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Learning in social networks: Selecting profitable choices among alternatives of uncertain profitability in various networks

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ABSTRACT

Social capital theory assumes that information is valuable. However, only rarely is this value explicitly modeled, and there are few examples of empirical tests of mechanisms that connect social network structure to valuable information. We model an individual decision problem in which individuals make choices that yield uncertain outcomes. The individuals can learn about the profitability of options from their own choices and from the network. We generate computer-simulated data to derive hypotheses about the effect of network characteristics on making profitable choices. We conduct a laboratory experiment to empirically test these hypotheses and find that, at the individual level, degree centrality has a positive effect on making profitable choices whereas betweenness centrality has no effect. At the network level, density has a positive effect on making profitable choices, whereas centralization does not have an effect.

1. Introduction

A great deal of research on social networks addresses the question of how different network structures affect the information diffusion in social networks and how different network positions in social networks provide benefits to individuals in terms of the valuable information they receive. In particular, Granovetter (1973) and Burt's (1992) influential theories on the strength of weak ties and structural holes specify conditions under which individuals are likely to receive novel information via social networks. In this sense, strategic social network positions are seen as a form of social capital, and much research has shown that certain network positions and structures are indeed associated with individual outcomes (Graaf de and Flap, 1988; Lin, 1999; Cowan and Jonard, 2004; Burt, 2004; Schilling and Phelps, 2007; Grund, 2012). This influence extends to both individual outcomes (we refer to this as the microlevel: an actor's individual outcome) (e.g., Burt, 2001) and network performance (or the macrolevel: actors' aggregated outcomes in a network) (e.g., Grund, 2012).

We argue that the exact causal mechanisms by which individuals benefit from information received via networks are understudied. In particular, to our knowledge, no experimental research exists that causally links the mechanism of information diffusion via network positions to better micro- and macrolevel outcomes. Empirically, most research relies on observational studies that merely establish correlations between network characteristics and outcomes. Theoretically, even formal game theory models on social capital formation (Jackson and Wolinsky, 1996; Buskens and Van de Rijt, 2008) typically *assume* that information is valuable to actors but without specifying *how* it becomes valuable to actors. One reason for this omission might be that it is not straightforward to extrapolate from the individual outcomes typically studied in observational studies (e.g., getting a job as in Granovetter, 1973) to a more generic setting that is abstract enough to be implemented in an experiment yet preserves the core features of the diffusion mechanism assumed in the theory.

We propose that a social learning setup as proposed by Goyal (2007: Ch. 5), in which individuals have the opportunity to use information from their social network to decide between different actions with uncertain outcomes, provides such a setting. When faced with a decision, we often have to choose between alternatives without knowing their relative advantages (Goyal, 2007). These choices have many implications for real-life outcomes. For example, farmers often adopt new crop seeds without being fully informed about which crop seeds are most profitable (e.g., Conley and Udry, 2010). Likewise, consumers often buy laptops of different brands without being fully informed about which brand

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is the best (Bala and Goyal, 1998). Moreover, how do consumers decide between competing alternatives, such as iPhone versus Android (cf. Kanoria, 2012)? When making multiple decisions of this type over a longer period, actors tend to update their beliefs about which choices are most profitable (Gale and Kariv, 2003; Jackson, 2008: Ch. 8). Moreover, when making multiple decisions and experiencing their outcomes in terms of profitability, actors learn which choice is most profitable. This is how we define *learning* (i.e., intrinsically valuable information) in this study: finding profitable choices among alternatives of uncertain profitability by integrating experiences from earlier decisions to optimize further decisions.

Nevertheless, how is this information diffused between actors? As we mentioned before, an important vehicle for information diffusion is a *social network*. Actors may learn not only from their own experiences but also from the experiences of others from whom they receive information via social connections. It is not only one's own choices and payoffs that are informative but also the choices and payoffs of others, which can generate valuable information on the relative attractiveness of different choices. Actors integrate this new information with previous information, including their own, to be able to make profitable choices. We thus model, in a very general way, not only situations in which information diffuses in networks but also situations in which information is intrinsically *valuable* to actors in helping them make better individual decisions. We believe this general framework not only captures core claims of social capital theory but also applies to a range of real-life situations. Again, imagine a farmer who is uncertain which crop seed to choose; only by learning from his own crop seed profit and that of other farmers with whom he interacts (i.e., his social network) will he know which crop seeds are most profitable. Alternatively, imagine an employee who has to renew his contract with his employer. From his own past experiences in renewing his contract with the same employer and from the experiences of (ex)-colleagues, he can decide how *profitable* (in terms of wage, treatment by boss and colleagues or benefits) it is for him to renew his contract or to try to sign a contract with another employer. This leaves us with specific questions such as: At which position in a network does the employee make the most profitable choice? And what network structure helps farmers maximize the sum of profitable choices? At which network position (microlevel), whether at the boundary or in the center, and in which network structures (macrolevel), whether dense or centralized, do actors make the most profitable choices (i.e., learn)? These questions are incorporated in the main question of our study: *What is the influence of microlevel and macrolevel network characteristics on selecting profitable choices among alternatives of uncertain profitability?*

1.1. An experimental approach

Choosing between alternatives without knowing their relative advantages is also referred to as the *multi-armed bandit* problem (Robbins, 1952; Gittins et al., 2011). Mathematically modeling learning in networks by actors who update their beliefs on the profitability of choices has been a goal of theoretical economists for the past few decades (cf. Goyal, 2007; Kanoria and Tamuz, 2011). However, to our knowledge, this is the first study to examine the influence of network structure and positions on solutions to multi-armed bandit problems empirically.[1] The requirements of the data for testing predictions about network characteristics on learning behavior are high. Specifically, detailed longitudinal data are needed on social relations and individual choices. To test hypotheses both at the micro- and macrolevel, sufficient variance and many observations at the macrolevel are needed. Moreover, when collecting field data, one must often compromise the number of observations at the macrolevel, the number of observed time points and the details of the microlevel observations (Corten and Buskens, 2010). Therefore, collecting field data with sufficient variance and many observations at the macrolevel often yields practical difficulties. While it is not impossible to collect data that are sufficient to test both microlevel and macrolevel predictions (i.e., studying network effects on individual level outcomes and complete network outcomes), these studies do remain scarce (see, for example, Grund, 2012 as an exception). Even with survey data that have properly defined networks and discrete time-points, it is difficult to distinguish learning from other phenomena that may give rise to similar outcomes (cf. Conley and Udry, 2010). Finally, it is also difficult to assess true payoffs of choice alternatives of uncertain profitability in field data setups.

We suggest laboratory experiments as a suitable alternative to test predictions about network effects at both the micro- and macrolevel. Whereas surveys generate large representative datasets, experiments provide control over information availability and incentive structures. Hereby, a clear distinction between cause and effect is possible, and causal inferences can be sustained more convincingly than in cross-sectional studies. Moreover, causal knowledge requires controlled variation, which experiments make possible (Falk and Heckman, 2009). Laboratory experiments yield precise information on behavior at every time-point. Multiple networks can be observed with varying network characteristics at the macrolevel. To generate experimentally testable hypotheses at the micro- and macrolevel, the focus in this study is on small four-person networks with different network characteristics. In essence, we vary several variables at the micro- and macrolevel to see what their effects are on the number of profitable choices actors make. At the microlevel, we vary degree centrality and betweenness centrality, and we argue that these characteristics capture, respectively, the amount of direct information and the amount of redundant information (i.e., brokerage) individual actors receive. At the macrolevel, we vary density (i.e., on average, how many actors does each actor know) and centralization, the degree to which some actors have more ties than others.

There are also disadvantages to experiments. First, the external validity of findings of abstract laboratory conditions is lower than for field data. Second, group size is often smaller than in real-life human interactions. Thus, we consider this study as an intermediate step between studies based on theoretical models on social learning and field data that are difficult to obtain.

To exploit our experimental approach, we align our experimental design and theoretical model. It is difficult to derive predictions solely by exploring informal arguments on learning because arguments and counter arguments for the same effect often exist. To solve this problem, we generate computer-simulated data within our experimental parameter space. In this manner, we can calculate for all network characteristics what their expected effect is on making profitable choices. Our hypotheses directly follow from the relations between network characteristics and profitable choices found in the simulated data.

The remainder of the paper is organized as follows. In Section 2, we specify our formal model of learning in social networks and discuss informal accounts of learning. Section 3 elaborates on the specific task that simulated actors and participants in the experiment face. In Section 4, we discuss the simulation and the predictions we derive, and in Section 5, we discuss the experimental procedure and the hypotheses tests based on the analyses of

[1] Conley and Udry (2010) study only social learning without involving network structures.