

Introduction: The Emergence of the Study of Networks in Politics

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Introduction

Politics is about relationships. Relationships form network structures that shape, enable, and constrain political action. Understanding the properties and consequences of these network structures is a critical part of understanding the political world. Over the past few decades, political scientists have increasingly applied network theory and methods to classic questions of governance, decision making, and political behavior. This has transformed our understanding of political phenomena ranging from legislative cooperation and voter turnout to environmental policy, nuclear proliferation, and terrorism. However, in part due to the dominance of methodological individualism, network analysis has only been taken seriously in a few subject areas within the discipline of political science. Yet it is neither a methodological fad nor a niche concept; indeed, network approaches link political science with a growing movement in other social and natural sciences that use networks to analyze interdependence in complex systems. All of these fields have benefited from increasing cross-disciplinary collaboration, developing techniques and analyzing patterns that span natural and social phenomena. As the cost of computing has dropped and tools have improved, the development and use of network theory and methods have grown significantly in political science. Indeed, political scientists have contributed significantly to the overall development of network analysis. Political science must take networks seriously: social relationships are a fundamental component of political systems, and must occupy a central place in the discipline.

Network approaches have already advanced our understanding of some of the most pressing questions in political science. Examples include: Why do individuals vote when the costs of voting exceed the benefits? Which members of Congress have the greatest potential to act as bridging agents between divergent coalitions? How do political organizations leverage long-standing relationships to their advantage? How can individuals structure democratic organizations to provide access to new information and innovations? How do governance and policy networks evolve to solve fundamental public policy problems? How can the strength of the relationship among countries encourage peaceful cooperation? Can international networks provide governance under anarchy? What are the most fruitful strategies for disrupting arms trade and violent extremist networks? Recent publications on these and other important topics reveal that answering these questions in the absence of networks results in an incomplete solution.

Until recently, however, the discipline of political science has not incorporated the basic intuition that relationships are at the heart of politics into its scholarship. This is largely because methodological individualism has been the dominant paradigm in political science during the latter half of the twentieth century and the beginning of this century. Theories and methods associated with individualism have been extraordinarily productive at advancing our understanding of politics. This paradigm has been a critical force for transforming the study of politics into a discipline that is focused on the logical principles of causal reasoning and hypothesis testing with empirical evidence. Although methodological individualism technically refers to a methodological position, in practice it frequently operates as a paradigm, taking atomistic units as ontological primitives and limiting epistemological approaches. Relational approaches challenge these assumptions.

Even those who continue to employ methodological individualism can incorporate some of the benefits of relational perspectives. After all, the strategic interactions between individuals that

are at the heart of rational choice approaches represent a relationship between players; who plays, what moves are allowed, and which payoffs are available can be deeply affected by network structures. More generally, political behavior is a result of an interaction between individual decision-making processes and the social processes that flow on networks. Advances in network models and methods allow an equivalent or higher level of empirical rigor as individualist approaches. The authors of this volume shift the disciplinary focus from individualism to network relationships and macro-level political institutions. Collectively, we argue strongly for a fundamental rather than an incremental change in perspective from individual actors to ties between those actors.

In our view, the study of politics stands at a critical juncture. We can choose to shift our thinking, models, and units of analysis to relational approaches, or we can continue to study politics as if political actors are atomistic units only constrained in their behavior by the institutions they created and the behavior of other actors. If we seek to make progress on the important questions of our time, we must consider the contributions of relational perspectives. Network theory and methods have played important roles and are part of robust research programs across a variety of academic disciplines. The statistical and methodological literature on network analysis encompasses not only social sciences such as sociology, economics, and anthropology, but also the natural sciences such as physics, mathematics, and computer science; the humanities; and applied fields such as public health, business, and public policy. Moreover, network analysis is an increasingly prominent area of research in business, communications, and defense.

Contemporary interest in studying relational politics is driven not only by the intuition and evidence that it is an important perspective but also by modern advances in data science. Empirical traces of political and other networks are often captured by information technology, but the quantitative study of such networks demands significant computational memory and processing allowances. Recent advances in the production, storage, management, and analysis of such data have played a critical role in driving engagement in topics on this scale; as personal computers have acquired the capacity to hold and process massive datasets, an increasing number of interested scholars have gained the capability to enter this field. As a consequence, network studies have gained supporters and practitioners in virtually every area of political study, including but not limited to political institutions, political behavior, public policy, parties and elections, public opinion, interest groups, social movements, political communication, political economy, democratization, transnational actors, international organizations, conflict resolution, peace studies, and security studies. Indeed, few tools of inquiry cut so broadly across the subfields, which is reflected in the depth and breadth of contributions to this volume. In short, we are at a critical moment in the development of a new approach to the study of politics – a moment when new generations of interdisciplinary scholars and graduate students are being exposed to network methods and the new ways of studying politics that they offer.

The study of political networks has also produced important innovations in the methodology of network analysis. Political network analysis requires a fundamental understanding of a variety of theoretical concepts as well as empirical research design and data analysis methods. Political network analysts have generated and adapted numerous methodological innovations, including a generalization of the powerful and popular exponential random graph model (ERGM) as well as a new method of MCMC estimation that allows the model to be applied to networks with where actors can have more than one interaction between them (Cranmer and Desmarais 2011; Cranmer, Desmarais, and Menninga 2012; Desmarais and Cranmer 2012). Furthermore, these

and other scholars have developed new techniques for performing unbiased maximum pseudo-likelihood estimation by bootstrapping across networks in temporal ERGMs (Leifeld, Cranmer, and Desmarais 2015; Leifeld et al. 2014). Political scientists have also made major contributions to latent space models that estimate the positions of actors in (unobserved) social spaces (M. D. Ward, Hoff, and Lofdahl 2003; M. D. Ward and Hoff 2008; Minhas, Hoff, and Ward 2016). These methodological innovations from political science are an important part of the overall interdisciplinary dialogue in network science, which is currently undergoing a high rate of methodological development in order to test relational hypotheses in new ways. This evolution is akin to the transformation in econometrics from basic regression models to more general approaches like maximum likelihood and Bayesian models.

The essays in this book revolve around three central questions: *What* is political network analysis? *How* does it provide insight to important political phenomena? *Why* is it crucial for all political analysts to engage in network analysis? In this introductory essay, we discuss why networks are crucial for bridging the micro-macro divide; provide a brief history of networks in the discipline; demonstrate the cross-cutting ties among subfields in the study of political networks, highlighting important foundational pieces; give an overview of the chapters in the handbook; and conclude with our thoughts on the future of political network analysis.

We build this Handbook on a number of introductory books that describe network methods and theory. For example, Hanneman and Riddle's online textbook (2005) is a great methodological introduction for beginners, although the examples primarily come from sociology. John Scott's textbook on networks is highly accessible, although again it is not specific to political science (Scott 2012). We also build upon political science-focused articles that describe the contributions of network methods to subfields like American politics (M. T. Heaney and McClurg 2009), international relations (Hafner-Burton, Kahler, and Montgomery 2009; M. D. Ward, Stovel, and Sacks 2011), and comparative politics (Siegel 2011) as well as broad overviews of the value of network research for political science (Lazer 2011). This Handbook seeks to fill the remaining gap by providing an overview of network analysis specific to political science—and its special set of applications and questions—without being constrained to a limited space in order to tackle a subject and material that have exploded over the last decade.

Why Networks?

For most people, the importance of networks is clear: social and business network contacts are instrumental to meeting a romantic partner, finding a job, or other social and economic opportunities. More broadly, networks have been fundamental in modern political and economic life to the creation and evolution of social and economic structures (Padgett and Powell 2012). Large-scale modern societies, with their multiple levels and spheres of social behavior, would not exist without social networks. Social networks are rooted in the evolution of human sociality (Apicella et al. 2012). Yet political analysis has largely been focused on individuals and institutions without considering how relationships constitute both.

Network analysis directly addresses a fundamental and enduring question in political analysis – a problem that has been called variously the “micro–macro divide” (Eulau and Rothenberg 1986; Eulau 1963) or individualism–holism (Wendt 1999). Quite simply, should our understanding of politics be focused on individual actors (i.e., micro-level) or aggregated social behavior in political institutions (i.e., macro-level)? Typically, scholars examine either the properties and collective actions of aggregate groups and political institutions or the choices,

attitudes, and strategies of individuals. Political scientists also often ask questions about how political institutions influence individual-level behavior, and vice-versa. Neither of these perspectives takes into account how individuals are embedded in social relationships. These relationships, in turn, enable the formation of groups which can ultimately influence the macro-level structure of political institutions. Conversely, the effects of political institutions on individual behavior are also mediated by networks. Hence, networks are an enduring meso-level component of political systems that merits fundamental research.

At the most basic level, this tension is a question of selecting an appropriate unit of analysis for each research question—a lesson included in any introductory course on research design. Since at least the 1960s, political science has been dominated by a focus on methodological individualism, resulting in an increased focus on individuals over systems. This paradigm has led to core discoveries in underlying causal mechanisms at work in many political and social circumstances. For example, without the focus on individuals we could not have developed the basic theory of re-election motivating legislative action (Mayhew 2004) or game theoretic concepts of nuclear deterrence (Schelling 1960; Schelling 1966).

At the same time, methodological individualism has sometimes come at a price, eroding the discipline's capacity to richly describe the historical and political processes guiding the evolution and normative consequences of political systems. The analytic challenges posed by methodological individualism have generated a number of theoretical and substantive shortcuts to make analyses tractable by treating groups or organizations as individuals; indeed, methodological individualism is more accurately termed methodological atomism, given that it is so frequently applied to units that are not individuals. The state as a unitary actor, the weight of public opinion, the public mood, existence of a political culture, and imposition of structural constraints are inventions constructed, at least in part, as explanatory devices to avoid the unwieldy and sometimes inappropriate apparatus imposed by a reliance on individuals as the unit of political analysis.

More importantly, when we focus solely on individuals or systems, analyses undertaken at only those levels are likely to provide incomplete or insufficient explanations. Theoretically, the field has been aware for some time that many political outcomes depend on interactions between actors—and, in turn, that these interactions are in turn constrained by critical institutions (Keohane and Nye 1977; Shepsle and Weingast 1987; Padgett and Ansell 1993; Ostrom 1995). To offer explanations about such circumstances scholars must understand not only the incentives of the actors but also the relationships between them and the institutions in which they operate.

Even worse, many empirical estimators rely on statistical assumptions that are grounded in methodological individualism, such as independence of error terms. Social reality violates these types of assumptions, leading to incorrect estimates of population parameters or standard errors. Thus, when we pose questions about politics and consider the appropriate unit of analysis with which to study a particular phenomenon, it becomes impossible to develop an analytical strategy that is wholly individualistic or group oriented. The interdependence between individual and system levels of analysis necessitates an intermediate level. Consequently, a solution to the problem of the micro-macro divide lies in an analytical strategy that accounts for complex interdependence: network analysis.

Beyond bridging the micro-macro divide, network analysis allows for studying meso-level phenomena in and of themselves. Often in network studies the unit of interest is not the

individual or the group, but the relationship. The relationship of interest may exist between individuals (e.g., campaign contributions between donors and candidates), organizations (e.g., country-to-country trade or conflict, civil wars), or between the two (e.g., citizen participation in government or non-governmental organizations). The pattern of relationships is generally hypothesized to reflect a particular social process, such as reciprocity or homophily. Network analysis provides the theoretical framework and tools to engage in analyses at these meso-levels that are neither wholly micro nor macro. Adoption of such a perspective provides the analyst with a powerful suite of analytical devices that can account for relational interdependence.

Part of the attraction of this approach is that it allows a scholar to develop models that may more closely resemble reality. Given the complex nature of interdependent relationships in the social and political world, network analysis gives a scholar the freedom to relax assumptions that are necessary in a more constrained framework. Whereas researchers may have previously recognized a tradeoff between parsimony and external validity, network approaches offer an analytical strategy that both satisfies the rigorous requirements of scientific reasoning and allows for inference in a complex context.

There are profound implications of a vigorous network focus for the study of politics: the challenges of this approach are observational, theoretical, and methodological, and apply to all levels of analysis. First, analysis may occur at the level of individuals, where relations between units are understood to affect the dependent variable under inquiry. Second, inquiry may occur at the level of the relationship between actors. Third, scholars may conduct inquiry at a systemic level using detailed knowledge of an entire network. Regardless of the level of analysis chosen, relations—and therefore networks—must be part of any analysis. Interdependence is both a fundamental theoretical postulate and a social fact that drives politics and political affairs, not a derivative conclusion; without considering the effects of relations, political analysis is necessarily incomplete.

A Short History of Networks in Political Science

The inclusion of network-oriented perspectives in political science has come in three waves over the past century. The first wave appeared around the 1930s and provided descriptions of the importance of relational conceptualizations to sociological questions. Perhaps the first prominent example of this is Jacob Moreno's study of the New York Training School for Girls, which resulted from his attempt to understand why some enrollees in this state-mandated reformatory program were more successful than others. His studies led him to develop the first sociograms, which depicted the relationships between individuals in a defined group. Not only did Moreno controvert then-dominant Freudian theory, but he also pioneered a new form of psychotherapy based on group interactions rather than individual interactions (Moreno 1934; Moreno 1951). His findings spawned an entire field of sociometry, which blossomed into social network theory and analysis. His findings were not alone; other scholars were making similar observations about the importance of human relationships for understanding the political and social world (Rouff 1938).

The second wave of network applications in political science accompanied the trend towards behavioralism that dominated the discipline in the 1950s and 1960s. During this wave, scholars conceptualized political actors as being driven primarily by psychological characteristics. A handful of researchers recognized that one's psychological approach to a community was

affected by one's depth of connectivity in that community (which we would now call embeddedness). For example, scholars began to study personal connections of state legislators (Patterson 1959; Monsma 1966; Eulau 1962; Wahlke et al. 1962; Young 1966). Others focused more on informal communication and strategic cueing as creating connections between political actors (Fiellin 1962; Matthews 1959), and the importance of networks for voters (Paul F. Lazarsfeld, Berelson, and McPhee 1968; Berelson, Lazarsfeld, and McPhee 1986). Ultimately, in the twentieth century, this line of inquiry became much less dominant in the discipline, compared to the exclusively individualistic rational choice approach. Some important network contributions were also made in the public policy realm, e.g., Hugh Hecho's study of issue networks (Hecho 1978).

We are currently experiencing the third wave of network study in political science, which is characterized by the development of theoretical and statistical network models of politics. In the 1980s, scholars began to focus on the intersection of institutions and public policy. Several groundbreaking studies on representation and lobbying in Washington spawned this third wave (Laumann and Knoke 1987; Heinz et al. 1990). Scholars also advanced an understanding of socially-dependent political decision making (Matthews and Stimson 1975; R. Huckfeldt and Sprague 1987a). Not coincidentally, in the 1990s we saw major advancements in computer science and technology as well as scholarship that recognized the importance of context and relationships for understanding all kinds of political behavior and outcomes. The network scholarship in political science is now heavily engaged in the broader interdisciplinary dialog of network science. The essays of this volume provide insightful and detailed literature reviews about the development of literature across many lines of inquiry.

American Political Institutions and Behavior

The study of political networks in American politics has progressed in two related threads that mirror the major topics of the subfield. These threads can be broadly described as institutional politics and behavioral politics.

In the behavioral thread, about seventy years ago scholars recognized the stickiness of political discourse: individuals do not often change their minds (Lazarsfeld, et al. 1948; Berelson 1954). In later research Robert Huckfeldt and John Sprague extended these findings to voters' choices (R. Huckfeldt and Sprague 1987b; R. R. Huckfeldt and Sprague 1995). More recently, the rational choice model of vote choice has been updated to recognize the importance of voters' contextual and interdependent decision making (Rolfe 2012; Sinclair 2012). Further research has brought nuance to understanding the ways in which social discourse contributes to individual decision making and behavior (C. A. Klofstad, Sokhey, and McClurg 2013; C. Klofstad 2010; McClurg 2006; Sokhey and McClurg 2012).

Much of the early research on networks in American political institutions focused on legislative networks. For quite some time scholars have recognized the relevance of social connections between lawmakers (Rouff 1938; Patterson 1959; Eulau 1962; Bogue and Marlaire 1975; Caldeira and Patterson 1987; Caldeira and Patterson 1988; Arnold, Deen, and Patterson 2000; Peoples 2008). More recently, scholars have focused on a variety of potential ties between legislators, including cosponsorship (Burkett and Skvoretz 2001; Crisp, Kanthak, and Leijonhufvud 2004; Fowler 2006a; Fowler 2006b; Kirkland 2011; Bratton and Rouse 2011; Cho and Fowler 2010), committee assignments (Porter et al. 2005; Porter et al. 2007), campaign contributions (Koger and Victor 2009; Victor and Koger 2016), legislative staff (Ringe, Victor, and Gross 2013), shared workspace and spatial proximity (Masket 2008; Rogowski and Sinclair

2012), legislative member organizations (Ringe and Victor 2013), and Dear Colleague letters (Craig 2015). Further research in political institutions has led to important understandings of the ways that groups interact with the judicial system and the nature of judicial decision making (Box-Steffensmeier, Christenson, and Hitt 2013; Box-Steffensmeier and Christenson 2014).

Policy Studies and Political Institutions

Recent progress in policy studies has been made through building on some of the earliest policy network studies (Heinz et al. 1997). Some of these studies involve the comparative analysis of relationships among political elites across political and policy systems (Laumann and Knoke 1987; Laumann and Pappi 1976).

More recent efforts involve network mappings of the policy process (Michael T Heaney 2006; Scholz, Berardo, and Kile 2008; Berardo and Scholz 2010; Lubell, Henry, and McCoy 2010), network impacts on tax compliance (Roch, Scholz, and McGraw 2000), and the involvement of the public in the supply and consumption of policy benefits (Schneider, Teske, and Marschall 2002; Schneider et al. 2003). Networks also play a prominent role in public administration research, particularly in the area of network governance (Provan and Kenis 2008; Jones, Hesterly, and Borgatti 1997). Recent research also points toward the role of social networks in both the creation and resolution of important public policy problems (Christakis and Fowler 2011). Moreover, students of institutions have introduced network concepts into the study of cooperation and conflict within and across institutions (Box-Steffensmeier and Christenson 2014).

Environmental policy and politics has witnessed one of the most robust applications of network theory and methods. Environmental issues are rooted in collective-action problems, where scholars like Elinor Ostrom have long pointed out the importance of networks as a form of social capital (Ostrom 1995). Environmental policy scholars have advanced theories of the policy process by examining how networks influence the formation of advocacy coalitions (Weible 2005; Henry 2011), patterns of policy learning (Berardo, Heikkila, and Gerlak 2014), capacity for cooperation (Schneider et al. 2003; Berardo and Scholz 2010), and the structure (Lubell, Robins, and Wang 2014) and performance (Lubell et al. 2016) of complex and polycentric institutional arrangements.

International Relations

Network analysis has a lengthy and often-forgotten tradition in international relations (IR) that, until recently, followed a different trajectory from the rest of political network analysis. Rather than focusing on connections between individuals or other units, early pioneers worked on examining the emergent structure of the international system resulting from ties derived from trade, international governmental organization (IGO) membership, diplomatic exchanges, and diplomatic visits (Brams 1966; Brams 1969; Christopherson 1976; Savage and Deutsch 1960; Skjelsbaek 1972). Another group used blockmodelling to determine the socioeconomic structure of the international system (Breiger 1981; Faber 1987; Nemeth and Smith 1985; Peacock, Hoover, and Killian 1988; Smith and White 1992; Snyder and Kick 1979; Van Rossem 1996). These early pieces took advantage of then-new techniques commonly used today. Nevertheless, these early pieces mostly observed the structure of the networks rather than using network analysis to test structural theories, predict outcomes of interest, or analyze the choices of individual units.

A second wave of research in international relations came as the rest of the discipline started showing a renewed interest in networks as a mode of analysis. This wave focused on using network metrics (whether traditional or newly created) into traditional monadic or dyadic regressions. Research in IR focused on IGOs (Dorussen and Ward 2008; Hafner-Burton and Montgomery 2006; Hafner-Burton and Montgomery 2008; Hafner-Burton and Montgomery 2012; H. Ward 2006; Warren 2010), human rights (Böhmelt, Koubi, and Bernauer 2014; Carpenter 2011; Carpenter 2014; Carpenter et al. 2014; Moore, Eng, and Daniel 2003; Murdie 2014; Murdie and Davis 2012; Murdie, Wilson, and Davis 2016), conflict (Corbetta 2010; Corbetta and Dixon 2005; Maoz 2006; Maoz 2009; Maoz 2011; Maoz et al. 2006; Maoz et al. 2007), arms trade (Kinsella 2006; Kinsella 2014; Montgomery 2005; Montgomery 2008; Montgomery 2013), and terrorism (Horowitz and Potter 2013; Asal, Ackerman, and Rethemeyer 2012; Perliger and Pedahzur 2011; Eilstrup-Sangiovanni and Jones 2008; Pedahzur and Perliger 2006; Brams, Mutlu, and Ramirez 2006; Sageman 2004; Krebs 2002). These approaches were theoretically innovative, taking seriously the idea that complex dependency structures among states were relevant. However, they primarily used network measures and concepts without methodologically challenging the dominant independence assumptions of the discipline. Still, these works blazed a path for more recent work that has questioned methodological individualism directly.

This wave continues to advance a productive research agenda today, and many of the chapters in this volume reflect the gains made in that wave. Yet we are also seeing the beginnings of a third wave of political network analysis in international relations. This wave was enabled by methodological advances that allowed researchers to throw out the long-standing assumption that observations (whether monadic or dyadic) were independent of each other (Snijders 2001; Hoff, Raftery, and Handcock 2002; Morris, Handcock, and Hunter 2008; Cranmer and Desmarais 2011). In exploring interconnectivity, models of geographical and social distance-based spatial networks and their dependencies have also become a topic of interest (Kristian S. Gleditsch and Ward 2000; Kristian S. Gleditsch and Ward 2001; M. D. Ward, Hoff, and Lofdahl 2003; Hoff and Ward 2004; Plümper and Neumayer 2010). While the previous wave treated networks seriously as a unit of inquiry, the third enabled the full implications of network approaches to be realized. These innovations have challenged previous long-held assumptions about the nature of politics, including casting doubt on the democratic peace, diffusion of democracy, alliance structures, preferential trade agreements, and international trade (Cranmer, Desmarais, and Menninga 2012; Cranmer, Heinrich, and Desmarais 2014; Kristian Skrede Gleditsch and Ward 2006; Kristian Skrede Gleditsch and Ward 2006; Hoff and Ward 2004; Kinne 2013; Kinne 2014; Manger, Pickup, and Snijders 2012; M. D. Ward, Ahlquist, and Rozenas 2013; M. D. Ward and Hoff 2007; M. D. Ward, Siverson, and Cao 2007).

The Network Structure of Political Network Research

We can observe these general waves of research through an introspective network analysis of the network literature. Bibliometric networks provide a useful approach for understanding the relational structure of knowledge within a discipline, typically through examining the strength of relationships between authors, articles, journals, or topics. Here we employ two techniques: co-citation and citation analysis. We start with co-citation analysis, where the more two works are cited together, the stronger their relationship (Small 1973); this metric has been widely used to measure the most important publications in a field of study (Dong and Chen 2015). We

complement this technique with citation analysis, in which two works are connected if one work cites another work.

We create two co-citation maps and one citation map using the literature in political networks. These maps are based on the same underlying data but analyze different units and relationships. First, we examine a co-citation network of journals, where two journals are more strongly related the more those journals have both been cited in other journals in the same article. Second, we examine a co-citation network of articles, where articles are more strongly related the more times both have been cited in other articles. Third, since many of the co-cited pieces are outside of the networks literature, we also examine which network articles cite each other. These approaches help us to understand how the political science network literature has developed by topic and subfield. It also helps us to understand where the anchors of the literature are, which can reveal important sources that have made outstanding contributions, and perhaps also areas of opportunity for expansion.

To analyze these citation networks, we used the Web of Science search engine and bibliometric graphing software VOSviewer (van Eck and Waltman 2014). We searched a set of relevant political science and related subfield journals for all articles using the word “network” in title, abstract, or keywords between 1960–2016.¹ The results of the search included 971 input articles from 28 political science journals, which in total cited more than 19,000 (non-unique) sources. In the graphs below, the size of a node and its label indicate its degree centrality (sum of number of ties, weighted by strength) in the network. The layout of items indicate the strength of the relationships between them: items that are more strongly related by being co-cited (or cited for the third figure) are generally closer to each other. The layout thus indicates clusters of highly related groups of sources.

Figure 1 shows the co-citation connectivity of journals. Journals are included in the graph if they have been cited a minimum of 20 times in other journals; the graph includes 286 journals. Journals are closer and larger as they receive more co-citations.

There are four distinct clusters apparent in the network. The red cluster on the left is made up of public administration journals, anchored by the flagship journal of that subfield, *Public Administration Review*. This large cluster also includes policy journals. The large green cluster near the bottom of the graph is made up of international relations journals, most prominently *International Organization*, along with some comparative politics and economics journals. The blue cluster in the top right are general political science journals and those focused on American politics. This cluster is dominated by the *American Political Science Review (APSR)*, the flagship journal of the discipline. The small yellow cluster in the center of the graph that bridges

¹ The search included the following journals: *American Political Science Review*, *American Journal of Political Science*, *Journal of Politics*, *British Journal of Political Science*, *Political Analysis*, *International Organization*, *World Politics*, *Comparative Political Studies*, *Comparative Politics*, *Policy Studies Journal*, *Public Administration Review*, *Journal of Public Administration Research and Theory*, *Legislative Studies Quarterly*, *American Politics Research*, *Politics & Gender*, *Party Politics*, *Perspectives on Politics*, *State Politics Policy Quarterly*, *Political Research Quarterly*, *Journal of Peace Research*, *Journal of Conflict Resolution*, *International Studies Quarterly*, *Political Behavior*, *Political Theory*, *Journal of Theoretical Politics*, *International Security*, *Polity*, *Political Psychology*, *European Political Science Review*, *Canadian Journal of Political Science*, *Annals of American Academy of Political and Social Science*. The *Canadian Journal of Political Science* turned out to be an isolate; no other journals cited it.

the other three clusters are primarily sociological and methodological journals, showing that many authors have cited sociological research in their political networks analysis. Additionally, some books are sufficiently co-cited that they appear in the graph (e.g. Russett and Oneal 2001, *Triangulating Peace*).

Note that while the source set of publications all have network content, they frequently cite non-network pieces as well; hence journals generally prominent in the field will still be quite central even if they have few or no network articles. For example, the APSR ranks first in co-citations from network articles in American politics (Table 1), but only fifth in citations to network articles, and eighth in total network articles published out of the 28 journals surveyed (Table 3). The flagship journal of political science has therefore played a modest role in publishing network research, but appears more prominently in the co-citation analysis simply because scholars tend to cite APSR articles.

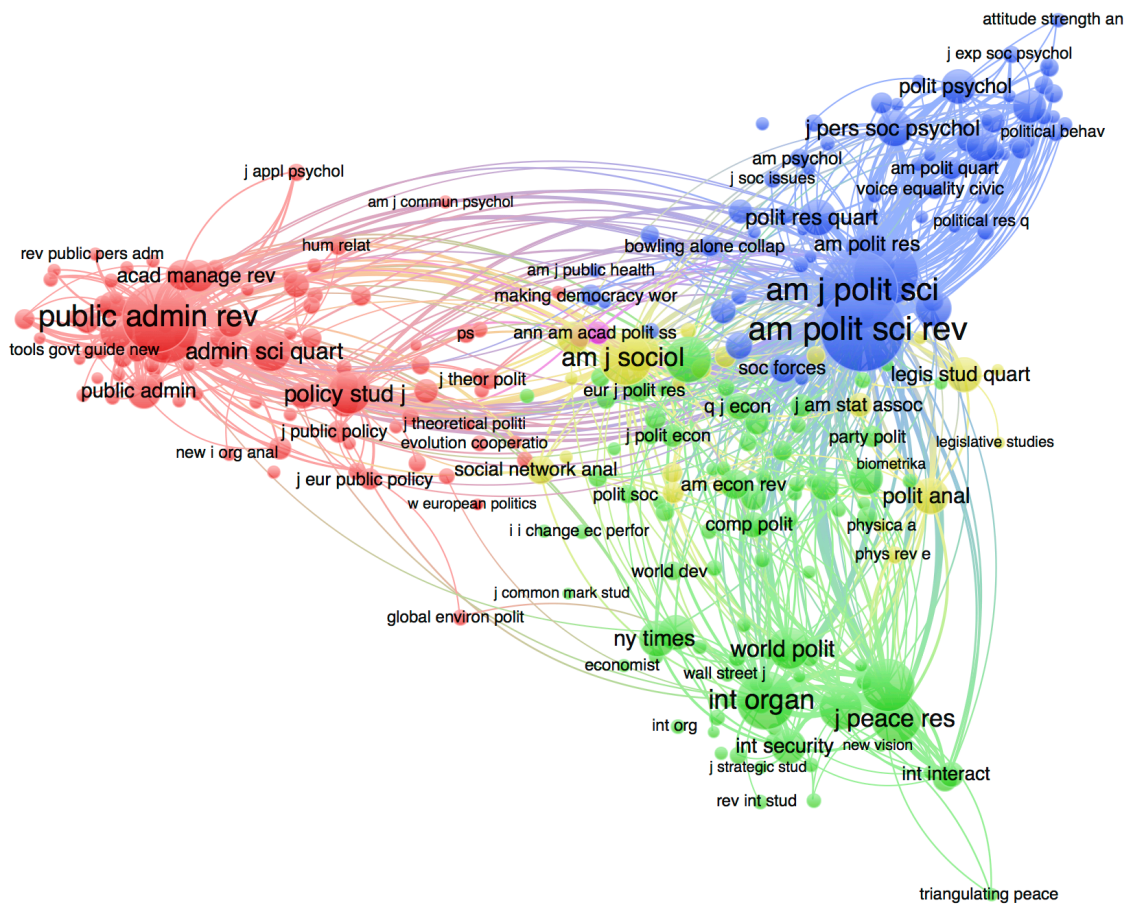


Figure 1: Co-citation connectivity among the 286 journals cited more than 20 times by political networks articles.

This visualization demonstrates both bridges and the gaps between political science subfields. First, there are three main subtopics on which political networks scholars have published, and

these are somewhat related to main subfields of the discipline: American politics; international relations and comparative politics; and public administration and policy. There is greater overlap in co-citation between American politics and international relations journals than there is between these clusters and the policy and public administration journals. Many of the policy-oriented journals represented here seem to be a bridge between public administration and other subfields. It is somewhat surprising that public administration is not more closely connected to American politics; however, network scholarship in this field has been strong and developed somewhat independently from the rest of political science. Finally, the American politics subfield has heavily cited the sociological journals, demonstrating the main path by which political science has incorporated network studies into the field.

Table 1 lists top journals represented in the graph with their respective weights. The algorithm in the bibliometric software calculates the clusters endogenously; we have not imposed clusters or their elements onto the graph. As a result, the graph has outliers such as the American Sociological Review, which is a prominent member of the cluster that primarily contains international relations and comparative politics journals rather than the cluster that contains many sociological journals. Also, the last and smallest cluster (yellow and central) is contains a mix of journals, several of which are sociological, while others are heavy on quantitative methods.

Table 1: Top journals in each co-citation cluster by source

Cluster/Subfield	Journal	Weight (Co-citations)
Public Admin	Public Administration Review	34756
	Journal of Public Admin. Research and Theory	32574
	Policy Studies Journal	12775
	Administration Science Quarterly	11913
	Administration & Society	7882
International Relations	International Organization	22579
	Journal of Conflict Resolution	19898
	Journal of Peace Research	16266
	American Sociological Review	14128
	International Studies Quarterly	12300
American Politics	American Political Science Review	52154
	American Journal of Political Science	48650
	Journal of Politics	32307
	Political Research Quarterly	9139
	Political Psychology	8716
Sociology & Methods	American Journal of Sociology	19543
	Social Networks	11497
	Political Analysis	8884
	Annual Review of Sociology	6495
	Legislative Studies Quarterly	6104

In our second graph, we take the same input dataset of 971 “network” articles in political science journals, and analyzed their bibliographies for co-citations. Again, references are more strongly related if they are both cited by the same source. Using the article as the unit of

analysis we can identify influential pieces. Articles that have been cited at least 8 times are included in the analysis, and then further limited to the top 500 cited pieces.

Figure 2 shows the co-citation network of individual published articles on “networks” published in political science journals.

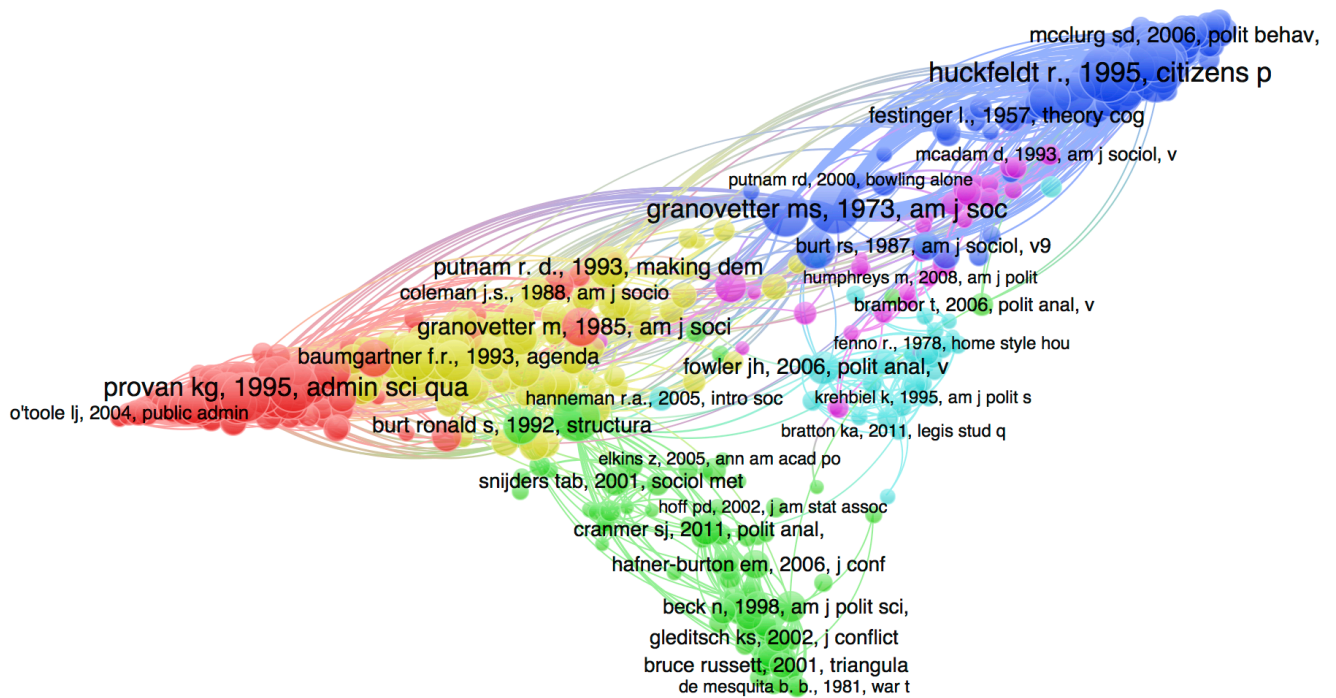


Figure 2: Co-Citations of political network articles, 1960-2016, minimum 8 citations, top 500 displayed

In Figure 2 we see a dense and tightly connected graph with four major clusters, and two minor ones. On the left-hand side of the graph we see a public administration cluster (red) that is prominent and has many highly cited pieces, but is not at the center of the graph. The network-oriented literature in public administration is strong, but not as well integrated with other threads of political science as some other fields. The public administration cluster includes works that have spawned considerable lines of research (Provan and Milward 1995; O’Toole 1997; Agranoff and McGuire 2003; M. Granovetter 1985; Agranoff and McGuire 2001). This set of articles are the foundation of the idea of network governance and public management of networks: how to organize networks of organizations to pursue policy goals that single organizations cannot independently achieve. As Agranoff and McGuire (2001, p.296) write, “networks constitute emergent phenomena that are distinctive managerial vehicles and that offer challenges for the single organization and its management.”

Table 2: Top articles/books in each co-citation cluster

Cluster/Subfield	Citation	Weight (Co-citations)
Public Administration	Provan and Milward 1995	1105
	O'Toole 1997	1073
	Agranoff and McGuire 2003	954
	M. Granovetter 1985	622
	Agranoff and McGuire 2001	618
American Politics	Huckfeldt and Sprague 1995	1501
	Granovetter 1973	1175
	Mutz 2002a	1029
	Putnam 2000	960
	Mutz 2002b	877
Public Policy	Sabatier 1993	873
	Putnam and Nanetti 1993	719
	Schneider et al. 2003	695
	Hecl 1978	534
	Berardo and Scholz 2010	493
Methods & International Relations	Wasserman and Faust 1994	979
	R. Burt 1992	503
	Beck, Katz, and Tucker 1998	349
	Cranmer and Desmarais 2011	326
	Hafner-Burton and Montgomery 2006	299

Figure 2 also includes a large (red) cluster at the top-right of the graph that is predominantly pieces in American politics. However, towards the middle of the graph but still in this cluster, we see cross-cutting pieces such as McPherson et. al's classic piece on homophily (McPherson, Smith-Lovin, and Cook 2001), Putnam's *Bowling Alone* (R. D. Putnam 2000) and sociologist Mark Granovetter's classic piece about the strength of weak ties (M. S. Granovetter 1973), which argues that weak social ties provide an individual with "strength" because they help to connect a single person with disparate others. Deeper in this cluster are classic American politics contributions by Diana Mutz, Robert Huckfeldt, and John Sprague (Mutz 2002a; Mutz 2002b; R. R. Huckfeldt and Sprague 1995; R. Huckfeldt and Sprague 1987a), who teach us about the importance of listening to countervailing information and the importance of local campaign effects. Bob Huckfeldt and John Sprague's field work in Indiana and Missouri provided a foundational base on which scholars have understood the spread of political information in communication networks. And Diana Mutz's work on persuasion, information, and our choices about how we expose ourselves to confirming and countervailing information have provided a base of understanding on which many scholars have built.

Bridging these two clusters is a public policy group (yellow) that is dominated by foundational pieces that are classics or instrumental in the development of the field (Sabatier 1993; R. L. Putnam and Nanetti 1993; Schneider et al. 2003; Hecl 1978; Berardo and Scholz 2010). The public policy literature has focused on networks as core ingredients of advocacy coalitions, where policy actors coordinate their behavior on the basis of shared policy beliefs. Public policy research has also deeply investigated the role of networks as social capital that catalyzes cooperation, coordination, and learning in fragmented institutional arrangements. The focus on

social capital derives from Elinor Ostrom's Nobel-prize winning research on the evolution of cooperation in the governance of common-pool resources. Interestingly, public policy research spans a structural hole between public administration and other political science subfields, most likely due to an overlap in interest between core ideas like social capital, embeddedness, social influence, and homophily as well as a common origin in network theory and methods from sociology.

The international relations cluster (green) also includes critical pieces in political methodology, reflecting both the focus on methods in network analysis in this subfield as well as innovations springing from it (Wasserman and Faust 1994; R. Burt 1992; Beck, Katz, and Tucker 1998; Cranmer and Desmarais 2011; Hafner-Burton and Montgomery 2006). This includes Wasserman and Faust's classic text on social network analysis, Beck, Katz, and Tucker's "Taking Time Seriously," and Cranmer and Desmarais's piece on inference that demonstrated significant third-party effects on the likelihood of conflict, both in terms of piling-on effects and the rarity of two disputants on the same side also fighting each other in international conflicts. This cluster also indicates international relations' concern with network theories, including both Burt's structural holes thesis and Hafner-Burton and Montgomery's hypotheses on centrality and group dynamics in international conflict.

Finally, two smaller clusters emerge that include subfield- or field-spanning works, including work on collective action in networks (Siegel 2009) and foundational network pieces in political science that, while associated with a particular subfield, contain insights that have been applied across such boundaries (Fowler 2006a). The bibliometric analysis suggests a fair degree of commonality in these threads of research. We are also struck by the relatively weak presence of comparative politics research among these citations. We see applications of network theories and methods to essential questions in comparative politics as a prime area for future research.

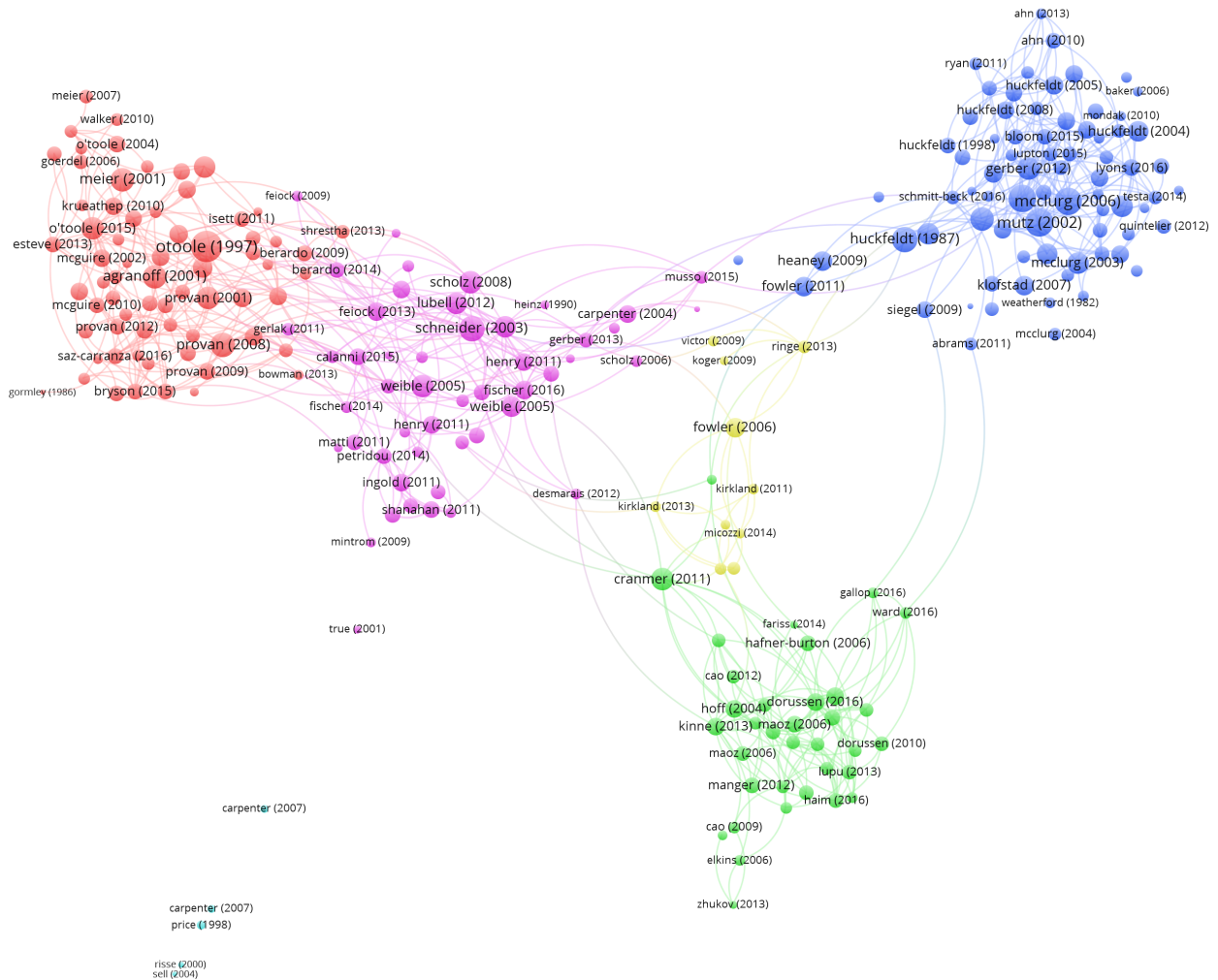


Figure 3: Citation among the top quarter (243) of our 971 network articles

While co-citation networks give an overall picture of how network articles are embedded in the larger discipline, the citation networks seen in **Error! Reference source not found.** within our sample demonstrate both connections and divisions within the political networks community. While quantitative network analysis in International Relations is clustered at the bottom (green), a disconnected group of qualitative IR approaches to networks can be seen in the lower left (light blue). Public Administration and Public Policy are in the upper left (red/purple), while American Politics is mostly grouped in the upper right (blue), with a few methodological and subject-area-spanning articles in the middle (yellow).

Table 3 details the distribution of the number of network articles and citations across the 27 connected journals in our pool of 28 journals (see also fn.1). It demonstrates how well-established network analysis is in public administration and public policy journals. As far as general field journals go, network articles in both the Journal of Politics and the American Journal of Political Science are more frequently published (and are cited) at higher rates than the APSR; similarly, the Journal of Peace Research, International Studies Quarterly, and the Journal of Conflict Resolution outrank the top IR field journals (International Organization and International Security).

Table 3: Citation among the sample journals

Journal	Network Articles	Network Articles Rank	Citations	Citations Rank
Public Administration Review	126	1	343	3
Journal of Public Administration Research and Theory	91	2	369	2
Policy Studies Journal	80	3	221	6
Journal of Politics	57	4	323	4
Journal of Peace Research	54	5	120	13
American Journal of Political Science	51	6	416	1
International Studies Quarterly	45	7	122	12
American Political Science Review	42	8	227	5
Journal of Conflict Resolution	41	9	128	10
Comparative Political Studies	40	10	38	19
Political Behavior	36	11	184	8
American Politics Research	35	12	198	7
Political Research Quarterly	35	13	136	9
International Organization	28	14	60	17
British Journal of Political Science	25	15	115	14
Political Psychology	24	16	126	11
Comparative Politics	21	17	7	26
Journal of Theoretical Politics	19	18	62	16
Party Politics	17	19	16	24
Political Analysis	14	20	88	15
Legislative Studies Quarterly	14	21	40	18
World Politics	14	22	23	21
International Security	14	23	20	22
Perspectives on Politics	14	24	17	23
Polity	12	25	13	25
State Politics & Policy Quarterly	11	26	28	20
European Political Science Review	9	27	6	27

This Handbook is being published at a time of increasing interest in network methods and applications for questions of politics. We calculate that in the 10-year period between 2002 and 2012 the number of scholarly social science articles focused on networks increased by 289 percent. Figure 3 below shows the distribution of social network related articles in political science journals over the past 30 years. Around the turn of the 21st century a leap of network articles appears. Our count includes only articles that have the word “network” in the title, abstract, or keywords, excluding those that clearly referenced networks of a non-social nature (e.g., computer networks).

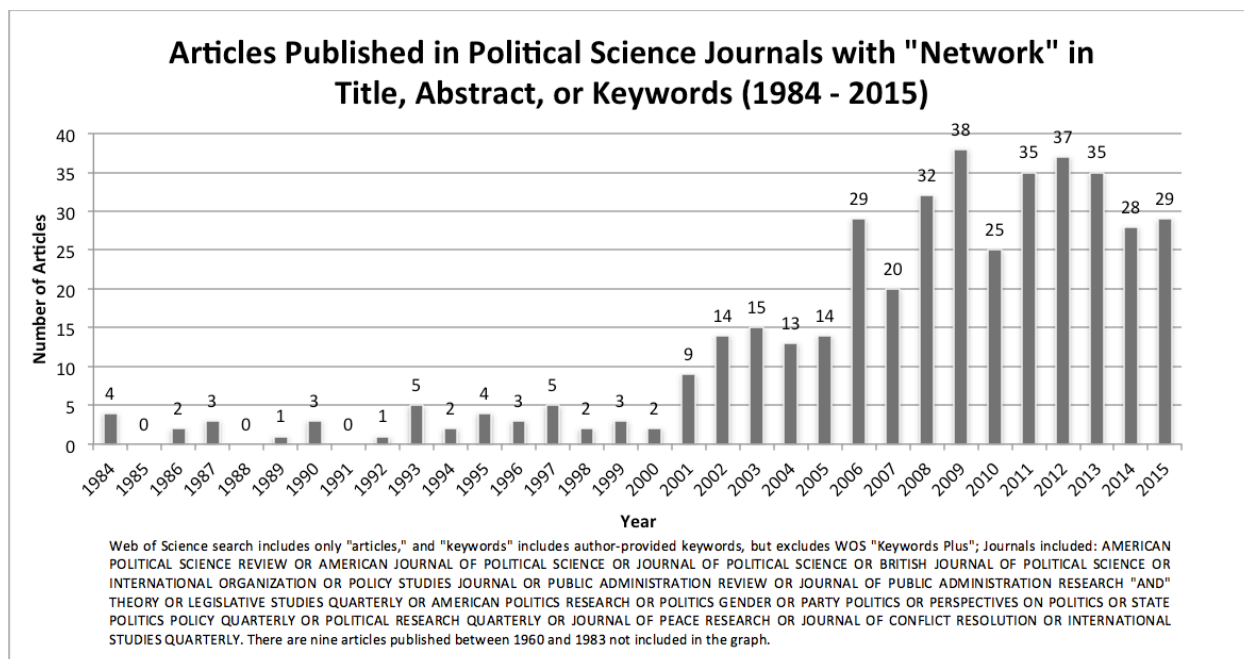


Figure 4: Frequency of scholarly political science articles on networks

We see this increase in popularity as a function of the intuitive nature of studying politics as relational phenomena, increased technological capacity to gather, manage, and analyze network data, and a multiplier effect that occurs from the coincidence of these events.

Structure of the Book

This book is divided into four primary sections. Section I provides five essays that focus on the theoretical foundations that underlie the study of political networks. In **Chapter 2, John Padgett** connects the emergence, maintenance, and evolution of formal organizations, markets, and states to the transposition of ties across multiplex networks and the autocatalytic reproduction of networks, reflecting on his recently published book co-authored with Woody Powell (2012). In **Chapter 3, David Knoke and Tetiana Kostiuhenko** describe the power structures present in policy networks. The study of power and political networks has a history that predates the recent rediscovery of network analysis in political science. This essay connects together historical and contemporary notions of structure and power in politics to networks. In **Chapter 4, David Lazer and Stefan Wojcik** provide a general introduction to the intersection of political networks and computational social science. Along with his laboratory partners, post-doctoral fellows, and students, Dr. Lazer has been at the forefront of young field at the cutting edge of harnessing technological innovation and methodological sophistication to engage in inferential modeling on topics as diverse as political communication and socialization to the complex world of political campaign donations. Lazer shows that "thinking big" is both computationally challenging and rewarding. In **Chapter 5, Jon Rogowski and Betsy Sinclair** discuss how to engage in causal inference in studies of political networks. Parsing homophilous relationships with causal ones has been a vexing obstacle for scholars of political networks. Sinclair and Rogowski offer concrete advice about how to approach causal inference in the study of political networks. In **Chapter 6, John Patty and Elizabeth Penn** provide an accessible introduction to major theoretical concepts in network analysis. The authors provide a roadmap between useful

network concepts, such as centrality and connectivity, to their empirical measurement in political science applications.

Section II includes seven essays that provide an introduction to the primary methodological concepts and approaches used in network analysis. This introduction is intended to be largely non-technical and accessible; for scholars who seek to enter this field, this provides a useful starting point from which to pursue further study on cutting edge methodological approaches to questions of politics that involve networks and interdependency. In **Chapter 7, Justin Gross and Joshua Jansa** provide a primer on introductory network analysis, focusing on instruction in important relational concepts, measurement, and data collection. They address challenges that are important to address in research design, such as missing data and sampling, while drawing comparisons with more traditional frequentist forms of statistical analysis. In **Chapter 8, Bruce Desmarais and Skyler Cranmer** provide an intermediate introduction to statistical inference in network analysis. They compare a sample of state-of-the-art techniques, including Exponential Random Graph Models (ERGM), for analyzing network data in ways that will be familiar to students of traditional statistical methods. In **Chapter 9, Tom Snijders and Mark Pickup** describe stochastic actor-oriented models for analyzing dynamic networks. The technique introduced in this chapter is designed for networks in which unbalanced panels can be described as evolving in a Markov process; the chapter also includes an overview of analysis using *RSiena* software. In **Chapter 10, Cassy Dorff, Shahyar Minhas, and Michael Ward** describe methodological approaches for latent and spatial networks. They enumerate the advantages and limitations of the latent space compared with other approaches, including guidance about useful software. In **Chapter 11, Jürgen Pfeffer and Momin M. Malik** provide an instructive introduction to visualization of network data. The authors discuss the principles of visualizing large interrelated data and offer useful, and attractive, examples. In **Chapter 12, Philip Leifeld** delivers an introduction to discourse analysis using networks. Verbal interactions between political actors provide a rich data source from which to study connections, commonalities, and conflict. Leifeld shows how such exchanges can be analyzed as data, with known properties that allow scholars to draw inference with the advantage of a temporal component. In **Chapter 13, Sijia Yang and Sandra Gonzalez-Bailon** describe techniques for analyzing semantic networks. Drawing from the rich literature on natural language processing and machine learning, this chapter introduces readers to essential methodological considerations when extracting and building up semantic networks from textual data.

Section III is the heart of this volume. It includes 24 essays broken into four subfield sections. These essays are authored by leading scholars in each of these subfields who have made important contributions to the literature. The essays provide not only a state-of-the-literature review, but also a sense of how network theories and methods are providing answers to some of the most important questions in each field. The first subsection includes eight essays on topics of American politics, covering topics relating to political institutions and political behavior. In **Chapter 14, Meredith Rolfe and Stephanie Chan** provide a summary of the state of modern research that seeks to understand voting and political participation. They describe a variety of methodological approaches to these questions, emphasizing that accounting for social context is critical for understanding these questions. Moving from the question about whether to vote, to one about how to vote, in **Chapter 15, Lauren Ratliff Santoro and Paul Beck** explore the effect of social networks on vote choice. They provide an excellent review of the literature on networks in vote choice, one of the oldest in our discipline, dating back to the behavioral revolution in the mid-twentieth century. This chapter also draws upon useful lessons in comparative politics on this topic, and outlines the challenges for making further progress on questions of vote choice. In **Chapter 16, Paul Hernnson and Justin Kirkland** examine

campaign finance networks in American politics. They provide descriptive evidence of large extended networks in the American parties that include formal and informal components that operate at the national and state levels. In **Chapter 17, Michael Heaney and James Strickland** discuss the state of networks in the study of organized interests in American politics. They explore the creation, maintenance, and influence of groups in American politics, emphasizing the important role networks play in understanding political organizations. In **Chapter 18, Gregory Koger, Seth Masket, and Hans Noel** explain how viewing political parties as extended networks improves our understanding of the role parties play in American electoral and legislative politics. In **Chapter 19, Nils Ringe, Jennifer Nicoll Victor, and Wendy Tam Cho** describe the long literature on networks in legislative politics. They outline the variety of ways scholars can think of networks as operating in legislatures and delineate the challenges and opportunities for future study on this topic. In **Chapter 20, Janet Box-Steffensmeier, Dino Christenson, and Claire Leavitt** describe how networks operate in the American judicial system. Focusing on judicial behavior and decision-making, these scholars provide an overview of the variety of ways of measuring connectivity in judicial politics. In **Chapter 21, Scott McClurg, Casey Klofstad, and Anand Sokhey** provide an overview of the deep literature on political discussion networks. They focus on political behavior as an outcome of interest, giving special attention to “ego-networks,” and the theoretical and technical challenges of drawing inference in this subfield.

The second subsection of Section III includes five essays that touch on leading topics relevant to public administration and public policy. In **Chapter 22, Richard Feiock and Manoj Shrestha** demonstrate how local governments develop formal and informal networks that help them to solve collective action problems in a self-organizing framework. In **Chapter 23, Adam Henry** uses a network framework to describe the process of learning in public policy. He focuses on segregation as an assumed characteristic of policy networks and demonstrates that traditional assumptions about policy networks may be shortsighted. In **Chapter 24, Paul Thurner** argues that as subject of study the European Union is naturally network-oriented because of the formal and informal structures, multi-level institutional features, and diverse yet connective components. He highlights how scholars have used, and can use, network perspectives to shed more light on the EU. In **Chapter 25, Ramiro Berardo, Isabella Alcañiz, Jennifer Hadden, and Lorien Jasny** focus on how network structures can inhibit policy makers and advocates to manage preferred outcomes related to environmental policy. Examining the domain of health policy, in **Chapter 26 Alexandra Joosse and H. Brinton Milward** show that a network perspective can reveal challenges and potential solutions in health policy formation and implementation.

The third subsection of Section III has six essays on topics in international relations, covering a wide range of relevant topics and network applications from trade to terrorism and human rights to arms proliferation. In **Chapter 27, Arie Perliger** explains how network analysis can shed light on understanding how terrorist organizations compete, cooperate, merge, and split. A network perspective on terrorism, he argues, can benefit national and international efforts to reduce violence from connected extremist organizations. In **Chapter 28, Giorgio Fagiolo** uses evidence to describe the properties and typologies of international trade networks, which provide a better understanding of extant trade relations and opportunities to predict future trajectories. In **Chapter 29, Mette Eilstrup-Sangiovanni** describes the various types of global governance networks and how they operate. She draws upon the global environmental protection movement to exemplify how these networks operate. In **Chapter 30, Amanda Murdie and Marc Polizzi** describe the network of human rights advocates. These scholars take an empirical approach to understanding the characteristics of human rights advocacy, focusing

on network properties to shed light the conditions under which human rights can be improved around the world. In **Chapter 31, Zeev Maoz** uses an analytical network perspective to explain international cooperation and conflict, arguing that the literature is ripe to move beyond dyadic models and toward systemic network approaches. In **Chapter 32, David Kinsella and Alexander Montgomery** detail theories and hypotheses on the factors that enable and constrain international arms trade and proliferation as well as the potentials and pitfalls of current data sources, suggesting that the field is ripe for further network analyses.

The final subsection of Section III includes five essays on topics in comparative politics, covering both institutions and political behavior. In **Chapter 33, Armando Razo** argues that the subfield of comparative politics has long been focused on relational concepts without fully embracing the benefits of network oriented theory and analytical approaches. In **Chapter 34, David Siegel** details how networks have a direct and indirect effect on the ways in which citizens interact with democratic institutions. He explores the interactive complexity in these relationships, showcasing the value of network perspectives in comparative politics. In **Chapter 35, Manuel Fischer** examines policy networks in Europe, focusing on country-level and sector-level institutions, as well as the connections between state actors. In **Chapter 36, Barry Ames, Andy Baker, and Amy Erica Smith** showcase network analysis, employing the case of the Brazilian electorate to examine egocentric discussion networks from a two-city panel study in 2014. Using the case of global climate change policy networks, in **Chapter 37 Jeffrey Broadbent** shows the value of using network theories and analyses to understand complex cross-national policy relevant phenomena.

Section IV is a somewhat unusual component of this volume that we hope readers will find particularly useful and interesting. It includes six short interviews with leading scholars from other disciplines reflecting on the state of network analysis in political science. The study of political networks is inherently interdisciplinary and, as we have already noted, the field has both borrowed heavily from advancement in other disciplines, and contributed to advancement in these disciplines. The collective knowledge on these topics is both cumulative and interdependent. We therefore posed a brief set of questions from luminaries in the fields of sociology (**James Moody**), computer science (**Derek Ruths**), statistics and psychology (**Stanley Wasserman**), mathematics (**Peter Mucha**), business (**Steve Borgatti**), and economics (**Matthew Jackson**). We find their insights on the ways in which political science is most likely to be productive in its contributions to be highly useful for developing future research plans, and we think the discipline would be wise to heed their advice about potential pitfalls of studying networks in politics.

Where does the field go from here?

The essays in this volume demonstrate the benefits of network theory and methods for addressing political puzzles. Over the past century scholars have advanced our collective knowledge on a variety of diverse topics by increasingly recognizing relational, contextual, or interdependent phenomena. Yet, the development and application of network theory and analysis to the study of politics is still in its nascent stages. As evidenced by the essays of this volume, a great deal of advancement has been made on a variety of topics in contemporary social science using network methods, but there are many unanswered questions and productive lines of inquiry to explore with network methods, theories, or perspectives. We view this as a healthy stage of development, and echo Agranoff and MacGuire's (2001; 295)

quotation of the mathematician Hilbert (1902), who said that “as long as a branch of science offers an abundance of problems, so long is it alive; a lack of problems foreshadows extinction or the cessation of independent development.”

However, we recognize that many political science scholars may remain skeptical of the value of network theory and methods, prognosticating it will have the same fate as other intellectual fads. Political network analysis faces a number of important challenges to avoid a “cessation of independent development.” Some of these are methodological challenges shared across many disciplines; with the increasing availability of data and improved computing power and algorithms, much headway has already been made. Still, we see six primary challenges and opportunities that we and our transdisciplinary partners are working on to further improve political network analysis.

The first challenge is working on untangling endogenous processes in networked systems. These systems evolve over time according to complex processes, making it difficult to discern different causal or constitutive mechanisms. For example, scholars continue to seek to discern natural homophily from causal peer effects. This is one of the classic challenges of endogeneity that makes it difficult to draw causal inferences from observations of interdependent populations. We know that humans especially have some innate likelihood to group with those who share their characteristics. Neighborhoods tend to have dominant language and ethnic identities, groups of family members and friends tend to share the same general political preferences, and groups of unrelated people who live together tend to adopt the same habits and natural patterns. But it is difficult to tease apart whether these commonalities arise because one person’s attributes or behavior cause others to be the same, or if others would have adopted the same patterns even in the absence of observing it from their peers. Political scientists are cleverly using experimental designs as well as longitudinal or panel data to help discriminate between these effects. This challenge is one of the most difficult in our field and there is a great need for creative, rigorous contributions on this topic.

A second major challenge for political network analysis is that of sampling and missing data. In frequentist statistics, one can draw an inference about a population by observing a representative sample of that population. When the distribution of data in the population and sample are the same, inference is reasonable, and we can measure its precision. By definition, the nodes or components of a network are interdependent and it may often be difficult or impossible to find the boundaries of such a population. When the size and attributes of a population are unknown, such that one cannot make reasonable assumptions about its parameters, then drawing a random sample involves making some arbitrary assumptions about network boundaries. Our inability to define whole network populations and draw random samples from these populations is a significant barrier to using social network analysis for causal inference. Furthermore, many network methods assume the researcher observes all existing nodes and relationships while real-world data collection processes are often vulnerable to missing data. This explains, at least in part, why social network analysis was used primarily for descriptive purposes for decades. It also explains the attraction to whole-network data when it is available (e.g., studying all the legislators in a congress, or all the member-countries of a treaty agreement). However, scholars have begun to make progress on this challenge (see especially Chapter 5), as increasingly creative solutions are developed to help scholars engaged in causal inference with network data.

Third, we see many opportunities for advancement in the area of so-called “big data.” This is discussed in depth in Chapter 4. “Big data” is a catch-all term that might not be descriptively

useful to distinguish different types of network analysis, insofar as network based data is often necessarily gathered on a large scale. The digitization of our modern world means that more and more data is being produced; fortunately, at the same time personal computing has also expanded our capacity to store, manage, and analyze datasets measured in terabytes, petabytes, or exabytes. All of this presents an incredible opportunity for exploration, theory development, and discovery about our social and political world since now more than ever before we can see, measure, and conceptualize our interconnectivity.

Fourth, in this same vein, we see great opportunity for progress in the area of analyzing multiplex data. Many areas of study involve units that are connected by many possible ties. For example, members of congress may be connected by common committee assignments, common policy preferences, shared professional histories, common campaign donors, and many other possibilities. Each set of connections may reveal something different about the relationships between members, and the combination of connections may be more revealing yet. We know that networks have emergent properties that can only be observed at the level of the whole network; additional properties may be revealed as we also understand the variety of ways that units or nodes might be tied. Developing better techniques for handling, theorizing, and analyzing complex network data will be an important avenue for future research. Of course, the computational demands of this type of data are intense, and political scientists may find productive co-authoring relationships with computer scientists or others with special technical skills in this area.

Fifth, a core challenge for network analysis is dealing with the evolution of networks over time. This is both a theoretical challenge (see, in particular, Chapter 2) and a methodological one. In this volume alone, we have three different quantitative approaches to dealing with the complex, time-dependent trajectory of networks (Chapters 8, 9, and 10). Yet these do not exhaust the complexities presented by dynamic networks, which can change function over time, may respond to shocks differentially, and are constantly shaping and are being shaped by wider, interlocking sets of institutions. Even if methodological hurdles can be overcome, it is nonetheless even more difficult to collect network data over time (particularly historical data) than it is to collect snapshots, although going forward the increasing collection and availability of data may ease this latter problem.

Finally, we think there is a strong need for greater theorizing about networks, their properties, and implications for questions of politics (see in particular Chapters 2, 3, and 6). From important work done in sociology we know that some network properties have consistent implications that are relevant for many political questions. For example, we know that triadic closure (when three nodes are connected to one another) occurs under conditions of cooperation and trust. We also know that nodes that are uniquely positioned between two clusters act as brokers and have significant power and control over the interactions between the clusters (R. S. Burt 2007; R. S. Burt 1995). We know that the emergence, maintenance, and evolution of social and economic structures depends on multiplex connections across networks (Padgett and Powell 2012). It is also important to understand the extent to which more general mathematical models of networks, such as preferential attachment or small-world processes, are relevant to the study of political networks. Political scientists may have useful insights, beyond what other disciplines have produced, regarding the implications of the unique properties of political networks. For example, a network perspective on policy advocates challenges the basic premise that we can understand political actors' behavior if we know the position of policy preferences in their utility functions (Leifeld and Schneider 2012). Reconceptualizing or challenging basic theories and assumptions in political science using a network lens may lead us to new insights.

In short, the theoretical and technical development of network analysis and its application to questions of politics presents incredible opportunities. As scholars seek to better understand the complexities of our political world, network approaches fit within an intuitive relational paradigm and offer a sophisticated set of tools. In the latter half of the twentieth century political science was dominated by a paradigm that was largely borrowed from economics. Methodological individualism was productive, but forced us to accept unrealistic assumptions of independence. We see the relational paradigm as a more realistic and potentially powerful lens through which to study politics. The essays in this volume are intended to introduce readers to the existing contributions to the literature that fit this description and to encourage curiosity about what contributions may come next. These essays present the tip of the iceberg of literature on network-relevant topics in the study of politics. We hope readers will find it instructive and motivating.

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