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Network effects on strategic interactions: A laboratory approach

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ABSTRACT

We examine the effect of interaction structure (network) on two classes of collective activities, herding and shirking, respectively referring to the situation where a player's incentive to take a certain action increases and decreases if more of her network neighbors follow the same action. In our experiment, we find that subjects do not act according to theoretical equilibrium, and their frequencies of making the socially beneficial choice in herding and shirking games are inversely influenced by the number of network neighbors they have. Moreover, the observed local network effect is stronger in shirking games, while the global network effect is more significantly present in herding games. We explain the behavioral regularities through a hybrid learning model, which extends SEWA learning into a network context. As such, our learning model provides a foundation for the observed dynamics, disequilibrium behavior, as well as the local and global network effects.

1. Introduction

Social and economic networks serve as platforms for trade and information exchange, and correlate the activities of separate individuals (Sundararajan et al., 2013). Activities of users of online networking sites, such as liking and following a movie or subscribing to a club, can generate considerable influences on their peers. This gives rise to positive correlations of demands of similar products or services across friends (Aral and Walker, 2011; Oestreicher-Singer and Sundararajan, 2012a,b). In other occasions, social networks help coordinate the individual choices, such as vaccination against viruses (Rao et al., 2007), the study of foreign languages (Galeotti et al., 2010), and software compatibility between coworkers (Lee et al., 2006). By means of laboratory experiments, this paper studies how the decentralized interaction of networked agents is

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affected by the network structure, which indicates "who interacts with whom". While the problem is generally difficult to tackle in both theory and empirical research, we are able to decompose multiple sources of network effects on agent activity in our experiment due to the incomplete information setting we consider. Our research goes beyond the linkage between aggregate network configurations and collective economic consequences, and inspect how the network affects activities at individual level (rather than group level). In this line, our study reveals how boundedly rational agents make use of the network information and adjust their strategies through learning, which shapes the aggregate observations.

In this paper, we represent decentralized activities in networks by two classes of games, *herding/shirking*, referring to the case where a player's incentive to take a certain action increases/decreases if more players in her network neighborhood follow the same action. Typical applications include technology adoptions under network effects (herding), and voluntary reduction of pollution (shirking). These concepts are illustrated by the examples that follow this paragraph. From the viewpoint of management and social planning, it is crucial to understand: *How does the network structure leverage the outcomes of herding and shirking, and foster socially beneficial behavior in strategic contexts? Why does the network exhibit the observed effect on behavior?*

1.1. Example 1. Product adoption under network effects (herding)

In the classical models for products with network effect (e.g. Katz and Shapiro, 1992, 1986, 1985), it is assumed that user adoptions of the product are affected by the entire user network size. Sometimes, however, a user's benefit from buying a product depends on the adoption decisions from a subset of agents in the user network, with whom he/she/it needs that product to interact. For example, suppose a firm decides whether to adopt the RFID (Radio Frequency Identification) system which carries readers and tags only working for the same type of system. For the system to function, the firm has to coordinate its installation decision with its business partners, but obviously it does not need to coordinate its adoption with every other firm. If we connect each company with the partners it needs to exchange data with RFID, we have obtained a network. In this language, Katz-Shapiro models studied the case where the network is *complete* (everyone connected to everyone else), whereas we concentrate on situations where each firm or customer only coordinates with a subset of the user population.

1.2. Example 2. Pollution reduction (shirking)

In many cases, pollution in one region yields a negative impact on the environment of all adjacent regions. Examples include water contamination, air pollution, among others. As such, the *costly* effort of reducing pollution made by the administration of one region can also benefit neighboring regions, giving rise to a shirking problem: Every region aspires to clean environment, but at the same time wants to free ride on neighbor's pollution reduction. The collective outcome of pollution reduction and its environmental consequence will then depend on the connection structure – "whose neighbor is whom".

In our experiment, subjects have incomplete information of the network structure. To be specific, subjects know about the number of their network neighbors, but have only distributional knowledge about the network structure outside their neighborhood. The setting of incomplete network information captures agents' cognitive limitation in large social networks, and gives rise to monotonic network effects in theory for both herding and shirking games (Galeotti et al., 2010; Sundararajan, 2007). In our experiment we observe some of the network effects inspired by the theory, and suggest a set of simple topological measures (e.g. degree, density) that provide sufficient predictions for strategic behavior in networks.

A major contribution of this paper lies in the behavioral model established to answer the research question. The model extends the SEWA learning paradigm (Chong et al., 2006; Ho et al., 2007) into a network context, and explains the emergence of network effects, deviation from equilibrium, and behavioral dynamics as a consequence of individual level learning. We show that it is the same type of learning that governs both herding and shirking in networks, despite the opposite appearances of the two games. The effectiveness of the proposed behavioral model is demonstrated through comparisons with alternative models of adaptive learning and learning towards equilibrium.

In Section 2, we review the relevant literature. Section 3 introduces the experimental design and empirical hypotheses. In Section 4 we outline the basic findings from our data. Then in Section 5, the learning model is developed to characterize the individual-level behavior. Section 6 concludes with further discussions.

2. Literature background

Decentralized interactions in networks have been gaining attention in economics and operations research in recent years. Theoretical models can be classified by the nature of games being studied and the settings of information. Assuming agents have full information about the network layout, Ballester et al. (2006), Bramoullé and Kranton (2007) and Bramoullé et al. (2014) investigate games with linear best replies. The games they explore exhibit strategic complementarity or strategic substitutability, which correspond to the notion of herding or shirking referred in our paper. Another stream of theoretical literature embraces incomplete information of the network structure, including Sundararajan (2007) on strategic complementary games, and Galeotti et al. (2010) on both games of strategic complements and strategic substitutes. Galeotti and Goyal (2010), Cho (2010), Hojman and Szeidl (2008) examine games of submodular nature, but with networks endogenously