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**Education:**

Ph.D., Economics, University of Pennsylvania, 2016 – 2021
Fields: Macro, Finance, Machine Learning, Networks, and Chinese Economy
Thesis Title: "Networks in Macroeconomics, Finance, and Machine Learning"
Master, Statistics, Department of Statistics, Wharton, Expected in 2021
M.A in Economics, CCER, Peking University, 2016
B.S in Materials Physics, University of Science and Technology, Beijing, 2009

THESIS COMMITTEE AND REFERENCES:

Professor Rakesh Vohra (Co-advisor)
University Professor, Department of
Economics and Electrical and Systems
Engineer, University of Pennsylvania
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Professor Linda Zhao (Co-advisor)
Department of Statistics, Wharton,
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Professor Frank Schorfheide
Department of Economics, University
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Professor Yiqing Xing
Business Economics, Carey Business
School, John Hopkins University
410-234-9269, xingyq@jhu.edu

**Research Fields:**

Primary Fields: Macroeconomics, Finance, Machine Learning
Secondary Fields: Networks Economics, the Chinese Economy.

**Relevant Position:**

Jun2018- Sep2018 IMF (International Monetary Fund), Machine Learning, Behavior Bias and Credit Market Crashes.
Jan2014 - Jun2014 R.A. Counsellor Office of the State Council, Central Government, China.

**Conference and Seminar Talk (* talk by coauthor):**

Joint Statistical Meetings (Aug2021,American Statistical Association), American Finance Association Annual Conference (Jan2021 AFA), NBER Chinese Economy Meeting (Dec2020)*, Winter Meeting for Econometric Society (Dec 2020), NSF 6th Annual Conference for Networks Economics(x4,UChicago,Booth), Financial Management Association Annual (Nov2020,NYC), MFA(x2, Mar2020), American Economic Association Annual (Jan 2020,Sandiego), Summer Meeting Econometric Society (NA, July2019), IMF (Apr2019)*, Jane Street PhD Symposium (Jan2019), Asian Meeting of Econometric Society (Jun2019, Xiamen), Bank of Finland (Jul 2019)*, Penn-Wharton-GSM (June2019), Penn Econ (Macro Lunch, 2019), Penn Econ (Micro Theory Lunch,2019), Penn Econ (Micro Lunch,2019), PKU (June 2018), Penn Econ (Econometric Lunch,

April 2018), IMF (April 2018)*, Wharton (Oct 2017, MBA Talk), American Economic Association Annual (Jan 2016)*, Alibaba (2016), NBER-CCER Conference (June 2015)*, Stockholm-China Meeting (Sep 2014).

**Teaching Assistance:**

Spring 2017 Teaching Assistant for Economics 102, Professor Rakesh Vohra
Fall 2017 Teaching Assistant for Economics 201, Professor Jose-Victor Rios-Rull
Spring 2021 Teaching Assistant for Modern Data Mining, Professor Linda Zhao

**Relevant Honors and Awards:**

Finalist of best Ph.D. paper (MFA,2020), Semi-Finalist of best paper in investment (Financial Management Association Annual, 2020), Wharton Mack Institute Research Fellowship (2020, Networks, Machine Learning, and Asset Pricing, with Junhui Cai, Linda Zhao), Wharton Global Initiatives Research Fund (2018,2019, under Linda Zhao), Meritorious Winner (First Prize), Mathematical Contest Modeling United States (2008), First Prize, Chinese National College Mathematical Competition of Modelling (2007), First Prize, the 17th and 18th College Mathematical Olympic of China.

**Programming and Skills:**

Python (High Proficiency), R (Proficiency), Stata (High Proficiency), and SQL.

**Research Statement:**

My research spans several fields: Macroeconomics, Finance, Machine Learning, Network Theory, and the Chinese Economy. However, it shares a common theme - the use of big data (firm-level) to emphasize the role of networks in investor behavior, business cycles, asset pricing, and systemic risk. Under this common theme, my work can be divided into three groups: *Innovation Networks, Machine Learning, and Equity-holding Networks.*

**Papers under Review:**

Note: These two papers are part of the project on equity-holding networks.

1. **The Network Effects of Agency Conflicts,** with Rakesh Vohra (Penn Econ and ESE) and Yiqing Xing (JHU), Under Review.
   *(Winter Meeting of Econometric Society (2020Dec), NSF 6th Annual Conference in Network Economics (U Chicago Booth))*
   It is customary to focus on the network of interdependencies between firms to understand how and whether a shock to one firm will propagate to others. This paper argues that agency conflicts at the firm-level and not just the network structure, play a crucial role in amplifying or muting the propagation of exogenous shocks. If firms can take investment decisions in response to an exogenous shock, whether their choices amplify or mute the propagation of the shock will depend on the nature of the agency conflict. When agents in our model are subject to default costs or limited liability, they make investment choices that serve to mitigate the spread of an initial shock. In the face of interest conflicts or moral hazard, however, shocks are amplified by firm-level investment.
   The presence of these agency conflicts counters the role of network structure in the propagation of shocks. For example, prior work argues that denser or more integrated networks facilitate the propagation of shocks. We show that in the presence of interest conflicts, this effect can be reversed. Under some conditions, the aggregate effect of an idiosyncratic shock via propagation does not diminish. This suggests a potentially important role that corporate governance plays in macro fluctuations.
2. **Tiered Intermediation in Business Groups and Targeted SME Support,** with Yu Shi (IMF) and Robert M Townsend (MIT), Under Review.
   ***(Finalist of the Best Ph.D. paper (MFA,2020),** AEA2020, IMF 2020, NSF 6th Annual Conference in Network Economics (UChicago,Booth,2020), Asian Econometric Meeting 2019, North American Econometric Meeting 2019, Penn, Wharton, IMF, PKU, CUFE, VOX China)*
   Using business registry data from China, we show that internal capital markets in business groups can play the role of financial intermediary and propagate corporate shareholders'

credit supply shocks to their subsidiaries. An average of 16.7% local bank credit growth where corporate shareholders are located would increase subsidiaries investment by 1% of their tangible fixed asset value, which accounts for 71% (7%) of the median (average) investment rate among these firms. We argue that equity exchanges is one channel through which corporate shareholders transmit bank credit supply shocks to the subsidiaries and provide evidence to support the channel.

**Papers on Innovation Networks:**

Overview: In this project, I constructed most comprehensive patent datasets of U.S. traced back to 1911, combined with various other datasets on analyst's coverage, news reports, institutional investors, business linkages, and equity-holding etc. I matched these datasets with CRSP/CompStat. Using the final datasets (roughly 50GB), I conducted several researches on business cycles and asset pricing.

***3.*** **Networks and Business Cycles.**

(**Job Market Paper**, with Yucheng Yang (Princeton Applied Math))

*(Talk: UPenn, Princeton)*

The speed at which the US economy has recovered from recessions ranges from months to years. We propose a model incorporating innovation network, production network, and cross-sectional shock and show that their interactions jointly explain the large variations in the recovery speed across recessions in the US.

Besides the production linkages, firms learn insights on production from each other through the innovation network. Using the eigenvalue decomposition, we show that the shock's sectoral distribution plays a crucial role in its amplification and persistence when the innovation network takes a low-rank structure.

We estimate a state-space model of the cross-sectional technology shock and document a set of new stylized facts on the structure of the innovation network and sectoral distribution of the shock for the US. We show that the specific low-rank network structure and the time-varying sectoral distribution of the shock can well explain the large variation in the recovery speed across recessions in the US. Finally, to emphasize the prevalence of the channel, we explore the application of the theory in asset pricing.

***4.*** **Innovation Networks, Linking Complexity, and Cross Predictability**

***(Nominee for the Best Paper in Investment*** *(Financial Management Association Annual,2020))*

This paper provides evidence that network complexity limits investors' ability to process non-local information, through the lens of return cross predictability. Using firm-to-firm citation networks, we find that the non-local indirectly linked firms can well predict the return of the focal firm, while the predictability of the local directly linked firms is weak. A long-short strategy using the indirect links yields a risk-adjusted monthly alpha of 198 (164) basis points with equal (value) weights. We further find that (i) the indirect citation links are much more complex than direct ones, (ii) the magnitude of cross predictability increases with the degree of link complexity, (iii) institutional investors don't adjust their positions in a stock with complex links, but in one with simple links immediately, (iv) firms with more complex links receive more public attention, are much larger in size, and exhibit less idiosyncratic volatility than those with simple links.

***5.*** **Networks, Long-Run Risk, and Asset Pricing**

*(Draft available, this is part of my job market work)*

This paper proposes a networked economy incorporating innovation network, production network, and cross-sectional technology shock with E-Z preference. We, theoretically and empirically, argue that the low-rank structure of the innovation network and the sectoral distribution of the technology shock provide a channel to yield a small but persistent component in the expected consumption growth – the long run risk in the consumption growth. This endogenized persistent component yields a very large time-varying variation in the stochastic discount factor and can well explain several puzzles of the financial market – equity premium puzzle, the risk-free rate, and the market return volatility. Besides the explanation of the theory on the puzzles at the aggregate level, we further explore the cross-sectional asset pricing implications of the networked economy.

**Papers on Equity-holding Networks:**

Overview: This project constructed several proprietary big datasets covering all firms registered in China (roughly 200GB and 90 million firms). These datasets recorded detail information on corporate shareholders and historical updates. Leveraging these, I wrote several papers, including two papers

under review, several well-polished papers, and papers in pipeline, to understand the implications of equity-holding networks on firm investment, systemic risk, and monetary policy.

6. **Ownership Networks and Firm Growth – What do 5 Million Firms Tell us about Chinese Economy?** with Allen Franklin (Imperial College), Junhui Cai (Wharton Stats, UPenn), Xian Gu (Durham), Jun "QJ" Qian (Fudan FISF), Linda Zhao (Wharton Stats, UPenn).
   *(AFA 2021, NBER China Workshop 2020, 6th Annual Network Conference 2020, MFA 2020, FMA 2020, 2nd Annual USYD Financing and Banking Research (Sydney,2019), Bank of Finland 2019)*
   The finance–growth nexus has been a central question in understanding the unprecedented success of the Chinese economy. With unique data on all the registered firms in China, we build extensive - ownership networks, reflecting firm-to-firm equity investment relationships, and show that these networks have been expanding rapidly since the 2000s, with more than five million firms in at least one network by 2017. Entering a network and increasing network centrality, both globally and locally, are associated with higher future firm growth rates. Such positive network effects tend to be more pronounced for high productivity firms and privately-owned firms. The positive effects of equity investments of the networks, however, were crowded out by the RMB 4 trillion stimulus, launched by the Chinese government in November 2008 in response to the global financial crisis. Taken together, our analysis suggests that equity ownership networks and bank credit tend to act as substitutes for state-owned enterprises, but as complements for privately owned firms in promoting growth.
7. **Centralization or Decentralization: Evolution of State Ownership in China**, with Allen Franklin (Imperial College), Junhui Cai (Wharton Stats), Xian Gu (Durham), Jun "QJ" Qian (Fudan FISF), and Linda Zhao (Wharton Stats, UPenn)
   This paper revisits the state sector and its role in Chinese economy. We propose a revised measure of Chinese SOEs (and partial SOEs) based on the firm-to-firm equity investment relationships. We are the first to provide identifiers of all SOEs among over 40 million of all Chinese firms. Our revised measure captures a significant larger number of SOEs than the existing measure. It shows parallel trends of decentralization (authoritarian hierarchy) and indirect control (ownership hierarchy) over time. Using the revised measure, we find mixed ownership is associated with higher firm growth and performance; while hierarchical distance to governments is associated with better firm performance but lower growth. Conclusions drawn from a stark distinction between SOEs and POEs could lead to misperceptions of the role of state ownership in Chinese economy.
8. **Microscopic Dynamics of Equity Ownership Networks in China,** with Allen Franklin (Imperial College), Junhui Cai (Wharton Stats, UPenn), Xian Gu (Durham), Jun "QJ" Qian (Fudan FISF), and Linda Zhao (Wharton Stats, UPenn)
   *(Preliminary draft available)*
   Using Chinese Business Registration Data covering all investee-investor relationship from 1978 to 2020, we document basic facts on the evolution of the ownership structure and the driving forces, shedding light on the role of institutional background and financial development on ownership structure.

**Papers on Machine Learning, Investment, and Networks:**

Overview: Understanding how investors collect and process information has been a central topic in economics and finance. In this project, we leverage the machine learning to identify latent network structure and boost prediction, especially incorporate behavior constraints on investment behaviors.

9. **Semi-supervised Learning in Networks,** with Junhui Cai (Wharton Stats, UPenn)), Haipeng Shen (HKU), Dan Yang (HKU), Linda Zhao (Wharton Stats, UPenn)
   *(JSM 2021, American Statistical Association)*
   Directed networks are ubiquitous in our lives and play a crucial role in information trans- mission. The network position, usually captured by centrality, affects individual's deci- sion making and thus provides information for inference and prediction. In many cases, network data is costly to collect and has insurmountable measure errors, which will compromise the centrality estimation and consequently the prediction. We propose a supervised network centrality estimation and prediction (SuperCENT) model that in- corporates centrality in the outcome regression model. The proposed method provides a superior estimate of centrality but also superior estimation and prediction in the outcome regression. Furthermore, the asymptotic properties for both centrality and parameters of interest are derived, followed by their confidence intervals. The model is also endowed with prominent economic implications as in numerous empirical network literature. We illustrate our method via a real data example of inferring the performance of Chinese firms with a complete equity holding network.

***10.*** **Deep Learning in Dynamic Networks and Foresting,** with Junhui Cai (Wharton Stats, UPenn), and Linda Zhao (Wharton Stats, UPenn)

*(In Progress)*

In reality, firms are usually linked through various relationship – customer-suppliers, geographical overlapping, technology flow, equity-holding, business overlapping etc. There are two things worth mentioning. First, the links usually dynamically change. Second, the links are usually partially observable either due to the high collection cost or sizable measurement errors. In this paper, we model the latent networks as state variable which evolves over time, each period the state variables will be updated based on its value of the last periods, the latest partially observable counterparts, and the stock returns. We incorporate this process into a Reinforcement Learning with super high dimension of state variables, and significant boost the cross-predictability.

***11.*** **Identifying Underlying Links and Cross Predictability,** with Junhui Cai (Wharton Stats, UPenn), Linda Zhao (Wharton Stats, UPenn)

*(In Progress)*

A heuristic examination from our previous research indicates that firms are linked by networks in a very complicated way, which usually complicated the information set to the investors and make them unable to impound useful information from other linked firms. One important question is to systemically examine how the link complexity shapes investors' decisions in information collection and its implication on the predictability of asset returns. For example, through various linkages, each firm can be linked with hundreds or thousands of other firms such that the fundamental relevant information is scattering across these counterparts. If the link is economically strong, institutional investors can quickly incorporate the relevant information and adjust their portfolio position, leading to a weak cross-predictability. However, the cross-predictability can be quite significant when the link is weak since institutional investors cannot well incorporate the relevant information either due to the limited capability or prohibitive cost. This trade-off between the link strength and cross-predictability implies a learning with additional economic constraints will boost the prediction. This paper develops a framework with underlying networks and investor behavior constraints to boost the cross-predictability.

**Quantitative Courses Taken (all PhD Level):**

Deep Learning in Theory, Optimization in Machine Learning, Non-Parametric & Machining Learning, Data Mining, Econometrics I, Bayesian Econometrics II, Econometrics IV, Continuous Time Asset Pricing, Asset Pricing, Empirical Methodology of Asset Pricing, Empirical Corporate Finance, Probability Theory, Stochastic Process I, Stochastic Process II, Measure Theory, Real Analysis, Financial Market and Macro Finance.