Research and Service Statement

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Finance Department, August 2024

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Overview of Research Activities

My research focuses on asset pricing and capital markets. It draws heavily from industrial organization (IO), macroeconomics, and econometrics for concepts, insights, modeling, and empirical tools. I am dedicated to developing novel theoretical models and establishing a tight connection between models and data. My empirical work is also guided by theory. My papers explore two themes:

1. Imperfect competition and the nexus of IO and finance ("imperfect competition in finance").
2. The robustness of macro asset pricing models ("model robustness").

In the first theme of my research, "imperfect competition in finance," a key innovation is integrating insights and tools from the IO literature into asset pricing and capital markets research. Although the incorporation of IO insights into corporate finance began decades ago, applying an IO perspective to asset pricing and capital markets research is new and timely. Market concentration has increased substantially across various product and asset markets over the past decades, despite already being high. Market leadership is often persistent, allowing leading entities to engage in strategic competition to sustain their market power. Consequently, imperfect competition, particularly strategic competitive interactions among leading entities, is central to modern economies. Therefore, understanding the interplay between imperfect competition and the decisions of corporations and financial institutions is crucial for studying asset pricing and capital markets. However, traditional frameworks and methodologies have often overlooked this critical perspective.

To bridge this gap, my research contributes to the literature by uncovering novel economic mechanisms that highlight the significant impact of imperfect competition, especially strategic competitive interactions among leading entities, on asset prices and capital market dynamics. My papers advance the understanding of industry-level financial fragility and dynamics, such as profit margins and security returns, that firm-level theories cannot explain. Industry-level theories are critical for comprehending aggregate fluctuations and capital market movements. For example, industry-level fluctuations often predict and even trigger economy-wide fluctuations. Often, credit crunches and asset bubbles in the economy are initiated or concentrated in a few industries. Understanding industry-level financial fragility is crucial for designing economic policies for macroeconomic stability. My research demonstrates that product market competition mechanisms play a unique role in shaping industry-level financial fragility and dynamics, explaining important long-lasting puzzles in finance that are beyond the scope of firm-level theories and studies. Moreover, my research emphasizes that focusing solely on firm-level financial fragility, without considering the feedback and

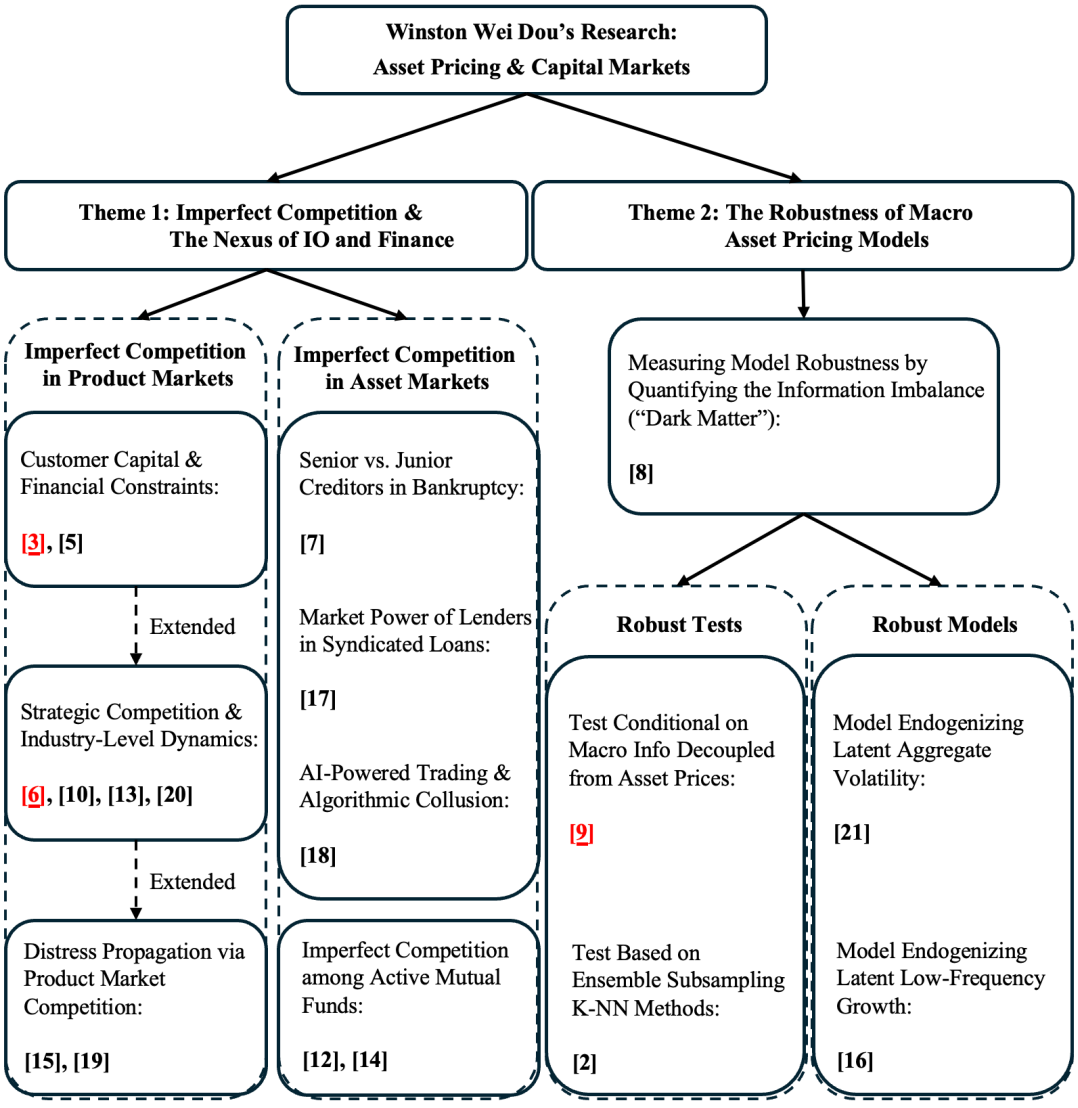
contagion effects of distressed competition among industry competitors, can severely underestimate industry-level financial fragility.

Furthermore, my research on this theme reveals how price formation, trading, risk sharing, asset allocation, and asset valuation are affected considerably by the market power of sophisticated institutional investors in imperfectly competitive asset markets. I present distinct mechanisms and new evidence to highlight the unique role of intermediaries in asset pricing, complementing the existing literature on intermediary asset pricing. My work also provides new insights for optimal interventions in asset markets to enhance efficiency and maintain stability.

While the first theme of my research investigates imperfections in competition faced by agents inside a model, my second research theme, "model robustness," addresses the informational limitations faced by economists outside the model. These limitations lead to model misspecifications. A model is considered fragile if its core implications are vulnerable to such misspecifications; otherwise, it is robust. Therefore, robustness is crucial for models to be practical and useful, particularly for counterfactual analysis and out-of-sample predictions. Despite a vast literature on macro asset pricing models, little is known about their robustness, let alone how economists should deal with models that exhibit excessive fragility. My research tackles this issue, beginning with two papers. First, one of my papers, published in the *Journal of Finance* (2024), formalizes the concept of "dark matter" in macro asset pricing models as the information imbalance between the model and the data regarding key parameters that govern the dynamics of fundamental variables, such as productivity. This paper introduces a measure for dark matter that quantifies this information imbalance and proves that dark matter captures a model's fragility. Models with a larger amount of dark matter are more prone to in-sample overfitting, making them harder to refute with data and resulting in poorer out-of-sample performance. This theoretical result is further reinforced by my second paper on this theme, published in *Econometrica* (2022), under a different econometric setting. Often, to generate desirable predictions, macro asset pricing models postulate subtle dynamics for fundamental variables, which are hard to identify directly from their data. However, these dynamics can be inferred indirectly from asset prices, with excessive statistical confidence, through the model-implied equilibrium relationship between fundamental variables and asset prices. This confidence is excessively derived from the postulated model structure rather than the fundamental data. Such overreliance on the postulated model structure without sufficient discipline from data raises robustness concerns, making the model's implications fragile to misspecification. Therefore, the measure for dark matter effectively gauges model fragility. How should economists deal with macro asset pricing models with excessive dark matter? In the *Econometrica* (2022) paper, I develop robust specification tests to evaluate the validity of such models, as standard optimal tests fail in this case. The new model evaluation methods developed in this paper, designed to be robust against significant dark matter, along with my other related work, contribute valuable additions to the economist's toolbox. In addition, my measure for dark matter identifies which model components are most responsible for model fragility. Guided by this diagnostic information, I conduct research that enhances the robustness of macro asset pricing frameworks by endogenizing the key processes of their fundamental variables, such as latent low-frequency growth rates. This research effort strengthens the data-based identification of these fundamental processes by connecting their dynamic properties to a

broad set of granular cross-sectional data on fundamental variables, thereby reducing the information imbalance between the model and the data in these frameworks.

I have completed **22** papers, consisting of **13** published journal articles and **9** active working papers, most under review at top finance and economics journals. I have presented my research at nearly **80** renowned universities and institutions, including central banks and regulatory authorities in the U.S. and Europe, and over **90** conferences. My papers have received multiple awards at these conferences. At Wharton, my research earned several awards, including the Marshall Blume Prize, Jacobs Levy Prize, Dean's Research Fund Award (twice), and Golub Faculty Scholar Award (twice). My research has been covered in MBA classes and PhD lectures at prestigious institutions such as Chicago, Columbia, MIT, Northwestern, NYU, Rochester, Stanford, Wharton, and Yale, among others. This statement provides a summary of my research. References to my papers are denoted by numbers in square brackets, matching their order on my CV. The diagram below illustrates how my papers are connected and collectively contribute to a theme. I have designated three publications as representative articles, indicated by red-colored and underscored numbers **[3]**, **[6]**, and **[9]**. Each of the three belongs to a series of cohesive and deliberate research endeavors.



Theme 1: Imperfect Competition and the Nexus of IO and Finance

Imperfect, highly strategic competition is at the heart of today's economy. Yet, most research on asset pricing and capital markets has largely neglected its critical role. Traditional economic paradigms have long assumed perfect competition, abstracting away from the complexities of strategic interactions. Consequently, these paradigms do not fully capture the realities of market concentration and the strategic competitive interactions among entities such as firms, funds, and banks. To bridge this gap, I have developed new models that explicitly account for imperfect competition and strategic interactions. These models offer fresh perspectives on central issues in asset pricing, leverage management, liquidity management, financial constraints, financial distress, and bankruptcy. In addition, my papers provide empirical evidence supporting these proposed economic mechanisms. Several fields in economics, such as monetary economics, economic growth, labor economics, and banking, have started integrating imperfect competition into their mainstream frameworks. Incorporating these IO insights into asset pricing and capital markets research is both new and timely, and this is where my work has been innovative.

Imperfect Competition in Product Markets. First, I introduce the branch of my research that explores the intricate relationships between finance and imperfect competition in product markets. As depicted in the diagram, my research portfolio in this branch includes eight papers that collectively contribute to the first research theme, "imperfect competition in finance," consisting of **[3]**, **[5]**, **[6]**, **[10]**, **[13]**, **[15]**, **[19]**, and **[20]**. The defining feature of these papers is their focus on the feedback effects between imperfect product markets and frictional capital markets. I explain these papers in more detail below, with particular focus on **[3]**, **[6]**, and **[13]**.

My first paper in this branch of research is **[3] "Inalienable Customer Capital, Corporate Liquidity, and Stock Returns"** (**representative paper #1**), published in the *Journal of Finance* in 2021. Customer capital reflects brand loyalty, leading to frequent purchases and reduced price sensitivity among consumers. This loyalty indicates imperfect competition in the product market. Customer capital is valuable to firms because loyal customers provide a steady revenue stream and enhance profitability. It is a crucial intangible asset that requires significant resources for retention. It also plays an important role in the macroeconomy, as highlighted by Hall (2014, NBER) and Gourio and Rudanko (2014, ReStud). Co-authored with Yan Ji (HKUST), David Reibstein (Wharton Marketing), and Wei Wu (TAMU), this paper is one of the first to explore the effects of customer capital, as a form of capitalized market power due to imperfect competition, on corporate liquidity and firm valuation.

In this paper, I address a critical question: When firms are hit by liquidity shocks that tighten financial constraints, does customer capital help firms recover liquidity or amplify the negative effects? Answering this question is crucial for deepening the understanding of corporate decisions, firm valuations, and co-movement in stock returns. Traditional theories, such as those of Chevalier and Scharfstein (1996, AER) and Gilchrist, Sim, Schoenle, and Zakrajsek (2017, AER), view customer capital as a resilient liquidity reservoir that firms can access when they are financially constrained. Those theories focus on niche product markets where the customer base is sticky and demand is very inelastic, predicting that financially constrained firms charge higher markups than their industry peers. In

contrast, paper [3] provides a more comprehensive perspective on general product market environments and introduces the novel idea of talent-dependent customer capital. The theory of paper [3] shows that customer capital, when heavily dependent on key talents, becomes vulnerable to financial constraint shocks. This vulnerability implies that, rather than mitigating these shocks, customer capital can often amplify their adverse effects, fundamentally altering the traditional view.

What makes customer capital vulnerable to financial constraint shocks? Customer capital ensures demand flows for firms. It relies on both pure brand recognition and the unique contributions of key talents. In this paper, I introduce the concept of inalienability of customer capital (ICC), which captures how much customer capital depends on talents. Because firms face financing costs, they hold retained earnings and manage liquidity as a precaution. There is an agency conflict between key talents and shareholders, characterized by two-sided limited commitment. Key talents have outside options and limited commitment to the firm. When firms are financially constrained, they tend to "escape the sinking ship" or "jump to a safer boat." If retaining key talents becomes too costly, shareholders may opt to reduce compensation to rebuild liquidity, replacing expensive incumbent talents with less costly new hires. When key talents leave, they take talent-dependent customer capital with them, damaging the firm's customer capital. Therefore, to retain talent-dependent customer capital, firms must maintain sufficient liquidity to compensate and retain key talents. This liquidity-driven talent turnover mechanism is new in the literature. Thus, firms with higher ICC have greater exposure to financial constraint shocks and higher talent turnover rates. Consequently, these firms tend to have higher expected returns, as financial constraint shocks carry a negative market price of risk.

Another main contribution of this paper is that it tests the theoretical implications using unique data. The main empirical challenge is to find consistent, granular, high-quality data on consumers' brand loyalty and talent dependence across firms. To address this, I construct a measure of customer capital's talent dependence using a proprietary brand perception survey database from the BAV Group. This database is the world's most comprehensive database of consumer brand perception. The BAV Group develops two major brand metrics: brand stature, which quantifies a firm's general brand loyalty, and brand strength, which quantifies brand loyalty linked to key talents through product innovativeness and management efficiency. I use the ratio of brand strength to brand stature to capture the talent dependence of customer capital (i.e., the ICC). To justify the connection between the survey-based ICC measure and its counterpart in the model—the talent dependence of customer capital—this paper shows that the empirical ICC measure indeed captures three key properties of its theoretical counterpart in the model. These formal tests provide convincing external validation for the survey-based ICC measure in [3], demonstrating that it accurately captures the degree to which customer capital depends on talents. With this empirical measure, I provide compelling evidence supporting the predictions of the model. Specifically, I empirically show that although customer capital often secures stable demand, it can be vulnerable to financial constraint shocks when it is reliant on talents who leave firms under financial stress, taking talent-dependent customer capital with them. Furthermore, I empirically show that firms whose customer capital is more dependent on their talents have higher average returns, higher talent turnover, and more precautionary financial policies compared to those whose customer capital is less talent dependent.

To conclude on [3], this paper introduces the novel idea of talent-dependent customer capital and provides an accurate measure for this concept using unique data. It shows that customer capital can be either resilient or vulnerable to financial constraint shocks, depending on its level of talent dependence. These findings fundamentally alter the traditional view of customer capital and have important implications for asset pricing and capital markets.

The novel mechanism in my *Journal of Finance* paper [3] is complemented by my paper in *Management Science* (2021), **[5] "External Financing and Customer Capital: A Financial Theory of Markups."** This paper introduces a unified theoretical framework for markup, customer capital, and corporate liquidity. Together, [3] and **[5]** show that firms whose customer capital is more talent dependent are more likely to reduce markups when financial constraints tighten. Why does this happen? Liquidity-driven talent turnover, as emphasized in [3], damages customer capital, causing the marginal value of customer capital to surge disproportionately relative to liquidity. This leads to lower markups because firms choose to retain customer capital by sacrificing liquidity. This paper is with Yan Ji.

As depicted in the diagram, in four subsequent papers, [6], **[10]**, **[13]**, and **[20]**, I extend the framework of [3] and **[5]** to incorporate strategic competition among a few market leaders, where competition intensity endogenously varies over time and across industries. The modern IO literature highlights the market power of leaders sustained by highly strategic competition tactics, such as tacit collusion or implicit coordination, across various industries (see Harrington and Skrzypacz, 2011, AER; Miller and Weinberg, 2017, Econometrica; and Miravete, Seim, and Thurk, 2018, Econometrica, among many others). However, there hasn't been sufficient effort to extend the traditional framework to incorporate these crucial IO insights in asset pricing and capital markets research, with the exception of Opp, Parlour, and Walden (2014, JET). My papers, along with the JET paper, fill this gap. These contributions are among the pioneering works exploring how strategic product market competition tactics, such as tacit collusion and implicit coordination, impact asset prices and capital market dynamics. They demonstrate how competition intensity is driven by capital market fluctuations, such as changes in the discount rate and financial distress, and explore how this endogenously varying competition intensity, in turn, shapes corporate decisions, firm valuations, and co-movement in security returns. Moreover, these papers are at the frontier of model solution methods. They develop novel numerical techniques to solve a collusive Nash equilibrium in stochastic dynamic macro-finance models with embedded repeated games. This extends beyond the standard global solution methods for macro-finance models, which I review in my paper published in the *Annual Review of Financial Economics* (2023), **[11] "Macro-Finance Models with Nonlinear Dynamics,"** with Xiang Fang (HKU), Andrew Lo (MIT), and Harald Uhlig (Chicago).

This subgroup of works began with my paper published in the *Journal of Financial Economics* (2021), titled [6] **"Competition, Profitability, and Discount Rates"** (**representative paper #2**). This paper develops a novel asset pricing framework that incorporates strategic competition. It explains how competition intensity, and thus profit margins, vary endogenously across industries due to inherent heterogeneity in market leadership persistence, and how they fluctuate over time driven by aggregate discount rates. This paper is with Yan Ji and Wei Wu.

Traditional asset pricing paradigms assume perfect competition, abstracting away from the complexities of strategic competitive interactions such as tacit collusion or implicit coordination. This leads to the oversimplified view that profit margins are either constant or independent of stochastic discount factors (SDFs). Moreover, these traditional theories primarily address firm-level securities returns, suggesting that industry-level dynamics, such as profit margins and securities returns, are merely extensions of firm-level patterns and thus can be explained simply by firm-level theories. Paper [6] provides a new perspective on industry-level dynamics. It introduces a novel economic mechanism that incorporates strategic competition, revealing its significant implications for asset prices and capital market dynamics. The theory of this paper shows that in industries with higher market leadership persistence, the capacity of tacit collusion, and thus profit margins, remain higher than in other industries. These profit margins are more sensitive to discount rate shocks, resulting in higher industry-level stock return exposure to these shocks. As profit margins account for a significant fraction of fluctuations in corporate earnings and cash flows, the theory of paper [6] contributes to the asset pricing literature by demonstrating how cash flow news and discount rate news are intertwined. This new insight fundamentally alters the traditional view. In addition, this paper documents a robust new industry-level asset pricing pattern—the industry-level gross profitability premium—which firm-level theories or empirical patterns cannot explain. The theory of [6] provides a compelling rationalization for this premium. Rationalizing industry-level stock return patterns is complex, even for small industries, as connecting industry-level risk exposure to industry characteristics is challenging. Firm-level theories do not directly extend to industries, making this paper's contributions to industry-level asset pricing valuable and significant.

What causes competition intensity to vary with aggregate discount rates in capital markets, especially in industries with high market leadership persistence? In my model, each industry has an oligopolistic market structure, dominated by a few market leaders. These leaders engage in strategic price-setting competition within a repeated game framework, maintaining tacit collusion to achieve the highest possible collusive profit margins. A central aspect of my model is that collusive profit margins decrease as discount rates for risky cash flows rise. High discount rates make the punishment for deviation—reverting to non-collusive competition or a price war—less threatening. As discount rates rise, firms become impatient, undercutting each other for current cash flows as the value of future cooperation decreases. The theory of [6] extends the folk theorem of Fudenberg and Maskin (1986, Econometrica) to a setting with risky cash flows and stochastic discount factors.

This novel economic mechanism generates important heterogeneous implications across industries, explaining the challenging industry-level gross profitability premium puzzle, a robust pattern newly documented in this paper. When leadership turnover occurs, existing leaders are replaced by new ones. The turnover rate of market leadership is a fundamental industry characteristic that varies considerably across different industries. In industries with frequent leadership turnover, the threat of future punishment for deviation is less significant than in industries where such turnover is less frequent. Consequently, leaders in these industries find it difficult to maintain collusion incentives that sustain supra-competitive profit margins. The lack of incentives for tacit collusion results in low profit margins with low responsiveness to fluctuations in discount rates.

Paper [6] tests the model's empirical implications using diverse data sources. Here, I highlight one data construction that exemplifies the novelty and rigor of the empirical analysis: the creation of a price war pressure index for the corporate sector. To construct this index, I perform textual analysis on media coverage and analyst reports warning of price war risks in specific industries and aggregate them into an overall index. This paper shows that price wars are a significant concern for investors. Notably, media and analyst coverage is strongly countercyclical and positively co-moves with discount rates. This supports the key time-series implication of the model: as discount rates rise, the capacity for tacit collusion decreases and thus price war risk increases, leading to increased competition intensity.

To conclude on [6], this paper introduces a novel mechanism that integrates market concentration and strategic competition into an asset pricing framework. It documents a new industry-level stock return pattern—the industry-level gross profitability premium—that cannot be explained by firm-level theories or empirical patterns. This paper shows that in industries with higher market leadership persistence, competition intensity is lower but fluctuates more with aggregate discount rates than in other industries. This results in profit margins that are higher and more sensitive to discount rates. This novel mechanism explains the newly documented premium and fundamentally alters the traditional view of industry-level asset pricing and the relationship between cash flow news and discount rate news.

Paper [6] develops a novel asset pricing framework with strategic competition in which the stochastic discount factor (SDF) is exogenously specified. The companion paper published in the *Review of Financial Studies* (2022), titled **[10] "The Oligopoly Lucas Tree,"** extends [6] to a quantitative general equilibrium model. In **[10]**, the SDF is determined by a habit-formation preference, inspired by Campbell and Cochrane (1999, JPE), with a predictable component of consumption growth. The calibrated model generates an intricate joint pattern of the industry-level gross profitability and value premium, closely matching the observed pattern in the data. It also aligns with the observed cross-sectional correlation of industry-level market leadership persistence and the industry-level book-to-market ratio. This work contributes to the literature by addressing a key quantitative question in the macro asset pricing literature and highlights the critical role of product market strategic competition. This paper is with Yan Ji and Wei Wu.

In papers [6] and **[10]**, I focus on all-equity firms to highlight the channel of product market strategic competition. In practice, firms are financially leveraged. My forthcoming paper in the *Journal of Finance*, titled **[13] "Feedback and Contagion of Distressed Competition,"** extends these models by exploring the interaction between financial distress and strategic competition. Co-authored with Hui Chen (MIT), Hongye Guo (HKU), and Yan Ji, this paper makes a valuable theoretical contribution by developing a novel dynamic industry equilibrium model with long-term defaultable debt and strategic competition, including tacit collusion. This model can generate various strategic interactions among product market competitors, such as predation and price war.

Traditional frameworks for capital structure and financial distress assume perfect competition, overlooking strategic forms of competition such as tacit collusion or implicit coordination (Leland, 1994, JF). This leads to an oversimplified view of the relationship between profit margins and financial distress. These theories focus on firm-level financial

fragility, suggesting that industry-level financial issues are mere extensions of firm-level problems. However, paper **[13]** offers a fresh perspective on industry-level fragility, fundamentally altering the traditional view. The theory of this paper reveals a competition-distress feedback loop and a new form of financial contagion. The competition-distress feedback effect introduces new distress costs related to leverage, explaining the negative relationship between profitability and leverage across industries and addressing the long-standing "profitability-leverage puzzle." Due to the contagion effect, firms' optimal leverage is often excessively high from an industry perspective, undermining the industry's financial stability. Often, credit crunches are concentrated or initiated in a few industries. Understanding industry-level financial fragility is crucial for designing economic policies for macroeconomic stability. This paper emphasizes that focusing solely on firm-level financial fragility, without considering the feedback and contagion effects of distressed competition, can severely underestimate industry financial fragility.

The core mechanism is intuitive. Financial distress (a high default rate) makes a firm impatient, such that it focuses on short-term gains and values future cooperation less than it would otherwise. This weakens its capacity for collusion, intensifying competition and reducing profit margins. Lower profit margins push the firm further into distress, completing the feedback loop. In addition, this intensified competition reduces the profits of other firms within the same product market, increasing their financial distress.

To conclude on **[13]**, this paper pioneers the study of financial distress and strategic competition in an industry. It reveals a new feedback effect between imperfect product and credit markets, addressing the long-standing "profitability-leverage puzzle" across industries. It also uncovers financial contagion through intensified competition in product markets resulting from financial distress, altering the traditional view of industry-level financial fragility.

Furthermore, the competition-feedback effect has important asset pricing implications that have not been explored before. My recent working paper, titled **[20] "Industry Distress Anomaly,"** documents a new industry-level distress anomaly that existing theories, which explain the analogous distress anomaly at the firm level, cannot account for. Building on the feedback effect introduced in **[13]**, I provide a theoretical explanation for the newly documented industry-level distress anomaly. This paper is also with Hui Chen, Hongye Guo, and Yan Ji.

Motivated by the contagion effect introduced in paper **[13]**, I conduct comprehensive empirical analyses in papers **[15]** and **[19]** to show how firms' distress risk propagates through strategic competition in product markets, leading to a previously unexplored channel of security return predictability. The first paper, titled **[15] "Evidence on the Importance of Market Competition in Distress Propagation,"** is with Wei Wu and Shane Johnson (TAMU). The second paper, titled **[19] "Competition Network and Predictable Industry Returns,"** is with Wei Wu. In paper **[15]**, using a quasi-experimental setting induced by local natural disasters, I find that shocked firms exhibit increased distress risk, leading them to reduce their profit margins as they attempt to generate liquidity. The distress risk propagates horizontally to unshocked industry competitors who respond almost one-for-one with their own margin reductions. The distress risk propagation is particularly strong in tradable industries or those with high price flexibility,

entry barriers, inventories, or financial constraints. This paper also reveals that distress risk can propagate horizontally to other industries through financially consolidated multi-industry firms. In paper **[19]**, I introduce the concept of a "competition network," linking industries through multi-industry leaders. This network shows strong industry return predictability due to learning frictions about the competition-driven distress propagation.

Imperfect Competition in Asset Markets. As shown in the diagram, this second branch of the research theme, "imperfect competition in finance," includes five papers: **[7]**, **[12]**, **[14], [17]**, and **[18]**. These papers examine the market power of institutional investors in imperfectly competitive asset markets, exploring their effects on asset prices and capital market dynamics. Many asset markets are concentrated and dominated by a few sophisticated institutional investors due to various entry barriers. Traditional asset pricing research often overlooks this critical perspective, leaving many phenomena puzzling. Motivated by this gap, I have focused on the critical role of imperfect competition among institutional investors in asset markets. I believe my work in this area offers valuable new insights for both economists and regulators.

My first paper in this branch is **[7] "Dissecting Bankruptcy Frictions,"** published in the *Journal of Financial Economics* in 2021, and co-authored with Wei Wang (Queen's), Wenyu Wang (Indiana), and Lucian Taylor (Wharton). It addresses a central question: How does the U.S. bankruptcy process affect asset valuation, or how costly is corporate bankruptcy? This question is crucial not only for bankrupt firms but also for all firms in terms of securities pricing and corporate financial policies, because it directly relates to financial distress costs. This paper examines this question from an asset pricing perspective, where asset value is significantly affected by strategic rivalry between institutional creditors. This paper focuses on two economic frictions: asymmetric information and conflicts of interest between large creditors. These frictions cause inefficiencies through excess liquidation, continuation, and delay. Using a structural-estimation approach, the results of this paper demonstrate that U.S. bankruptcy is quite inefficient, meaning that significant asset valuation losses could be avoided by better coordination among major institutional creditors. Removing asymmetric information would increase average payouts by 4%, and removing conflicts between creditors would add another 18%. The main inefficiency arises from excess delay. Coordination benefits asset value and market efficiency.

The insights and empirical findings in papers **[7]** and **[13]** are complemented by my recent work **[17] "The Cost of Intermediary Market Power for Distressed Borrowers."** Together, these three papers significantly contribute to understanding corporate financial distress costs through the lens of imperfect competition in both product and asset markets. This paper studies the pricing of loans for distressed corporate borrowers. Traditional models of loan pricing attribute high yields to the premium associated with high credit and liquidity risk. However, this paper challenges that view, showing that distressed borrowers pay a substantial markup due to lender market power. This paper documents high market concentration dominated by a few specialized lenders, and ultra-high yield spreads, even after accounting for credit and liquidity risk. Using a structural-estimation approach, this paper dissects the cost of lender market power for distressed borrowers into three components: (i) pass-through of latent costs of loan making, (ii) markup due to

non-collusive market power, and (iii) markup due to the tacit collusion of specialized lenders, facilitated by repeated syndication interactions. This paper develops and estimates a dynamic game-theoretic model that accounts for endogenous collusion capacity, endogenous syndication participation, and latent heterogeneity. Notably, the model of this paper has closed-form solutions, allowing estimation using Bayesian machine learning to identify latent demand shifts. This is an important methodological contribution to the demand-estimation literature. This paper's findings reveal that lender market power accounts for roughly 85% of the risk-adjusted yield spreads, with a significant portion attributable to tacit collusion. Smaller borrowers are more susceptible to lender market power. Both specialized lenders and distressed borrowers would be worse off if tacit collusion among specialized lenders were completely prohibited, suggesting that overly aggressive antitrust policies might be efficiency-retarding. As a main contribution, counterfactual analyses based on the estimated model can provide valuable insights for economists and regulators to achieve optimal intervention in distressed loan markets. This paper is with Wei Wang and Wenyu Wang.

Congress and regulators note a rise in AI applications in the financial market, especially by hedge funds, to inform or determine trading decisions. There is an urgent call for studies on the implications of AI-powered trading for market efficiency and stability. My recent paper, titled **[18] "AI-Powered Trading, Algorithmic Collusion, and Price Efficiency,"** co-authored with Itay Goldstein (Wharton) and Yan Ji, scientifically investigates the mechanism behind algorithmic collusion and the risk of AI-driven market manipulation through collusive trading. This collusive trading among AI algorithms ("AI collusion") can occur without any agreement, communication, or intent. This paper shows that AI collusion can robustly emerge through two distinct mechanisms. My anticipation was that AI collusion through price-trigger strategies would emerge only in environments with low noise trading risk. However, this paper teaches us that AI collusion can still arise in environments with high noise trading risk when the level of AI sophistication is relatively low compared with the environment's complexity level. This paper shows that AI collusion compromises market efficiency by decreasing market liquidity, diminishing price informativeness, and widening mispricing, all of which can have adverse real consequences. As an important contribution, I believe that these unintended effects of AI on price formation and financial markets can reshape regulators' and practitioners' beliefs about the impact of AI on financial markets. For example, current concerns about AI in the financial sector focus on the technological aspects, such as the homogenization of AI algorithms due to similar foundational models and compliance challenges due to the opacity of AI systems. My work emphasizes the importance of understanding the intricate equilibrium behavior of AI algorithms, where one AI trader's learning and decisions are influenced by other AI traders. It also identifies factors that determine AI collusion capacity, such as the concentration of AI technologies, data monopoly, algorithm homogenization, the demand elasticity of information-insensitive investors, and noise trading risk. Regulators can mitigate AI collusion and its adverse effects by addressing these factors.

As depicted in the diagram, in two subsequent papers, **[12]** and **[14]**, I study the effects of imperfect competition among active equity mutual funds on asset prices and allocations. Fund companies face imperfect competition in attracting clients, leading to rigid fees. Fund flows reflect changes in client demand for delegation services, driven by variations in the fundamental investment environment, such as economic uncertainty, or by changes in investors' risk

aversion and sentiment, with the funds' fee-setting behavior having little influence. In addition, fund companies face imperfect competition in retaining managers, holding strong market power in the labor market. Consequently, fund manager compensation primarily depends on assets under management (AUM), driven by both fund returns and fund flows, with a strongly concave dependence. This creates an incentive for fund managers to tilt their portfolios to hedge against fund flows even at the expense of funds' return performance, causing a misalignment between their objectives and those of their clients.

My forthcoming *Journal of Finance* paper, **[12] "Common Fund Flows: Flow Hedging and Factor Pricing,"** co-authored with Leonid Kogan (MIT) and Wei Wu, shows that common fund flows emerge as a compensated risk factor in equilibrium due to agency conflicts between mutual fund managers and their clients. Traditional neoclassical asset pricing frameworks assume that intermediaries, such as mutual funds, can be ignored because they have no real effects. They are seen as a veil, not affecting asset prices or allocations. Instead, multiple factor asset pricing models with fundamental factors evidenced in the data are primarily rationalized by the intertemporal capital asset pricing model (ICAPM), in which household retail investors are intertemporally sophisticated and have rational expectations. However, many challenge this perspective, arguing that investors and fund managers are typically myopic, even naïve, in portfolio construction. As a main contribution, this paper highlights the role of non-bank intermediaries in linking asset prices to economic fundamentals, generating ICAPM-like results, even when agents are myopic. It offers a distinct mechanism and direct evidence, complementing existing theories on intermediary asset pricing (e.g., He and Krishnamurthy, 2013, AER; Savov, 2014, JFE). The idea underlying this paper is intuitive. Fund flows exhibit significant common time-series variation at a higher frequency than business cycles. Fund managers hedge against common flows by tilting portfolios toward low-flow-beta stocks. In equilibrium, other investors overweight high-flow-beta stocks to absorb this hedging demand. Thus, high-flow-beta stocks offer higher excess returns to attract these investors. These stocks earn higher excess returns and CAPM alphas, resembling ICAPM outcomes, even with myopic agents. Data show that household retail investors overweight high-flow-beta stocks and earn the risk premium. However, active equity funds overweight low-flow-beta stocks and pay the risk premium. This asset holding pattern supports the proposed flow hedging theory and rules out the possibility that the higher CAPM alpha of high-flow-beta stocks is due to household retail investors hedging against macroeconomic shocks driving fund flows. To summarize, **[12]** provides an important new insight into intermediary asset pricing: endogenous fund flows act as "invisible hands," linking macro fluctuations to asset prices, even when all agents are myopic. The model's implications for stock returns and asset allocations match observed patterns and differ from the classic institution-free ICAPM mechanism.

Central to the argument of paper **[12]** is the idea that fluctuations in a fund's AUM causally affect its managers' pay. Ibert, Kaniel, Van Nieuwerburgh, and Vestman (2018, RFS) demonstrate a statistically significant but strongly concave relationship between a fund manager's pay and the fund's AUM using Swedish data. However, there has been little evidence for U.S. funds until recently. My recent paper, titled **[14] "Fund Flows and Income Risk of Fund Managers,"** fills this gap. It provides direct and causal (contractual) evidence concerning the factors that affect

fund managers' pay in U.S. active equity mutual funds. This paper is with Leonid Kogan, Xiao Cen (TAMU) and Wei Wu. It has received a strong R&R request from the *Review of Financial Studies*. Undertaking this empirical exploration is challenging due to the scarcity of comprehensive data on the compensation and career trajectories of individual fund managers. Consequently, while there is a vast literature on the asset management industry, little is known about fund managers' incentives derived from their compensation contracts. Until recently, little progress had been made in exploring this issue. To contribute to the literature, this paper uses U.S. Census LEHD data and extensive textual analysis to create the first database on the compensation and career trajectories of U.S. active mutual fund managers. The main finding of this paper is that, contrary to fund self-disclosures, fund managers' pay is largely driven by AUM, not fund performance. This finding significantly revises previous conclusions that were based on less comprehensive data. This paper finds that the dependence of pay on AUM exhibits a strong concave pattern, and that fund flows, rather than fund performance, significantly impact the downside career outcomes of fund managers. These findings suggest that fund companies hold market power over their fund managers in the labor market and face a customer-based market when competing for clients. I plan to write several more papers using this new dataset on fund manager compensation. Just as there is an extensive literature on executive pay, I anticipate a fast-growing body of research on fund manager compensation, particularly given the data construction procedure developed in my recent work **[14]**. I will continue to contribute to this field, examining the organizational and compensation structure of the mutual fund industry and its impact on asset pricing and capital markets.

Theme 2: The Robustness of Macro Asset Pricing Models

My paper in the *Journal of Finance* (2024), titled **[8] "Measuring 'Dark Matter' in Asset Pricing Models,"** co-authored with Hui Chen and Leonid Kogan, formalizes the concept of "dark matter" in macro asset pricing models as the information imbalance between the model and the data regarding key parameters that govern fundamental processes, such as productivity. It introduces a measure for "dark matter" that quantifies this information imbalance. This measure is intuitive and easy to implement. A main contribution of this paper is the rigorous proof that dark matter captures a model's fragility. A model with more dark matter is more prone to in-sample overfitting, making it harder to refute with data and resulting in poorer out-of-sample performance. This theoretical result is further reinforced by the companion paper [9] under a different econometric setting. Intuitively, a large amount of dark matter indicates that a model cannot be effectively disciplined by observable data on fundamental variables, making it prone to in-sample overfitting with low refutability and poor external validity.

To elaborate on the intuition, the concept of dark matter is inspired by cosmology. To generate desirable predictions, macro asset pricing models often postulate subtle dynamics for fundamental variables, which are hard to identify directly from their data. However, these dynamics can be inferred indirectly from asset prices, with excessive statistical confidence, through the model-implied equilibrium relationship between fundamental variables and asset prices, often referred to as cross-equation restrictions or asset pricing moment restrictions. This excessive confidence is derived from the postulated model structure rather than the fundamental data. Such overreliance on the postulated

model structure without sufficient discipline from data raises robustness concerns, making the model prone to in-sample overfitting. Therefore, the measure for dark matter effectively gauges model fragility.

How should economists deal with macro asset pricing models with excessive dark matter? As depicted in the diagram, I develop robust specification tests to evaluate the validity of models with excessive dark matter, as standard optimal tests fail with these models. In addition, the dark matter measure introduced in my work reveals which model components are most responsible for model fragility. Guided by this diagnostic information, I conduct research that enhances the robustness of macro asset pricing frameworks by endogenizing the key processes of their fundamental variables, such as latent aggregate volatility and latent low-frequency growth. This research effort strengthens the data-based identification of these fundamental processes by connecting their dynamic properties to a broad set of granular cross-sectional data on fundamental variables, thereby reducing the information imbalance between the model and the data in these frameworks.

Robust Tests. Closely related to paper **[8]**, a companion paper published in *Econometrica* (2022), titled **[9] "Macro-Finance Decoupling: Robust Evaluations of Macro Asset Pricing Models,"** co-authored with Xu Cheng (Penn Economics) and Zhipeng Liao (UCLA Economics), provides a specification test robust to severe information imbalances or large dark matter. This test builds on the C statistic and recent developments in conditional inference using a sufficient statistic. The sufficient statistic in the test captures information in the fundamental data decoupled from asset pricing moment restrictions. Such decoupling preserves limited information in the fundamental data and efficiently evaluates the asset pricing moment restrictions using the discipline from this preserved information.

I choose **[9]** as the third of my three representative papers for three reasons. First, this paper, together with its companion paper **[8]**, makes valuable contributions to the asset pricing and econometrics literature, as well as the literature on model robustness (Hansen and Sargent, 2001, AER). Second, this paper, along with **[8]**, justifies a novel model robustness measure based on the information imbalance between the model and the data. The dark matter issue is distinct from the weak identification issue of model parameters; a model with large dark matter may not suffer from a weak identification issue. Third, the specification test proposed by this paper can serve as a powerful tool for constructing data-driven model uncertainty sets in both practice and research. Data-driven uncertainty sets are crucial in studying climate change uncertainty (Barnett, Brock, and Hansen, 2020, RFS).

Paper **[9]** proposes a moment-based specification test. Distribution-based tests can have higher power than moment-based tests in some cases. However, macro asset pricing models often lack closed-form solutions, making analytical distribution unavailable. Two-sample tests based on simulated data from the model address this issue. If information imbalance is severe, a much larger simulated sample relative to the observed data sample is required, leading to imbalanced samples. My paper in the *Journal of the American Statistical Association* (2013), titled **[2] "Ensemble Subsampling for Imbalanced Multivariate Two-Sample Tests,"** proposes a two-sample test based on a machine learning procedure. It is robust to severely imbalanced samples. This paper is with Lisha Chen and Zhipeng Liao.

Robust Models. In my solo-authored paper, titled **[21] "Embrace or Fear Uncertainty: Growth Options, Limited Risk Sharing, and Asset Prices,"** I develop a general equilibrium model with heterogeneous agents and incomplete markets. Aggregate volatility is endogenously driven by the cross-sectional dispersion of firm-level productivity and investment opportunity. My recent paper, titled **[16] "Misallocation and Asset Prices,"** develops an endogenous growth model with heterogeneous firms facing financial frictions. Misallocation emerges as a slow-moving endogenous state variable. It drives the long-run growth. This paper is with Yan Ji, Di Tian (HKUST), and Pengfei Wang (Peking). Both papers, **[21]** and **[16],** connect the key dynamics to cross-sectional information, addressing concerns of dark matter.

University Services and Professional Activities

University Services. Since I joined Wharton in 2016, I have actively engaged in several functions within the department and the school. I organized our finance seminar series for the 2017–2018 academic year and have served on the junior faculty recruiting committee three times. Within the department, I have been a member of the Doctoral Prelim Exam Committee for three years, from 2022 to 2024. At the school level, I have contributed to the Faculty IT Steering Committee, the Faculty Panel for the 2019 Wharton PhD Orientation, and the Faculty Panel for the 2023 Annual IDDEAS@Wharton Meeting of the Wharton PhD Program.

As a unique service to my department, I have taught **3** distinct courses, each requiring different preparations: FNCE934 "Advanced Topics in Dynamic Asset Pricing," an advanced second-year PhD course on asset pricing and macro finance; FNCE911 "Foundations for Financial Economics," a first-year PhD course on financial economics; and FNCE217/206/717 "Financial Derivatives," an undergraduate and MBA course. The PhD courses welcomed students from other departments, such as accounting and economics. Typically, junior faculty members in the finance department teach two sessions of the same course, thus involving only one set of preparation, before becoming senior faculty members. Despite the additional time and effort in teaching **3** distinct courses, I have truly enjoyed teaching all our students at Wharton. I have received Wharton teaching excellence awards for my efforts.

I have taken an active role in mentoring doctoral and undergraduate students. I have served on **8** students' PhD dissertation committees and chaired one of them. Two of these students were from outside Wharton (Universitat Pompeu Fabra and Kellogg at Northwestern University). Of these students, six have graduated and joined tenure-track positions at universities or accepted economist positions at monetary authorities, and I am currently serving on the dissertation committees of two Wharton PhD students. I have co-authored two papers with my former students and have been working on another paper with a current doctoral student for the past few years. I have been invited twice to be a faculty judge for the Doctoral Research Forum and Thesis Prize at MIT Sloan and to be a mentor for the MIT Rising Scholars Mentoring Program. I have conducted mock interviews for our job-market candidates almost every year. I have advised **9** Wharton undergraduate students and **3** undergraduates from other universities on their theses and research projects. Among them, Shaolong (Lorry) Wu, a Wharton undergraduate, joined the HBS doctoral

program to pursue an academic career, and Yifeng (Vic) Wu from HKUST joined the Princeton Economics doctoral program. In addition, Willow Wilkes, one of my undergraduate students at Wharton, won the prestigious 2024 Rose Award for her thesis on the spillover effect in international trade and financial markets.

Professional Activities. Externally, I have been active in the profession. Since joining the profession in 2016, I have been invited to present my research at nearly **80** renowned universities and institutions, including Berkeley, Boston College, Columbia, Duke, Maryland, MIT, Northwestern, Ohio State, Penn Economics, Rochester (twice), UBC (twice), UCLA, UNC Chapel Hill, University of Chicago (twice), University of Michigan, University of Minnesota (twice), USC, University of Toronto, University of Wisconsin, WashU, and Yale. In addition, I have been invited to present my research at regulatory and monetary authorities, including the European Securities and Markets Authority (ESMA), the Financial Industry Regulatory Authority (FINRA), the International Monetary Fund (IMF), the Federal Reserve Bank of Dallas, the Federal Reserve Bank of Philadelphia, and Sveriges Riksbank.

In February 2023, I was invited to visit the finance department at the Booth School of Business at the University of Chicago as a Fama-Miller Research Visitor. During my visit, I had the opportunity to present my research and receive valuable feedback from colleagues at Booth. I enjoyed office meetings with many finance faculty members and doctoral students, engaged in research discussions over lunches and dinners, and participated in departmental seminars. Moreover, I have been an invited presenter at over **90** conferences and an invited discussant at **55**, including all the top conferences such as the NBER, AFA, and WFA, as well as nearly all the prestigious boutique conferences in my profession. I have received multiple best paper awards from these conferences and the Best Discussant Award at the London Business School Summer Finance Symposium in 2024.

I have served as a session chair for **9** conferences and regularly on the program committees of **6** large finance conferences and **8** other boutique conferences. In addition, I have been on best paper award committees at top conferences. Together with my Wharton colleagues Nick Roussanov and Tim Landvoigt, I co-organized the Spring 2020 meeting of the Macro Finance Society. Alongside Tom Sargent and a few other economists, I co-organized the PKU/PHBS Sargent Institute Macro-Finance Annual Workshop every year from 2019 to 2022.

I am a Faculty Research Fellow of the NBER in the Asset Pricing Group. I have participated in the presentation and discussion of papers **8** times in front of different NBER groups, including Asset Pricing, Corporate Finance, Big Data and Securities Markets, Dynamic Equilibrium Models, and Capital Markets and the Economy. Additionally, I have been invited to present my research at the CEPR Asset Pricing Group meeting.

Finally, I have served as a referee for **20** finance, management, and economics journals. Currently, I am an associate editor for **3** academic journals in finance and economics: *Review of Finance, Journal of Corporate Finance*, and *Journal of Economic Dynamics and Control*.