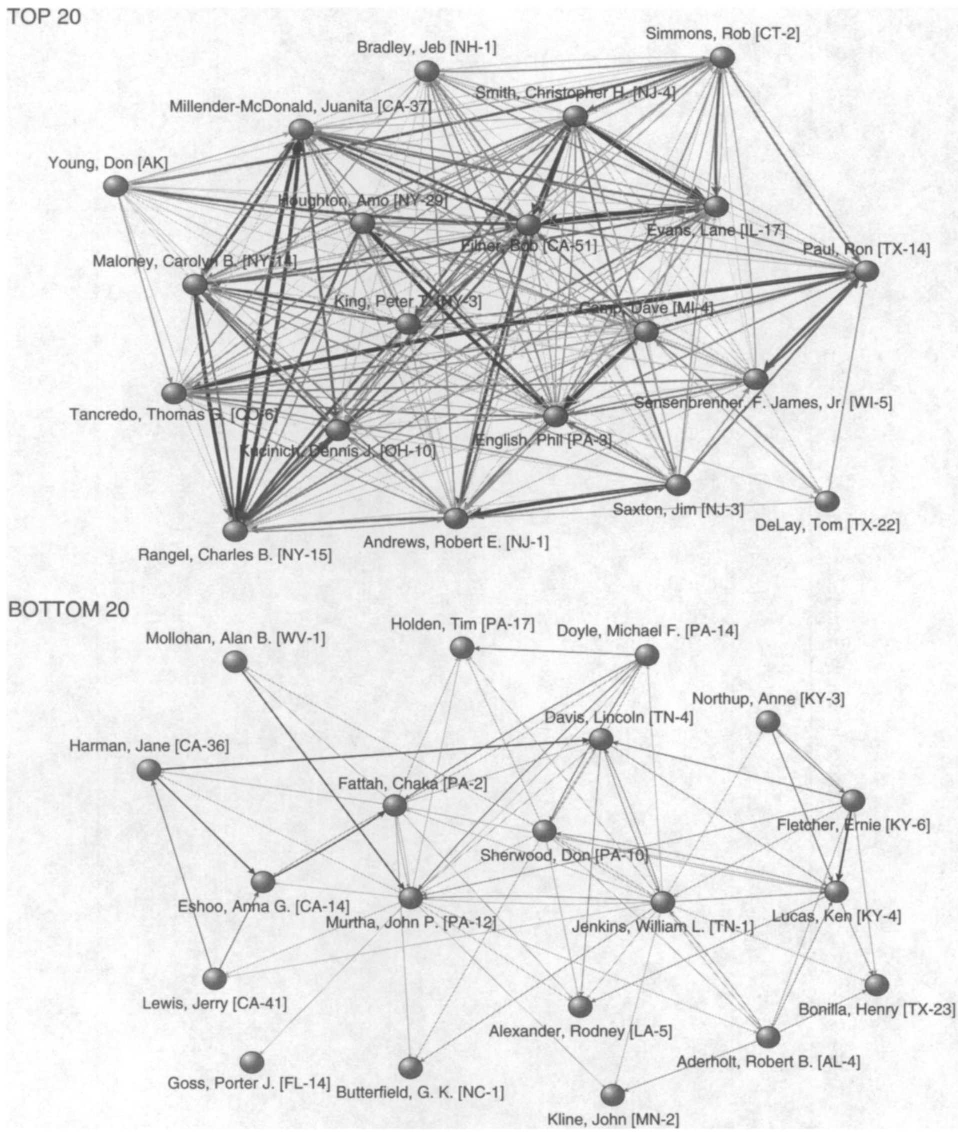

Fig. 3 Most and least connected legislators in the 108th House. These graphs only show connections among the 20 most connected (top 20) and among the 20 least connected (bottom 20). Connections between these two groups and to the other legislators in the 108th House are not shown. Graphs are drawn using Pajek (de Nooy, Mrvar, and Batagelj 2005).

9 Connectedness, Centrality, and Legislative Influence

So far the connectedness measure has been shown to be reliable, yielding similar results in different chambers and Congresses. It has also been shown to have face validity—the measure seems to identify party leaders, committee chairs, and other well-connected people in the legislative network. However, the same is true for the traditional centrality measures. To what extent is the connectedness measure externally valid, and how does it compare to the alternatives? One way to test the external validity of the connectedness measure is to compare it to measures of legislative *influence*. Legislators who are able to

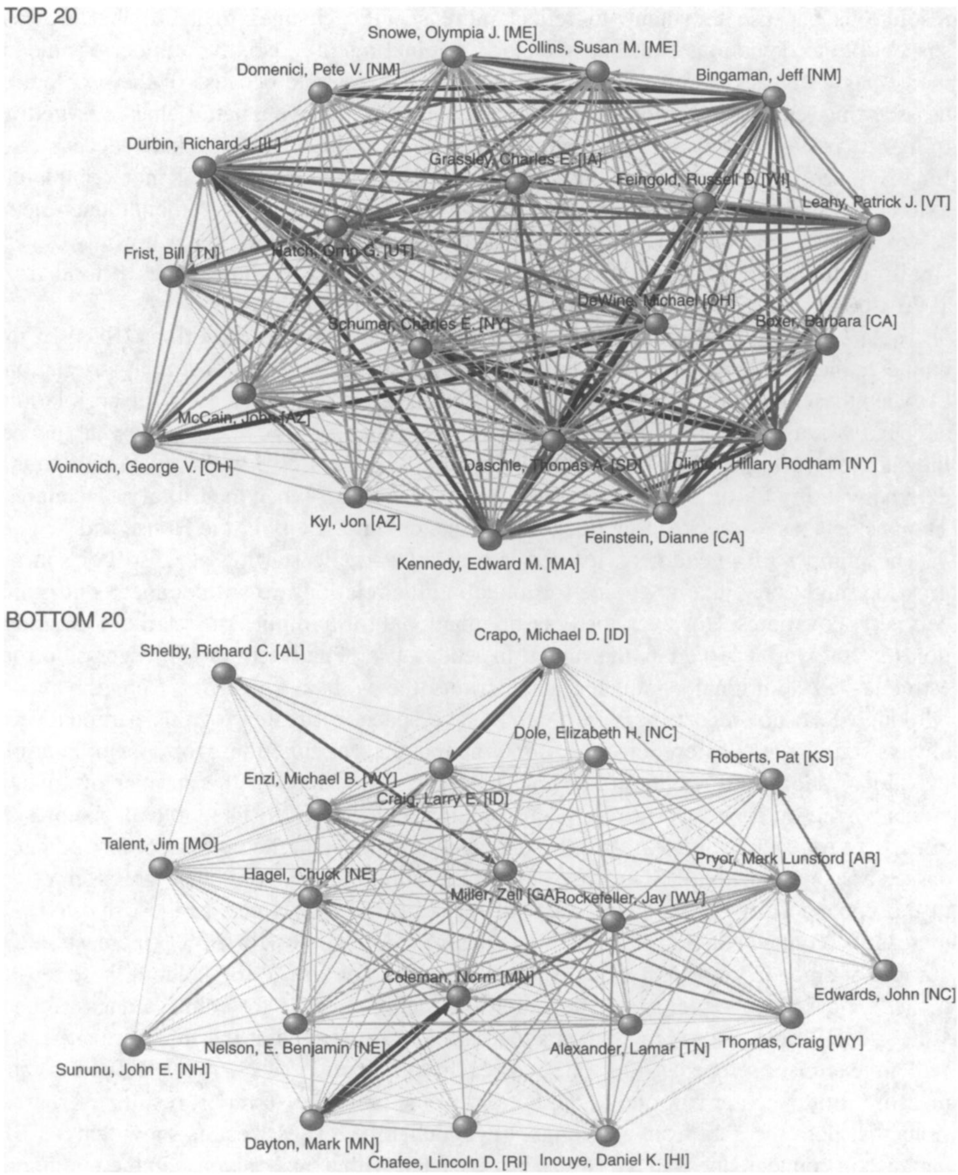

Fig. 4 Most and least connected legislators in the 108th Senate. These graphs only show connections among the 20 most connected (Top 20) and among the 20 least connected (Bottom 20). Connections between these two groups and to the other legislators in the 108th Senate are not shown. Graphs are drawn using Pajek (de Nooy, Mrvar, and Batagelj 2005).

elicit support in the cosponsorship network because they are broadly connected or well connected to other important legislators ought to be better able to shape the policies that emerge from their chamber. But how do we measure this capacity?

The most widely used measure of legislative influence is the number of successful floor amendments (Sinclair 1989; Smith 1989; Weingast 1991; Hall 1992). In particular, Hall (1992) argues that the more amendments one manages to pass on the floor, the more direct influence one has on the legislative process. Amendments are used instead of bills and resolutions because they tend to reflect more specific changes to a bill that are less susceptible to deviations from the sponsor's original intent. Also, the number of amendments passed is used as a measure instead of the success rate because of the problem of crosscutting tendencies—more influential legislators who have a better chance of getting things to pass probably propose more amendments, which reduces their success rate. Finally, one might worry that this measure of legislative influence is not completely external to measures derived from the cosponsorship network since amendments themselves may be cosponsored. However, cosponsored amendments make up only a very small portion of the data, are exceedingly rare in the House (there were 19 total from 1973–2004), and their exclusion does not alter substantive results.

Table 6 provides information about the means and standard deviations (SDs) of the connectedness and centrality measures for comparison. It also shows simple correlations between these measures by chamber and Congress. Not surprisingly, all of the correlations are positive, suggesting that connectedness and centrality scores overlap somewhat in what they are measuring. Although I show values for all Congresses, I will only be able to test external validity for the 97th Congress and later since that is when the Library of Congress Thomas database starts keeping track of all amendment activity in the House and Senate.

The number of amendments passed is a count variable starting at 0, so Poisson regression might be a natural choice for modeling the relationship with connectedness and centrality covariates. However, the Poisson functional form implies the restrictive assumption that the variance equals the mean. Instead, I use negative binomial regression that estimates an additional parameter that permits the variance to differ from the mean. Although I do not report them in order to save space, estimates for this parameter are always significantly different from 1, implying that the true functional form is not Poisson.

Table 7 shows the results of separate bivariate regressions of the number of amendments passed on each measure for each chamber and Congress. The table also shows an effect size for each estimate, reflecting the percent increase in the number of amendments passed associated with a 1 SD increase in the measure. For example, the regression results in the upper left of the table for connectedness in the 97th House suggest that a 1 SD increase in connectedness for a given legislator is associated with a 33% increase in the number of amendments passed by that legislator. Another way to think about these results is that we can expect a legislator ranked at the 95th percentile for connectedness to pass $1.33^4 = 3.13$ times more amendments than a legislator ranked at the fifth percentile.

This exercise is repeated 96 times for each combination of chamber, Congress, and measure. In the center row and at the bottom of the table, I also report results for regressions that pool the data from all Congresses by chamber. These results show that a 1 SD increase in connectedness in the House is associated with a 54% increase in the number of amendments passed, compared to 40% for closeness, 32% for betweenness, and 45% for eigenvector centrality. The results in the Senate differentiate the measures even more strongly—1 SD in connectedness is associated with a 65% increase in the number of amendments passed, compared to 31% for closeness, 19% for betweenness, and 32% for eigenvector centrality. A Senator ranked at the 95th percentile for connectedness passes about seven times as many amendments as a Sentor ranked at the fifth percentile.

Table 8 reports multivariate results that include all four measures in a single regression for each chamber and Congress. In each case, I show the model combination with the best fit (lowest AIC). For example, in the regression for the 97th House, both closeness and betweenness are dropped—only connectedness and eigenvector centrality remain. Notice that connectedness is the only measure that remains in each regression for all Congresses in both chambers. Closeness and betweenness drop out of the pooled regression models for

Table 6 A comparison of connectedness and centrality measures in each Congress

	Connectedness		*Closeness centrality*		*Betweenness centrality*		*Eigenvector centrality*		*Correlation between connectedness and*		
Congress	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Closeness centrality*	*Betweenness centrality*	*Eigenvector centrality*
House											
93rd	0.24	0.07	0.53	0.08	397	460	0.035	0.033	0.60	0.49	0.67
94th	0.26	0.08	0.54	0.08	371	431	0.036	0.031	0.51	0.44	0.59
95th	0.28	0.09	0.56	0.08	345	409	0.037	0.030	0.48	0.40	0.50
96th	0.17	0.06	0.58	0.08	319	367	0.038	0.029	0.31	0.30	0.34
97th	0.17	0.05	0.60	0.10	305	335	0.038	0.028	0.23	0.23	0.27
98th	0.16	0.05	0.63	0.11	274	275	0.039	0.028	0.30	0.25	0.30
99th	0.15	0.05	0.64	0.11	256	230	0.040	0.026	0.25	0.25	0.26
100th	0.15	0.05	0.64	0.11	255	230	0.040	0.025	0.31	0.22	0.31
101st	0.17	0.05	0.65	0.11	250	211	0.041	0.025	0.33	0.28	0.36
102nd	0.15	0.05	0.64	0.11	259	257	0.040	0.026	0.32	0.28	0.34
103rd	0.14	0.04	0.61	0.10	282	286	0.038	0.028	0.35	0.31	0.38
104th	0.13	0.05	0.58	0.08	320	370	0.036	0.031	0.26	0.29	0.28
105th	0.13	0.04	0.59	0.09	309	340	0.038	0.029	0.40	0.36	0.43
106th	0.16	0.05	0.62	0.10	288	259	0.040	0.026	0.42	0.35	0.46
107th	0.16	0.04	0.61	0.09	294	288	0.040	0.026	0.35	0.34	0.37
108th	0.17	0.05	0.61	0.09	292	271	0.040	0.026	0.30	0.28	0.33
Senate											
93rd	0.61	0.15	0.70	0.11	46	33	0.091	0.040	0.57	0.54	0.57
94th	0.64	0.16	0.70	0.12	47	34	0.091	0.042	0.62	0.53	0.64
95th	0.57	0.13	0.68	0.11	52	43	0.088	0.043	0.46	0.49	0.47
96th	0.52	0.13	0.71	0.13	45	32	0.090	0.043	0.51	0.41	0.51
97th	0.62	0.13	0.79	0.13	31	19	0.094	0.034	0.43	0.37	0.40
98th	0.81	0.19	0.83	0.12	24	13	0.097	0.024	0.65	0.19	0.61
99th	0.86	0.20	0.83	0.12	24	16	0.095	0.029	0.61	0.31	0.58
100th	0.87	0.21	0.87	0.11	17	8	0.097	0.021	0.48	0.48	0.44
101st	0.92	0.20	0.87	0.12	17	8	0.098	0.022	0.47	0.35	0.43
102nd	0.84	0.18	0.85	0.12	21	9	0.096	0.026	0.54	0.57	0.50
103rd	0.77	0.18	0.79	0.13	30	16	0.094	0.031	0.56	0.45	0.56
104th	0.88	0.17	0.73	0.11	41	23	0.093	0.033	0.46	0.52	0.42
105th	0.89	0.18	0.77	0.12	32	15	0.096	0.029	0.40	0.46	0.39
106th	0.97	0.17	0.82	0.12	24	11	0.096	0.026	0.47	0.43	0.46
107th	1.05	0.24	0.79	0.12	30	17	0.096	0.027	0.34	0.38	0.37
108th	1.04	0.19	0.81	0.12	27	14	0.096	0.027	0.48	0.41	0.46

both the House and Senate, and the effect size for connectedness is larger than the effect size for eigenvector centrality. Even controlling for the effect of centrality, a 1 SD in connectedness is associated with a 39% increase in the number of amendments passed in the House and a 59% increase in the Senate.

10 Connectedness and Roll Call Votes

Better connected legislators clearly have an important impact on the *shape* of legislation since they are able to sponsor and pass more amendments on the floor. However, this tells

Table 7 Bivariate relationship between connectedness, centrality measures, and the number of amendments passed by each legislator in each Congress

Dependent variable: number of amendments passed	Independent variables																			
	Connectedness					Closeness centrality					Betweenness centrality					Eigenvector centrality				
	Coefficient	*SE*	*p*	*AIC*	*Effect size*	*Coefficient*	*SE*	*p*	*AIC*	*Effect size*	*Coefficient*	*SE*	*p*	*AIC*	*Effect size*	*Coefficients*	*SE*	*p*	*AIC*	*Effect size*
House																				
97th	5.85	1.51	0.00	1373	33%	2.49	0.70	0.00	1373	28%	0.51	0.20	0.01	1380	19%	9.19	2.47	0.00	1372	29
98th	7.76	1.36	0.00	1432	50	2.71	0.58	0.00	1445	36	0.56	0.24	0.02	1461	17	10.83	2.39	0.00	1446	35
99th	9.27	1.49	0.00	1543	53	3.04	0.59	0.00	1555	40	1.52	0.27	0.00	1555	42	13.58	2.56	0.00	1554	41
100th	9.24	1.64	0.00	1283	57	2.05	0.67	0.00	1306	25	0.99	0.31	0.00	1306	25	10.41	3.03	0.00	1304	29
101st	12.89	1.79	0.00	1297	85	3.32	0.67	0.00	1329	45	1.57	0.35	0.00	1333	39	15.75	3.12	0.00	1328	47
102nd	13.31	2.00	0.00	1217	84	3.09	0.71	0.00	1249	40	1.32	0.29	0.00	1250	40	15.45	3.07	0.00	1243	49
103rd	17.58	2.56	0.00	1223	89	5.15	0.75	0.00	1224	69	1.58	0.26	0.00	1233	57	18.22	2.85	0.00	1230	66
104th	9.93	1.53	0.00	1349	60	6.11	0.70	0.00	1323	67	1.03	0.15	0.00	1340	47	17.10	1.89	0.00	1320	70
105th	14.00	1.97	0.00	1175	80	3.83	0.78	0.00	1209	43	1.00	0.20	0.00	1210	41	13.77	2.56	0.00	1205	48
106th	9.56	1.77	0.00	1221	55	2.88	0.75	0.00	1242	34	1.27	0.28	0.00	1239	39	12.06	2.90	0.00	1240	37
107th	12.62	2.66	0.00	934	64	1.54	0.97	0.11	953	16	0.36	0.31	0.25	955	11	5.33	3.56	0.13	954	15
108th	4.61	1.68	0.01	1059	25	2.46	0.78	0.00	1058	26	0.48	0.27	0.07	1064	14	9.39	2.92	0.00	1057	27
97th–108th	8.89	0.49	0.00	15315	53	3.26	0.20	0.00	15399	40	0.98	0.07	0.00	15470	32	13.19	0.80	0.00	15383	45
Senate																				
97th	3.76	1.17	0.00	341	62%	2.57	1.07	0.02	346	41%	6.31	7.45	0.40	350	12%	12.01	4.58	0.01	345	49
98th	1.79	0.34	0.00	713	41	3.41	0.58	0.00	710	48	17.54	5.22	0.00	731	26	17.55	2.91	0.00	707	52
99th	2.13	0.31	0.00	716	52	3.08	0.54	0.00	727	46	16.05	4.31	0.00	745	29	13.60	2.49	0.00	728	46
100th	2.73	0.29	0.00	710	76	2.40	0.70	0.00	758	29	28.68	9.78	0.00	760	24	12.40	3.73	0.00	758	29
101st	1.98	0.26	0.00	709	50	1.89	0.53	0.00	741	25	24.15	7.83	0.00	745	21	9.64	2.86	0.00	742	24
102nd	2.21	0.28	0.00	707	48	1.74	0.53	0.00	744	22	20.97	6.58	0.00	746	21	7.96	2.63	0.00	746	21

Continued

Table 7 (continued)

Dependent variable: number of amendments passed	Independent variables																			
	Connectedness					*Closeness centrality*					*Betweenness centrality*					*Eigenvector centrality*				
passed	*Coefficient*	*SE*	*p*	*AIC*	*Effect size*	*Coefficient*	*SE*	*p*	*AIC*	*Effect size*	*Coefficient*	*SE*	*p*	*AIC*	*Effect size*	*Coefficients*	*SE*	*p*	*AIC*	*Effect size*
103rd	2.83	0.38	0.00	718	65	2.21	0.55	0.00	749	33	19.05	4.34	0.00	743	35	8.99	2.32	0.00	750	33
104th	2.29	0.33	0.00	736	47	1.87	0.54	0.00	763	24	10.88	2.64	0.00	760	29	6.86	1.96	0.00	763	24
105th	2.12	0.29	0.00	688	45	2.35	0.46	0.00	709	32	15.04	3.61	0.00	715	26	10.22	1.91	0.00	707	34
106th	2.10	0.32	0.00	725	44	1.79	0.53	0.00	751	23	18.10	5.77	0.00	752	22	9.33	2.61	0.00	750	25
107th	2.00	0.23	0.00	664	60	2.17	0.51	0.00	704	30	14.00	3.54	0.00	705	27	10.46	2.27	0.00	701	33
108th	2.64	0.29	0.00	682	67	2.59	0.53	0.00	723	38	15.23	4.77	0.00	733	25	12.22	2.48	0.00	721	39
97th–108th	2.29	0.09	0.00	8552	65	2.12	0.18	0.00	8881	31	10.61	1.42	0.00	8956	19	10.40	0.85	0.00	8877.16	32

Note. Coefficients and standard errors calculated from negative binomial regression. The 97th–108th model pools data for all Congresses. Effect size represents the percentage increase in the number of amendments passed associated with a 1 SD increase in the independent variable. Betweenness coefficients and standard errors are multiplied by 10^3.

Table 8 Multivariate relationship between connectedness, centrality measures, and the number of amendments passed by each legislator in each Congress

Dependent variable: number of amendments passed	*Independent variables*												
	Connectedness			*Closeness centrality*			*Betweenness centrality*			*Eigenvector centrality*			
	Coefficient	*SE*	*Effect size*	*Coefficient*	*SE*	*Effect size*	*Coefficient*	*SE*	*Effect size*	*Coefficient*	*SE*	*Effect size*	*AIC*
House													
97th	4.51	1.53	+25%							7.21	2.55	+22%	1366
98th	6.55	1.40	39	3.28	0.91	+43%	−0.82	0.37	−20%				1423
99th	7.62	1.50	46							9.62	2.58	28	1533
100th	8.27	1.71	51							4.93	3.09	13	1282
101st	11.21	1.86	75	1.90	0.67	23							1290
102nd	11.14	2.06	75	−5.55	3.15	−46				31.46	13.71	127	1212
103rd	12.78	2.59	67	10.74	3.47	193				−28.18	13.10	−55	1203
104th	6.27	1.45	37							13.83	1.91	54	1303
105th	12.06	2.15	62							5.13	2.71	16	1174
106th	8.28	1.86	51				0.59	0.29	16				1219
107th	12.62	2.66	66										934
108th	3.20	1.75	17							7.28	3.08	21	1055
97th–108th	6.94	0.50	39							9.12	0.83	28	15158
Senate													
97th	3.76	1.17	76										341
98th	0.96	0.41	17							12.39	3.48	68	704
99th	1.63	0.36	24							6.71	2.77	33	713
100th	2.73	0.29	43										710
101st	1.98	0.26	29										709

Continued

Table 8 (continued)

Dependent variable: number of amendments passed	Independent variables												
	Connectedness			*Closeness centrality*			*Betweenness centrality*			*Eigenvector centrality*			
passed	*Coefficient*	*SE*	*Effect size*	*Coefficient*	*SE*	*Effect size*	*Coefficient*	*SE*	*Effect size*	*Coefficient*	*SE*	*Effect size*	*AIC*
102nd	2.21	0.28	52										707
103rd	2.41	0.41	62				8.40	4.26	14				716
104th	2.29	0.33	62										736
105th	1.88	0.31	46				−8.15	5.44	−6	9.22	2.87	22	680
106th	2.10	0.32	46										725
107th	1.80	0.25	38							3.69	2.13	12	663
108th	2.47	0.32	52	−3.73	2.17	−34				20.68	10.01	98	680
97th–108th	2.12	0.10	59							3.35	0.81	9	8540

Note. Coefficients and standard errors calculated from negative binomial regressions for each Congress. The 97th–108th model pools data across all Congresses. Models shown are best-fitting (lowest AIC) combination of the four independent variables. Effect size represents the percentage increase in the number of amendments passed associated with a 1 SD increase in the independent variable. Betweenness coefficients and standard errors are multiplied by 10^3.

us nothing about the *success* of the amended legislation. Senators and members of the House can add all the amendments they want, but if the bill fails final passage it will be all for naught. To what extent is connectedness associated with the outcome of final votes on the floor? If better connected legislators are indeed more influential, then they should be able to recruit more votes for the bills they sponsor.

To study this question, I obtained data from http://voteview.org on every roll call vote for the 108th Congress and then identified which votes were for final passage of a piece of legislation. In order to determine how a bill sponsor's connectedness is related to votes by members of the sponsor's chamber, the sample of final votes is restricted to those that concern legislation that originated in the same chamber. Logit regression can be used to analyze the relationship of the connectedness score of the bill sponsor to each legislator's vote choice on each bill ("Aye" = 1, "Nay" = 0, abstentions are dropped). Sponsors' vote choices for each piece of legislation are removed since the sponsor's connectedness score is not posited to have any effect on the sponsor's own behavior.

A vast literature on vote choice models in the U.S. Congress has observed a strong ideological regularity in voting patterns (Polsby and Schickler 2002). We have already noted that connectedness is sometimes based on shared ideology, so the vote choice model must control for the legislators' ideological proximity to the status quo and the proposed legislation. The DW-NOMINATE procedure produces ideology scores in two dimensions for each legislator and the ideological location of the bills identified and their status quo alternatives (Poole and Rosenthal 1997). This information can be used to derive a probability that each legislator votes "Aye" on the bill in question. Poole and Rosenthal (1997) indicate that this probability is

$$\Pr(\text{Aye}) = \Phi\left\{\beta\left(\exp\left(-\sqrt{(x_1-b_1)^2+\omega(x_2-b_2)^2}\right)\right.\right.$$
$$\left.\left.-\exp\left(-\sqrt{(x_1-q_1)^2+\omega(x_2-q_2)^2}\right)\right)\right\},$$

where x_i, b_i, and q_i are, respectively, the ideology scores for the legislator, the bill, and the status quo in the ith dimension; ω and β are chamber-specific weights on the second ideology dimension and spread of the probability distribution (0.3463 and 5.654 for the 108th House and 0.375 and 6.401 for the 108th Senate, respectively); and Φ is the cumulative standard normal distribution. Since DW-NOMINATE ideology scores have previously been shown to predict accurately a very large portion of the roll call votes, including them should ensure a strong test of the relationship between connectedness and vote choice.

Table 9 shows the results of the analysis. The coefficients on the connectedness score indicate that it is positively associated with the probability a legislator votes "Aye" in both the House and Senate. To interpret these coefficients, I use them to estimate the relationship of a 1 SD change in connectedness to the expected increase in the number of "Aye" votes in each chamber. This procedure yields an expected increase of 5.2 votes in the House and 8.2 votes in the Senate. This may not seem like much but consider how close many of these roll call votes are. Changing the connectedness of the sponsor by 2 SDs (e.g., from the 95th to the 50th percentile—from very high to average) would change the final passage outcome in 16% of the House votes and 20% of the Senate votes.

Even though we have controlled for ideology, one might argue that these numbers are not surprising since connectedness incorporates social relationships that are based on partisan ties. To be sure that the relationship between connectedness and vote choice is

Table 9 Effect of connectedness on roll call votes in the 108th Congress

	Dependent variable: roll call vote (1 = yea, 0 = nay)											
	House						*Senate*					
Independent variables	*Coefficient*	*SE*	*Effect size*	*Coefficient*	*SE*	*Effect size*	*Coefficient*	*SE*	*Effect size*	*Coefficient*	*S.E.*	*Effect size*
Connectedness score of sponsor	1.41	0.30	+5.2	0.76	0.30	+2.6	2.52	0.59	+8.2	2.51	0.59	+7.7
Probability of voting for bill												
Given DW-NOMINATE score in two dimensions	6.86	0.04		5.96	0.05		5.84	0.35		5.63	0.36	
Legislator same party as sponsor	—	—		1.59	0.03		—	—		0.81	0.19	
Constant	−3.39	0.06		−3.37	0.06		−5.94	0.69		−6.06	0.68	
N	79303			79336			1421			1417		
Deviance/null deviance	34617/100410			32373/100381			867/1503			846/1496		

Note. Coefficients and standard errors calculated from logit regression of vote choice for final passage of bills in the 108th Congress. Effect size represents the expected increase in the number of "yea" votes associated with a 1 SD change in connectedness, holding all variables at their means. To be included in the sample, a roll call must be for final passage on a bill that originates in the same chamber, and the bill in question must be assigned a DW-NOMINATE score. There were 190 such votes in the 108th House and 15 in the 108th Senate.

not purely driven by partisanship, a dummy variable is added to the model that equals 1 if the voting legislator is from the same party as the sponsor and 0 otherwise. In Table 9, notice that there is still a positive relationship between connectedness and vote choice in the models with controls for partisanship. This suggests that the connectedness measure is capturing social effects that transcend shared ideology and shared partisanship. Moreover, the relationship between connectedness and vote choice is weakened in the House but virtually unaffected in the Senate. Thus, partisanship may play a more important role in structuring social relationships between members of the House than it does for members of the Senate.

11 Conclusion

In this article, I use legislative cosponsorship networks to try to infer social relationships in the U.S. Congress that may influence legislative behavior. Analysis of these networks reveals several interesting features. Institutional changes in the rules regarding cosponsorship seem to have had only a minor effect—for example, legislators in the House submitted duplicate bills to accommodate additional signatures when there was a 25-cosponsor maximum. An analysis of the distance (geodesic) between legislators shows that the House and Senate are both densely connected, but the Senate is even more densely connected than the House, conforming to recent work on the committee assignment network (Porter et al. 2005). Moreover, there appears to be a great deal of mutual cosponsorship in the network. Legislators who receive support tend to return the favor.

I use several traditional measures of centrality to estimate the prominence of each legislator in the network and then report the top-scoring individuals in several categories. However, these methods do not take advantage of information about the number of bills cosponsored and the number of cosponsors per bill to estimate the strength of each tie. I include this information in a measure of legislative connectedness. Applying the connectedness measure to all the legislators in the network, I find that the strongest ties between legislators occur between committee chairs and ranking members (institutional ties), legislators from the same state or contiguous districts (regional ties), legislators who work closely together on a particular issue (issue-based ties), and those who are friends (personal ties). Legislators with high connectedness scores tend to sponsor more legislation and acquire more cosponsors, but some manage to score highly by being connected to other legislators who are themselves well connected.

Scholars with detailed knowledge of the legislators studied here may have different opinions about whether or not those with high connectedness scores are actually well connected. However, connectedness appears to outperform other measures of centrality in predicting the number of successful amendments proposed by each legislator. This result is important because past work has used amendments passed as a proxy for legislative influence. The connectedness measure also helps to predict legislator roll call votes, even when controlling for ideology and party affiliation. Legislators are more likely to vote for final passage of bills sponsored by well-connected Senators and Representatives. Since many roll call votes are closely contested, even small changes in the connectedness of the sponsor can change a significant fraction of the legislative outcomes.

The connectedness measure thus helps to identify the most influential legislators. We might alternatively use expert evaluations to identify the most influential legislators, but doing so for several Congresses would be costly, time consuming, and subject to the partisan bias of the evaluators. In contrast, connectedness scores are calculated using publicly available data and an objective, automatic process that requires very little manpower.

Moreover, the cosponsorship data used by this process are based directly on the actions of legislators instead of third-party opinions about those actions, increasing the chance that the measure is based on decisions that are actually relevant to the legislators under study.

Opportunities for future empirical work abound. For example, this work raises several questions about the correlates of connectedness. Are better connected legislators more senior? Although the ability to become connected may be innate, one would expect legislators to be able to learn how to better build connections over time. Do better connected legislators come from the Republicans or the Democrats? The majority party or the minority party? Liberals, moderates, or conservatives? It seems unlikely that ideology and partisanship would be related to the ability to connect, but the institutional power of the majority party may provide its members more opportunities to connect with other legislators. We might also find that partisanship plays a crucial and perhaps increasingly important role in determining which legislators are connected to one another. What is the relationship between district characteristics and connectedness? Are richer or better educated districts more likely to have well-connected legislators? One might expect higher status districts to have higher status representatives, both because they draw from a higher status pool and because there may be more competitive pressure in a district with higher stakes outcomes. Does district ideology or partisanship play a role? Evenly balanced districts may have the most connected legislators since they are more susceptible to competitive elections.

This work also raises several questions related to legislative effectiveness and electoral success. What impact do previous connectedness scores have on within-party leadership prospects and future committee portfolios? It seems reasonable to expect that better connected legislators will be more likely to capture prestigious committee assignments and leadership positions. What is the relationship between connectedness and election results? If intralegislative connectedness helps legislators provide more goods for their districts, one would expect them to be more successful in the electoral arena as well. Are quality challengers less likely to enter contests against well-connected incumbents? Are well-connected legislators more effective at soliciting campaign contributions? It is possible that the ability to elicit support from fellow legislators is indicative of other qualities that would permit a legislator to campaign effectively and deter quality entrants. The answers to these questions and many others should help us to understand better the important role that social networks and personal relationships play in the exercise of political power.

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