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Economics and Complex Networks

Introduction to the special issue "Economics and Complex Networks"

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Since the late 1990s, network analysis has been playing an increasingly important role in various fields of social sciences, natural sciences, engineering, and industry among others (Christakis and Fowler 2009; Easley and Kleinberg 2010; Barabási 2016; Newman 2018). This new research field, collectively called network science, has been benefiting from interdisciplinary research efforts and a growing quantity and variety of network data.

In economics, the role of networks has long been studied in particular fields, such as game theory (Vega-Redondo 2003; Goyal 2007; Jackson 2008) and payment systems (Allen and Gale 2000; Eisenberg and Noe 2001). However, in many fields of economics, network analysis has not received much attention until recently. Over the past few years, there have been a growing number of papers that try to better describe economic phenomena by introducing network analysis in otherwise standard economic models. Nowadays, we see many papers published in top economics journals having "network" in their title (see Fig. 1).

On the other hand, collaboration between economics and network science seems to be still scarce. This may be due to cultural differences between the two fields. Here are examples: (i) How to write a paper is considerably different between the two fields. For example, the length of a majority of papers in economics may be fairly long for network scientists. As another example, like in pure mathematics, it is customary that the authors are listed in an alphabetical order in economics papers. By contrast, the author order in many other fields including network science and

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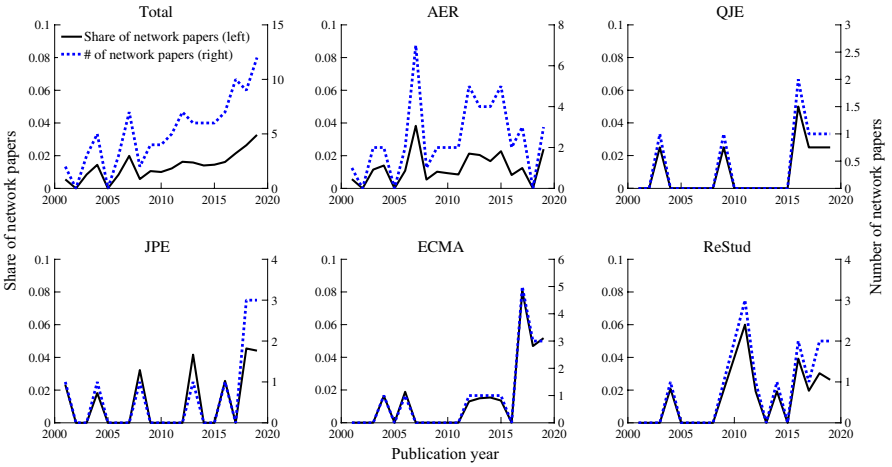

Fig. 1 Number and share of papers published in top economics journals that include "network(s)" in their title. *AER* American Economic Review, *QJE* Quarterly Journal of Economics, *JPE* Journal of Political Economy, *ECMA* Econometrica, *ReStud* Review of Economic Studies

wider interdisciplinary sciences has specific meanings. (ii) Collaborative teams of authors may struggle to decide on the journal to submit their work to. Network scientists tend to prefer interdisciplinary journals or natural science journals, or perhaps network science journals, whereas economists would prefer economics journals. Economists tend to undervalue papers published in non-economics journals when assessing their research achievements. We also remark that it usually takes much longer time for papers to be accepted in economics journals than in journals that network scientists would go for.

Another observation is that, in our view, a relatively small fraction of network science researchers are strongly devoted to the study of economic systems. This situation is somewhat ironic given that a number of researchers in network science have been studying social systems, such as face-to-face networks, online social networks, and human mobility, which all have to do with economic activity. This gap may be due to a difference in the accessibility of open data sets on social and economic systems. Specifically, for social systems, relational data that are necessary to study networks are abundant and many of them are freely available (Netzschleuder; SocioPatterns Project; The Colorado Index of Complex Networks). By contrast, high-resolution economic data that contain relational information are usually not open, and, if they are available, they tend to be too expensive for most researchers.

The shortage of intersection and collaboration between economics and network science is potentially a huge loss. Our knowledge of complex economic systems would be advanced further if economists take advantage of recent developments in network science and if more network science researchers are engaged in research of economic systems. We should alleviate the aforementioned and other invisible barriers surrounding economics. What one can do for this includes enhancing dialog among researchers from different disciplines, making high-quality economic data

widely accessible, and providing outlets for interdisciplinary research in journals and other publication media that are well recognized in economics communities.

In this special issue, we called for submissions from interdisciplinary as well as economics researchers with the aim of promoting interactions between economists, network scientists, and many others. Japanese Economic Review has traditionally published solid and disciplined economics studies. However, in this issue, we also encouraged submissions of manuscripts based on network science approaches as long as the research topic largely belongs to the interest of economics. We received 13 submissions, including those that economists would perceive as standard economics papers and those that use interdisciplinary analysis techniques. Among them, six submissions have been accepted for publication.

This special issue is composed of the following six papers.

The paper by Iino, Inoue, Saito, and Todo investigates the role of the network structure formed by patent collaborations, asking whether research collaborations improve the quality of technological innovation. Using worldwide patent data between 1991 and 2010, the authors have found that firm-to-firm research collaboration has led to substantial improvement in innovation quality. In addition, they argue that some structural measures of the collaboration network may explain the quality of innovation.

The paper by Nirei, Shoji, and Yu studies the evolution of networks formed by venture capital syndication in China. The authors have revealed that the number of connections newly established by a venture capital firm is positively correlated with the number of previously established connections, which is consistent with the preferential attachment models celebrated in network science. They have found that, owing to preferential attachment, connections among firms are quite heterogeneous such that several giant firms are connected with a large number of firms, whereas many small firms have only a few connections.

The paper by Itoh and Nakajima considers the importance of a domestic firm-to-firm supply chain network in firms' decision-making on foreign direct investment (FDI). Using a coordination game with incomplete information, the authors have shown that firms having higher Katz–Bonacich centrality values are more likely to implement FDI. An intuition is that these "central" firms would be able to promote other firms in the network to follow their decision. By analyzing a Japanese inter-firm transaction network, they have confirmed that the theoretical implication of their model is consistent with empirical data.

The paper by Itoh and Li develops a two-stage model of competitive taxation that local and central governments conduct to maximize their tax revenues. The model features the role of two relevant networks, i.e., an inter-firm transaction network and an inter-country geographical network, in the governments' tax competition. The authors have shown that the effects of the network structure on firms' location choices and governments' tax strategies are characterized by the Kronecker product of the adjacency matrices of the two networks.

The paper by Kawamoto and Hashimoto analyzes a data set, Flow of Foreigners-Data, which contains information about mobility patterns within Japan of foreigners traveling to Japan. Understanding such data should be important for tourism industry. The authors use second-order random walks to model mobility of the travelers,

called the memory networks in network science. In particular, they have carried out community detection for the constructed memory networks to reveal that different network communities characterize grouping of different travel segments (e.g., from Tokyo to Kyoto).

The paper by Kito, Moriya, and Yamanoi investigates the network of patent opposition among companies. In contrast to co-applicant networks and patent citation networks, which are more commonly investigated, patent opposition networks are adversarial networks and have different practical implications. The authors have shown that patent citation networks are not similar to social networks with negative ties. They have examined the patent opposition networks using several network analysis methods including network motif analysis (over-represented, e.g., three-node subnetworks) and its time-varying counterparts.

We believe that the network approaches showcased by these papers provide new insights into how economic systems work and a valuable opportunity for us to appreciate the role of networks in economic phenomena. We also hope that this special issue will stimulate interaction between economists, network science researchers, and others.

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