The Study of Social Networks In Economics

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1 Introduction

As Joel Podolny and James Rauch point out in their introductory chapter, social networks are endemic to economic interactions. The rise of what one might refer to as "social economics" comes very much from the realization by economists that there are many economic interactions where the social context is not a second-order consideration, but is actually a primary driver of behaviors and outcomes. Obvious examples range from the primary role of social networks in obtaining jobs, to their influence on decisions of which products to buy, how much education to pursue, and whether or not to undertake criminal activity.

While the widespread realization of the importance of the embededdness of economic activity in social settings has been fundamental to sociologists for some time, and quite eloquently exposited by Granovetter (1985), it was largely ignored by economists until the last decade. The recent interest comes from having pushed many economic models to their limits, and having found that social circumstances can help explain observed economic phenomena (e.g., persistent wage inequality) in ways that narrower economic models cannot. I draw a parallel to the recent rise of interest in "behavioral economics," which comes the realization that a deeper exploration of

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the psychological underpinnings of human behavior can help enrich the modeling of economic decision makers. Similarly, the recent rise of interest in social economics comes from a realization that a deeper exploration of the social underpinnings of human behavior can enrich the modeling of economic interactions. This is important to understand because it actually results in a distinction with regards to the interest in social networks in economics. Much of the interest comes from a social economics perspective where social context provides an enriching of economic models, but the ultimate interest is in understanding the allocation of scarce resources. However, as exposure to the literature on social networks has grown so has the interest in understanding social structure independently of its effect on economic behavior. Both of these motivations lead to bridges with sociology, but with differences in the interface and the extent to which sociologists are part of the intended audience of the studies.

In this chapter, I provide a broad level overview of the economics literature on economic and social networks. The plan is to examine the evolution of that literature, and in doing so to provide an idea of the approaches that have been taken and the perspective from which networks have been analyzed. Given the objectives of this volume, I am not attempting to provide a detailed description of what has been asked and answered by the literature,[1] but rather to examine what economists might hope to gain from the analysis, how their paradigm has influenced their approach and the questions that they have tended to ask, and some examples of the research. The discussion is aimed at a general audience, with no presumption of any familiarity with the economics literature.

2 Some Background on Perspective

To begin, let me emphasize the obvious from the outset: namely that much of the economic study of interactions in a social context lies within a "rational choice" framework. So as not to get side-tracked on a discussion of what is embodied in the notion of rationality, let me be a bit more specific. One of the basic presumptions that underlies much of the economic modeling of network formation is the view that

[1] I have written at more length on this in other places (e.g., Jackson (2004, 2005, 2006)).

the individuals involved in networks choose with whom they interact.[2] Individuals are assumed to form or maintain relationships that they find beneficial, and avoid or remove themselves from relationships that are not beneficial. This is sometimes captured through equilibrium notions of network formation, but is also modeled through various dynamics, as well as agent-based models where certain heuristics are specified that govern behavior. This choice perspective traces the structure and the properties of networks back to the costs and benefits that they bestow upon their participants. This does not always presume that the individuals are fully rational or cogniscent of their potential options, or even that they are "individuals" rather than groups or organizations. But, most importantly, on some level the analyses generally embody the the idea that networks where there are substantial gains from forming new relationships or terminating old ones will be more ephemeral than networks where no such gains exist. What to conclude beyond this, is open to more debate.

Along with this point of view, also comes an interest in the welfare implications of the interaction for the society in question. This interest can be understood from two directions. First, once one begins by working with decision making actors who somehow weigh costs versus benefits, one is clearly led to the question of how well the system performs. Costs and benefits need to be carefully spelled out, and so there is a natural metric with which to evaluate the impact of a social network or changes in a social network. Second, since some of the interest in social surroundings comes from the fact that models that ignore those surroundings are unable to explain some observed phenomena, such as persistence in inequality among different groups in terms of their employment or wages, one is led back to the issue of why the phenomena are important to begin with. The interest in these issues often emerges from some fairness criteria or from an overall efficiency perspective, where there is a question of whether or not a market is operating as it efficiently as it should or could. When markets are viewed in a social context, this can change the ways in which one predicts that resources will be allocated. This then leads back to some welfarist evaluation of the network and behavior that emerge.

[2] So, with respect to "rational choice," the emphasis is on the word choice and not on the word rationality. While models differ in how they view decision making, whether agents are myopic, adaptive, Bayesian, forward looking, etc., models generally build from economic agents making decisions.

Another apsect of economists' thinking is worth emphasizing. Their interest tends to go beyond describing what is, and often tries to explain why things are the way they are. This may also seem to be an obvious point, but differences in researchers' perspectives on this issue is often a basic source of misunderstanding and miscommunication. This interest in the "why" naturally leads to some abstraction away from the full detail of a setting, which can lead to the omission of important factors. At the same time, the tendency towards abstract modeling can help provide insights into why certain regularities might appear in social and economic networks. For instance, below I will talk some about how some fundamental economic reasoning can help explain "small world" network phenomena.

With this background perspective in mind, let me now turn to a overview of the literature.

3 An Overview of the Incorporation of Networks into Economics

3.1 Early Roots and Examples

Although the explosion in networks studies in economics has largely taken place in the last decade, there were, of course, much earlier studies where social networks were central in economic studies.[3] Some of the earliest studies involved the documentation of the importance of social networks as means of obtaining jobs by Myers and Shultz (1951) and Rees and Shultz (1971), which served as important precursors to Granovetter's (1973, 1974) seminal work. The interest in social networks in the context of labor markets continued, and there were two further papers of note that were important early bridges between the sociology literature and the economics literature. These were studies, by Boorman (1975) and Montgomery (1991), that examined the strength of weak ties in labor contact networks, where individuals make explicit choices about the strong and weak ties that they maintain with an eye to

[3]The importance of the interplay between economic interactions and social circumstances obviously has a rich history, including whole fields such as Marxian economics. Here, I restrict my attention to studies that explicitly involve networks of relationships.

the impact this has on their employment and wages. These studies helped enrich the study of the strength of weak ties by examining the explicit tradeoffs between them from a given person's perspective and also provided new insights into employment and wages. These studies already exhibit the choice-based approach discussed above.

Another place where the importance of network externalities is quite evident was in product adoption decisions. In many product choices, such as over software or technologically based products where some sort of standards are needed, or where individuals care about the compatibility of their product choices with those of others, one cannot view the decisions of individuals in isolation. The term "network externality" embodies such relationships. Here there can be effects where groups of consumers lock in on an inferior technology simply because it is pervasive, even when it is clear that some other technology is superior. This results in interesting dynamics in a product's market over time and also in the ways in which firms try to sell such products. Important work on this was by Katz and Shapiro (see Katz and Shapiro (1994) and Economides (1996) for surveys). Although this involed studies where social pressures were critical, the attention was mainly on situations where individuals cared about population averages in activities and so the specifics of a social network never entered in a meaningful way.[4] This has changed recently, with a renaissance in the diffusion literature, where explicit social network structures are included and I mention some references in Section 4.

3.2 Cooperative Game Theory

An early example of the explicit modeling of network structures, with some perspective on their influence on economic outcomes, came through the cooperative game theory literature. Although the modeling approach is quite abstract, cooperative games are meant to capture a variety of productive enterprises where the cooperation among individuals is fruitful. Into this setting, Myerson (1977) introduced graph structures, with a premise that groups can only cooperate to the extent that they are path connected. So, people who can communicate can cooperate, and generally in cooperative game settings, cooperation leads to higher production or utility than

[4] This is also true of a large set of studies in labor economics and the economics of education where peer effects are considered, but where explicit network modeling has only recently emerged.

separate efforts. Myerson's interest was not in modeling social networks per se, but in characterizing a cooperative game theoretic solution concept (the Shapley value) without directly imposing a technical condition that was common before that (an additivity axiom). Imposing conditions on how cooperation depended on the communication graph in place and how players were rewarded for their cooperation, Myerson produced a new prediction of how the value should be split among the members of a society, which is now referred to as the Myerson Value. There have been a number of studies of cooperative games following up on this work (e.g., see the overview by Slikker and van den Nouweland (2001)).[5] A more direct precursor to the recent modeling of network formation emerged when Aumann and Myerson (1988) examined a three player example where players could propose to open a communication link with one another. In this setting players anticipate the effect that communication has on cooperative opportunities, and thus utlimately on the value that they will obtain, and then propose links with this in mind.

3.3 Modeling the Costs and Benefits of Network Formation

Although the cooperative games literature found interesting implications of communication structures, the strategic (or game theoretic) modeling of strategic network formation took off when networks became the basic social structure governing interactions rather than an extension to a cooperative game. This first appeared in work by Jackson and Wolinsky (1996). In their modeling, the network of relationships among individuals leads to a productive value, or utility value. That is, costs and benefits to individuals are specified as a function of what the network looks like. Then viewing the individuals as self-interested parties who form and sever links in order to maximize their eventual benefits (net of the cost of links), one can make predictions about which networks will form.

Outlining this approach is useful, as it typifies much of the recent literature from the economics perspective. The networks of relationships are represented by a graph,

[5] Another branch related to cooperation structures and graphs is found in work by Kirman (1983) and Kirman, Oddou and Weber (1986), who, in the context of core convergence in exchange economies, analyze the impact of limiting blocking coalitions to connected groups, where connection is defined relative to a Bernoulli random graph.

for instance, captured via an $n \times n$ matrix, g, where n is the number of individuals in question. In many applications, the entries of the matrix take on a value 1 if the two individuals are linked and a value 0 if they are not. If this is a network of friendships, it would be non-directed so that it is a symmetric matrix ($g_{ij} = 1$ if and only if $g_{ji} = 1$), but in other situations where relationships indicate things like trust, the links could be directed. The important aspect is that there is some utility or productive value that is realized as a function of the network. That is, there is a function $u_i(g)$ which indicates the value or utility (benefits net of costs) that acrues to individual i if the network of relationships in the society is described by g. If this is a network of buyers and sellers, then this would be the profits that would be anticipated based on the trades that would occur if the network were g. If this is a network of alliances among countries, then this would be the anticipated welfare of each country as a function of the alliances in place. If this is a network of friendships, then this might be some proxy for the happiness or well-being of each individual as a function of the relationships in the society. If this is a network of job contacts, then this might be the future expected earnings of an individual as a function of who knows whom.

With such a utility function in hand, we then see the two ingredients of the approach underlying much of the economic discussion of network formation. The payoffs to each individual underlie the incentives to form or sever links, and they also provide the basis for a welfare evaluation.

Let us start with the welfare considerations. If one network leads to higher payoffs for all individuals in a society, then there is an obvious sense in which it improves welfare. This is a standard notion known as Pareto dominance (named after Vilfredo Pareto, who introduced the idea in the late nineteenth century). We can also ask for a stronger notion of efficiency, namely that a network maximize the total payoffs to the individuals in a society. This idea has its roots in utilitarianism and is more controversial than Pareto efficiency, but is very useful in network contexts as it can often single out a specific network architecture as maximizing total welfare and is natural in contexts where transfers can be made among individuals, which is the case in many economic applications.

In terms of the choice considerations, the individuals in a society can be modeled as forming or breaking relationships depending on whether the links improve or hurt the individuals' overall utility or payoff. The notion of pairwise stability, introduced by Jackson and Wolinsky (1996), is a simple way of embodying this principle. A network is pairwise stable if[6]

- if a link between two individuals is absent from the network then it cannot be that both individuals would benefit from adding the link (with at least one benefitting strictly)
- if a link between two individuals is present in a network then it cannot be that either individual would strictly benefit from deleting that link.

This concept captures the discretion of individuals in the links they are involved with, and the response of individuals to the costs and benefits they see from network relationships.

This notion is appropriate when it takes consent to form a relationship, as in many applications. but is is just one way of modeling which networks one expects to form. There are many alternatives to this notion that have been explored in the literature, but they basically keep with same principles of discretion in forming links and the response to incentives. What has been varied is how much discretion people have and how rational they are in responding to incentives. For example, one can allow individuals to consider changing multiple relationships at a time rather than just considering one relationship at a time (e.g., Gilles and Sarangi (2006)). One can also allow groups to coordinate their changes in relationships (for instance seceding and forming new relationships - see Dutta and Mutuswami (1997) and Jackson and van den Nouweland (2002)). In the case where relationships are directed, it may be that consent is not needed so that agents can unilaterally form new relationships (e.g., Bala and Goyal (2000)). One can also model this as a dynamic process where agents potentially make mistakes over time and the network gradually evolves (e.g., Jackson and Watts (2002)). There are potential variations based on whether or

[6] In more formal terms the definition is as follows. Let $g+ij$ denote the network formed when the link ij is added to a network g, and $g-ij$ denote the network formed when the link ij is deleted from a network g. Then a network g is pairwise stable if: for all ij such that $g_{ij}=0$, if $u_i(g+ij) > u_i(g)$ then $u_j(g+ij) < u_j(g)$; and for all ij such that $g_{ij}=1$, $u_i(g) \geq u_i(g-ij)$ and $u_j(g) \geq u_j(g-ij)$.

not agents anticipate the further changes that will occur in the network (e.g., see Page, Wooders and Kamat (2005), Dutta, Ghosal and Ray (2005), Mauleon and Vannetelbosch (2004), and Herings, Mauleon and Vannetelbosch (2004)).

3.3.1 An Example

It will be helpful to examine an example that helps illustrate the approach and some of the types of questions that have been asked. Consider a very stylized model of the value of relationships, which was one of the examples from Jackson and Wolinsky (1996) under the name of the "Connections Model." Here, relationships convey both direct benefits and indirect benefits. The direct benefits are based on the interaction between two individuals, for instance the exchange of favors or information, while the indirect benefits come from the access to friends of friends. In the connections model, a given individual gets a benefit of δ from each direct relationship that he or she has. The individual also gets a benefit of δ^2 for each other individual who has a minimum path length of 2 to the individual. This is the value of the friend of a friend. When δ is less than one, then the value of a friend of a friend is less than the value of a friend. The individual gets a value of δ^3 for individuals at a distance of 3, etc. Maintaining relationships is also costly in terms of time and effort, and so each direct relationship results in some cost to maintain, c.

Figure 3.3.1 gives the utility payoffs under the connections model for a particular network of relationships among five individuals.

To get a feeling for the concepts, we can ask whether or not this network is pairwise stable. For instance, it has to be that $\delta > c$ in order for 3 to be willing to maintain the link with 5. If $\delta < c$, then this network would not be pairwise stable. It would also have to be that $\delta^3 > \delta^2 - c$ in order for 1 and 5 not to want to form a link. More generally it is not hard to deduce properties that pairwise stable networks will need to have as a function of the benefits (captured through the parameter δ) and the costs (captured through the parameter c).

We can also characterize the networks that are efficient in this model. There are only three simple architectures that can be efficient: if c is low enough relative to δ then the unique efficient network is a complete network (i.e., where every individual is directly linked to every other individual). The idea here is that direct relationships

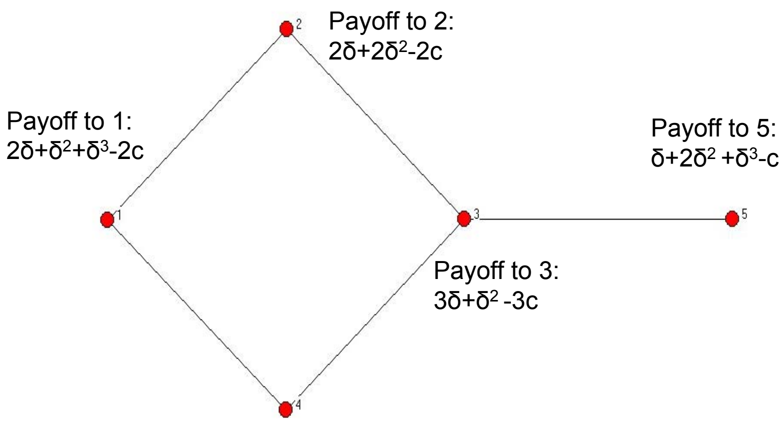

Figure 1: Payoffs in the Connections Model

are more valuable than indirect ones, and so if the cost of a relationship is small enough, then it is preferable to have all potential relationships be direct relationships. If instead, the cost is very high relative to the benefits, then we see the opposite extreme where the empty network will be the only efficient network, as costs simply outweigh whatever potential benefits there may be. The interesting case is the middle range of costs relative to benefits. In that range, it turns out that there is a unique efficient architecture (in the sense of maximizing the total society utility), which is a "star" network. So, the efficient network structure is to have a single individual who is connected to each other individual, but where the other individuals are only connected to this center individual. There is a strong intuition behind why this configuration is the efficient one. It connects all members of society and does so with a minimal number of links. Also, it does so in a way that makes sure that every individual is at a distance of at most two from every other individual. Unless the cost is so low that two indirectly connected individuals would gain by shortening the distance between them (in which case we would fall in the range of costs where the complete network is efficient), there is no way to improve the total utility of the society by altering the network.

3.4 A Tension Between Individual Incentives and Societal Welfare

The connections model also illustrates another fundamental point, namely that there can be a disparity between the networks that are efficient and those which are formed at the discretion of individuals. For example, in this model the center of a star bears a large cost by maintaining many relationships. The center thus provides a service to the society in providing many indirect relationships between other pairs of individuals. If the center of the star is not compensated somehow for maintaining these relationships (e.g., in a case where $c > \delta$) it can turn out that the star is not pairwise stable even though it is the unique strongly efficient configuration. Without some sort of extension of the model where other agents can help compensate the center, there will be an inefficiency in the networks that will form. Whether or not the center can be properly compensated depends on how easy it is for the other individuals to transfer benefits to the center. If this is a trading situation, then monetary transfers might be possible, while in other situations it might be that the center ends up gaining some power or status that translates into a higher utility.[7] The connections model provides the raw benefits and costs, and then any reallocation or transfer of values needs to be modeled in order to understand if some sort of transfer can help lead efficient networks to be pairwise stable.

One might expect that if agents are free to make promises or transfers of goods, favors, or services to each other, then that could help reconcile individual incentives with societal objectives and thus lead efficient networks to emerge. The basic idea is that the efficient network results in the higest level of total resources or utility, and so if these are appropriately redistributed, then everyone should be better off than at some inefficient network. In some situations, one can envision a government stepping in and using taxes or subsidies to help promote an efficient network to emerge. We see such interventions in a variety of settings, such as government subsidies to foster

[7] The payoffs in the connections model do not always reflect the fact that the center fills a structural hole in the sense of Burt (1992). There are alternative specifications of payoffs, even with the same total value as a function of the network, that would be more in line with this. For instance, under the Myerson value the center of the star would enjoy a much higher payoff (see Jackson (2007)).

collaborations in research and development activities, especially when firms could gain from forming relationships along R & D dimensions, but might be reticent to do so if competing along other dimensions. Given the importance of this question, and the strong intuition that some sorts of transfers or redistributions should be helpful, this has been an active area of research.

It turns out that even a fully benevolent government who only intervenes in the form of taxing and subsidizing individuals and relationships in order to try to promote the formation of the efficient network cannot always provide the right incentives. Jackson and Wolinsky (1996) showed that there were some very basic situations where in order to lead self-interested individuals to form an efficient network one either has to treat identical individuals (who sit in structurally equivalent positions) very differently, or one has to make transfers away from groups that are producing benefits and give it to individuals who are not contributing at all to the productive value. Thus, there are some very simple settings where the only networks that are pairwise stable are inefficient ones, unless there is some intervention that involves transfers that are inherently unfair in one way or another. Dutta and Mutuswami (1997) showed that this unfairness could be avoided on certain networks and only imposed on others, and could be done in a way such that the individuals are treated fairly provided they end up forming the efficient network, and are only treated unfairly when they do not. Curarrini and Morelli (2000), Mutuswami and Winter (2002), and Bloch and Jackson (2005) have also shown that if individuals are able to make certain promises to compensate each other for relationships when those relationships are formed, then efficient networks can emerge in a fairly wide class of settings.

This tension between stability and efficiency arises from the fact that the externalities in network settings can be quite involved, given that individuals are affected not only by who their neighbors are, but also who their neighbors' neighbors are, etc. Individual incentives to form or maintain relationships in such a setting can be at basic odds with overall societal welfare. Overcoming this conflict can require strong forms of intervention.

This tension between individual incentives and overall societal efficiency has been further investigated in the context of various specific applications. For example, Kranton and Minehart (2001) examined the formation of networks between buyers and sellers. In their model, buyers each want a good and sellers each have a good for sale. The buyers differ in how much they value a unit of the good. In a fully centralized market, one could hold an auction and the goods would end up being sold to the buyers who value it most, and societal welfare would be maximized. However, for a variety of reasons centralized markets are more the exception than the norm. Generally, buyers will form relationships with certain sellers and then tend to trade mainly with them (e.g., see Uzzi's (1996) study of the garment industry or Weisbuch, Kirman, and Herreiner's (2000) description of the Marseille fish market). In particular it may be costly for a buyer to form a relationship with a given seller; for instance, in setting up credit, conforming to the seller's inventory and other systems, arranging for delivery, and so forth. In terms of getting a good price, buyers would prefer to have less competition from other buyers and at the same time be in touch with a large number of sellers who would then compete for a sale. Analogously, sellers would like to be connected to many buyers who would compete for a purchase, but be in competition with a small number of other sellers. The optimal configuration given costs to relationships will involve having some buyers connected to more than one seller and vice versa, to make sure that goods end up in the hands of the buyers that happen to value them the most in any given instance, but will have fewer relationships as they become more costly. It is not obvious as to whether or not the buyers and sellers will have the right incentives to form the correct number of relationships, and the right ones, from an overall societal efficiency perspective. Kranton and Minehart show that if buyers bear the full cost of forming relationships with sellers, then the efficient network will be pairwise stable. It also turns out if sellers bear a nontrivial cost of forming relationships with buyers, then this efficiency result can fail as shown in Jackson (2003). Buyers turn out to have incentives to form relationships that align with society's objectives, while sellers do not. The buyers end up getting their marginal value compared to the next highest valued buyer and so internalize the welfare effect, while sellers simply wish to see as high a price as possible.[8]

Buyer and seller models are an example of a setting where the tension between indi-

[8] Another model of buyer-seller networks, with a very different bargaining protocol, was developed by Corominas-Bosch (2005) and explored in laboratory experiments by Charness, Corominas-Bosch and Frechette (2005). While the details differ, efficiency again depends on who bears the cost of relationships.

vidual incentives to form relationships and overall societal welfare has been explored. There are also studies of networks of collaboration among firms (see Bloch (2004) for a recent survey), the formation of job contact networks (e.g., Calvo-Armengol (2004)), international trading alliances among countries (e.g., Furusawa and Konishi (2005)), information networks (e.g., Rogers (2006)), risk-sharing networks (e.g., Bloch, Genicot and Ray (2005) and Bramoullé and Kranton (2005b)), just to mention a few areas.

4 The Explanatory Power of an Economic Approach

Up to this point, I have emphasized the modeling approaches taken by economists studying network formation, and some of the questions that are naturally asked and answered in tandem with such an approach. In addition to understanding tensions between individual incentives and societal welfare, this approach can also offer some fundamental insights into why certain regularities in networks should be observed across applications.

A good example of the insights that economic modeling can yield behind why networks exhibit certain features concerns "small-worlds" aspects of network. Much has been made of the "small-world" nature of networks, starting from seminal experiments of Milgram (1967) who found that the chains of acquaintances needed to connect individuals who might be quite geographically and professionally distant is remarkably low. Watts and Strogatz's (1998) (see also Watts (1999)), showed that starting with a regular lattice that is highly clustered on a local level, one only needs a small amount of random rewiring of links in order to have a network that exhibits two key features found in many social networks: highly clustered links on a local level, and relatively short distances between any two randomly selected nodes. While this provides an important insight that a relatively small number of bridging links can dramatically decrease the diameter of a network, it still leaves us questioning *why* social networks tend to exhibit these features. It answers the how, but not the why. Insights from the economic perspective complement the Watts and Strogatz approach and instead of offering a process that will exhibit such features, offer an explanation of why people would tend to form networks with such features. Ideas related to this have been examined in a series of papers where there is some heterogeneity in costs (Johnson and Gilles (2000), Carayol and Roux (2003), Jackson and Rogers (2005), Hojman and Szeidl (2006), and Galeotti, Goyal, and Kamphorst (2006)). The basic idea is that high clustering emerges between individuals who have low costs of forming relationships. These low costs of forming relationships arise because people are close geographically, or in terms of profession or other characteristics. While the costs to relationships at greater distances can be quite high, again either due to geographic or in terms of some other characteristics, some such relationships still emerge since they can be very valuable. Such relationships bring access to distant parts of the network, and thus they provide information and access that one does not have from local sources. The network diameter that emerges cannot be too large precisely because it is valuable to connect to distant parts of a network. Given high costs across larger distances, we expect fewer distant links, but we expect some such links to form because of the rewards they offer.

This is just one example of how such an economic approach offers insights into why networks might emerge that exhibit certain characteristics. Another good example of such research is the Kranton and Minehart chapter in this volume concerning supplier networks. By analyzing the incentives to form certain supply relationships, they are able to explain why one would see a company only dealing with a small number of suppliers when it might be in their short-term interest to deal with more suppliers in order to get them to compete and offer better prices. The insight is that the long-term investment decisions are shaped by the network of supplier relationships. Again, understanding what the costs and benefits are from various configurations of links helps to sort out why (and under what circumstances) one might see specific sorts of networks emerging.

5 Beyond the Formation of Networks - Behavior Influenced by Networks

While this volume's focus is on the network formation, we are naturally led beyond this question. Let me explain exactly why. One of the primitives of many economic models of network formation is the costs and benefits that individuals enjoy as a function of various network configurations. In order to be able to assess what the costs and benefits are from different networks, we have to have some idea of what will occur once a network forms. This necessitates having a forecast of how behavior and the allocation of resources changes as the network changes. Moreover, beyond how critical this is in terms of providing the base for incentive-based network formation models, it is also interesting in its own right. For instance there are obvious questions as to how social network structures influence decisions to buy products, to become educated, to select professions, to adopt certain political ideologies, to engage in criminal activity, etc. Again, the interest in introducing networks into the study of economic interactions in the first place is to understand the impact of the social context on economic behavior. This provides another natural bridge between studies by sociologists and by economists. The body of research in sociology regarding how social structure affects behavior is extensive, both on the empirical and theoretical sides. As this has become an increasingly active research area in economics, the connections between the literatures has grown. Let me briefly discuss one example of such research and then mention some other directions that the research is expanding to.

An illustrative example of a study of how a network of relationships influences behavior is the work of Ballester, Calvo-Armengol and Zenou (2006), which concerns the incentives of individuals to engage in crime. They build a model based on the premise that the benefits from criminal activity depend on the level to which an individual's friends and neighbors engage in it. There are complementarities both in learning about crime and in cooperating in criminal pursuits, and so the benefits depend on the extent to which friends are involved. There are also competition effects at the level of overall criminal activity in the society, where there may exist competition among groups or individuals, and there might also be tighter enforcement as overall criminal activity grows. These two forces, local through the network and global through the overall society, influence each individual's decisions of whether or not to become a criminal and with what intensity. Ballester, Calvo-Armengol and Zenou use an equilibrium approach to predict criminal activity, where each individual chooses a level of criminal activity in reaction to the choices of their neighbors as well as the overall level of criminal activity in the society. Interestingly, notions of centrality related to those of Katz (1953) and Bonacich (1972) figure prominently in characterization of behavior, and individuals with higher levels of centrality are more influential in affecting other individuals' criminal activity.

There are a variety of other recent studies of how network structure influences behavior, and these increasingly tie back to ever richer models of network structure and to the sociology literature. These include models of information gathering and public goods provision (e.g., Bramoullé and Kranton (2005)), network structure in labor markets (Calvo-Armengol and Jackson (2004), Ioannides and Datcher-Loury (2005)), exchange and markets (Kakade et al (2004)), communication of information (DeMarzo, Vayanos and Zwiebel (2003)), to name a few. Beyond the analysis of specific situations, there are also more general models based on graphical games (e.g., see Kakade, Kearns, Ortiz (2003)) that seek to characterize how network structure relates to individual behaviors. This literature (e.g., Lopez-Pintado (2005), Galeotti, Goyal, Jackson, Vega-Redondo, and Yariv (2005), Sundararajan (2005), Jackson and Yariv (2006)) makes heavy use of degree distribution information to predict behavior. For example, consider a world where actions are complementary. As an illustration, an individual's benefit from buying some products (such as a given cell-phone plan) increases with the number of friends that the individual has who have bought the same product. In such a world, individuals who are more highly connected are more likely to undertake the behavior. As the distribution of degrees is varied, this then changes the overall distribution of behaviors in the society. This leads to new insights about tipping points and the diffusion of ideas, technologies, opinions, and behaviors through a society. This is a promising area for research, that brings together details about social network structure and economic and equilibrium reasoning.

6 Some Concluding Thoughts

6.1 Choice versus Chance and Heterogeneity in Modeling

One limitation faced by an incentive-based approach to modeling network formation is that many of the models that are analytically tractable end up with some limitations on their range. They can provide broad insights regarding things like incentive-efficiency tradeoffs, and they can help explain why one might see small worlds, and some other prominent characteristics of observed networks. However, many of the models are quite stark in their detail, and as a result end up with networks that are quite simple emerging as the stable and/or efficient networks. Networks like stars are quite special, and rarely observed in real social settings. While these can be thought of as analogs to hub-and-spoke sorts of networks, it is clear that the models are not so well suited in terms of trying to match the observed form of many large social networks, where there is a huge amount of heterogeneity in the network structures.

There are two ways to deal with this. One is to work with simulations and agent-based modeling to introduce heterogeneity (e.g., see Tesfatsion (1997)). Another is to bring in some randomness to the settings. Random network models have provided some simple models that end up providing insights into some observed networks (e.g., Barabasi and Albert (2001)). Such random models, however, end up being somewhat mechanical and new processes can be needed everytime some difference in network structure is observed empirically. On the one hand the economic approach leans too heavily on choice and at the other extreme random network models lean too heavily on chance. Reality is clearly a mix of these two, where individuals only end up seeing some opportunities to form relationships. There is some chance in which relationships they have an opportunity to form, and then they use discretion in which ones of those they follow through on.[9] This appears to be a potentially very useful future avenue of research.

6.2 Bridges between Literatures

In closing, I offer some thoughts on the formation of bridges between research on networks in sociology and economics. It is easy to find reason to complain about the lack of attention that one discipline pays to another, as literatures tend to be introspective. The barriers across disciplines in terms of backgrounds, terminology, approach and perspective can be quite substantial, making it very costly to understand, synthesize and incorporate research from another discipline. It is often easier simply to discount another discipline's approach as being flawed or uninteresting and to ignore it. However, as the settings and questions that researchers in different disciplines are examining begin to naturally converge, researchers have no choice but to

[9] For example, see the discussion in Jackson and Rogers (2005) and Jackson (2006).

take note of each other and to begin to incorporate key ideas, insights, and methods from each other's disciplines. Just to point to one example: an important nexus between computer science and economics/game theory has emerged in the last five years or so. Computer scientists have become increasingly interested in protocols for routing, queuing, file-sharing, and more generally designing systems where many different actors may be involved at once and may have different objectives. Designing such systems leads to the recognition that the actors respond to incentives and that understanding incentives is critical to designing efficient stystems. At the same time, economists have been designing markets and auctions that involve potentially many buyers and or sellers, and combinations of trades and objects for sale. The computational complexity involved in making such markets work, both on the part of the participants and the market protocols, has become a serious constraint and needs to be properly understood and accounted for. This has resulted in a very healthy exchange, and an increasingly seamless and interdisciplinary field of research that involves both incentives and limited computation is emerging. A very similar confluence between social economics and economic sociology is taking place, given the numerous settings where economic interactions shape social structure, and where social structure shapes economic interactions. As the subjects of study overlap more and more, researchers from the different disciplines have no choice but to take notice of each other. Here again, the tools and perspectives coming in can be quite complementary. The substantial body of work in sociology tells us (among other things) how and when networks matter, and helps us describe them from a variety of structural perspectives. The economic perspective brings decision making actors and takes incentives as a serious input, and with an eye to efficiency and welfare measures, can yield new insights regarding the formation of networks and the influence that networks have on behavior. We already see studies that draw heavily from both sources, and this trend is likely to continue. This volume would not have existed a decade ago, and hopefully will be just one example of a growing dialog between sociologists and economists.

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