



Assortative mixing, preferential attachment, and triadic closure: A longitudinal study of tie-generative mechanisms in journal citation networks



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ABSTRACT

This study reveals the roles of three tie-generative mechanisms, namely, assortative mixing, preferential attachment, and triadic closure, in forming citation links in journals through the exponential random graph modeling approach. The study also adopts a longitudinal design to examine how the roles of the three mechanisms evolve over time. The data involve citation exchanges in Internet research among 680 journals in 12 subject areas from 2000 to 2013. Assortative mixing by discipline and publication foci is a significant tie-generative mechanism in journal citation networks. The magnitude of assortative mixing by discipline remains stable over time, whereas that by publication foci declines over time. Journals in Internet research demonstrate an increasing preference for influential journals to form citation links over time. The indegree of journals does not exert a significant impact on citation link formation among journals, whereas the outdegree of journals imposes a significantly negative impact on citation link formation among journals. Triadic closure is an important force that facilitates the formation of citation links among journals. The findings of this study improve our knowledge of the organizing principles that underlie journal citation networks and advance our understanding of the production process of scientific knowledge in Internet research.

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1. Introduction

Although Price (1965) has established that bibliographic data can be presented as directed graphs in his ground-breaking work, empirical research on journal citation networks only prevailed in the recent decade because of the massive digitization of scholarly outputs, continuous development of sophisticated algorithms, and rapid advancement of computational capacity (Newman, 2010; Radicchi, Fortunato, & Vespignani, 2012). A wide array of research concerns have been addressed in empirical studies on journal citation networks, some of which have focused on the structural characteristics of journal citation networks (e.g., Franceschet, 2012), sub-group or community detection in journal citation networks (e.g., Leydesdorff, de Moya-Aregon, & Guerrero-Bote, 2010; Leydesdorff, 2004), measuring the influence of journals on the scientific community (e.g., Nerur, Sikora, Mangalaraj, & Balijepally, 2005; Peng & Wang, 2013; Stringer, Sales-Pardo, & Amaral, 2008), capturing the

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interdisciplinarity of a subject area (e.g., Leydesdorff, 2009; Leydesdorff & Rafols, 2011; Leydesdorff, Rafols, & Chen, 2013), and describing the knowledge flow across disciplines (e.g., Park & Leydesdorff, 2009; Yan, Ding, Cronin, & Leydesdorff, 2013).

Although the aforementioned studies have advanced our understanding of the topological characteristics of journal citation networks, little is known about the types of tie-generative mechanisms that give rise to journal citation networks with certain characteristics. Journal citation networks are both information networks and social ones (Newman, 2003b). They are information networks because they provide compact representations of the relationships between scholarly outlets in both sciences and social sciences (Eom & Fortunato, 2011); they are also social networks because they reflect the underlying social structure in human society (White, Wellman, & Nazer, 2004). This study adopts theories from both information science and sociology to uncover tie-generative mechanisms that underlie journal citation networks. The findings can improve our knowledge of the organizing principles that underlie such networks and advance our understanding of the production process of scientific knowledge implied in such networks.

2. Literature review and research questions

We examine the roles of three tie-generative mechanisms in journal citation networks, namely, assortative mixing, preferential attachment, and triadic closure. The assortative mixing mechanism focuses on how the compatibility of the exogenous attributes of journals (i.e., their disciplines and publication foci) affects the formation of citation links (Rivera, Soderstrom, & Uzzi, 2010). The preferential attachment mechanism focuses on how the global structure of all journals (i.e., degrees and attractiveness) in a citation network affects the formation of citation links (Bianconi, Darst, Iacovacci, & Fortunato, 2014). The triadic closure mechanism focuses on how the local structure of journals (e.g., their neighbors or second neighbors) affects the dynamics of citation link formation (Peter & Stefan, 2013).

Assortative mixing, which is also known as “homophily” in sociology, refers to the phenomenon that nodes in a network prefer to link with others that they perceive as similar to themselves in some aspects. As a fundamental rule that regulates tie formation in information and social networks (McPherson, Smith-Lovin, & Cook, 2001; Newman, 2002, 2003a), assortative mixing mechanisms have been widely studied in empirical research, such as assortative mixing by race (Wimmer & Lewis, 2010) and partisanship (Peng, Liu, Wu, & Liu, 2015) in social networks and assortative mixing by degree in journal citation networks (Franceschet, 2012; Newman, 2003a). In the present study, we consider two exogenous characteristics that are fundamentally relevant to assortative mixing in journal citation networks; these two characteristics are disciplines and publication foci. Discipline associated with academic journals creates an explicit affinity among them, and publication foci develop an implicit shared identity (Kossinets & Watts, 2009); both can drive journals to develop mutual preference for one another and can increase the likelihood of forming citation links among them. Therefore, the following hypotheses are proposed.

Hypothesis 1 (H1). Journals from the same discipline are more likely to form citation links than journals from different disciplines.

Hypothesis 2 (H2). Journals with similar publication foci are more likely to form citation links than journals with different publication foci.

The preferential attachment (Barabasi & Albert, 1999) mechanism argues that network links are preferentially attached to nodes with high numbers of degrees in a network, which is also known as “cumulative advantage” (Price, 1965) in information science. Preferential attachment is an influential mechanism that accounts for tie formation in social and information networks, such as human sexual networks (Jones & Handcock, 2003), research collaboration networks (e.g., Abbasi, Hossain, & Leydesdorff, 2012), and article citation networks (e.g., Wang, Yu, & Yu, 2008). Moreover, empirical studies have argued that the probability for a node to receive a link is proportional not only to its degree but also to its overall attractiveness (e.g., Dorogovtsev, Mendes, & Samukhin, 2000; Eom & Fortunato, 2011; Krapivsky, Redner, & Leyvraz, 2000). Specifically, in journal citation networks, the preferential attachment mechanism is driven not only by the degrees of journals, which is the number of incoming/outgoing citations a journal receives/sends, but also by the overall attractiveness of journals, which can be their influence over other journals in scholarly research. Therefore, the following hypotheses are proposed.

Hypothesis 3 (H3). Journals are more likely to attach citation links to those with a large number of incoming/outgoing citations than to those with a small number of incoming/outgoing citations.

Hypothesis 4 (H4). Journals are more likely to attach citation links to those with high influence than to those with low influence.

In many networks, if node i is connected to node j and node j to node k , then node i is likely to be connected to node k (Easley & Kleinberg, 2010). This process is known as triadic closure, which is a strong candidate mechanism for the creation of links in various networks (Bianconi et al., 2014; Newman, 2003b). In journal citation networks, two journals may not have direct citation links; instead, they may be indirectly linked via a third-party journal that functions as a knowledge processor that absorbs and distributes value-added knowledge to other journals (Yan et al., 2013). Sharing a third-party journal provides information on potential connections through referrals, which eases the process of developing a new tie by decreasing the uncertainty and risk of a new connection (Burt & Knez, 1995; Rivera et al., 2010). In other words, indirectly

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