Ph.D. Dissertation Defense

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Degree:	Doctor of Philosophy
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Date:	Monday, August 12, 2024
Time:	9:00 am – 11:00 am
Location:	https://stevens.zoom.us/j/93104095348
Title:	Design of Reinforcement Learning Control in Agent-based Modeling: An Investigation of System Risks in Interbank Lending Market
Chairperson:	Dr. Steve Yang, Financial Engineering, School of Business
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Abstract

The Great Financial Crisis has prompted researchers to study contagion risks under different lens as the magnitude of shocks propagation cannot be assessed under the existing understanding of contagion risk. During the past decade, traditional macroeconomic models have been developed to explain the occurrence of the financial crisis. However, most of the existing studies relied on the view that all agents act under rational expectations and hence ignore the decision-making process of individual banks. We argue the existing methods for financial counterparty risk modeling and consequent contagion modeling suffer three major shortcomings: 1) most of the models tackle the problem with highly stylized structures; 2) the assumption of rational agents and equilibrium points in bank lending and borrowing is broadly applied; 3) organizations' decisions and behaviors are largely missing in the dynamic modeling process. The reality is that financial institutions are more performance-driven, and their performance may be individually optimal, but collectively suboptimal. Furthermore, these organizations are autonomous decision-making agents with various constraints, and they learn and adapt to market changes to achieve their performance objectives. This characteristic is largely not present in a pure network optimization setting or equilibrium-based approach and therefore when these networks are used for stress testing of real banking systems, the results likely deviate significantly from the reality. We propose a learning agent-based framework through three essays.

In the first essay, we use data from the U.S. Federal Deposit Insurance Corporation (FDIC) and build a model to represent the U.S. interbank lending system, aiming to investigate how different institutions interact, how risk preferences influence lending/borrowing decisions, and finally how these endogenous interactions lead to converging policies of different agents. This framework reconstructs interbank exposures of autonomous banks by having each bank learn how to achieve their borrowing and lending decisions with different risk preferences. In contrast to the exiting fixed-point approach to interbank clearing framework, the proposed model captures the dynamic nature of interbank lending networks, including overnight (federal funds), short-term and long-term debt markets. The primary contribution of this study is to develop a heterogeneous multi-agent computational model to reconstruct the banking system based on banks' behavioral patterns and to understand how banks' risk preference can influence the interbank market structures. Results show that the network degree begins to decline as bank agents continue to tighten their lending policies. The risk averse attitude makes the banks become less prone to contagion due to the interbank network structural changes because of banks' adaptive decisions.

In the second essay, we show when banks learn that others are tightening their balance sheets, they adapt their policies accordingly which result in overall liquidity hoarding under a distress market condition. Many have argued the existence of liquidity hoarding behaviors, but we use a computational learning model to show that hoarding is a result of banks' learning and adaptation behaviors. We further examine the model from network perspective and compare with the observed bank failures in the 2007-09 financial crisis and confirm that the adaptive banks tend to hoard liquidity to maximize their total utility given the information they observe in the interbank market. We conclude that fire sales would drive banks to increase the interbank lending to balance their market risk under a distressed market. In other words, adaptive banks hoard less liquidity when fire sales are considered. We show when faced with a trade-off between market risk caused by fire sales and counterparty risk, banks choose to lend more in the interbank market. We show that liquidity hoarding, and fire sales jointly change the topology of interbank markets, and in the end, they tend to reduce the clustering, shortest path, and average degree of interbank networks, which would reduce the probability of contagion through interbank markets.

In the last essay, we study the impact of Basel III regulatory reform and information transparency on market stability by investigating the driving factors that lead to a more resilient interbank market that is less at risk to contagion. In an adaptive learning setting, we let bank agents to have different levels of information transparency in the interbank market. In another word, when banks adopt a reinforcement learning method to derive their lending and borrowing policies, they are given different levels of access to the information that they use to derive their counterparty choices in making borrowing and lending decisions. In a control experimentation setting, we project that some banks will gain the benefits from additional information due to Basel III regulation. The results confirm that certain banks are less prone to defaulting and their contagion index improves due to the superior information. We also identify the driving factors that contribute to a more resilient interbank market that is less at risk to contagion and showcase how Basel III regulation has increased the financial stability.

Overall, this dissertation proposes a learning agent framework which has several advantages over the other existing models, such as it is not equilibrium based, agents are adaptive in nature, and it can be calibrated with real bank and market data. More importantly, the agents' behaviors are calibrated based on the real bank and market data, and thus a macro-prudential based stress test can be easily performed with many perceivable scenarios. Such modeling paradigm can also be used to evaluate the effectiveness of new regulations.