Non-cooperative Bargaining Dynamics in Trading Networks

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We outline a recently developed method for analyzing non-cooperative bargaining games in networks, and discuss some applications.

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1. INTRODUCTION

In the study of economic models of trade, it has long been recognized that institutional or physical barriers limit direct trade between some pairs of agents. Network models have been used to study such scenarios since the early 1940s, but only recently did they become objects of active research. This is partly because more and more important network-related phenomena in our economic systems are being observed. Examples of these phenomena include the relationship between network centrality and bargaining/influencing power in social networks; the bull-whip effect in supply chains; and more recently the widespread disruption of financial asset markets. The study of economic networks is becoming increasingly important because it is clear that many classical models that abstract away from patterns of interaction leave certain phenomena unexplained.

Non-cooperative bargaining is a game theoretical framework that has been studied extensively by economists, see for example [Osborne and Rubinstein 1990]. Recently, there has been a substantial line of work in both economics and computer science that investigates these models in network settings. Networked bargaining games are interesting not only because in practice many transactions are negotiated (as opposed to being determined by market forces), but also because, conceptually, bargaining is the opposite of the idealized "perfect competition" that is often used in classical models of markets; moreover, when market transactions are constrained by a network, the perfect competition assumption is hard to justify. However, one of the biggest challenges along this line of research is the complexity of networked bargaining games. It has been noted by in [Jackson 2008] that in network games, analyzing "a non-cooperative game that completely models the bargaining process through which ultimate payoffs are determined [...] is usually intractable."

Having a basic, tractable game theoretical framework and powerful mathematical tools to overcome this complexity is important because this will allow researchers to investigate qualitatively how network influences the economic outcome, and to

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further extend the model to incorporate other aspects of economic network systems.

In [Nguyen 2012a] we develop a new method, based on convex programming, to fully characterize equilibrium outcomes of a general class of non-cooperative bargaining games. We use this result to study the connection between an agent's bargaining power and the centrality of his position in the network. We show that in a trading network, a notion of bargaining power defined by the outcome of this game coincides with the congestion level in an associated traffic network.

This model is extended in [Nguyen 2012b], for studying the question of instability in networked markets: how the underlying network can propagate and amplify shocks to make the economic system fragile. To answer this question we incorporate a non-cooperative bargaining process into a competitive economy by analyzing the limit of the replicated bargaining game as the size of the population goes to infinity. We show that because of the incentive structure in the bargaining process and the underlying network, even in a perfectly competitive environment, all equilibria are inefficient and non-stationary. This result shows that the micro trading dynamics constrained by a network structure can be seen as an important source of friction that leads to an inefficient market outcome.

2. COALITIONAL BARGAINING GAME

In the basic model of [Nguyen 2012a] is as follows. Given a set of agents and a set of feasible coalitions (a family of subsets of agents), bargaining is modeled as an infinite horizon discrete time game. In each period a feasible coalition is picked according to a stationary distribution, then an agent in the coalition is chosen at random to be the proposer.

The proposer can decline to propose or sequentially suggest a division of the coalition surplus to its members. If the proposer declines to propose or at least one member of the coalition objects to the suggested share, the game continues to the next stage where another coalition is selected. Otherwise, agents in the coalition exit the game with their proposed division, and are replaced by clones. The game repeats, and each agent discount their payoff by a constant factor.

We show that in this model a stationary equilibrium exists, and the payoff of any stationary equilibrium is the *unique* solution of a strictly convex program. A constraint of this program corresponds to a feasible coalition, and if it is slack in the optimal solution, then the corresponding coalition never forms at equilibrium. In contrast with the core of the same TU game, which is characterized by a *linear* program, our solution always exists and is unique. Hence, it provides a robust prediction on the prices and pattern of trade that will emerge in the bargaining process.

In [Nguyen 2012a], we consider an application to trading networks with intermediaries, where agents trade through a network via one or multiple intermediaries. Given such a network, we define the set of feasible coalitions as the set of agents that form a "path" connecting a seller and a buyer. Using the convex program characterization of the bargaining game, we can connect the outcome of the bargaining game with a notion of network centrality. Specifically, we show that this measure of network centrality coincides with the well known concept of "congestion level" in an associated traffic network.

3. LOCAL BARGAINING MODEL

In [Nguyen 2012b], we consider a non-cooperative bargaining process along a trading path consisting of multiple middlemen, and then incorporate it into a large, competitive networked market as follows. First consider a bargaining game with a finite number of agents, then define its replications and examine agents' behavior in the limit as the size of the population goes to infinity. This is a novel approach that deviates from the standard way of modeling large markets that assumes a continuum of agents, whose payoff is determined by an axiomatic bargaining solution.

The most important aspect of considering replications is the following. It is conventional wisdom that when the population grows, a single agent will have a vanishingly small influence on the economy and behaves myopically. Therefore, by the law of large numbers the market converges to a stationary competitive outcome.[1] However, if agents' behavior does not converge to a stationary outcome, then the model will reveal a friction causing endogenous fluctuations.

We find that even when the economy is large so that an agent has vanishing influence on the economy, agents' strategies need not lead to an efficient and stationary equilibrium. In this economy, the non-cooperative bargaining process constrained by an underlying network leads to a chain of sunk cost problems and gives rise to endogenous fluctuations. This result also shows that a small shock to the economy can be amplified through the network non-linearly and causes a "stable" market to become one that does not have a stable outcome.

4. CONCLUSION

The framework and techniques developed in [Nguyen 2012b; 2012a] have allowed us to overcome the usual complexity of dynamic network games. This is a first step of an exciting, and rich research theme that we hope to develop. Specifically, one can potentially use our approach to ask questions like: how changing the network topology influences agents' bargaining payoffs, and would they have incentive to change the network? If agents change the network structure for their benefit, does it lead to an efficient outcome? One can also extend the models in [Nguyen 2012b; 2012a] to include other features of markets such as: search frictions, the speed of negotiating; the risks of defaults and asymmetric information. This would allow us to investigate questions such as what is the impact of high-frequency trading on the micro structure of markets? How do the underlying networks of liabilities among financial intermediaries relate to potential financial contagion? Currently, with my co-authors at Northwestern, we are studying these questions and have obtained some initial results [Berry et al. 2012], but there is much more work to be done along this line.

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[1]There is an extensive literature along this line including core convergence results, approximation of large games by a non-atomic model or mean-field equilibrium approach.

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