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Article *in* Quality & Quantity · March 2014

DOI: 10.1007/s11135-014-0010-2

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Qual Quant (2015) 49:581–598
DOI 10.1007/s11135-014-0010-2

A webometric approach to policy analysis and management using exponential random graph models

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Published online: 9 March 2014

Abstract Many studies have examined citizen participation in policymaking and its delivery mechanisms through social media tools such as Facebook, Twitter, and YouTube, but few have explored empirical strategies to investigate the nature of online citizen participation in the field of policy analysis and management. The webometric approach is a quantitative tool for capturing network-based intercommunication derived from the Web 2.0 sphere as user-generated content by using diverse methods in informetrics. By applying this approach to examine citizen participation on social media, this study introduces an empirical strategy for collecting data on social media tools used by governments and identifies patterns of citizens' e-participation and relationships between citizens, governments, and various organizations involved in policymaking processes through social media. The results based on the 311 service platforms of New York City and San Francisco suggest that the webometric approach can not only extract government agencies' communication behaviors toward others on social media but also capture the overall network structure, the pattern of interactions between participants, and network properties of participants.

Keywords Webometrics · Policy analysis and management · e-Participation · Government 2.0

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1 Introduction

Many studies (Choi and Park 2014; Chung et al. 2014; Khan et al. 2014a, b; Lee and Park 2013; Park 2013; Sams and Park 2014) have investigated citizens' electronic participation (e-participation) in policymaking and its delivery mechanisms through social media tools such as Facebook, Twitter, and YouTube, but few (Yoon and Park 2014) have explored the empirical strategy that can facilitate the nature of citizen participation in the field of policy analysis and management.

The webometric approach is a quantitative tool for capturing network-based intercommunication derived from the Web 2.0 sphere as user-generated content by using diverse methods in informetrics (Park 2010; Park et al. 2011; Sams et al. 2011). By applying this approach to e-participation through social media, the present study introduces an empirical strategy for collecting data from social media tools used by governments and identifies patterns of citizens' e-participation and relationships between citizens, governments, and other organizations involved in policymaking through social media. The 311 service platforms of New York City and San Francisco present distinct cases for employing the webometric approach to better understand the nature of e-participation through social media.

In the era of Government 2.0, advanced ICT (information and communication technology) applications have facilitated civic engagement in policymaking and decision making through social media (Bruns and Burgess 2011). Sæbø et al. (2009) asserted that social media can better facilitate reciprocal and transmittable relationships between public organizations and administrators and citizens than other web-based platforms. By employing social media tools, the 311 service (a government portal), for example, has extended the range of civic engagement in Government 2.0 (Holzer et al. 2006). In particular, this service has played a crucial role through social media in facilitating communication between citizens and government agencies, which depend on citizens' feedback and information. Haque (2002) noted that the formation of multilateral interconnections between all relevant information users is crucial for assessing e-government practices. Similarly, Norris (2001) pointed out that the nature of the relationship between relevant stakeholders is fundamental to assessing e-governance. Cho et al. (2013) provided support for this argument by analyzing social media use in Japan during the 2011 earthquake and finding that most of the relevant issues and conversations came from peer-to-peer communication, not from the government's leadership. That is, understanding the dynamics of e-participation networks should not be limited to a single relationship between citizens and governments, and therefore research based on the webometric approach should focus on all ties between stakeholders, between citizens and public servants, between policymakers and public servants, and between citizens and policymakers.

This study examines e-government practices in a democratic society and citizen participation through social media by taking a webometric approach and employing exponential random graph modeling and provides a case study of social media use and social networks formed for the 311 services of New York City and San Francisco. The study uncovers the communication networks of Twitter accounts for two 311 services (@nyc311 and @sf311), employs the exponential random graph model (ERGM) to examine the pattern of e-participation, and provides important empirical implications and suggestions for future research.

2 Webometric approach to policy analysis

The U.S. federal government and agencies have pursued a new government paradigm referred to as "Government 2.0" based on advanced ICT applications. Government 2.0 emphasizes the management of online interactions between governments and stakeholders (e.g., citizens and businesses) and the development of meaningful relationships between the government and the public (Chung et al. 2014). State and local policymakers have paid close attention to the potential of social media as a tool for two-way communication between governments and citizens (Sæbø et al. 2009). Margetts (2011) stated that the Internet can facilitate transparency in government communication, particularly in democratic states. Previous studies have examined the advantage of social media in the domain of political communication (Hsu et al. 2013; Otterbacher et al. 2013; Tumasjan et al. 2010).

In particular, Twitter has been recognized as an important platform for understanding the public's interests (Margetts 2009; Bruns and Burgess 2011). Previous studies have noted that Twitter is not only useful for disseminating information and ideas but also capable of enhancing public participation in political issues by enabling the public to talk about their opinions and thoughts regarding specific issues of interest (Panagiotopoulos and Sams 2012). Given that Twitter provides users with rich opportunities for discussions (Hsu et al. 2013; Honey and Herring 2009), for government officials and public service providers, Twitter can be an important tool for gathering collective knowledge and facilitating collaboration with the public. One of the major barriers to e-participation is a lack of civic participation in implementing and developing public services, and therefore Twitter can be an alternative platform for attracting the public and encouraging its involvement in the policymaking process (Sæbø et al. 2009). Twitter can be deployed for such purposes in the context of e-government. Previous studies have suggested that taking the full advantage of using the platform depends largely on government performance in creating meaningful connections and interactions with the public (Park and Lim 2014). Although the Internet's potential to facilitate interactions between governments and citizens as well as public participation in the policy process has received much attention, the government's use of social media and its implications have rarely been analyzed (Margetts 2009). In this regard, empirical studies of social media practices of government agencies are necessary for a better understanding of the extent to which they use social media efficiently and the implications for policymakers. For these reasons, e-government scholars have shifted their attention from investigating the potential of social media to analyzing the immense amount of data from social media (Chun et al. 2010).

An increasing number of social scientists have focused on the collection, classification, analysis, and visualization of data from social media based on e-science technologies (Park and Thelwall 2003; Park 2010). In this regard, researchers have applied the webometric method to measure social networking patterns, communication behaviors, and text in the web sphere. Almind and Ingwersen (1997) introduced the webometric approach as a quantitative measure for analyzing network-based communication based on methods in informetrics. Although the approach originates from the bibliometric analysis and the citation network in information science, it has been applied to analyze web information in other fields such as computer science, statistical physics, and communication studies (Thelwall et al. 2005). Informetrics generally tracks citation patterns of scholars, but some researchers have employed the approach to measure online communication between owners of webpages through the so-called "hyperlink analysis" (Park and Thelwall 2003). Recently, some scholars in humanities and social sciences have sought to extend this approach to more diverse web objects such as intercommunication, public discourse, and information flow by using computer-based analytic tools (Park 2010). Webometric tools enable the researcher to capture, analyze, and visualize large data sets on web objects such as hyperlinks, blocks of text, and patterns of information exchanges without requiring deep expertise in computational analysis methods (Panagiotopoulos and Sams 2012). In other words, this approach can facilitate the automation of the research process, including the collection, analysis, and visualization of data (Park 2010).

Previous studies have applied the webometric approach to the domain of political communication and policy analysis and acknowledged that tracking web practices of governments and interactions between governments and citizens can provide useful empirical data for understanding the quantity and quality of information structures (Cho and Park 2012; Park and Lim 2014). Lorentzen (2014) noted that the webometric method is particularly useful for exploratory studies. In the domain of policy analysis, webometric indicators can identify problem statements and dynamics of communication patterns and interactions between organizations and relevant sectors (Thelwall et al. 2010). For example, Olson et al. (2013) and Dugas et al. (2012) found that Google's "flu trends" service is a relevant influenza surveillance system reflecting influenza-related activities of patients. Dugas et al. (2012) suggested that such search engine query data can serve as a surveillance tool for emergency services.

In this regard, Park (2013) argued that the structural properties of communication systems obtained from the webometric method can serve as indicators of the pattern of civic engagement and public opinion toward political events and policymaking processes. Nam et al. (2013) examined the web ecology of the 2010 local elections in South Korea by using the hyperlink analysis method and found that the political network structure is closely related to the public's perceived awareness and interest. This implies that studying the structure of networks and the pattern of interconnections between network members can reveal the information behavior of these members in the course of a political event. Lee and Park (2014) pointed out that the use of social media by governments signals their explicit efforts to reach out to the widest public, and in this regard, taking a webometric approach to social media use by government officials and the construction of social networks can provide important insights for evaluating e-government practices. This study makes an important contribution to the literature by taking a webemetric approach to the collection and analysis of data and addressing the limitation of exponential random graph modeling, which has difficulty coping with large-scale networks (Ackland 2009; Lewis 2014). This analytic combination of the webometric approach and exponential random graph modeling offers empirical data on the government's performance in employing social media and the status quo of interconnections between stakeholders, which can be useful for accessing e-government practices.

3 A case study of the application of the webometric approach

3.1 Citizen participation in policymaking and delivery processes through social media

Because e-participation can be defined through various perspectives, it has been defined in diverse ways, including civic engagement and citizen involvement. These terms can sometimes be interchangeable. For example, citizen involvement is "initiated and controlled by government to improve and/or to gain support for decisions, programs, or services" (Langton 1978, p. 21). Yang and Callahan (2005, p. 193) defined citizen participation as "government efforts to involve citizens in administrative decision-making and management process." However, existing definitions of citizen participation imply different views and purposes with respect to the policymaking process. Regarding this definition, Thomas (2012) asserted that citizen participation in public resource allocation is presumed to be an important means of ensuring responsiveness. In addition, e-participation has been used in the policymaking process. For instance, Franklin et al. (2009, p. 52–53) suggested that participation is " an important way to align budgetary decisions with differing priorities and values [...] Through public discourse, citizens have opportunities to educate themselves about government activities and community needs, and through budget decision, promote the common welfare of a community."

Because of the increasing diversity of research issues in citizen participation, however, examining electronic citizen participation (e-participation) through social media can be methodologically complex (Kweit and Kweit 2007), and measuring e-participation can be limited by some problems related to its definition (Roberts 2005). Some studies have classified e-participation into various categories based on its different functions. Langton (1978) suggested four types of civic participation: citizen action and interactions with governments (e.g., petitioning and protesting); citizen involvement in municipal participation (e.g., attending public hearings by cities and participating in satisfaction/opinion surveys), electoral participation (e.g., attending party activities and voting); and obligatory participation (e.g., paying taxes).

Verba et al. (1993) asserted that political participation can be classified into the following four major types: citizen-initiated contact, cooperative activities, voting, and campaign activities. However, e-participation and political participation are different. That is, political participation focuses on individuals' participation in public affairs and political issues, whereas e-participation emphasizes the interaction interface between citizens and public officials (Verba et al. 1993; Yang and Callahan 2005). According to a 2007 study by the International Association for Public Participation (IAPS), public participation can be grouped into five levels based on its function and impact on policy decisions: information provision, consultation, involvement, collaboration, and empowerment. These categories imply that e-participation can be viewed as formal as well as informal mechanisms instituted by local governments. For formal mechanisms, Berner and Smith (2004) found that many municipalities establish e-participation mechanisms because of state laws and that states' attitudes and mandates have considerable influence on e-participation in local governments. Callahan (2002) asserted that citizen advisory committees are common and play an important role at the local level. However, governments frequently encounter representative crises because of the unwillingness of citizens to embrace formal participation mechanisms. Informal participation approaches have been advocated to deliver citizens' will and voice to public managers. For example, citizen surveys are widely used to evaluate citizens' current views of public services, identify areas of their desire, and monitor the effectiveness of cities' efforts to improve services (Hassett and Watson 2003).

E-participation has important benefits for governance by actualizing democratic values through the mechanism of participation (Thomas 1995; Berner 2001). Policy implementation can be more successful and face less opposition from citizen when the policy better integrates their views into the planning process. Criticisms of the government may be reduced through various strategies incorporating participation and information sharing (Berman 1997). This facilitates more transparent information and government actions. Citizens can also directly supervise how cities actually work and protect their interests through public forums in the policy process (Challanhan 2002). Public officials and administrators can obtain feedback from citizens, which can provide an important foundation for future policies. However, there are some limitations in studying e-participation. The policymaking process has become more complex and sensitive to stakeholders and external environments, and therefore a satisfactory agreement is less likely. Because individual citizens have limited information and influence, interest groups and ambitious politicians may dominate their thoughts and policy agendas for their personal interests (Thomas 1995). Elected officials may be limited by citizens' views because they are concerned about losing their next election (Rubin 2000), and public managers' professionalism may weaken because they need to negotiate with civic groups to resolve any gridlock. Although an attention-grabbing policy agenda can attract citizens to engage in the policy process (Wang 2001), most are not likely to pay attention to public affairs because of their lack of interest. Some citizens are free riders in policy outcomes because they assume some benefits from others' efforts and participation.

3.2 The 311 service as an E-participation mechanism

In general, citizens are dissatisfied with governments and thus are disinterested in public affairs because actions of governments have been questioned for their ineffective service delivery, distrusted decision-making processes, and unfair resource distribution (Berman 1997). In particular, a lack of a reliable, transparent, and accessible mechanism for interacting with governments and monitoring their actions has been viewed as one of the major causes of citizens' limited access to government officials (Wang 2001). However, the 311 service system has been viewed as a platform for citizen relationship management (CRM) because it can simplify the process of delivering public services, enable mutual communication and interactions between citizens and government officials, and enhance local governments' ability to respond to services requested by residents (Holzer et al. 2006; Oldenburg 2003). The key mechanisms of the 311 service can be categorized as reciprocity, transitivity, popularity, and activity:

Reciprocity The 311 system is based on social media and is an alternative communication tool for promoting the reciprocal exchange of information through a citizen-government interaction interface (Fleming and Barnhouse 2006; Kavanaugh et al. 2012). In particular, the more the 311 service is used, the more likely the city government is to obtain broad information from mutually interacting with the public. Schwester et al. (2009) indicated that the collection of performance data and citizens' information requests can help government officials deploy city resources more efficiently and strategically as well as consider future policies. This implies that the 311 service through social media can foster the reciprocity of e-participation.

Transitivity Because the 311 service is a a Government 2.0 tool providing ubiquitous government services though social media, citizens' needs and opinions transmitted from e-participation can be readily delivered to appropriate agencies responsible for supporting them (Lee and Kwak 2012; Thomas 2012). For example, a city government relays requests from e-participation to reliable agencies so that they can respond to these requests immediately. That is, because the 311 service is based on social media, it allows administrators to provide a timely response. In addition, many nonemergency services of municipalities are consolidated by the 311 service, which allows seamless city services for citizens from routine to critical operations through social media (Kavanaugh et al. 2012).

Popularity IT facilitates citizens' access to governments and participation in public affairs, and therefore Government 2.0 tools based on social media have become more popular than traditional ones such as paper-based requests and call-in help desks (Wang 2001; Peterson, 2006; Schwester et al. 2009). One of the advantages of the 311 service is the reduction of citizens' uncertainty and time spent searching for needed information (Holzer et al. 2006). Because the 311 system provides a convenient way for citizens to contact local governments and agencies, they no longer have to search large phone books and websites of individual city departments to find needed services. Instead, by using social media tools through laptops and wireless equipment, citizens can easily access needed public services.

Activity The 311 service enables administrators and citizens to actively communicate with each other by addressing various problems induced by limited personnel and fiscal resources (Smith et al. 2009; Lee and Kwak 2012). In the U.S., for instance, the increased activity of the 311 service has ultimately enhanced city governments' internal capacity to satisfy citizens' needs through e-participation (Schwester et al. 2009; Smith 2010). That is, as a Government 2.0 tool, the 311 service uses various social media platforms such as Facebook and Twitter to help city governments not only to actively monitor and track citizens' requests on a real-time basis but also to vigorously respond to citizens' requests, complaints, and suggestions by coordinating appropriate services with government agencies.

In terms of these e-participation mechanisms, Thomas (2012) asserted that social media tools for the 311 service reflect new mechanisms of participation, not traditional approaches such as public hearings and citizen advisory boards. In particular, this implies the importance of citizen's interaction with government officials or access to public services as a form of participation. For example, Wang (2001) suggested that e-participation can be measured by the number of citizens using city-calling services and/or social media tools to communicate with government officials and found that 81.6 % of the 244 cities used the Internet to communicate and deliver policy information to citizens. From this perspective, this implies that the 311 system can be viewed as a participation mechanism for two-way communication and interactions between citizens and local governments as well as a tool for them to enhance responsiveness and accountability (Schwester et al. 2009; Nam and Pardo 2012). Holzer et al. (2006) also viewed the integration of diverse public services into the 311 system as an alternative to strengthening the capacity of the government to respond to citizens' requests. Information on needs and requests from citizens may flow into the 311 system by their participation and use of the system. Citizens can realize a direct linkage between municipal services and information (Gorecki 2004), and local government officials can assess their feedback and complaints in a timely and effective manner (Holzer et al. 2006). Based on the above discussion, citizens' 311 calls belong to the stage of information communication with local governments and officials. The 311 system records all requests of citizens and determines the extent to which they are addressed, allowing for the measurement of service performance and the consideration of future policy adjustments.

City policymakers and decision makers pay closer attention to those issues frequently addressed by citizens. In addition, citizens' information, when accumulated to a certain amount, can provide government officials with important data for policymaking (Holzer et al. 2006). Given the 311 service, e-participation can ultimately enter the policymaking and decision-making process because city managers can better identify issues of special interest to residents and thus deliver "demand" information to city governments through the CRM system. That is, when a number of citizens continue to make requests concerning a particular issue, they are more likely to interact with government officials, and their participation is likely to move to the stage of involvement and even that of collaboration.

4 Research design and methods

To collect and map communication networks for San Francisco and New York 311 services, a social network analysis was conducted using the API tool in NodeXL embedded in Excel 2007 (Hansen et al. 2011). From the data set, either "reply-to" or "mention" relationships were visualized to map intercommunication between network participants. Then Tweets were gathered based on the keywords “@SF311” and “NYC311” on June 6, 2013. A total of 278 Tweets were collected for the San Francisco 311 service, and 173 were obtained for the New York 311 service. Descriptive network metrics were computed to measure the structure and properties of the Twitter network based on NodeXL, including the network density, clusterability, and centrality of each node. In addition, UCINET 6.3 was used to visualize the network (Bogatti et al. 2002).

The webometric approach was applied to the exponential random graph model (ERGM) by using SIENA P^* (Snijders et al. 2006). The basic idea behind the P^* analysis is as follows: When the researcher considers an observed network shown as a dependent variable, the P^* model can estimate the potential arrangement of network patterns that may occur from the observed network (Snijders et al. 2010). In the present study, some hypotheses about whether the observed pattern of interpersonal communication can occur more frequently than can be explained by random graphs with the same numbers of nodes and ties were tested. More specifically, the P^* model was used with webometric data to estimate the likelihood of hypothesized patterns as predictors of observed networks. The P^* model in SIENA uses the Metropolis-Hastings algorithm to generate random graphs from an exponential random graph distribution and employs the stochastic approximation algorithm to estimate the pattern of relationships (Snijders et al. 2007). Then the model implements the Markov chain Monte Carlo (MCMC) estimation, in which the algorithm computes the maximum likelihood estimates. This allows the model to check for convergence. If the absolute value of the algorithm’s diagnostic statistics for convergence is less than 0.2, then the parameter estimate is generally considered to show sufficient convergence, and strong convergence is indicated by an absolute value less than 0.1 (Snijders et al. 2010). The diagnostic, covariance, and derivative matrices for convergence were based on 1,000 iterations. The significance of the estimated parameters was evaluated based on the t-value.

4.1 E-participation

E-participation in Government 2.0 was determined based on San Francisco’s Twitter account for the 311 service. As discussed earlier, the webometric approach is specialized for collecting data from social media tools such as Facebook, Twitter, and YouTube. Because NodeXL captures only directed mentions for Twitter accounts (in this study, @sf311 and @nyc311), e-participation was considered as mentions of 311 service users on Twitter. NodeXL is specifically designed to capture relationships between social media actors. To test the ERGM through SIENA P^*, the data were systematically managed by transforming webometric data into a sociomatrix in which actors’ intercommunication ties were coded as an N x N matrix reporting all ties between all N actors.

4.2 Network effects: reciprocity, transitivity, popularity, and activity

Four network effects were considered (reciprocity, transitivity, popularity, and activity) to determine the nature of e-participation in Government 2.0. The left-hand side of Fig. 1 graphically illustrates the reciprocity effect. For example, when actor i seeks information from actor j, the tie between the two actors can be operationalized as x_{ij} to indicate the existence of a tie from actor i to actor j. The reciprocity effect is formally defined as $\sum_{i<j} x_{ij}x_{ji}$ to account for the total number of mutual relationships between actor i and actor j (Snijders et al. 2005; Snijders 2007).

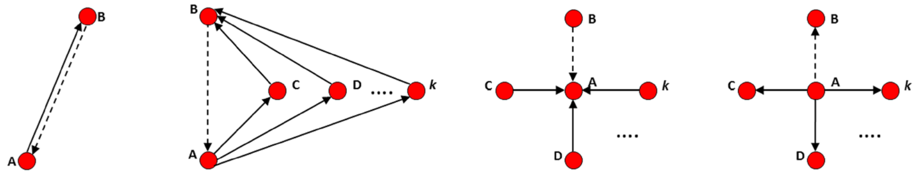

Fig. 1 Hypothesized networks: reciprocity, transitivity, popularity, and activity. (Color figure online)

The transitivity effect was measured by the "alternating k-triangle, parameter two," which suggests that the tendency to form a highly transmittable network structure is very likely. The left-hand side of Fig. 1 shows the bonding effect, which can be formally written as $k\sum_{i,j} x_{ij}\left\{1-\left(1-\frac{1}{k}\right)^{L_{2ij}}\right\}$, where $L_{2ij} = \sum_{h} x_{ih}x_{hj}$ is the number of two paths connecting actors i and j. A positive parameter suggests the tendency of actors in the network to forge a tie toward a comparatively large number of transmittable structures as a set of triangles.

The popularity effect was captured by "alternating k-in-stars," which indicates a localized structure of an actor receiving ties from k numbers of actors supporting this ego network (Buchanan 2002; Robins et al. 2007; Snijders et al. 2010). The popularity effect can be formally defined as $c^2\sum_{i=1}^{n}\left\{\left(1-\frac{1}{c}\right)^{x+i}+\frac{x+i}{c}-1\right\}$ for some value c to explain the probability of incoming ties from exactly k actors in the network. A positive parameter implies the propensity of ego networks in a given network to have incoming ties from those actors who formulate a localized structure in transmitting information, whereas a negative one proposes that actors are less likely to have ties from them in the expected network based on random graphs.

The activity effect was measured by "alternating k-out-stars," which captures the likelihood of establishing an ego network by actively supporting k actors (Robins et al. 2007; Snijders et al. 2010). The activity effect can be formally defined as $c^2\sum_{i=1}^{n}\left\{\left(1-\frac{1}{c}\right)^{x_i+}+\frac{x_i+}{c}-1\right\}$ to explain the total number of outgoing ties with exactly k actors. A positive estimate suggests the propensity for actors with high outdegree centrality in the given network to form an active ego network, whereas a negative one proposes that an active ego network rarely appears in the expected network based on random graphs.

5 Results and discussion

Figures 2 and 3 show Twitter networks of the New York and San Francisco 311 services, respectively, including their structure, services, and user interactions. Here each node indicates the user's Twitter ID and the tie between two nodes denotes their interactions in terms of mentions, replies, or retweets targeting each other. The strength of ties refers to the extent of interactions between users. For instance, the thicker the line, the deeper the exchange between two users in terms of their mentions, replies, or retweets about the 311 service.

According to the generated matrix, there were a total number of 115 users and 173 ties between users in the New York 311 communication network, whereas the San Francisco 311 communication network showed 50 users and 278 interactions. This indicates that, although there were far more participants in the New York 311 network than in the San Francisco

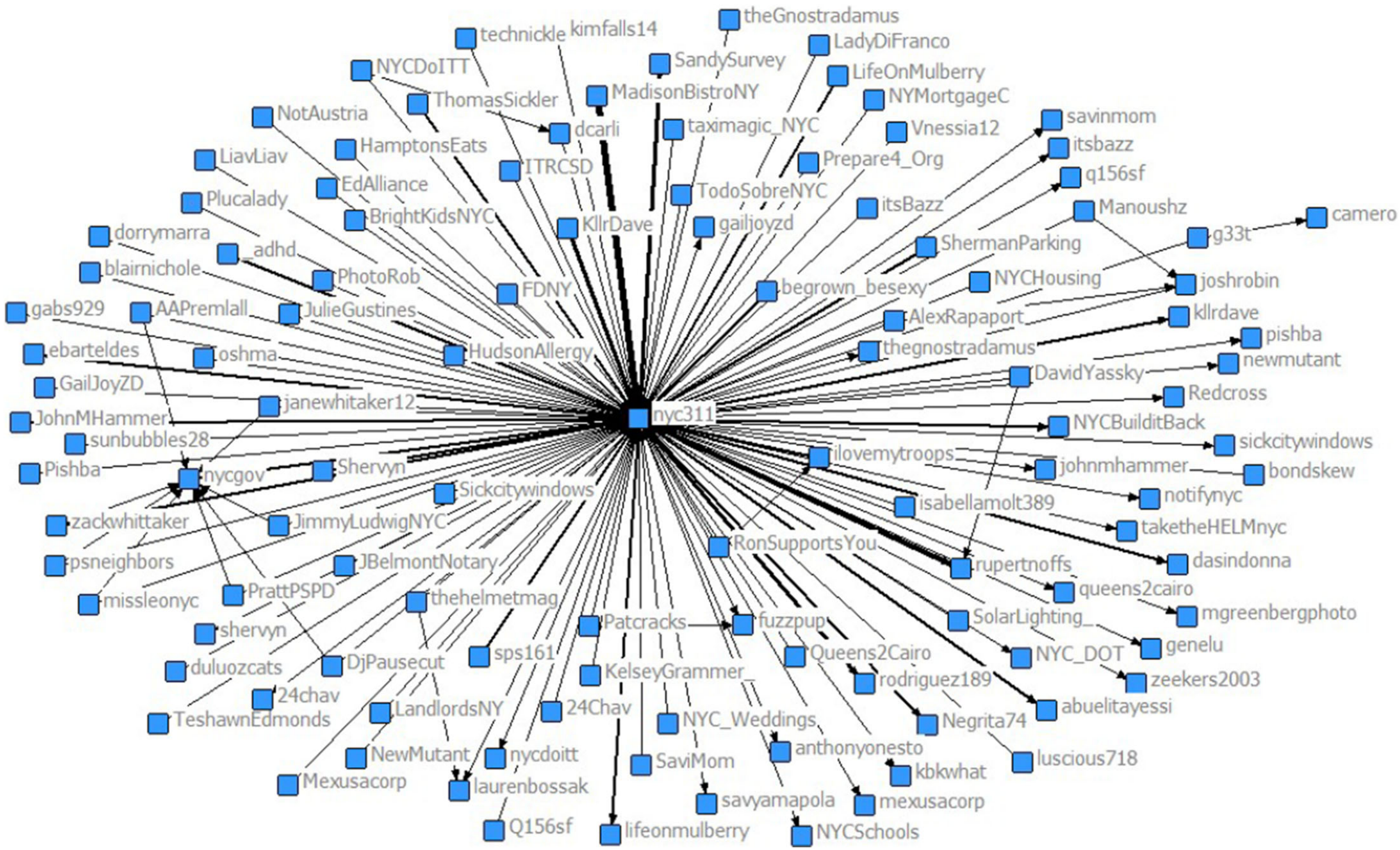

Fig. 2 Communication network of the New York 311 service on Twitter. (Color figure online)

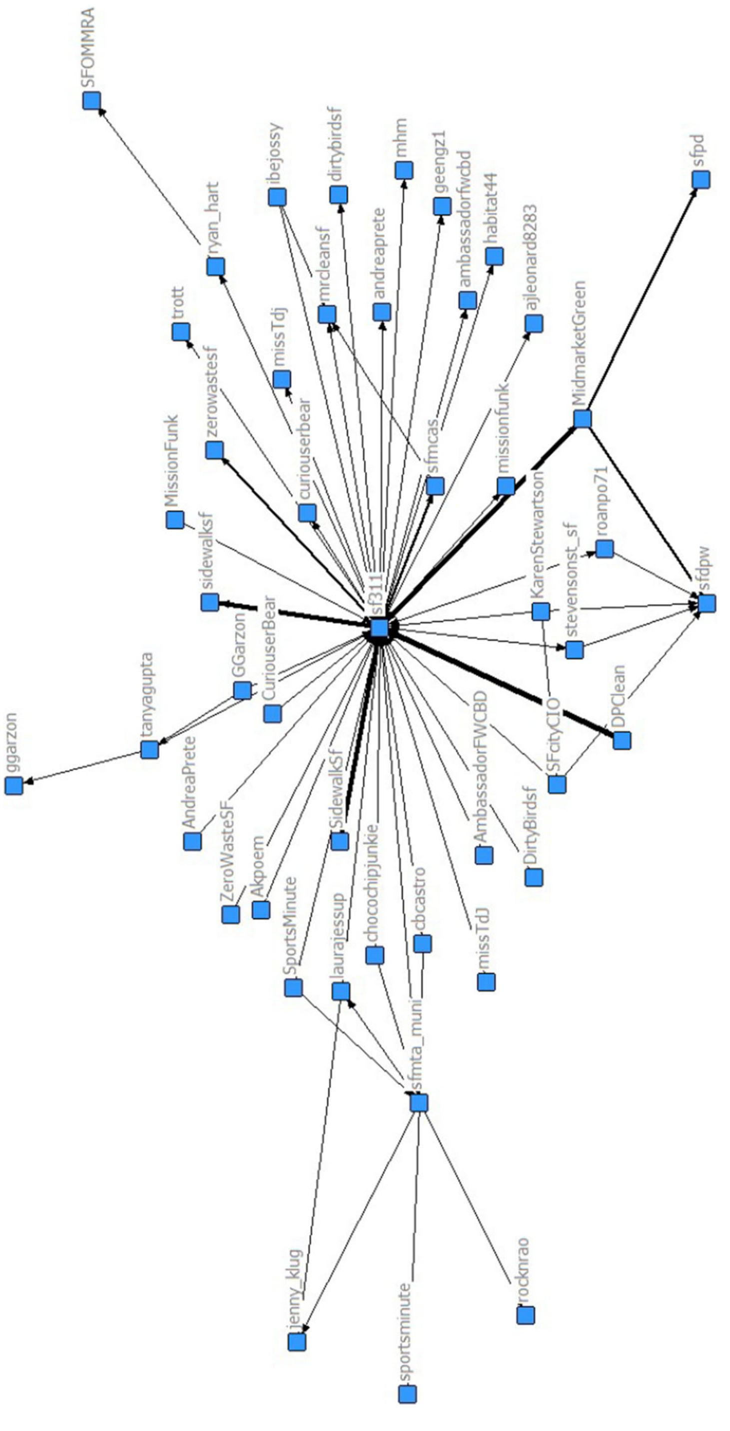

Fig. 3 Communication network of the San Francisco 311 service on Twitter. (Color figure online)

311 network, the San Francisco network showed stronger interactions between participants, implying that the actors tended to be connected through smaller networks. This result provides support for previous studies suggesting that network density, which refers to the ratio of the number of connections to that of all possible connections between actors in a given network, depends on the number of nodes (Barnett and Rice 1985; Monge and Contractor 2003).

As shown in Fig. 2 and 3, the 311 service networks of the two cities on Twitter showed similar network structures. Not surprisingly, both networks reflected a hub-and-spoke topology ("star" network), indicating that their network traffic tended to be concentrated around the two governments' accounts (Bryan and O'Kelly 1999). However, noteworthy is that there was a clear difference in the formation of subcommunities between the communication networks. In particularly, the results for the betweenness centrality (BC) of each actor show different patterns of e-participation. BC measures the extent to which a node mediates two other nodes (Barnett et al. 2011). There were a limited number of actors who were connected to others in the New York 311 network, whereas several sub-hubs with extremely high BC formed sub-conversation communities by mediating others in the San Francisco 311 network. For instance, @g33t (BC=226), a local resident, and @nycgov (BC=28), the official Twitter account of New York City, played central roles in the New York 311 service network. Noteworthy is that various types of actors, including government agencies, NGOs, and residents, led the sub-conversation San Francisco 311 network to active information transmission: the San Francisco Municipal Transportation Agency (@sfmta_mini: BC=268.267), an environmental NGO (@MidmarketGreen: BC=176.410), and local residents (@ryan_hart: BC=142.325; @Chocochipjunkie: BC=111.125; @Cbcastro: BC=111.125).

With the ERGM and webometric data collected from the Twitter accounts of the two cities, the hypothesized network structures were tested to examine the pattern of e-participation in Government 2.0. The network structures shown in Fig. 2 and 3 are based on the geodesic distance calculated using the degree centrality of each node (Bogatti et al. 2002). Both Twitter network structures are based on intercommunication relationships between metropolitan governments and citizens. As indicated by these structures, government agencies such as the Department of Public Safety and the Environmental Agency were connected to citizens participating in the administrative process by providing them with information. These results are consistent with the finding of Thomas (2012), who suggested that government agencies' accessibility and responsiveness have considerable influence on the likelihood of citizens' engagement in political affairs. In addition, the results suggest that pattern of e-participation in Government 2.0 may emerge from the horizontal structure of networks on social media. Noteworthy is that, in the field of policy analysis and management, e-participation consisting of citizens, city governments, and public agencies has not been fully examined by horizontal triad relationships because of the hierarchical structure of administrative procedures (Picazo-Vela et al. 2012). Based on the webometric approach, the present study explicitly fills the gap in the literature by explaining the data collection and analysis procedures as an innovative way for scholars and practitioners in this field to diagnose and investigate the pattern of e-participation on social media.

To investigate reciprocity, transitivity, popularity, and activity effects, the ERGM was employed with 1,000 iterations based on SIENA P^*. Table 1 shows the descriptive network statistics for both e-participation networks. In the overall New York network, there were eight mutual and 101 asymmetric dyads between government agencies and citizens. The density of the network was .009, and the average degree of nodes was 1.017. The second column of Table 1 shows the overall San Francisco network. Here there were 13 mutual and

Table 1 Descriptive statistics

	New York	San Francisco
Overall network statistics		
Dyadic counts	6555	1128
Mutual	8	13
Asymmetric	101	47
Null	6446	1068
Network density	.009	.032
Average degree	1.017	1.521
Observed value of target statistics		
Reciprocity	8	13
Alternating k-triangles	8	13
Alternating in-k-stars	71	67.875
Alternating out-k-stars	154.016	66.625

47 asymmetric dyads. The density of this network was .032, and the average degree was 1.521. More importantly, although the two e-participation networks showed differences in their dyad composition and network density, their overall network structures indicate that both 311 services through Twitter motivated citizens to engage in e-participation based on Government 2.0. This also implies that they play a critical role in facilitating administrative procedures of metropolitan governance by bridging between other government agencies and citizens.

In particular, Table 1 shows the key differences between two Twitter networks each for New York and San Francisco. A total of 115 actors engaged in the 311 Twitter network of New York, relying mainly on unilateral communication from citizens to the city government or the city government to citizens (7.3 % of mutual ties and 92.7 % of asymmetric ties). In particular, this type of citizen participation generally resulted in lower levels of reciprocity and transitivity and higher levels of popularity and activity on the 311 Twitter network (see the observed values for target statistics in Table 1). For instance, the provision of general information from the city government to the public, such as "The first day of school is Sept 9. Find your child's school bus stop and route: http://on.nyc.gov/RwFvZH" (@nyc311, September 2, 2013), seldom facilitated citizens to engage in mutual communication with the city government. On the other hand, the San Francisco network showed higher levels of reciprocity and transitivity (21.7 % of mutual ties and 78.3 % of asymmetric ties), although only 50 actors participated in the network. For example, in contrast to New York, San Francisco focused on building a reciprocal relationship by responding actively to citizen participation, such as "Problem has already been reported thank you SR#3190514 Crews are on the way no ETA @goldngater" (@SF311, December 21, 2013). The descriptive statistics imply that differences in strategies for using social media between New York and San Francisco led to some characteristics of citizen participation.

Table 2 shows the results based on the ERGM to explain the pattern of e-participation in Government 2.0. These results are consistent with the estimated parameter values (E) and standard errors, indicating the statistical significance of the effects based on the ratio of the parameter value to the corresponding standard error (i.e., t-statistics). In the ERGM, a positive parameter suggests that, with other effects held constant, network effects are more likely to appear in the observed network structure than in the network predicted by a random

Table 2 Exponential random graph model for network effects

	New York		San Francisco	
	Estimates	Std. err.	Estimates	Std. err.
Network effects				
Reciprocity	2.789***	.516	2.575***	.365
Transitivity (alternating k-triangles)	.644***	.208	1.135***	.246
Popularity (alternating in-k-stars)	2.259***	.151	1.177***	.233
Activity (alternating out-k-stars)	−.389	.267	−.258	.197

Note: All statistics converged with a t-statistic <.10 based on a minimum of 1,000 iterations
* $p<.10$, ** $p<.05$, *** $p<.01$

graph with the same numbers of nodes and dyads (Robins et al. 2007; Snijders et al. 2010). As indicated earlier, the results indicating significant effects provide relatively clear evidence of patterns of e-participation and those with whom Twitter actors formed relationships.

The analysis results for each model in Table 2 provide strong evidence of the reciprocity effect. That is, e-participation in Government 2.0 (i.e., the relationship between government agencies and citizens) tended to be tied to each other in the Twitter networks of two cities (E = 2.789 and 2.575 in each model; $p < .01$). In addition, the results showing positive estimates for the transitivity effect (E = .644 and 1.135 in each model; $p < .01$) also provide straightforward evidence that the relationships between any three actors on Twitter are likely to form transmittable ego networks. As indicated earlier, the popularity effect was significant for both Twitter networks, which suggests that an ego network with incoming ties from other actors is more likely to be formed than networks expected by random graphs (E = 2.259 and 1.177 in each model; $p < .01$). As Thomas (2012) highlighted, these results suggest that e-participation in Government 2.0 can promote mutual communication across diverse stakeholders, transmitting information beyond a dyadic relationship between a single citizen and a city government, and citizens' access to portals providing timely responses to their needs.

The results suggest that e-participation in Government 2.0 is more likely when inter-communication between government agencies and citizens emerges through a popular ego network that seeks to forge outgoing ties with other actors than through an active ego network with social status and prestige by establishing outgoing ties with other actors in government Twitter accounts. In this regard, the results verifying the hypothesized network effects on transitivity and popularity suggest that, in terms of directly connected e-participation in Government 2.0, government agencies can obtain not only critical information on policy and decision-making processes from citizens but also insights into how administrative problems can be addressed by sustaining credible commitment in Government 2.0 (Putnam 2000). Despite these important benefits of social media, without sufficient efforts by the government to respond to citizens' requests, complaints, and suggestions on a real-time basis, Government 2.0 tools through social media may not fully satisfy these needs because of overwhelming sources of communication and information. This notion also implies that enhancing social capital through e-participation relies on the maturity of Government 2.0, which consists of management conditions, transparent procedures, spontaneous engagement, and expeditious collaboration.

6 Conclusions

In the Government 2.0 era, social media services such as Facebook, Twitter, and YouTube have offered crucial platforms for facilitating mutual communication between citizens and government entities and sharing information between diverse stakeholders beyond administrative boundaries. Many studies have focused on the importance of e-engagement in Government 2.0 (Schwester et al. 2009; Smith 2010; Lee and Kwak 2012; Kavanaugh et al. 2012; Thomas 2012), but few have systemically examined the pattern of e-participation in the context of social media. In this regard, the present study applies the webometric approach to the field of policy analysis and management, thereby contributing to the literature by introducing new empirical strategies for analyzing the efficacy of government intervention through social media platforms. In particular, the results suggest the usefulness of the webometric approach in less manipulated research settings in terms of filling gaps in the literature on social media policies, which has been perceived as a problem inherent in traditional research methods such as surveys and audience interviews (Park 2010).

The proposed webometric technique enables the extraction of a government agency's Twitter activities and the mapping of public discourse among participants mentioning the agency's Twitter account. In addition, it provides the participants' demographic characteristics (e.g., geographic locations) and user profiles (e.g., numbers of followers, followings, and Tweets and descriptive user information provided by users themselves) (Yoon and Park 2014; Hsu et al. 2013). In this way, the technique allows for the tracking of government agencies' communication behavior toward the public on a real-time basis and can demonstrate how various types of audiences create social networks with the purpose of participating in the formulation and implementation of policies and identify actors and their networking properties (e.g., indegree centrality, outdegree centrality, and betweenness centrality). The webometric approach not only allows for the extraction of government agencies' communication behavior toward social media users but also captures the overall network structure, patterns of interactions between participants, and their network properties. In addition, it archives the content of Tweets created by users, although this study does not address this feature.

This case study of the two 311 service networks based on the webometric technique has important practical implications for empirical research on communication strategies between information providers of government services, including citizens, private firms, nonprofit organizations, and government agencies. Based on the ERGM, a webometric approach to the field of policy analysis and management enables scholars and practitioners to investigate the dynamics of e-participation through social media, including its reciprocity, transitivity, popularity, and activity. The results offer valuable guidelines for collecting and analyzing data through the webometric approach in determining how social media can be used as an alternative tool for attracting the public and the nature of e-participation (Sæbø et al. 2009) but has two important limitations. First, the word occurrence (i.e., Twitter IDs of public services) was used as an indicator of information sharing, but other forms of information (e.g., URLs, pictures, and videos) exchanged by users were not captured. Second, the generalizability of the results may be limited by a restricted time frame in crawling Twitter data to capture interconnections between governments and the public.

Future research should address these limitations by considering qualitative interviews with government agencies that use social media and with participants who use government social media platforms. In addition, more qualitative interpretations and efforts are needed to verify this study's results.

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