Topics on social and economic networks

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2016

document version
Publisher's PDF, also known as Version of record

Chapter 1

Introduction

Nowadays the Internet has become an indispensable tool in human life. People use it to find and share information, communicate with families and friends, listen to music, watch movies, do shopping, search for business opportunities, etc. The driving force of the penetration of the Internet contains not only the development of technology, but also the power of social connections.

Everybody is connected with others in some sense. Friendship may be the most typical and most cherished social connection. The success of online social network services like Facebook relies mostly on the driving force of friendship. Sometimes people are also influenced by the behavior of whom they do not know so well. Online shopping sites use this tendency to build their reviewing and recommending system to provide a chance of exchanging ideas. Those question and answer sites, we name stackoverflow.com among others, give a more direct way of information aggregation in order to assist people to solve problems. All these are examples of benefits of social connections. On the other hand, our society can also be harmed by the impact of social interactions. The role of social media in the Arab Spring[1] (revolutions that occurred in the Middle East and North African countries in 2011) has been pointed out by many social scientists, see e.g. Eltantawy and Wiest (2011), Khondker (2011), and Lotan et al. (2011). Spreading of untrue rumors through social media after the Great East Japan Earthquake of March 2011 is another example of the downside of social networks (see Kaigo (2012) and Zhao et al. (2012)).

The study of social networks (including economic networks) grew rapidly in the past half century. Started from the pioneering work of Milgram (1967) on the small-world phenomenon, researchers have investigated various aspects of social networks. The research

[1] In some views, especially in the western communities, the Arab Spring is seen as liberation of oppressed people and therefore it is celebrative. Here I am not going to argue that point. It is true that after a revolution, a country as a society may be broken. In this sense the former society is suffered, regardless of whether a new one will be formed and whether the members can eventually become better.

can be roughly categorized in the following three directions: network characteristics, network formation methods, and applications.[2] The applications of social networks in economics contain cascading of information and behavior, collective actions, information aggregation, epidemics, strategic decision making, pricing theory, among others.

In this dissertation, we are interested in understanding the effect of social and economic networks in the interaction of decision makers. It is a collection of four studies of application of social and economic networks, all with different focuses and thus using different approaches. The common assumption about social networks is that we take them as given. Therefore the main theme in each study is not the network itself, but an effect that caused by the network or a decision problem based on a network structure.

1.1 Summaries of chapters

In the subsequent chapters we focus on interactions of agents in social and economic networks. Each chapter considers a decision making problem, where an underlying network is given to describe the interdependency of agents. Each chapter is self-contained and independent from the others.

1.1.1 Chapter 2 – dynamics and collective action

In Chapter 2, we consider a dynamic binary decision problem with myopic agents. Each agent is supposed to make a choice between two actions which can be interpreted as choosing for the innovation or staying with the status quo. Time is discrete, and agents must make their decision at each time period. The decision is based on payoff maximization, where payoff functions are dependent on the choices of other agents in the network, as well as the choices of the neighbors of the decision maker. Agents are myopic in the sense that they only use historical information to predict the choices of others in the next period, but ignore the potential impact of their choices on the periods thereafter.

We focus on the dynamics of the fraction of people picking the alternative action. The object of the study contains two variables, one is the adoption rate, i.e. the fraction of agents who choose the alternative action, and the other is the inclinations reflecting preferences of agents towards this choice. The inclination is another determining variable of agents in their decision, and is also influenced by the choices and inclinations of others. We establish a multivariate dynamic process in order to make inclination as an endogenous variable. In doing so, we employ the network game model of Jackson and Yariv (2005, 2007) as the basic

[2] Since the literature is huge, we leave literature review to each chapter.

model of the adoption rate, and combine it with the social learning model in Young (2009) to incorporate the inclination dynamics.

The network underlying the decision makers is supposed to be large. Hence it is difficult to work with full information of connection structure. Instead, in this chapter we represent a social network by a degree distribution and analyze the dynamics with the so-called mean-field approach. As a result, agents do not know exactly who their neighbors are. They instead use a representative "average" agent in predicting the behavior of their neighbors.

Our model is essentially a multivariable nonlinear dynamical system. We study the existence of different types of equilibria and the long run behavior of convergence to attractors with positive adoption rate. Numerical simulations show the existence of non-monotonic convergence behavior of adoption rate, which is not a property of the model without considering endogenous inclinations.

This chapter is based on the discussion paper Huang, Koster, and Lindner (2013).

1.1.2 Chapter 3 – coordination in non-cooperative games

Game theory is an extensively used tool in studying interactions in social networks. In this chapter we study the coordination problem in non-cooperative games with a multi-period structure. Similar to Chapter 2, agents are supposed to make a choice from two actions. Choosing the status quo is always safe, i.e., it makes zero profit for agents. The alternative action is risky in the sense that if the number of adopters in the end of the game is less than the agent's threshold, which is the minimum number of adopters that can make the agent happy, a negative payoff will be receiced. The difference with Chapter 2 is that agents are assumed to be fully rational. They are aware of the consequences of their actions and take them into account in deciding which action to choose.

The network here expresses the observability of actions and thresholds of neighbors. In other words, information is restricted by the social network. Therefore, even in a situation where all agents choosing the alternative action can lead to a Pareto optimal outcome, agents may not be able to do so. This is a classic coordination problem. The game with single-period and its repeated version has been studied in Chwe (1999, 2000). We extend the model to a multi-period game, where all agents start with the status quo and can make a irreversible choice in each period until switching to the alternative or the end of the game. This extension makes it possible for agents to pass an indirect message to their unconnected neighbors about the thresholds of others' by acting in an earlier period. However, it does not always make coordination easier since an earlier action can be untruthful.

It is a common intuition that raising thresholds and reducing connections in the network make it harder to coordinate. This is true for the single-period games studied in the literature. However, in multi-period games, we show that it might be that raising some thresholds and reducing connections in the network make it easier to have a broader coordination. Our study represents the impact of actions as signaling devise in dynamic strategic decision making problems.

This chapter follows from the joint research with Maurice Koster, Ines Lindner and Roald Ramer.

1.1.3 Chapter 4 – a bounded rational learning model

The research on how information from others is used in individual decision making is called social learning theory. The previous chapters contain social learning as a hidden mechanism. In Chapter 4, we focus on social learning itself. No decision making problem is involved in this chapter. We consider a situation where people want to know the truth about some fact but they can only get a noisy signal. Learning from neighbors in the network is the main focus in this chapter.

A traditional approach of social learning is rational learning, where agents use Bayes' rule to update their beliefs about the true state of nature. This approach becomes extremely difficult to work in social networks research due to the complicated structure of the problem. We employ the famous naïve learning model of DeGroot (1974) in order to allow a more realistic assumption about the underlying social network. In this model, agents update their beliefs by simply taking weighted averages of beliefs of their neighbors. DeGroot (1974) discovers that with this simple model the society is possible to reach a consensus when the underlying network satisfies some sufficient conditions. Recently the research is extended by Golub and Jackson (2010) by allowing networks growing in size, showing that it is even possible that the consensus reaches the true state of nature. They call this property the wisdom of crowds.

We further allow the underlying network to be variable. Precisely, we consider that the communication structure is randomly selected from a finite set of alternatives, independently for each period. This relaxation reflects the fact that people do not talk to exactly the same group of people everyday. With our new assumption, we find that consensus can still be reached but the conditions are tighter. Wisdom of crowds, on the other hands, is indeterminable. We can still observe some outcomes showing that the true state of nature is reached in numerical examples, however, we cannot confirm the substantial finding of Golub and Jackson (2010) that a growing society is wise if and only if no agent remains more influential than others. Based on our finding we discuss the difficulty of model selection and relate it to real world problems.

This chapter is based on the joint research with Bernd Heidergott and Ines Lindner.

1.1.4 Chapter 5 – sharing cost among connected agents

In this last chapter, we study a cost sharing problem of polluted rivers. The decision makers are governments of territories that owe a segment of a river. The network here is derived from the river structure, indicating the interdependence of territories sharing the river.

The problem under consideration is how to distribute the total cost of cleaning a polluted river to its territories, who agree on sharing the cost. This is an application of cooperative game theory. Several sharing methods have been proposed in Ni and Wang (2007) and Dong, Ni, and Wang (2012) for line rivers and rivers with a tree structure. We provide new axiomatizations of the Upstream Equal Sharing (UES) method and the Downstream Equal Sharing (DES) method by linking them to the conjunctive permission value studied by Gilles and Owen (1994) and van den Brink and Gilles (1996) in games with permission structures, and further propose a new sharing method with an axiomatization motivated by the disjunctive permission value of Gilles and Owen (1994) and van den Brink (1997).

Each solution method corresponds to the Shapley value of a corresponding game derived from the cost sharing problem. The Shapley value is one of the most famous single point solutions of cooperative games. It is characterized by a set of desirable properties, but is usually expressed by a mathematical formula in order to evaluate the values in practice. The cost sharing methods studied in this chapter are all defined by mathematical formulas, therefore are easy for evaluation but difficult for decision makers to judge. The purpose of axiomatization is to find the properties that characterize a solution method. Axiomatizations of solutions can help decision makers to determine the method that fits their needs most. In our axiomatizations we use two fairness axioms, which describe what happens to the amount of shares when some territories decide to leave the coalition. Together with a set of other axioms, each of these two fairness properties characterizes a cost allocation method.

This chapter follows the discussion paper van den Brink, He, and Huang (2015).