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ECONOMIC ANALYSES OF SOCIAL NETWORKS

VOLUME I

THEORY

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Economic Analyses of Social Networks Volume I

Theory

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Volume I

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Introduction*

Matthew O. Jackson[†] *and Yves Zenou*[‡]

Economists have long been aware that social networks play a significant role in determining economic outcomes; yet only in the past two decades has substantial effort been devoted to understanding that role.[1] Social networks are indeed important in numerous facets of our lives. For example, the decisions by individuals of whether to buy a new product, attend a meeting, commit a crime, or choose a certain career are often influenced by friends and acquaintances. Also, information about jobs can be obtained through direct and indirect acquaintances through word-of-mouth communication. The network structure of those interactions can impact the efficiency of a labor market as well as the incentives that individuals have to invest in obtaining education and job-related skills. The spread of diseases, such as AIDS, also strongly depends on the geometry of social contacts. Similarly, the structure of networks, especially their density, has a strong impact on criminal activities. Criminals learn from each other, and networks of criminals or gangs can amplify delinquent behaviors. In education, a positive correlation has been found between connectedness (as measured by friendship ties in school) and years of schooling attained as well as the probability of having attended college. In a very different application, a firm's embeddedness in a network of interfirm relations impacts its innovation and performance. The voluminous empirical evidence on a wide array of such issues motivates the theoretical analysis of networks.

In these two volumes, we have collected some of the fundamental economic analyses of social networks. This literature has grown rapidly over the past two decades and having such volumes that collect many of the essential articles on the subject should be helpful to researchers in the area. Of course, in any such endeavor there are difficult decisions that need to be made as to what to include. Analysis of social and economic networks involves many fields and bodies of literature, some of which have been around for more than a century, and some of which blossomed more recently. Given the enormity of the literature on the subject, we could not hope to represent all fields, and so we have mainly focused on the study that has grown out of economics. Not only does economics have numerous important applications that require an understanding of networks, it also brings new perspectives to the analysis of networks in terms of questions of efficiency and welfare, as well as techniques emanating from game theory.

Even with such a field focus, we needed two volumes to collect some of the important papers on the subject. We have grouped the papers by subfield, mainly by the approaches and methodologies they embody.

Volume I begins with the first papers on the subject, ordered chronologically, which involve examining network formation from a strategic perspective: people (or other agents such as firms, countries, etc.) choose with whom they interact. These papers brought a new approach and toolbox to bear on the study of network formation. People clearly exercise discretion in which friends they see, with whom they collaborate, which papers they cite, and who they

emulate. Moreover, when moving to more purely political and economic arenas, such as alliances between countries, collaborations between firms, selection of trading partners, and so forth, it is not only that choices are made, but also that often substantial effort goes into making those choices. Although this perspective was not absent from the sociological literature, formal modeling and study of choice-based network formation had not appeared before. The first paper in the first volume, by Aumann and Myerson (1988, Chapter 1, Volume I), provided a model of multilateral bargaining that allowed the communication structure between individuals to be endogenous. Although it was narrowly focused and not about network formation per se, it was the first paper that used game-theoretic techniques to derive an endogenous network structure.[2] The first general formulation of a strategic network formation model is in Jackson and Wolinsky (1996, Chapter 2, Volume I), who posited that individuals derive payoffs that depend on the network structure in the society. They also provided a basic equilibrium concept for predicting which networks would form, which they called 'pairwise stability', and allowed the investigation of which networks individuals would tend to form based on their own interests, in contrast to which networks are optimal from society's perspective. The modeling of network formation based on individual payoffs allows explicit welfare comparisons that were missing in the previous literature, and is perhaps one of the more important aspects that the economic perspective brought to network analysis. Although, given the externalities present in most network settings of interest, it is not surprising that individual incentives may lead to inefficient network formation. Nonetheless, it is vital to understand the circumstances under which efficiency is precluded and what might be done to ameliorate such situations. The literature that followed (including the next two papers in the first volume, Dutta and Mutuswami (1997, Chapter 3, Volume I) and Bala and Goyal (2000, Chapter 4, Volume I); as well as many not included here) continued the exploration begun by Jackson and Wolinsky of strategic network formation and the extent to which emerging networks will be efficient in different settings. The first part of Volume I then continues to include papers that explored a variety of issues surrounding strategic network formation including dynamics (Brock and Darlauf (2001, Chapter 5, Volume I), Jackson and Watts (2002, Chapter 6; 2002, Chapter 7, Volume I), Dutta, Ghosal, and Ray (2005, Chapter 8, Volume I), Page and Wooders (2005, Chapter 9, Volume I)), and coalitional considerations. These papers began a critical and fruitful bridging of the economics and sociology literatures that had little intersection before, along with other papers that followed such as Goyal and Vega-Redondo (2005) and Jackson and van den Nouweland (2005).

Interestingly, network modeling followed two largely independent streams for some time: that based on random network modeling and that based on game-theoretic techniques. Clearly, network formation involves larger structural forces (tendencies towards closed groups) and random meeting that may depend on structure, as well as explicit discretion. Capturing many features of observed networks involves developing models that incorporate both; a literature that has been growing recently. The last two papers in the first part of the first volume (Jackson and Rogers (2007, Chapter 10, Volume I) and Currarini, Jackson, and Pin (2009, Chapter 11, Volume I)) move in that direction.

The second part of the first volume examines a more recent branch of the literature that ignores network formation, but is instead concerned with how network structure influences individual behaviors. In particular, it concerns behaviors of individuals who are connected in a network and who are influenced by the choices and opinions of their neighbors. This is

modeled by what are sometimes referred to as 'games on networks' or 'network games'. The theory of 'games on networks' considers a game with n agents (that can be individuals, firms, regions, countries, etc.) who are embedded in a network and are choosing actions (e.g., buying products, choosing levels of education, engaging in criminal activities, investing in Research and Development (R&D), etc.). Agents choose actions to maximize their payoffs, given how they expect others in their network to behave. Thus, agents implicitly take into account interdependencies generated by the social network structure. Game theory is a natural tool with which to understand such interactions and resulting behaviors. These papers make new predictions about how human behavior relates to the patterns through which people interact: when will people adopt a new technology, how will they decide whether to become criminals, how much education will they pursue, how do they bargain, and how do these choices interact with and depend on the behaviors of their friends as well as their position in the network? The papers in this part of the volume include early ones on networked bargaining and trade (Myerson (1977, Chapter 12, Volume I), Corominas-Bosch (2004, Chapter 18, Volume I), and also Uzzi (1996, Chapter 21, Volume II) and Kranton and Minehart (2001, Chapter 18, Volume II) which appear in the second volume), learning and diffusion (Parikh and Krasucki (1990, Chapter 13, Volume I), Bala and Goyal (1998, Chapter 14, Volume I), Chwe (2000, Chapter 16, Volume I), DeMarzo, Vayanos, and Zwiebel (2003, Chapter 17, Volume I), López-Pintado (2008, Chapter 22, Volume I), Golub and Jackson (2010, Chapter 24, Volume I), Acemoglu et al. (2011, Chapter 28, Volume I), Choi et al. (2011, Chapter 29, Volume I), and Hagenbach and Koessler (2010, Chapter 26, Volume I)), as well as basic modeling of games on networks (Morris (2000, Chapter 15, Volume I), Ballester, Calvó-Armengol, and Zenou (2006, Chapter 19, Volume I), Bramoullé and Kranton (2007, Chapter 20, Volume I), Jackson and Yariv (2007, Chapter 21, Volume I), Galeotti et al. (2010, Chapter 23, Volume I), Galeotti and Goyal (2010, Chapter 25, Volume I), Cabrales, Calvó-Armengol, and Zenou (2011, Chapter 27, Volume I)).

The third part of the first volume includes a few important papers on the econometrics of network analysis, partly motivated by the strategic interactions in the earlier sections. For example, situations in which people may care about the behaviors of their friends and acquaintances present substantial challenges in identifying interactive effects and sorting them out precisely because the network itself is a choice variable. Do people behave similarly to their friends because their friends influence them or simply because they are similar to their friends and may even choose to be friends with others who behave similarly? Indeed, an obstacle to empirically identifying peer and social network effects is an important issue identified by Manski (1993, Chapter 30, Volume I) which he called the *reflection problem*: absent further assumptions on the nature of peer influence, it would be impossible to distinguish the causal impact of peers' behavior on an individual's behavior from the causal impact of peers' background characteristics on an individual's behavior. Furthermore, there may also be unobserved factors that affect who interacts with whom as well as how they behave, and so it can be difficult to disentangle the peer effects from the correlated effects, for example, effects arising from the fact that individuals who are linked to each other tend to behave similarly because they face a common environment or have similar characteristics. Consider, for example, a child's decision to initiate drug use. Is it because his/her next-door neighbor's child initiated drug use? Or is it due to the fact that some peer background characteristic, such as a substance-abusing parent, caused both children to adopt the same behavior? Or is it because they live in a neighborhood with special characteristics? The distinction between these explanations is

important for policy purposes. When true contagion effects operate, intervening to alter one child's behavior may affect several others' behaviors. Absent such peer effects, but when children initiate substance use because adults in their household provide opportunities to do so, these multiplier effects would not exist. Correctly distinguishing endogenous from exogenous social effects is thus important in accurately gauging the benefits of interventions. The Lee (2007, Chapter 31, Volume I) and Bramoullé, Djebbari, and Fortin (2009, Chapter 32, Volume I) papers make advances in identifying peer effects and are just part of an emerging literature.[3]

The second volume turns to applied theory as well as empirical and experimental analyses. These are grouped mainly by specific domain of application. The papers that we have collected in the second volume are representative of the more recent literature that has drawn on some of the theory for its analysis. We omit some early classics (e.g., early papers on the role of social networks in transmission of job information) that were more descriptive in nature. The domains of application in the second volume are varied and represent the rich set of areas where social networks are instrumental in shaping behavior and where the literature is illuminating that relationship.

The first part of the second volume focuses on applications to labor and education. There is plenty of evidence that social networks play an important role in labor markets. Social contacts are important conduits of information about job opportunities and help connect workers and employers. In a very influential study, Granovetter (1973, Chapter 1, Volume II) and Granovetter (1974)) interviewed people in a suburb of Boston and analyzed how they found their current jobs. He found that a large fraction of the workers (roughly 50 percent) had found their jobs through personal contacts. He also emphasized the difference between strong ties (with a high frequency of interactions) and weak ties (with a low frequency of interactions), noting that weak ties played a non-trivial role in job contact networks. Granovetter's was an important early contribution to what has become a large literature in economics and sociology investigating the role of networks in labor markets. These include studies that provide more detailed investigations of weak and strong ties (Boorman (1975, Chapter 2, Volume II), Montgomery (1991, Chapter 3, Volume II)), job-contact network formation (Calvó-Armengol (2004, Chapter 5, Volume II)), and empirics of job contract networks (Topa (2001, Chapter 4, Volume II), Bayer, Ross, and Topa (2008, Chapter 8, Volume II)). Another paper (Calvó-Armengol and Jackson (2004, Chapter 6, Volume II)) demonstrates implications of the fact that information about jobs is communicated via social networks: that the employment and wages of agents connected through networks is positively correlated by social distance and across time, that unemployment exhibits duration dependence, and that inequalities across individuals can persist in networked labor markets. The influence of peers on education outcomes has also been extensively studied by economists (e.g., Calvó-Armengol, Patacchini, and Zenou (2009, Chapter 9, Volume II)). As for the labor market, results show that not only peers, but also the structure of the network affects education. We include an important survey on networks and labor markets and related topics by Ioannides and Loury (2004, Chapter 7, Volume II).

The second part of the second volume concerns issues related to development economics. Networks are clearly important in numerous aspects of day-to-day life that affect development. These include the labor markets discussed above, as addressed by the papers of Munshi (2003, Chapter 10, Volume II) and Wahba and Zenou (2005, Chapter 12, Volume II) in this section. In addition, the adoption of new agricultural technologies can be a route out of poverty for

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many and yet innovations are often adopted slowly (see Bandiera and Rasul (2006, Chapter 13, Volume II)). Risk sharing is also vital to people in the developing world and has a strong network component, as demonstrated by Fafchamps and Lund (2003, Chapter 11, Volume II). Given idiosyncratic risks and the absence of formal credit and insurance markets, the informal exchange of favors and wealth plays an important role in developing economies, and is the study of a number of recent papers.

The third part of the second volume considers the role of social networks in crime. Criminal activity involves peer effects, and crime and delinquency relate to positions in social networks (e.g., see Sutherland (1947)). Indeed, delinquents often have friends who have committed offenses. This suggests that the properties of social networks should be taken into account in understanding peer effects on criminal behavior. The four papers in this section (Glaeser, Sacerdote, and Scheinkman (1996, Chapter 14, Volume II), Calvó-Armengol and Zenou (2004, Chapter 15, Volume II), Ballester, Calvó-Armengol, and Zenou (2010, Chapter 16, Volume II), and Patacchini and Zenou (2012, Chapter 17, Volume II)) are important ones that develop theory that links network structure to criminal behavior, and also work with data to better understand that relationship.

The fourth part of the second volume moves in a different direction. Much of the rest of the volumes applies to social networks and to individuals. Here, nodes are exclusively firms and the analysis is the industrial organization aspect of networks, especially R&D networks. R&D partnerships can be critical to determining the advances made in industries, especially in those with rapid technological development like the pharmaceutical and computer industries. The potentially important role of R&D collaborations has spawned theoretical models of such relationships, such as Goyal and Moraga-González (2001, Chapter 20, Volume II) and Goyal and Joshi (2003, Chapter 21, Volume II). In these models, firms jointly form R&D collaborations to lower their production costs while competing on the product market. The models enable one to ask questions about potential policy interventions that might tax or subsidize various collaborations between firms.

In the fifth part of this volume, we include some of the important papers employing experimental methods, as those methods are becoming increasingly vital, both in the laboratory and the field. Indeed, given the enormous difficulty of identifying social effects in empirical studies, laboratory and field experiments that allow the researcher to control and directly measure how players' behaviors relate to network structure are very useful. Experiments have been used to study strategic network formation, learning in network settings, as well as games played on networks (including the Goeree, Riedl, and Ule (2009, Chapter 24, Volume II) paper included here, and see Kosfeld (2004) and Jackson and Yariv (2011), for more background). For instance, Charness, Corominas-Bosch, and Fréchette (2005, Chapter 22, Volume II) test the predictions of the Corominas-Bosch (2004, Chapter 18, Volume I) trading model, finding support for significant aspects of the theory. Experiments (Goeree et al. (2010, Chapter 25, Volume II)) have also found that play in games is related to social distance in a network, with players being more cooperative or generous to those who are direct friends or close in a social distance sense compared to those who are more distant in the network. Experiments are also playing an increasing role in the field, and are helping the analysis of network structure in developing economies (e.g., Karlan et al. (2009, Chapter 23, Volume II)).

As we mentioned above, it is always difficult to decide what to include in such an endeavor, and the multitude of applications has meant that we have focused on just a few. However, to

illustrate the broad reach of network theory, we close the second volume by including a few papers with other applications. These include international trade (Rauch (1999, Chapter 26, Volume II)), which is an important but still nascent arena for network studies. The recent financial crises have also made it clear that it is vital to understand networks of financial interactions and contagions, and so we include an early paper in that literature by Allen and Gale (2000, Chapter 27, Volume II). We conclude the volume with a paper by Echenique and Fryer (2007, Chapter 28, Volume II) that uses network techniques to develop a new measure of segregation.

We do not attempt to survey the literature here as there are a variety of sources that provide some overview of the various topics covered here (see, for example, Goyal (2007), Jackson (2008), and Jackson and Zenou (2013)). Our purpose is in helping the researcher access a set of classic papers on this subject all in one place, some of which may be difficult to access otherwise.

Author's note

It was our intention to include the Goyal and Vega-Redondo (2005) and Jackson and van den Nouweland (2005) papers but due to the copyright problems we were not able to use them. We apologize to the authors

Notes

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1. There is an older and rich literature in sociology that sheds significant light on these issues, much of it through case studies. The newer research that we cover here concerns modeling, with emphasis on strategic formation of networks, games on networks, and applied theoretical and econometric methods for identification of network effects. These topics are essentially absent from that previous literature.
2. An even earlier paper that incorporates some endogeneity of a network is the Boorman (1975, Chapter 2, Volume II) paper in the second volume that examined job contact networks. He allowed people to split a budget of time between strong ties (which take more time per tie, but have higher priority in the passing of information) or weak ties (which are less likely to pass along job information, but take less time to maintain). Although there are a few bugs in the analysis, it was also a model that involved choice in terms of the ties people would like to have.
3. See Blume et al. (2011) for a recent survey on this issue.

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