Legislative Success in a Small World: Social Network Analysis and the Dynamics of Congressional Legislation

Wendy K. Tam Cho University of Illinois at Urbana-Champaign
James H. Fowler University of California at San Diego

We examine the social network structure of Congress from 1973 to 2004. We treat two Members of Congress as directly linked if they have cosponsored at least one bill together. We then construct explicit networks for each year using data from all forms of legislation, including resolutions, public and private bills, and amendments. We show that Congress exemplifies the characteristics of a "small world" network and that the varying small-world properties during this time period are related to the number of important bills passed.

In a seminal article about "small world" networks, Watts and Strogatz (1988) identified a variety of different kinds of networks that exhibit two common properties. First, they had a small average shortest path length so that most nodes in the network could be reached by any other node in a small number of steps. Second, they had a large amount of clustering so that the nodes connected to a given node are also likely to be connected to one another, forming dense overlapping triads throughout the network. A small-world network is said to exist if the mean shortest path length is significantly smaller than the mean-shortest path length in a random graph of the same size, and the average level of clustering is significantly higher than it is in a corresponding random graph. Further research has shown that the small-world phenomenon is manifested in many networks, including telephone call graphs, networks composed of proteins, food chains, and metabolite processing networks, to name a few (Albert and Barabasi 2002; Watts 1999).

Although there has been a rush to identify small-world networks and their theoretical properties, there has been comparatively less work focused on the consequences or impact of small worlds. That is, how does the unique structure of a small-world system, where actors are densely interconnected with few intermediaries, affect the dynamics of the system? Some of the work that has been done indicates that the characteristics of small worlds do indeed have an impact on the dynamics of these social systems. For instance, Newman (2001) studied the scientific collaboration of scholars and concluded that the small-world structure may have an impact on the speed of information and idea dissemination in academic work. Kogut and Walker (2001) show that firms with higher centrality and lower average path lengths are more likely to be involved in takeovers and restructurings. Davis, Yoo, and Baker (2003) found the small-world structure to affect the dynamics among directors of corporations with "linchpins" holding the network together. Uzzi and Spiro (2005) examined the small world of Broadway musicals from 1945 to 1989 and found that the varying small-world properties affected the creativity of Broadway musicals. And, Fleming and Marx (2006) demonstrated that patent inventors comprise a small world and that the structure of this small world affects how innovation is realized. The common thread among these studies is their demonstration of how the small-world structure of networks plays an important role in the way they perform.

In this paper, we seek to extend this line of research into studies of the U.S. Congress, which appears to be clearly a small world. In particular, we examine how the social structure of Congress affects the dynamics of legislation. Thus far, virtually all studies of Congress

The Journal of Politics, Vol. 72, No. 1, January 2010, Pp. 124–135 doi:10.1017/S002238160999051X

ISSN 0022-3816

focus heavily on characteristics of a particular Congress (e.g., the partisan divide, the party of the President) or external forces (e.g., economic situation), with nary a nod to how the social connections between members of Congress might be tied to legislative output and productivity. We begin by describing our congressional network and how we measure social connectedness between members of Congress. We then formally define the characteristics of a small-world network and describe how, and the extent to which, Congress exhibits small-world properties. We proceed with an analysis anchored in a seminal study on legislative productivity and seek to explore how the variation in small-world network characteristics affects the output of important legislation. We conclude by discussing the impact of social network structure on the performance of Congress.

Cosponsorship of Congressional Legislation

Congress is an example of a social network (Porter et al. 2005), a social entity where the actors are interdependent and have relationships with others in the network. Of course, describing a social network requires a way to define relationships between the actors, and there are various ways in which one might specify how the members of the network are connected to one another. Here, we define two members of Congress as linked if they have cosponsored the same bill.

Although the cost of cosponsorship is low (Kessler and Krehbiel, 1996), a number of scholars have provided evidence that cosponsorship contains valuable information about how well members of Congress work together. Campbell (1982) notes that legislators expend considerable effort recruiting cosponsors with personal contacts and "Dear Colleague" letters. Representative Joseph Kennedy, wrote in a Dear Colleague letter dated January 12, 1998,

> . . . It is time we dissociate ourselves with the School of the Americas once and for all. Join 129 of your colleagues in closing down the School by becoming a cosponsor of H.R. 611. To cosponsor, call Robert Gerber at 5-5111.

Moreover, legislators frequently refer to these cosponsorships in floor debate, public discussion, letters to constituents, and campaigns. In a hearing of the House Ways and Means Committee on January 28, 1998, Representative Wally Herger paraded both the number of cosponsors as well as the bipartisanship represented by the cosponsors for H.R. 2593, the Marriage Penalty Relief Act. Further, in Representative William Colmer's words in support of the bill to formalize cosponsorships in the House in 1967,

> The cosponsorship of a bill adds prestige and strength to the proposed legislation. For there is strength in unity. The proposal is given status by numbers (Congressional Record 1967: 10710).

Thus, legislators themselves behave in a way that indicates they find some value in cosponsorship, suggesting that it is not merely "cheap talk." Cosponsorship activity has also been used by scholars to identify leadership hierarchies in the UN (Stokman 1977), as a measure of coalition-building proclivities (Wawro 2001), and as a predictor of which sponsors are most likely to achieve success in floor votes (Fowler 2006). Koger (2003) shows that legislators increasingly cosponsor with members of the other party when they are under electoral pressure. In short, even if scholars disagree on the exact informational content of bill cosponsorship, scholars and politicians alike appear to agree that cosponsorship is a social act that is meaningful and significant.

Although there are different theories for why cosponsorship occurs, each of these theories recognizes that cosponsorship embodies a social component by bringing together members of Congress via shared interests or attributes. Electoral connection theories (Mayhew 1974) posit that legislators who cosponsor are ideologically similar or are perhaps linked by electoral security (e.g., marginal versus safe districts). Theories of intralegislative signaling suggest cosponsorship is meant to influence other legislators (Kessler and Krehbiel 1996). Scholars have also used cosponsorship to document links between legislators defined by expertise and budgetary preferences (Gilligan and Krehbiel 1997; Krehbiel 1995). Whatever the linking mechanism, a common thread in this literature is that groups of cosponsors share significant experiences and attributes.

We do not purport that cosponsorship defines the social relationships in Congress, but is merely one facet of the social fabric of Congress, and one that is important for legislation. If cosponsorship indicates either a working relationship or the degree to which legislators have a history of working together, then we expect greater interconnectivity in cosponsorship to signal an increase in cooperation which may lead to increased productivity by the Congress as a whole. It is clear that it is difficult for any single member of Congress to construct landmark legislation in isolation. Both crafting legislation and passing legislation are aided by the help of others. A Congress where the members did not interact would plainly behave differently and have a different impact than one in which collaboration and cosponsorship were commonplace. Indeed, the act of cosponsorship aids legislative functions in a variety of ways. Cosponsors help craft legislation in the early stages, and innovation may be enhanced through joint collaborations. Cosponsors are instrumental as well in later stages when the sponsors of a bill need to gather support. Some work actively while others help simply by the signal of support they provide as a cosponsor (Campbell, 1982; Kessler and Krehbiel, 1996; Mayhew, 1974). We therefore expect that the structure of cosponsorships would be instrumental to the successes claimed by Congresses.

The literature on Congressional productivity has focused on characteristics of Congress or external factors such as "mood" or the budgetary situation, but it has yet to consider the social facets within the Congress. The best known model of productivity is Mayhew (2005), and it would be difficult to overstate its influence. Mayhew (2005) has been cited well over 1,000 times and has additionally inspired a literature aimed at understanding legislative productivity (see, e.g., Binder 2003; Clinton and Lapinski 2006; Howell et al. 2000). At the same time, none of this literature has explicitly considered how the variation in the aggregate patterns of social relationships might affect the policies produced by Congress. Although congressional scholars, such as Kingdon (1973), long-ago generated descriptions of how members of Congress relate to one another and how these relationships affect their voting decisions, these theories have scarcely been quantified and tested.[1]

We intend to demonstrate that the Congressional social network is an instance of a special class of networks, "small-world networks." Moreover, this network type creates a social organization with unique dynamics that influences creativity and productivity and thereby affects the performance of Congress. We will show that the more the network exhibits the properties of a small-world network, the more connected the actors are to each other and the more they are able to produce landmark legislation.

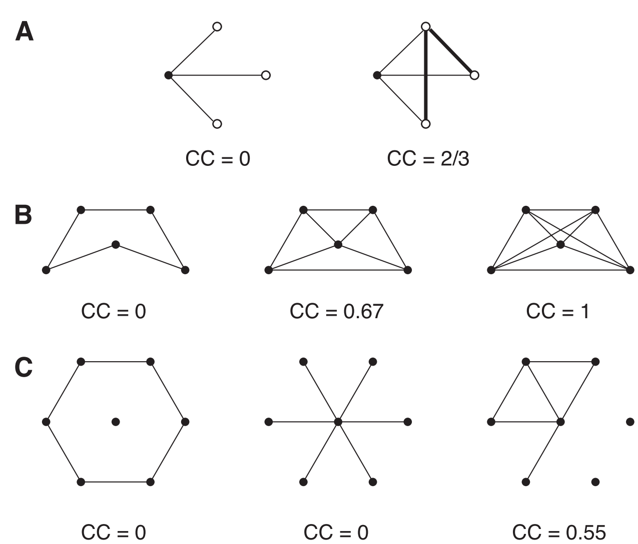
[1]One exception is a recent study of the social interactions between members of different committees where Baughman (2006) showed that in spite of increasing overlap in jurisdictions between committees, cooperation has actually improved and is strongest when members from each committee share similar interests. He also demonstrated that a history of prior working relationships helps to promote cooperation because it helps to define expectations about both interests and jurisdictions.

Small Worlds and Social Networks

The small world as folklore has recently been formalized as a network structure defined by a graph with nodes and links that exhibit both high levels of local clustering and a short average path length between nodes (Watts 1999; Watts and Strogatz 1998). The small-world measure can be operationalized through the "small-world quotient," Q, which is a function of two specific characteristics of the network, the clustering coefficient (CC) and the average path length between any two nodes (PL). The clustering coefficient measures transitivity in relationships by reflecting the average fraction of a legislator's cosponsors who are also cosponsors with one another. A relation is transitive if whenever i and j are friends and j and k are friends, then i and k are friends. So there is a fully linked triad of nodes. As the proportion of transitive relations increases in a network, the network is regarded as being more "balanced" and having more stability than one in which a link of the triad is missing.

Figure 1 gives some examples of how the clustering coefficient is computed for a network. In row A, the clustering coefficient is given for the solid black node. Lines indicate connections between the nodes, and the open circles are neighboring nodes of the solid black node. The darker lines show links among the neighboring open-circle nodes. In the network on the left, the clustering coefficient (CC) is 0 because none of the neighbors are linked with one another. In the network on the right, CC is two-thirds because two of the three possible links among neighbors exist while one does not. The examples in row B of Figure 1

Figure 1 Clustering Coefficient, CC



demonstrate how the clustering coefficient is calculated for a slightly larger network. For the network on the left, the clustering coefficient is 0 for the entire network because while there are links connecting nodes, none of the neighbor nodes are directly linked to one another. For the network in the middle, the clustering coefficient is 0.67 because, on average, about two-thirds of a node's neighbors are directly linked to one another. The network on the right is fully connected, so its clustering coefficient is 1. In row C, we have three different networks, all of the same size (seven nodes and six links). While the number of nodes and links is the same, the flow of information differs greatly because of the pattern of links. In the left network, information flow is slow and less reliable because it must always be disseminated in "telephone tree" fashion. In the second network in row C, information flow is dependent on the central node. The outer nodes are unable to communicate without traveling through the central node. In the right network, while two nodes are not connected to the network, information flow among the other nodes has multiple, reinforcing, short, and complementary paths. The connected nodes have easier access to one another in this configuration. The linked community is more tightly knit. As we can surmise from these examples, as the clustering coefficient rises, the structure of the network becomes not simply increasingly dense, but increasingly dense with overlapping clusters. The particular *pattern* of overlapping clusters is critical to information flow and is independent of the density of network links.

Formally, define a graph G as a set of n vertices or nodes, $V = v_1, v_2, \ldots, v_n$, and a set of edges or links, $E = e_{ij}$, between those vertices where e_{ij} denotes a link between vertex i and vertex j. Each vertex has a neighborhood, N, which is defined as its directly connected neighbors,

$$N_i = \{v_j\} : e_{ij} \in E. \quad (1)$$

Let $k_i = |N_i|$ be the degree of vertex i. The clustering coefficient for vertex i, CC_i, is the proportion of links between the vertices within its neighborhood divided by the number of possible links in the neighborhood. For an undirected graph, the clustering coefficient is

$$CC_i = \frac{2|\{e_{jk}\}|}{k_i(k_i - 1)} \qquad v_j, v_k \in N_i, e_{ij} \in E. \quad (2)$$

For the entire graph, the clustering coefficient is the average of the individual-clustering coefficients,

$$CC = \frac{1}{n} \sum_{i=1}^{n} CC_i. \quad (3)$$

In our network, each member of Congress is a node. Members of Congress who cosponsor at least one bill together have a direct link between them.

To obtain a measure of the degree of small worldness in a network, Watts and Strogatz (1998) proposed comparing the actual network's path length and clustering coefficient to that of a random graph with the same number of nodes and links.[2] Since the average path length of a random graph is low and all nodes have few intermediaries between them in a small world, it follows that as the PL ratio (PL of the actual network/PL of a random graph) approaches 1.0, the network begins to resemble a small world. In addition, in a random graph, since the clustering of nodes is low, the more the actual clustering coefficient deviates from the clustering coefficient in a random graph of the same size, or as the CC ratio (CC of the actual network/CC of the random graph) increasingly exceeds 1.0, the greater the degree to which the network resembles a small world. Or simply, the larger the small-world quotient (Q = CC ratio/PL ratio), the greater the resemblance to a small world.

As the CC ratio rises, there are not simply, or necessarily, more links, but rather, the links exhibit a peculiar *pattern*—the links are increasingly made up of legislators who have third-party cosponsors in common. This may occur because legislators who work together on bills are inclined to prefer cosponsors who

[2]There are many ways to define a random graph. Following (Watts 1999), we use simple expressions to calculate the clustering coefficient and path length of a random graph that were derived from approximations of random graphs calculated on lattices. The CC of a random graph can be approximated as k/n, where n is the number of nodes and k is the number of links. The average path length can be approximated as $L_M = D - \frac{k(k-1)^D}{(n-1)(k-2)^2} + \frac{k(D(k-2)+1)}{(n-1)(k-2)^2}$, where D can be approximated as $D = \frac{\ln\left[\frac{k-2}{k}(n-1)+1\right]}{\ln(k-1)} + 1$, and where n and k are defined as above.

One alternative to this approach is to consider cosponsorship as a bipartite network between legislators as one set of nodes and bills as another set. For example, (Robins and Alexander 2004) generate random networks that conform to the empirical distribution of the marginals of a bipartite network (in other words, in our case the random network would have the same distribution of cosponsorship activity by legislators and the same distribution of signatures on each bill). However, this is a conceptually different approach than we use here—we are interested in whether there are systematic patterns in the way legislators form working relationships with one another, not whether there are systematic patterns in the bills they choose to support. This means we should focus on the random alternative to the unipartite network of legislators instead of the random alternative to the bipartite projection when we are determining whether social path lengths and transitive social relationships are different than random.

have cosponsored with others with whom they have worked in the past, a process that is a result of reciprocity, partisanship, and reputation principles (Granovetter 1973). The more a network exhibits the properties of transitivity or clustering, then, the more tightly knit the network is. Congressional ''communities'' or tight-knit groups might be formed through, for example, partisan leanings, gender, race, or caucuses that join members of Congress who work or are interested in a particular area of legislation.

When Q is low, there are fewer links between members of Congress or congressional communities and the links have low cohesion in the sense that they are not disproportionately formed through third-party ties among members of Congress. As Q increases, the network becomes more interconnected and connected by members of Congress who work together because there are more transitive relationships, and the links are disproportionately made up of collaborators who share common third parties. At high levels of Q, the small world becomes a very densely woven network of overlapping clusters. Many members of Congress or congressional communities are linked by more than one member of Congress and the relationships that make up the intercommunity ties are highly cohesive.

Congress as a Small World

We computed the small-world network statistics by year from 1973 to 2004 for the U.S. House of Representatives and the U.S. Senate. The cosponsorship data were originally collected from the Thomas database of bill summaries made available by the Library of Congress (Fowler 2006). Although cosponsorship has been practiced in the Senate since the mid-1930s, and in the House since 1967, cosponsorship data in electronic format is currently available only from 1973 to the present. For the purposes of this study we include cosponsorship ties for the whole population of legislators in the House and Senate during this time period, drawing on all forms of legislation including all available resolutions, public and private bills, and amendments. Although private bills and amendments are only infrequently cosponsored, we include them because each document that has cosponsors contains information about the degree to which legislators are connected to one another.

A very large number of bills (156,270 or 55% of the total) are not cosponsored by anyone, so these bills do not provide information about social connections between legislators. The remaining 127,724 bills, however, each indicate which legislators were willing to work together. The average bill received 10.5 cosponsorships in the House and 3.4 in the Senate. However, the number of bills cosponsored by each legislator does not differ systematically by chamber—the mean House member cosponsored 244 bills per Congress while the mean Senator cosponsored 250. While these numbers may seem large, they represent only a tiny fraction of the bills they might have chosen to support. The average House member cosponsored only 3.4% of all proposed bills and the average Senator cosponsored only 2.4%.

In the House, the clustering coefficient ranges from about 30% to almost 60%, meaning that two members of the House have a 30% to 60% (depending on the year) likelihood of cosponsoring the same bill if they have both cosponsored with a third common member of the House. The clustering coefficient for random graphs of the same size are always smaller meaning there is more clustering than one would expect to occur from random connections between individuals. The average clustering coefficient over this span of years is 0.457. The average path length for the various years spans from about 1.5 to just over 2, with an average path length of 1.74. For the corresponding random graph, the average path length is generally a bit larger, primarily hovering around two links. In addition, there is a good amount of variance in the small-world quotient in these various years even between the two years that define a single Congress. This is not unusual as even when the actors do not change, their interactions should not be expected to be static.

The House and the Senate differ by institutional design, and so one might expect the behavior in these separate chambers to exhibit unique factors as well. These expectations are in fact borne out in the data. Both the characteristics of the clustering coefficient and the path length differ between the House and Senate, implying that contrasting social structures characterize the House and Senate. The Senate appears to be even more tightly knit than the House in that the clustering coefficient is much higher, ranging from over 46% to over 82%. The average clustering coefficient is 0.66, compared with 0.46 in the House. This is coupled with a path length that is always shorter, averaging just 1.3, versus 1.7 in the House.

Small World Impact on Important Legislation

We seek now to relate more formally how changes in the small-world characteristics in Congress affect how it performs. Our analysis follows the highly influential work of Mayhew (2005). We move forward using Mayhew's model and data as a point of departure because of Mayhew's centrality to this literature and the importance of having a base model and data for comparison. Changes in the effect of any particular variable or the substantive implications of the model can be more easily interpreted when the models closely match the original model.

Accordingly, we begin by replicating Mayhew's analysis exactly for the time period that he examines (1946–90).[3] These results are shown in Column 1 of Table 1 where the data are analyzed, as Mayhew did, by Congress. The data are exactly the same set Mayhew used and the dependent and independent variables are defined in precisely the same manner. In particular, the dependent variable is the number of important laws enacted by Congress.[4] The divided government variable is a dichotomous variable indicating whether or not different parties controlled the Presidency, Senate, and House. The start of the term variable is also a dichotomous variable designed to capture the idea that more laws are likely to pass at the beginning of a presidential term and is coded 1 for the first two years of a presidential term and 0 for the last two. Activist mood is coded 1 during 1961–76 to match Schlesinger's "public purpose" (Schlesinger 1999) and Huntington's "creedal passion" eras (Huntington 1981). The historian, Arthur Schlesinger, identified periods of history where the United States was rooted in a national mood of public purpose (rather than private interest). These are periods where the government must intervene in order to ensure the protection of the common good, perhaps by attempting to redistribute wealth or to protect civil rights. Huntington describes the basic ideas of the American Creed as equality, liberty, individualism, constitutionalism, and democracy. He argues that periods of creedal passion describe historical periods of political reform and cultural uprisings in the United States. These times are characterized by general discontent around the country with a negative response to authority and a feeling that the government has strayed too far from the American creed. Lastly, the budgetary situation variable indicates the size of budget surplus or deficit as the percentage of government outlays.[5]

In the second column of the same table, we extend Mayhew's analysis to 2004 using his same variables and model specification, again using a two-year period as the unit of analysis. As we can see, the results for the extended time period (1946–2004) hold strongly to those reported in Mayhew (2005) despite the shorter time period he examined (1946–90). The R^2 has declined somewhat for the data set with the additional 14 years, but the basic patterns stand the test of time, i.e., the significant variables remain significant and the substantive story does not change. In Column 3, for the same model specification, we restrict the Congresses we examine to the years for which we have cosponsorship data. Again, there is some decline in the R^2 value but the results do not change appreciably. Notably, the activist mood variable remains significant despite the much restricted time period examined and a fairly large change in the number of years that fall into the "activist mood" category (i.e., the 1960s, which were all coded as "activist mood" Congresses are not included). Lastly, even when we alter the analysis so that we examine each year rather than each Congress, the results (shown in Column 4 of Table 1) do not differ much. The activist mood variable remains significant.

Since cosponsorship was not practiced in the House during this entire time period (1946–2004), we cannot compare our results directly to those reported by Mayhew. However, as demonstrated by the results in Table 1, the basic Mayhew results

[3]To be sure, Mayhew's analysis is not perfect. One point of contention has arisen over the stationarity of the data across time (Howell et al. 2000). Howell et al. (2000) conducted a battery of augmented Dickey-Fuller tests and showed that the data were not stationary. They included an appropriately fitted polynomial in time as an independent variable to render the data trend stationary. A Poisson regression was then run since the data are counts. Their conclusion was that "OLS regressions generate virtually identical results, though they do not fit the data as well" (Howell et al. 2000, 288). Therefore we stick to Mayhew's model as a "model standard" to maximize comparability.

[4]Mayhew (2005) provides an extensive discussion of how he formed his dependent variable. A list of the specific important enactments by Congress from 1946 to 2002 is provided in Chapter 4 and the Epilogue to the book. The appendix includes a list of sources that were used in deriving judgments about important enactments as well as a defense of the methodological choices.

[5]We note that several of our variables are ratios or proportions of ratios. Accordingly, some caution should be taken because of validity issues that may arise from this data peculiarity. For instance, the data aggregation method used to compute the clustering coefficient creates a mean of the individual clustering coefficients, already a proportion, and thus hides information about distributional effects. One might gain from paying closer attention to the distribution of the clustering coefficients, since ties can be distributed in dramatically different ways within a neighborhood (e.g., clumped versus uniform). It would be interesting to explore whether or how different distributions of data may reflect different political processes. Our data aggregation method does not allow us to tap into this richness in the data.

TABLE 1 OLS Regression. Dependent Variable: Legislative Productivity. Examination of Various Changes in the Mayhew Specification.

	1946–1990 (by Congress)	1946–2004 (by Congress)	1973–2004 (by Congress)	1973–2004 (by year)
Intercept	7.90*	7.56*	7.84*	4.54*
	(1.01)	(0.99)	(1.71)	(1.04)
Divided Government	−0.59	0.18	1.49	0.38
	(1.12)	(1.04)	(1.69)	(0.96)
Start of Term	3.47*	3.29*	2.48	1.05
	(1.07)	(1.05)	(1.63)	(0.82)
Activist Mood	8.52*	8.20*	8.91*	3.98*
	(1.12)	(1.20)	(2.59)	(1.26)
Budgetary Situation	0.05	−0.00	−0.00	0.00
	(0.06)	(0.00)	(0.00)	(0.05)
N	22	29	16	32
R^2	0.80	0.70	0.55	0.31
Adjusted R^2	0.76	0.65	0.39	0.21

Standard Errors in Parentheses.
$^*p < 0.05$

remain across various time periods in Congress and even from an examination of entire Congresses (i.e., two-year periods) to an examination of single years. Hence, our point of departure need not mirror exactly the original Mayhew specification either in overall time span or in examining two-year Congresses. We choose to examine yearly data for several advantageous and critical reasons. First, it allows us to keep the total number of observations in the range of 30. Second, there is a substantial amount of data within each year given the large number of bills proposed yearly that need not be lost in aggregation. Third, we have substantial variation that can be exploited in both the budgetary situation and the small-world quotient even within a single Congress. Our point of departure then is shown in the column 4 results of Table 1 (the yearly data from 1973 to 2004). Notice that these estimates are in agreement with Mayhew's (2005) results and further maximize the time period for which we are able to compute our social network statistics.

The basic hypothesis underlying our analysis is that ''successes'' in Congress are related not only to characteristics of Congress, but to the social dynamics of Congress as well. That is, all else equal, greater interconnectivity in the cosponsorship network leads to increased productivity of the Congress as a whole. We extend the analysis in Table 2 to explore the role of social dynamics that are manifested through cosponsorship. Column 1 lists the results when we retain Mayhew's basic model specification but add the small-world quotient. Interestingly, Mayhew's activist mood variable, which remained significant through multiple subsets and various time periods of data, is no longer significant when we include the small-world quotient for the U.S. House. Instead, the only significant variable is the small-world quotient. The positive and significant sign on the small-world quotient indicates that Congress passes more important legislation as the Congressional network becomes a smaller and smaller world. The specification in Column 2 adds in the small-world quotient for the Senate. The small-world quotient for the Senate is not significant and does not appear to improve the model fit even marginally. Perhaps this result is due in part to the generally much higher levels in the clustering coefficient and the smaller path lengths in the Senate. That is, at some point, it may be that a threshold has been crossed where becoming an even smaller world is less consequential. Indeed, the Senate is a different political institution because of its smaller and more intimate size, longer terms, and greater visibility. With less than a quarter of the members of the House, the Senate is more conducive to the informal transfer of ideas. As well, partisanship is less of a barrier. The literature has been extensive on how the different institutional structures have affected the relationships in and the operations of these two chambers of Congress (Brady and Epstein 1997; Chappell and Suzuki 1993; Lebo, McGlynn, and Koger 2007; Fenno 1978; Jacobson 1983; Sinclair 1986).

TABLE 2 OLS Regression. Dependent Variable: Legislative Productivity.

	1973–2004	1973–2004	1973–2004	1973–2004	1973–2004	1973–2004	1973–2000
Intercept	−10.31	−17.32	10.21*	−6.52	6.63*	2.68	−0.37
	(5.11)	(12.99)	(2.70)	(5.06)	(1.43)	(19.35)	(0.21)
House Small World *Q*	7.39*	9.04*					0.27*
	(2.50)	(3.78)					(0.10)
Senate Small World *Q*		1.87					
		(3.19)					
House Clustering Coefficient			−13.01*			−7.50	
			(5.78)			(15.20)	
House Path Length				6.37*		2.95	
				(2.86)		(7.51)	
House Density					−10.22		
					(5.07)		
Divided Government	0.31	0.69	−0.49	−0.09	−0.02	−0.34	−0.03
	(0.85)	(1.07)	(0.98)	(0.92)	(0.93)	(1.06)	(0.04)
Start of Term	1.28	1.33	1.09	1.18	1.09	1.13	−0.02
	(0.73)	(0.74)	(0.76)	(0.77)	(0.78)	(0.78)	(0.03)
Activist Mood	1.98	1.91	2.47	2.15	2.94*	2.26	−0.05
	(1.30)	(1.32)	(1.36)	(1.44)	(1.30)	(1.48)	(0.05)
Budgetary Situation	0.03	0.05	−0.04	−0.01	−0.01	−0.03	0.00
	(0.05)	(0.06)	(0.05)	(0.05)	(0.05)	(0.06)	(0.00)
N	32	32	32	32	32	32	28
R^2	0.48	0.49	0.42	0.42	0.40	0.43	0.28
Adjusted R^2	0.38	0.38	0.31	0.31	0.29	0.29	0.11

Standard Errors in Parentheses.
$^*p < 0.05$

There are many possible model specifications, and it would be ideal if we could control for many different variables. However, our model specifications are constrained by the relatively small number of observations, which limits our degrees of freedom and thus the numbers of variables it is reasonable to include in a single model specification. Accordingly, we must be judicious in our choices. One important decision is whether the small-world measure should be the network measure of choice given the many other ways to characterize graphs. The small-world property depends simultaneously on clustering being high and average path length being short. Clustering and path length are two of many ways to characterize graphs and the ratio of these entities is but one means to assess a characteristic of these congressional networks. Columns 3–6 of Table 2 explore some alternative specifications: the effect of triads alone (column 3); path length alone (column 4); graph density (column 5); and clustering and path length together, but not as a ratio as in the small-world measure (column 6). Columns 3 and 4 show that both triads and short path length help to explain legislative productivity, and quite significantly so.[6] Graph density does not have quite the same effect, is not significant (though it is close to significant), and activist mood remains significant in the specification that includes graph density. Interestingly,

[6]Note that the clustering coefficient (as well as the path length variable) in the column 3 (and 4) model is the raw clustering coefficient for the network. It has not been standardized by the clustering coefficient for a random graph of the same size. This accounts for the perhaps nonintuitive negative coefficient on this variable. We had expected transitivity to increase legislative productivity. If the clustering coefficient variable is changed to its standardized version, the coefficient for the standardized variable is positive (3.52) as expected and remains significant. Our point in including this variable and this series of regression models is to demonstrate the logic that leads us to favor the small-world *Q* measure as the appropriate network statistic in our analysis. The counterintuitive signs on these models is yet more evidence that it is not raw transitivity or path length that drives our results, but their particular simultaneity and their relation to random graphs of the same size. Small worlds are not characterized by simple transitivity or simple path length, but their simultaneous deviance from the expected values in corresponding random graphs. Also, quite interestingly, the "reversal" in signs seem to be consistent with Granovetter's argument that sheer denseness in clustering decreases the transmission of new information, and the number of weak ties increases the transmission of new information. That is, the unstandardized version of these variables have important features that distinguish them from their standardized counterparts that appear in the small-world measure.

when both the clustering coefficient and average path length are included together in a specification, nothing is significant. The R^2 is elevated despite the lack of statistical significance in the individual regressors. These are classic symptoms of multicollinearity. In fact, it does appear that the clustering coefficient and the average path length are highly negatively correlated ($\rho = -0.91$, implying a small-world structure where short path lengths are generally associated with high levels of clustering). Accordingly, column 1 with the small-world measure has the preferred specification because it allows us to include two measures that are apparently relevant but combines them in such a manner as to allow their inclusion without the problems associated with multicollinearity.

Another consideration is that the model specifications we have discussed thus far, like Mayhew's, do not account for the volume of legislation. One might guess that the number of important laws passed would be related to the size of the legislative agenda (Binder 2003). This amounts to a slightly different question but certainly is a plausible hypothesis and should ideally be tested as well. In the first two columns of Table 2, we attempted to follow, as closely as possible, Mayhew's analysis. Mayhew (2005) argues that the important element in his analysis is the numerator (i.e., the number of important laws passed) and not the denominator (i.e., a ratio of the number of important laws passed to the size of the legislative agenda). Others (Howell et al. 2000; Binder 2003) have argued that a "denominator" approach is important to developing an understanding of success or gridlock in Congress. The last column of Table 2 displays a model specification aimed at this alternative formulation. In the third column, the dependent variable is the number of important laws passed (from Mayhew) divided by the total number of issues on the agenda in each Congress, the denominator advocated by Binder (2003).[7] Binder's values are available only by Congress and not by year since Congress's productivity is typically assessed by what they accomplish as a Congress (i.e., a two-year period). It is not possible to disaggregate her data to the year-level because of how her database was constructed. Conducting an analysis by Congress creates an obvious difficulty—reducing the sample size by half. Binder's data, moreover, is available only until 2000, not 2004, reducing the sample size further. Since we already have a somewhat small set of observations to begin with, the sample size problem is acute. To preserve what few degrees of freedom remain, we conduct the analysis by year but use her values for two years. That is, 1973 and 1974 have the same value for the gridlock variable, 1975 and 1976 have the same values, and so on. This model, accounting for the size of the legislative agenda, again accords with our main result—small-world characteristics are significantly related to legislative productivity. Thus in spite of severe limitations on the data, the connection between the dynamics of the small world and legislative productivity remain through several different specifications.

One might also be concerned that the small world quotient is not exogenous in our model. In particular, the observation that the rise in important laws is related to small-world characteristics is consistent with the story we have profferred, but may also occur if Congress's consideration of major legislation "awakens" the strong ties that already underlie the network binding members of Congress together. This line of reasoning is bolstered by Granovetter's (1973) argument that while weak ties are less likely to be linked to one another, strong ties more commonly exhibit transitivity. In this sense, cosponsorship would not be exogenous in our model. To explore this possibility, we conducted a Durbin-Wu-Hausman endogeneity test (Durbin, 1954; Hausman, 1978; Wu, 1973). We found that we could not reject the null hypothesis, implying that OLS is consistent and endogeneity is not a problem. The p-value was 0.71. While this result would not rule out the possibility of dual causation or endogeneity, it does provide evidence that any endogeneity in the small-world quotient variable does not have a deleterious effect on the OLS estimates, so an instrumental variables approach would not necessarily be a suggested course.

Discussion

We have uncovered an intriguing connection between small-world characteristics and the production of important pieces of Congressional legislation. We need

[7]The results displayed are from using the "gridlock 3" variable. She supplies five different gridlock variables. Gridlock 1 includes the widest range of issues. It includes issues that were featured in at least one editorial and so includes the widest range of issue salience. The other four gridlock variables include fewer issues depending on level of salience. Gridlock 5 includes issues that received five or more editorials and thus were more salient. Binder's analysis is often conducted for all of her gridlock variables. The analysis here results in a significant small-world Q coefficient when we use any of her gridlock variables and so our choice of displaying the gridlock 3 results is of no consequence. Note that the gridlock 2, 3, 4, and 5 variables are highly correlated (between 0.87 and 0.96) while the gridlock 1 variable including the most issues displays lower correlation values with the other four.

to untangle this quantity to get a sense of what this connection entails. To begin, however, let us emphasize that what appears to be uncontroversial in this connection is that social relationships would be connected to legislative productivity. As congressional scholars (e.g., Kingdon 1973) long ago surmised, and as our intuition would suggest, Congress is not 535 members working in isolation, affected only by outside forces such as the "start of term," the budgetary situation, or whether there is an "activist mood" pervading the session. How well the members of Congress work together has an impact on the efficiency and productivity of Congress. The dynamic social relationships—constant maintenance of older established relationships and forging relationships with new members of Congress—matter. And the small world quotient taps these social phenomena in Congress.

What do these small-world characteristics in Congress indicate? One interpretation is that cosponsorship is a form of communication. When communication is easy and simple, the likelihood of effectiveness and success in a shared endeavor increases. When friends are friends with friends, what emerges is a system where communication is enhanced because commonalities are reinforced and the number of paths through which information flows increases. In addition, barriers are broken down by the nature of the system—enlarged and numerous friendship circles. A well-known regularity in prisoner's dilemma games in social networks is that clustering increases the likelihood of cooperation since it permits the evolution of reciprocity and trust (Ifti, Killingback, and Doebelic 2004). In Congress, the dynamics are similar (Baughman 2006). Low values of the small-world quotient indicate that members of Congress are more isolated and fewer are willing to extend support outside their local networks of friends and supporters. As the world gets smaller, the friendship circles that define relationships and interactions begin to break down barriers. As communication is enhanced, links become increasingly interconnected, and the distance between any two members of Congress declines. Congress becomes more efficient, more cohesive as a legislative body, and a more effective conduit for passing important pieces of legislation.

Moreover, as the numbers of links that exist between members of Congress rises, not only is communication strengthened, but we see an increase in and an enhancement of the channels through which other types of "legislation enhancing" elements can flow. Creativity, for instance, both in terms of content as well as in methods for reigning in support, is enhanced. The transfer of ideas which is more difficult when the number of actors is large and disjointed is also facilitated in the small-world setting. Allegiances are built and strengthened. Conditions conducive to reciprocity are established and can either be built upon immediately or leveraged for later use. These conditions are reinforced as the links increasingly resemble a small-world structure.

When the small-world quotient is low, the members of Congress are more isolated. Moreover, the links that exist do not indicate the same type of cohesion since they are not disproportionately formed through common third-party cosponsors. So, while links exist and bills are certainly cosponsored among congressional teams or communities, the favorable impact of the structure is not accounted for by a simple enumeration of the number of cosponsorships (as indicated by the lack of significance in the graph density coefficient). Our method of measuring small-worlds controls for legislative activity by normalizing real network observations to a hypothetical network with the same number of relations that are randomly distributed. Random networks will have low path lengths between individuals, but they do not have the same strong clustering that occurs in real networks. Granovetter (1973) first noted that the existence of "weak ties" between these clusters are critical for individual and organizational success, so it is hardly surprising that we find the types of links that make up small-world systems are especially prevalent in effective Congresses. Indeed, all cosponsorships are not equal or comparable in their impact upon Congress's ability to pass important legislation. Instead, the particular structure of the links that make up small-world systems are especially prevalent in effective Congresses.

The finding that the small-world quotient is significant while the mere density of links is less consequential also helps us deconstruct our measure by allowing us to rule out some competing explanations for the role of cosponsorship links. Our small-world measure, for instance, is not an indicator of the popularity of bills or how well the proposed bills fit the needs of the members. The number or density of cosponsorship links might be a measure of bill popularity or member needs, but our small-world quotient measures the *relationship structure* (i.e., the interconnectedness of the triads) of cosponsorship links where density of cosponsorship links is helpful but not necessary. Density is not inconsequential, but our results turn on the structure, not the number, of links. While theories of bill popularity and member fit are inconsistent with our empirical results, there remain other consistent theories for the causal mechanisms that yield improved cooperation in Congress. The small-world quotient might be tapping into other quantities such as degree of partisanship, party polarization, or ideological polarization among individual members. Fleshing out completely the small-world quotient is beyond the scope of this study, but we do observe that the party polarization measure from McCarty, Poole, and Rosenthal (2006) appears not to be tied to the small-world quotient.[8] Likewise, the small-world measure is not highly correlated with any of the other variables in our model.

We also note that the data in our study have been subject to aggregation. We have taken data on individual Members of Congress and aggregated them over the entire Congress. Surely, much information is lost in the aggregation process, and there is much to be gained from increasing the granularity of the data or even from examining different levels of aggregation. In future work we hope to shift the focus from the aggregate to the individual level. In this article, although we have been concerned with the macroscopic structure of the relationships legislators form with other legislators, we recognize an important and complementary question concerns the extent to which we can use the bipartite version of the network of legislators and bills to learn how legislators make decisions about specific legislation. This work may also help us to understand better the specific causal mechanisms that contribute to the relationship between small worlds and legislative success. In other words, this study truly represents a first step and sets the foundation for a more extensive literature that seeks to delineate the factors that lead to a small world and further attempts to understand the role of social connectedness in the effectiveness of Congress. Identifying and illuminating these processes may help us to design institutions that will enable legislatures to promote the types of social interactions that lead to the production of important legislation.

Acknowledgments

Thanks to Neil Baer, Adam Berinsky, Sarah Binder, Andrea Campbell, Ira Carmen, Jamie Druckman, Zachary Elkins, Brian Gaines, Elisabeth Gerber, Jeff Jenkins, Georgia Kernell, Jim Kuklinski, Gabe Lenz, Mark Meredith, Kris Miler, Jeff Mondak, Chuck Shipan, Charles Stewart, Tracy Sulkin, Nathaniel Swigger, Mike Ward, and Stanley Wasserman for helpful comments.

Manuscript submitted 4 August 2008
Manuscript accepted for publication 31 March 2009

[8]For the House, the correlation between the party polarization measure (by Congress) and the small-world quotient (by Congress) is –0.17. A simple bivariate regression between the two quantities shows that the McCarty et al. measure explains virtually none of the variance in the small-world quotient. The R^2 value is 0.029 and the adjusted R^2 is negative. The coefficient is not significant. This suggests that the small-world quotient is capturing changes in social relationships that are not due to increasing ideological or partisan polarization.

References

Albert, R., and A. L. Barabasi. 2002. "Statistical Mechanics of Complex Networks." *Reviews of Modern Physics* 74 (1): 47–97.

Baughman, John. 2006. *Common Ground: Committee Politics in the U.S. House of Representatives*. Stanford University Press.

Binder, Sarah H. 2003. *Stalemate: Causes and Consequences of Legislative Gridlock*. Washington, DC: Brookings Institution Press.

Brady, David, and David Epstein. 1997. "Intraparty Preferences, Heterogeneity, and the Origins of the Modern Congress: Progressive Reformers in the House and Senate, 1890–1920." *Journal of Law, Economics, and Organization* 13 (1): 26–49.

Campbell, James E. 1982. "Cosponsoring Legislation in the U.S. Congress." *Legislative Studies Quarterly* 7 (3): 415–22.

Chappell, Henry W., Jr., and Motoshi Suzuki. 1993. "Aggregate Vote Functions for the U.S. Presidency, Senate, and House." *Journal of Politics* 55 (1): 207–17.

Clinton, Joshua D., and John S. Lapinski. 2006. "Measuring Legislative Accomplishment, 1877–1994." *American Journal of Political Science* 50 (1): 232–49.

Davis, Gerald F., Mina Yoo, and Wayne Baker. 2003. "The Small World of the American Coporate Elite, 1982–2001." *Strategic Organization* 3: 301–26.

Durbin, James. 1954. "Errors in Variables." *Review of the International Statistical Institute* 22 (1): 23–32.

Fenno, Richard F. 1978. *Home Style: House Members in their Districts*. Scott Foresman and Co.

Fleming, Lee and Matt Marx. 2006. "Managing Innovation in Small Worlds." *Management Review* 48 (1): 8–9.

Fowler, James H. 2006. "Connecting the Congress: A Study of Legislative Cosponsorship Networks." *Political Analysis* 14 (4): 454–65.

Gilligan, Thomas W., and Keith Krehbiel. 1997. "Specialization Decisions within Committees." *Journal of Law, Economics, and Organization* 13 (2): 366–86.

Granovetter, Mark. 1973. "The Strength of Weak Ties." *American Journal of Sociology* 78 (6): 1360–80.

Hausman, John A. 1978. "Specification Test in Econometrics." *Econometrica* 46 (6): 1251–71.

Howell, William G., E. Scott Adler, Charles Cameron, and Charles Riemann. 2000. "Divided Government and the Legislative Productivity of Congress, 1945–1994." *Legislative Studies Quarterly* 25 (2): 285–312.

Huntington, Samuel P. 1981. *American Politics: The Promise of Disharmony*. Cambridge, MA: Harvard University Press.

Ifti, M., T. Killingback, and M. Doebelic. 2004. "Effects of Neighbourhood Size and Connectivity on the Spatial

Continuous Prisoner's Dilemma." *Journal of Theoretical Biology* 231 (1): 97–106.

Jacobson, Gary C. 1983. *The Politics of Congressional Elections*. Boston: Little Brown and Co.

Kessler, Daniel, and Keith Krehbiel. 1996. "Dynamics of Cosponsorship." *American Political Science Review* 90 (3): 555–66.

Kingdon, John W. 1973. *Congressmen's Voting Decisions*. 3d ed. New York: Harper and Row.

Koger, Gregory. 2003. "Position Taking and Cosponsorship in the U.S. House." *Legislative Studies Quarterly* 28 (2): 225–46.

Kogut, Bruce, and Gordon Walker. 2001. "The Small World of Germany and the Durability of National Networks." *American Sociological Review* 66 (3): 317–35.

Krehbiel, Keith. 1995. "Cosponsors and Wafflers from A to Z." *American Journal of Political Science* 39: 906–23.

Lebo, Matthew, Adam McGlynn, and Gregory Koger. 2007. "Strategic Party Government: Party Influence in Congress, 1789–2000." *American Journal of Political Science* 51 (3): 464–81.

Mayhew, David R. 1974. *Congres: The Electoral Connection*. New Haven, CT: Yale University Press.

Mayhew, David R. 2005. *Divided We Govern: Party Control, Lawmaking, and Investigations, 1946–2002*. New Haven, CT: Yale University Press.

McCarty, Nolan, Keith T. Poole, and Howard Rosenthal. 2006. *Polarized America: The Dance of Ideology and Unequal Riches*. Cambridge, MA: MIT Press.

Newman, Mark E. 2001. "The Structure of Scientific Collaboration Networks." *Proceedings of the National Academy of Sciences* 98: 404–09.

Porter, Mason A., Peter J. Mucha, M. E. J. Newman, and Casey M. Warmbrand. 2005. "A Network Analysis of Committees in the U.S. House of Representatives." *Proceedings of the National Academy of Sciences* 102 (20): 7057–62.

Robins, G., and M. Alexander. 2004. "Small Worlds Among Interlocking Directors: Network Structure and Distance in Bipartite Graphs." *Computational & Mathematical Organization Theory* 10 (1): 69–94.

Schlesinger, Arthur M. 1999. *The Cycles of American History*. Houghton Miffin Company.

Sinclair, Barbara. 1986. "The Role of Committees in Agenda Setting in the U.S. Congress." *Legislative Studies Quarterly* 11 (1): 35–45.

Stokman, F. N. 1977. *Roll Calls and Sponsorship: A Methodological Analysis of Third World Group Formation in the United Nations*. AW Sijthoff.

Uzzi, Brian, and Jarrett Spiro. 2005. "Collaboration and Creativity: The Small World Problem." *American Journal of Sociology* 111 (2): 447–504.

Watts, Duncan J. 1999. *Small Worlds: The Dynamics of Networks between Order and Randomness*. Princeton, NJ: Princeton University Press.

Watts, Duncan J., and Steven H. Strogatz. 1998. "Collective Dynamics of 'Small-World' Networks." *Nature* 393: 440–42.

Wawro, Gregory. 2001. *Legislative Entrepreneurship in the U.S. House of Representatives*. Ann Arbor: University of Michigan.

Wu, De-Min. 1973. "Alternative Tests of Independence between Stochastic Regressors and Disturbances." *Econometrica* 41: 733–50.

Wendy K. Tam Cho is Associate Professor in the Departments of Political Science and Statistics and Senior Research Scientist at the National Center for Supercomputing Applications at the University of Illinois at Urbana-Champaign, Urbana, IL, 61801.

James H. Fowler is Associate Professor of Political Science, University of California, San Diego. San Deigo, CA 92093.