UNIVERSITY OF CALIFORNIA
RIVERSIDE

Essays on Information and Asset Liquidity

A Dissertation submitted in partial satisfaction
of the requirements for the degree of

Doctor of Philosophy

in

Economics

by

Xinchan Lu

June 2024

Dissertation Committee:

Professor Jang-Ting Guo, Co-Chairperson
Professor Victor Ortego-Marti, Co-Chairperson
Professor Michael Choi
Professor Athanasios Geromichalos
Professor Matthew Lang
Professor Guillaume Rocheteau

The Dissertation of Xinchan Lu is approved:

Committee Co-Chairperson

Committee Co-Chairperson

University of California, Riverside

Acknowledgments

I am deeply grateful to my advisors, Dr. Jang-Ting Guo and Dr. Victor Ortego-Marti, for their invaluable support and guidance throughout my PhD journey. Dr. Jang-Ting Guo has been instrumental in the development of my career as an independent researcher. Our countless conversations and coffee talks over the past six years have profoundly shaped my approach to independent research, presentations, and effective communication. Dr. Victor Ortego-Marti has consistently provided helpful advice and made valuable suggestions for my projects. His encouragement has been a constant source of motivation.

I would also like to extend my sincere thanks to my dissertation committee members. My projects could not have reached their current form without the help of all these remarkable individuals.

Dr. Michael Choi has provided insightful comments during my Brownbag presentations at UC Irvine and our meetings. His advice to junior researchers has been particularly helpful as I prepare to embark on my academic career.

Dr. Athanasios Geromichalos has also offered insightful feedback during my presentations and meetings. I am especially grateful for his support in the development of my projects and brainstorming the ideas. His encouragement and passion have been truly inspiring.

Dr. Matthew Lang has made significant contributions through his insightful comments during my seminar presentations at UC Riverside. Our conversations have been inspiring, as he adeptly connects theoretical models to real-world scenarios.

Special thanks to Dr. Guillaume Rocheteau for being an inspiring advisor and mentor. His guidance during my Brownbag presentations at UC Irvine and our numerous lunch meetings have been crucial in shaping me into a researcher. His continuous support has been invaluable. Additionally, I have been motivated by his presentations and teaching. His enthusiasm was contagious and made me passionate about my own research.

I would also like to thank my classmates and friends at UC Riverside and UC Irvine. I am grateful to all the faculty and staff members who have supported me. Special thanks to Dr. Jeffrey Allen who has made insightful comments on my projects and provided help throughout the job market. I would also like to express gratitude towards Mr. Gary Kuzas and Mr. Mark Tankersley for their administrative support.

Finally, I am deeply indebted to my husband, Shuo, for his unconditional love, understanding, and constant encouragement. I would also like to thank my parents, Ping and Xiaofen, for their unwavering belief in me and their endless support. Their contributions have been instrumental in helping me achieve this milestone.

To Shuo.

ABSTRACT OF THE DISSERTATION

Essays on Information and Asset Liquidity

by

Xinchan Lu

Doctor of Philosophy, Graduate Program in Economics
University of California, Riverside, June 2024
Professor Jang-Ting Guo, Co-Chairperson
Professor Victor Ortego-Marti, Co-Chairperson

Asset liquidity, crucial for understanding asset pricing anomalies and the transmission mechanism of monetary policy, is significantly interacted with information frictions among market participants. Employing the New-Monetarist framework pioneered by Lagos and Wright (2005) and Rocheteau and Wright (2005), this dissertation comprises three essays investigating the presence and acquisition of private information and its impact on asset liquidity. Chapter 1 provides an overview.

Chapter 2 explores the implications of private information acquisition for asset liquidity within a New-Monetarist model. The model incorporates a bargaining protocol with private information and strategic information acquisition decisions, revealing how economic fundamentals and monetary policy influence private information acquisition. A non-monotonic effect of nominal interest rates on asset liquidity is identified, with insights applied to interpret the 2007-2008 financial crisis.

Chapter 3 extends the model to account for hidden information status in real-world markets. This chapter uncovers strategic behaviors among dealers under hidden information

status, leading to equilibrium configurations characterized by separating, semi-pooling, and pooling equilibria. Notably, a non-monotonic response of private information acquisition to monetary policy emerges, contrasting with Chapter 2.

With the rising portion of international investment executed by portfolio managers, Chapter 4 addresses the home bias puzzle in international finance literature by considering the influence of delegated portfolio management on international portfolio allocation strategies. Furthermore, I discuss the future research agenda and the development of the existing literature.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

"As a medium of exchange, money has to be continually handed about, and it will occasion great trouble if every person receiving currency has to scrutinize, weigh, and test it."

William Stanley Jevons, Money and the Mechanism of Exchange, 1875

Asset liquidity has been recognized as a crucial factor in determining the demand for asset holdings, explaining asset pricing anomalies, and understanding the transmission mechanism of monetary policy. Inspired by Jevon's work in 1875, which highlighted the essential nature of "cognizability" in assessing asset liquidity, this dissertation places particular emphasis on the significant role of information frictions in determining asset liquidity.

To provide a comprehensive understanding of asset liquidity, I adopt the New-Monetarist framework, building on the works of Lagos and Wright (2005) and Rocheteau and Wright (2005). Within an environment characterized by search frictions, imperfect commitment, and a lack of record-keeping, my research incorporates additional friction – information friction – and investigates the valuation of assets through a liquidity premium, reflecting their roles as mediums of exchange in facilitating bilateral trades. This dissertation contains three essays that investigate the presence and acquisition of private information, which in turn shapes the liquidity of assets.

Chapter 2 studies the implications of private information acquisition for asset liquidity. To formalize private information acquisition about the quality of liquid assets, I develop a New-Monetarist model that incorporates a bargaining protocol with private information and strategic information acquisition decisions. The decisions to acquire private information depend on various economic fundamentals and monetary policy, revealing that a higher nominal interest rate encourages the acquisition of private information. The chapter identifies a non-monotonic effect of an increased nominal interest rate on asset liquidity, highlighting a novel channel through private information acquisition. Lastly, the chapter discusses an application of the model to interpret the financial crisis in 2007-2008.

While Chapter 2 assumes the acquisition of private information to be common knowledge, real-world markets often operate under hidden information status. Chapter 3 extends the model in Chapter 2 and explores the implications of hidden information status for private information acquisition in asset trading. As hidden information status impedes households' ability to discern dealers' information acquisition decisions, the model unveils strategic behaviors among dealers, leading to equilibrium configurations characterized by separating, semi-pooling, and pooling equilibria. Crucially, I find that hidden information status induces a non-monotonic response of private information acquisition to monetary policy in contrast to Chapter 2. Specifically, dealers choose not to acquire information when nominal interest rates are high or low. Furthermore, I compare the effects of the degree of information asymmetries on the demand for real money balances and welfare in order to further understand the implications of hidden information status.

Chapter 4 highlights the importance of integrating asset liquidity considerations with information asymmetries to analyze a long-lasting puzzle in the international finance literature. As pointed out in the seminal works of French and Poterba (1991) and Tesar and Werner (1995), individual investors tend to hold a disproportionate share of domestic equities. Despite the potential gains from incorporating foreign equities, as suggested by the standard finance theory, investors seem reluctant to fully benefit from international diversification. One plausible explanation for this behavior lies in the presence of information asymmetries concerning the trading of domestic and foreign assets. However, with a significant portion of international investments now overseen by portfolio managers, traditional information-based explanations for home bias appear inadequate. In Chapter 4, I summarize the stylized facts of the home bias puzzle in equities at the fund level. I discuss future research agenda and the development of the existing literature, aiming to fill this gap by considering the influence of portfolio managers on the international portfolio allocations.

Chapter 2

Asset Liquidity, Private Information Acquisition, and Monetary Policy

”Because if the market catches on to everything, I probably have the wrong job. You can’t add anything by looking at this arcane stuff, so why bother? But I was the only guy I knew who were covering companies that were all going to go bust during the greatest economic boom we’ll ever see in my lifetime. I saw how the sausage was made in the economy and it was really freaky.”

Michael Lewis, *The Big Short: Inside the Doomsday Machine*, 2011

2.1 Introduction

Private information acquisition plays a crucial role in determining asset liquidity. As formalized by Dang et al. (2020), the production of private information leads to an endogenous adverse selection problem that hinders asset liquidity. A prime example of this idea is the drying-up of liquidity that emerged in the mortgage-backed securities (MBS) market during the 2007-2008 financial crisis. As Gorton (2010) describes, when housing prices declined in late 2007, MBS became risky with surging defaults and foreclosures. The subprime risk was revealed, incentivizing some parties in asset trading to acquire information about the quality of the securities (Gorton, 2010, p.8). The endogenous adverse selection problem emerged in this scenario. Some agents, such as financial institutions, dealer banks, and government entities, possessed specialized expertise in asset trading, allowing them to derive information about the quality of MBS, while others could not due to the complex structure of the design of those securities. (Gorton, 2010, p.126).

The main objective of this paper is to formalize the role of private information acquisition in the analysis of asset liquidity. More specifically, this paper aims to understand the following questions: How information acquisition affects asset liquidity? What triggers information acquisition? And, how monetary policy impacts asset liquidity in the presence of private information acquisition?

To address these questions, I develop a New-Monetarist model to study asset liquidity embedding private information acquisition.[1] Two assets - fiat money and a one-period lived Lucas (1978) tree - are valued for liquidity depending on their usefulness in facilitating

[1]Recent surveys on the New-Monetarist literature include Lagos et al. (2017) and Rocheteau and Nosal (2017).

bilateral trades as means of payments (or collateral). Fiat money cannot be counterfeited, making it a universally accepted medium of exchange. In contrast, the tree pays a stochastic dividend at the beginning of each period before bilateral meetings are formed. Households holding the trees are not informed about the dividend. With some probability, they match with better-informed buyers of the trees who are dealers with private information about the dividend. To elaborate on the impacts of private information in bilateral trades, I adopt Rocheteau (2011), which incorporates a bargaining protocol with asymmetric information. Then, I formalize dealers' decisions for private information acquisition based on Lester et al. (2012).

As a first step, I characterize the steady-state equilibrium with an exogenous fraction of the informed dealers who purchase the trees. I revisit the effects on asset liquidity and welfare when asymmetric information is more severe, i.e., an increased fraction of informed dealers. In the second part of the paper, I endogenize this fraction such that the dealers can choose to become informed by acquiring private information. Specifically, the model suggests a unique Nash equilibrium that characterizes the fraction of dealers acquiring private information, stemming from the strategic substitutability among dealers' information acquisition decisions. This result can be attributed to the intensified information asymmetries resulting from an increased fraction of dealers acquiring private information. As a result, the households are incentivized to distort terms of trade, reducing the value of the dealers' private information.

The main insight of this paper is the role of monetary policy on the information acquisition decision and, in turn, on the asset liquidity. To be more specific, I investigate a money injection, i.e., inflation, which increases the nominal interest rate according to the Fisher effect. I start with showing that an increase in the nominal interest rate encourages more dealers to acquire private information. The intuition is that a higher nominal interest rate makes real money balances more costly to hold. As the two assets in the model are substitutes in facilitating trade, the demand for the trees becomes higher, and dealers benefit more from possessing private information about the dividends of the Lucas trees. As a result, an increased nominal interest rate can have a non-monotonic effect on the asset liquidity, which arises from two opposing effects of monetary policy on asset liquidity. First, an increase in the nominal interest rate has a positive effect on asset liquidity, as the two assets in the economy are substitutes in facilitating trades.[2] Second, there is an indirect effect through private information acquisition. When the interest rate is neither too high nor too low, an increased nominal interest rate encourages dealers to acquire private information, which intensifies information asymmetries and potentially hinders asset liquidity. In addition, for the normative analysis, the welfare cost of inflation is amplified with the presence of private information acquisition as a result of the second channel. Furthermore, I explore the impacts of various economic fundamentals, such as search frictions, average asset quality, and riskiness, on the dealers' decisions for private information acquisition.

Lastly, I discuss an application of the model to interpret the 2007-2008 financial crisis, aligning with the information view of financial crises illustrated by Gorton (2010). Through the lens of my model, I demonstrate the importance of private information acquisition in causing illiquidity during the crisis. Then, I explain the impact of the launch of the ABX index on the incentives for information acquisition and asset liquidity. Finally, I

[2]This effect is broadly identified in the New-Monetarist literature. See 2.1.1 for additional references.

discuss two effective approaches to discourage private information acquisition and preserve asset liquidity: (i) reduce the macroeconomic uncertainty and (ii) reduce the asset supply through a government asset purchasing program.

2.1.1 Related Literature

This paper employs the New-Monetarist framework, e.g., Lagos and Wright (2005) and Rocheteau and Wright (2005), to study the interaction between private information acquisition and the liquidity of assets.[3] The closest related study is Lester et al. (2012), which studies the effect of recognizability, endogenized through information acquisition, on asset liquidity. To emphasize the role of private information in asset trading, I incorporate a bargaining protocol under asymmetric information in line with Rocheteau (2011).[4] I show that private information acquisition can amplify information asymmetries, potentially hindering the asset's role as a means of payment.

The paper revisits monetary policy and asset prices within the New-Monetarist framework. Examples include Geromichalos et al. (2007), Lagos (2011), Lagos and Rocheteau (2008), Lester et al. (2012), Nosal and Rocheteau (2013) and Hu and Rocheteau (2015). In line with those papers, fiat money and a real asset compete as a medium of exchange. Therefore, an increased nominal interest rate shifts the demand for fiat money to the real asset, positively affecting asset prices. In addition, this paper identifies a novel chan-

[3]The link between information and asset liquidity has been explored in previous studies within the New-Monetarist framework such as Williamson and Wright (1994), Banerjee and Maskin (1996), Berentsen and Rocheteau (2004), Li et al. (2012), Zhang (2014), and Choi and Liang (2023).

[4]There is a vast literature on asymmetric information in trading and exchanges. A seminal work by Akerlof (1970) studies the lemon problem and quality uncertainty in the asset market. Guerrieri et al. (2010) study adverse selection in the asset market under competitive search. Some recent work includes Kurlat (2013), Camargo and Lester (2014), Guerrieri and Shimer (2014), Kurlat (2016), Chiu and Koeppl (2016), Choi (2018), and Lester et al. (2019).

nel for monetary policy transmission through private information acquisition. An increased nominal interest rate incentivizes information acquisition, which may lead to a decrease in asset prices. Consequently, this paper suggests a non-monotonic impact of monetary policy on asset prices. In contrast to the models in which fiat money and the real asset are substitutes in facilitating trade, Lagos and Zhang (2020) suggest that an higher nominal interest rate increases asset illiquidity, leading to a reduction in asset price since real money balances, as payment instrument in asset market, become scarcer, reducing the resalability of financial assets.

Additionally, this paper relates to the literature on the social value of information. Following Hirshleifer (1971), Andolfatto and Martin (2013) suggest that nondisclosure of information enhances asset liquidity and improves social welfare. Andolfatto et al. (2014) expand on this by allowing the agents to acquire private information, suggesting that disclosure can be constrained-efficient only when the agents have strong incentives to discover information themselves. In this paper, private information acquisition magnifies information asymmetries as well as the welfare cost of inflation. Consistent with the existing literature, the Friedman rule is optimal. When deviating from the Friedman rule, the welfare effect of asymmetric information, generated by information acquisition, is non-monotonic.

Lastly, this paper contributes to the literature of the information view of the financial crisis, including Gorton and Pennacchi (1990), Gorton (2010), Gorton and Ordonez (2014), Dang et al. (2015), and Dang et al. (2020). My paper resonates with these studies, illustrating that private information acquisition leads to adverse selection problems that impede asset transactions. Moreover, this paper establishes a micro-founded general equilibrium framework, wherein dealers purchase assets from households, akin to Duffie et al. (2005), determining asset liquidity in bilateral trades that embed private information within the bargaining protocol, and allowing for explorations of monetary policy implications.[5]

2.2 Environment

The environment is based on Lagos and Wright (2005). Time is discrete, starts at $t = 0$, and continues forever. Agents are infinitely-lived and discount the future between periods with a discount factor $\beta \in (0, 1)$. There are two stages in each period. Stage 1 features bilateral matches as in the search theory and information frictions. Stage 2 is a Walrasian settlement market in which all agents can enter and rebalance their portfolio holdings.

There is a unit measure of households, sellers, and dealers, distinguished by their roles in Stage 1. A competitive market for a "special good" exists in Stage 1, in which households want to consume but cannot produce, whereas sellers can produce but do not want to consume the good. The major role of the dealers is to purchase assets, which will be explained more carefully after we define the financial assets in the economy. Furthermore, there is a lack of monitoring or record-keeping technology such that the agents cannot commit to repaying their debts. In Stage 2, all three types of agents can consume and produce a "general good" by supplying labor. Both goods are divisible and perishable between periods. The period utilities for each type of agent is $\mathcal{U}(q, X, H) = u(q) + X - H$

[5]In related work, Gu et al. (2021) study market freeze in a searching-and-bargaining framework, focusing on the liquidity role of the asset and self-fulfilling prophecies, whereas this paper focuses on the incentives for private information acquisition. Lagos and Zhang (2015) formalize investors' speculative premiums and investigate the impacts of monetary policies. With the endogenous entry of dealers, their model exhibits sunspot equilibria that resemble liquidity dries up and the speculative bubble bursts.

for the households, $\mathcal{V}(q, X, H) = -q + X - H$ for the sellers, and $\mathcal{D}(X, H) = X - H$ for the dealers, where q denotes the special good, X denotes the general good, and H hours being supplied in Stage 2. I assume that $u(q)$ is twice continuously differentiable, strictly increasing, and strictly concave, with $u'(q) > 0 > u''(q), u(0) = 0, u'(0) = +\infty$, and $u'(\infty) = 0$. Then, the optimum quantity of the special good being traded is $q^* \equiv \{q : u'(q) = 1\}$.

There are two financial assets - fiat money and a one-period lived Lucas (1978) tree. Households endow with $A > 0$ units of trees at the beginning of Stage 2. The fiat money supply (M) changes at a gross rate γ, with $\gamma > \beta$, accomplished by injecting (or withdrawing) via lump-sum transfers (or taxes) to households in Stage 2. Fiat money cannot be counterfeited, but the trees are subject to an aggregate dividend shock at the beginning of Stage 1 before bilateral matches are formed. In particular, the dividend can be a high type, $\delta = \delta_h$, with probability $\pi \in (0, 1)$, or a low type, $\delta = \delta_\ell$, with complementary probability $1 - \pi$, where $0 < \delta_\ell < \delta_h$. Then, the expected dividend is $\delta^e = \pi\delta_h + (1 - \pi)\delta_\ell$. Agents do not realize the value of δ but understand the stochastic process. The actual δ will be revealed at the beginning of Stage 2. The households can hold fiat money and the trees at the (real) prices ϕ_m and ϕ_a in terms of the general good.

The no counterfeiting assumption guarantees that fiat money is universally accepted by the sellers as a medium of exchange.[6] However, households with higher liquidity needs must liquidate the trees through a dealer. The dealers have deep pockets, allowing them to purchase the trees from the households and issue liquid IOUs, assuming that

[6]Not discussed in this paper, the effect of counterfeiting on assets' usefulness as mediums of exchange has been studied by Rocheteau (2009), Li and Rocheteau (2011), and Li et al. (2012). According to these studies, producing counterfeited assets at a positive cost affects terms of trade and asset liquidity, even though no counterfeiting occurs in equilibrium.

the dealers can credibly promise payments to the sellers.[7] (See Figure 2.1) The bilateral matches between a household and a dealer are subject to search frictions, with a meeting probability $\alpha \in (0, 1)$.

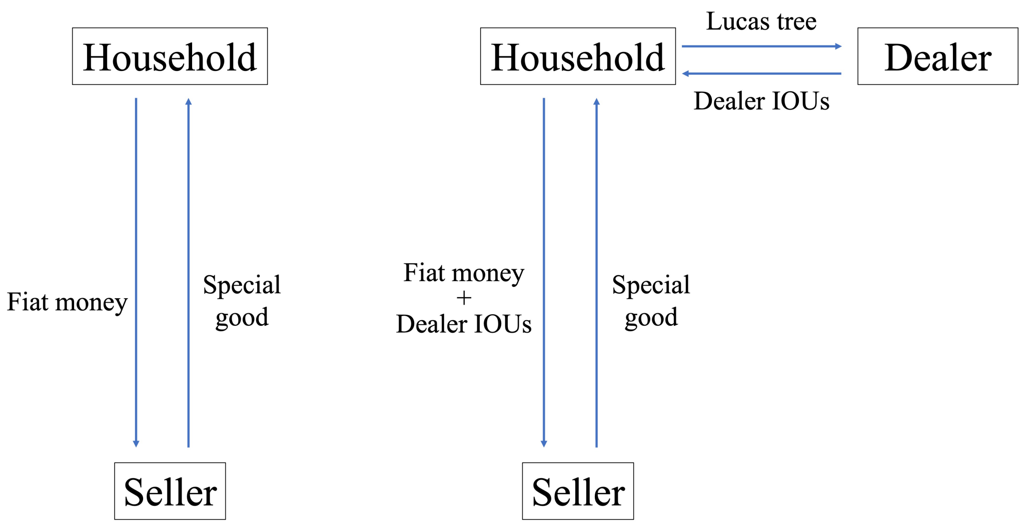

Figure 2.1: The role of dealers.

In addition, the bilateral matches between households and dealers are subject to asymmetric information, with dealers potentially possessing an informational advantage regarding the dividend. Furthermore, I assume that dealers' information status is common knowledge.[8] Therefore, households can distinguish between informed and uninformed dealers. Henceforth, the bilateral matches are referred to as Type I meetings, in which a household meets with an uninformed dealer; otherwise, Type II meetings. Let $\rho \in [0, 1]$ denote the fraction of informed dealers who can realize the actual value of the dividend.

[7]The introduction of dealers is similar to the model setup in Geromichalos and Herrenbrueck (2016). In that paper, assets can be valued for indirect asset liquidity, such that an illiquid asset can be liquidated for a liquid asset and facilitate trades. However, instead of deep pockets, the buyers of the illiquid asset face a liquidity constraint. Geromichalos et al. (2021) study the coexistence of direct and indirect asset liquidity. Recent works that incorporate asymmetric information include Madison (2019), Wang (2020), and Geromichalos et al. (2022).

[8]This assumption is released in Chapter 3.

Equivalently, ρ also represents the probability of a Type II meeting. As a starting point, I treat ρ as exogenous. In Section 2.4, ρ is endogenized by allowing dealers to make private information acquisition decisions.

2.3 Equilibrium

In this section, I describe the agents' problem and define the steady-state equilibrium with exogenous ρ. I start with the value functions of the two stages. Then, I characterize the equilibrium contracts of the bargaining games for the bilateral matches. Lastly, given the equilibrium contracts, I solve the households' optimal portfolio choices.

2.3.1 Value Functions

Let z and a denote the household's holding of real money balances and the trees. The value function of a household entering Stage 2 with portfolio holdings (z, a) and the realized dividend of the trees $\delta \in \{\delta_h, \delta_\ell\}$ is

$$W(z, a, \delta) = \max_{X,H,z',a'} \{X - H + \beta \mathbb{E} V(z', a', \delta')\} \tag{2.1}$$

$$\text{s.t. } X + \gamma z' + \phi_a a' = H + z + \delta a + \phi_a A + T \tag{2.2}$$

Variables with a prime denote the future values in the next period. In Stage 2, households finance their next-period portfolio holdings and the consumption of the general goods, X, with supplying labor hours, H, their initial liquid wealth, $z+\delta a$, and their initial endowment of the trees, $\phi_a A$. In addition, they receive a lump-sum transfer, $T \equiv (\gamma - 1)\phi_m M$, for accomplishing the changes in the fiat money supply. By substituting $X-H$ from (2.2) into (2.1), the value function $W(z,a,\delta)$ is linear in z and a. Therefore, households' portfolio choices for next period, (z',a'), is independent of their current portfolio holdings (z,a).

$\mathbb{E}V(z',a',\delta')$ denotes the value function of a household who enters the next-period Stage 1 with portfolio holdings (z',a'). The expectation is taken with respect to δ', which is unknown to the households in Stage 1. The value function is defined as

$$\begin{aligned} V(z,a,\delta) = (1-\alpha)[u(q_0(z)) + W(z-q_0(z),a,\delta)] \\ + \alpha[u(q(z,a,\delta)) + W(z-\tau(z,a,\delta),a-d(z,a,\delta),\delta)] \end{aligned} \tag{2.3}$$

The interpretation is as follows. With probability $1-\alpha$, the household fails to match with a dealer and only uses fiat money as means of payment. Therefore, the household will consume $q_0 = \min\{q^*, z\}$ unit of the special good, purchased directly from the sellers.[9] Otherwise, the household meets a dealer with probability α and bargains over the terms of trade. In this case, the household gets utility from q and makes payments with real money balances, τ, and the trees, d, which are the equilibrium contracts characterized in Section 2.3.2.

2.3.2 Bargaining Game

In this section, I characterize the bargaining protocol between a household and a dealer in Stage 1. The equilibrium contract consists of the quantities of the special good

[9]The assumption of the sellers' linear production cost implies a unit price of the special good in the competitive market. Hence, the household can consume the optimal quantity, q^*, if the money holding is abundant or use up all the money holding and consume z units of the good.

traded, q, the transfer of real money balances as payment, τ, and the transfer of the trees, d. Then, the value of the liquid IOUs issued by dealers is represented by $q - \tau$.

For tractability reasons, I assume that the households make a take-it-or-leave-it offer when the bilateral match is formed. To be more specific, the bargaining protocol for the Type II meetings will feature a screening game that do not rely on refinements of sequential equilibria to characterize the equilibrium contract. In Appendix A.5, I discuss a more general setup that allows both households and dealers to make alternating offers. I show that dealers making take-it-or-leave-it offers leave no surplus to households in the bilateral meetings. Therefore, the liquidity premium disappears. Furthermore, private information has non-positive value to the dealers if the dealers are making the offer, and therefore, no information acquisition when we endogenize ρ. Now, we characterize the equilibrium contracts.

Type I Meeting

In Type I meetings, a household with portfolio holdings (z, a) meets with an uninformed dealer and bargains under symmetric information. That is, neither of them realizes the actual dividend of the trees. The household solves the following optimization problem subject to the dealer's participation constraint,

$$\max_{(q_1,\tau_1,d_1)} [u(q_1) - \tau_1 - \delta^e d_1] \text{ s.t. } -(q_1 - \tau_1) + \delta^e d_1 \geq 0 \tag{2.4}$$

and the feasibility constraints $0 \leq \tau_1 \leq z$ and $0 \leq d_1 \leq a$.

Lemma 1. Define $y^e \equiv z + \delta^e a$ as the liquid wealth of the household. The equilibrium contract offered by the household solves (2.4).

(a) If $q^* \leq y^e$, then $q_1 = q^*$ and $\tau_1 + \delta^e d_1 = q^*$;

(b) If $q^* > y^e$, then $q_1 = y^e$, $\tau_1 = z$, and $d_1 = a$.

The proof is omitted as one can easily verify that the contract solves the household's problem. In Type I meetings, real balances and the trees are perfect substitutes as means of payment. The equilibrium contract depends on whether the liquidity wealth, y^e, is sufficient to trade the optimal quantity, q^*. If so, the household consumes q^* of the special good; otherwise, the household uses up all the portfolio wealth, $z + \delta^e a$, to consume the good.

Type II Meeting

In Type II meetings, a household meets an informed dealer who realizes the true value of the dividend, $\delta \in \{\delta_h, \delta_\ell\}$. The household with portfolio holdings (z, a) offers a menu of contracts, $\{(q_h, \tau_h, d_h), (q_\ell, \tau_\ell, d_\ell)\}$, where the subscript denotes the state of the dividend. The household maximizes the expected payoff from the bilateral trade subject to the dealer's participation constraints and incentive-compatible constraints for each dividend state $\chi \in \{h, \ell\}$ as follows,

$$\max_{\substack{(q_h,\tau_h,d_h)\\(q_\ell,\tau_\ell,d_\ell)}} \{\pi[u(q_h) - \tau_h - \delta_h d_h] + (1-\pi)[u(q_\ell) - \tau_\ell - \delta_\ell d_\ell]\} \tag{2.5}$$

$$\text{s.t.} \; -(q_\chi - \tau_\chi) + \delta_\chi d_\chi \geq 0 \text{ and } -(q_\chi - \tau_\chi) + \delta_\chi d_\chi \geq -(q_{-\chi} - \tau_{-\chi}) + \delta_\chi d_{-\chi}$$

and the feasibility constraints $0 \leq \tau_\chi \leq z$ and $0 \leq d_\chi \leq a$.

Lemma 2. The participation constraint for the low-dividend state and the incentive-compatible constraint for the high-dividend state are binding.

$$-(q_\ell - \tau_\ell) + \delta_\ell d_\ell = 0 \tag{2.6}$$

$$-(q_h - \tau_h) + \delta_h d_h = -(q_\ell - \tau_\ell) + \delta_h d_\ell = (\delta_h - \delta_\ell) d_\ell \tag{2.7}$$

Proof. See Appendix A.1. □

Intuitively, the dealers in the high-dividend state have incentives to pretend that the tree pays a low dividend. In this case, the high-state dealers benefit from issuing less IOUs to buy a high-dividend tree, whereas the low-state dealers do not have incentives to mimic those in the high state. Therefore, the households only need to make sure the low-state dealers participate in the trade and leave no trade surplus to those dealers. However, (2.7) suggests that, in the high-dividend state, the households have to prevent the dealers from mimicking those in the low-dividend state. Therefore, the households compensate those dealers with an informational rent, $(\delta_h - \delta_\ell)d_\ell$, to make them indifferent from deviating from the high to the low dividend state. Lemmas 3 and 4 summarize the equilibrium contract that solves (2.5).

Lemma 3. Define $\bar{y} \equiv z + \delta_h a$ as the liquid wealth of the household for the high dividend state ($\delta = \delta_h$). The equilibrium contract for the high state, taken d_ℓ as given, is

(a) If $q^* + (\delta_h - \delta_\ell)d_\ell \leq \bar{y}$, then $q_h = q^*$ and $\tau_h + \delta_h d_h = q^* + (\delta_h - \delta_\ell)d_\ell$;

(b) If $q^* + (\delta_h - \delta_\ell)d_\ell > \bar{y}$, then $q_h = \bar{y} - (\delta_h - \delta_\ell)d_\ell$, $\tau_h = z$, and $d_h = a$.

Proof. See Appendix A.1. □

The intuition of Lemma 3 is similar to that of Lemma 1. Real balances and the trees are perfect substitutes as means of payment if the trees pay a high dividend. However, due to adverse selection, the households' liquid wealth becomes the value of their portfolio holdings net the informational rent, $(\delta_h - \delta_\ell)d_\ell$, that they have to compensate the dealers.

Lemma 4. Define $\underline{y} \equiv z+\delta_\ell a$ as the liquid wealth of the household for the low dividend state ($\delta = \delta_\ell$). Furthermore, denote $z^*(a, \pi, \delta_h, \delta_\ell)$ s.t. $z = \hat{q}_\ell(z, a, \pi, \delta_h, \delta_\ell)$ and $a^*(z, \pi, \delta_h, \delta_\ell)$ s.t. $a = [\hat{q}_\ell(z, a, \pi, \delta_h, \delta_\ell) - z]/\delta_\ell$, where $\hat{q}_\ell$ solves

$$u'(q_\ell) = 1 + \frac{\pi}{1-\pi}\frac{\delta_h - \delta_\ell}{\delta_\ell}u'(q_h) \tag{2.8}$$

The equilibrium contract for the low state is

(a) If $z \geq q^*$, then $q_\ell = \tau_\ell = q^*, d_\ell = 0$;

(b) If $z^*(a, \pi, \delta_h, \delta_\ell) < z < q^*$, then $q_\ell = \tau_\ell = z, d_\ell = 0$;

(c) If $0 \leq z \leq z^*(a, \pi, \delta_h, \delta_\ell)$ and $a \geq a^*(z, \pi, \delta_h, \delta_\ell)$, then $q_\ell = \hat{q}_\ell$, $\tau_\ell = z$, and $d_\ell = (\hat{q}_\ell - z)/\delta_\ell$;

(d) If $0 \leq z \leq z^*(a, \pi, \delta_h, \delta_\ell)$ and $a < a^*(z, \pi, \delta_h, \delta_\ell)$, then $q_\ell = \underline{y}$, $\tau_\ell = z$, and $d_\ell = a$.

Proof. See Appendix A.1. □

First, the equilibrium contract, as suggested by Lemma 4, is unique since $\hat{q}_\ell$ is unique. According to Lemma 3, the right-hand side of (2.8) is weakly increasing in q_ℓ while the left-hand side is decreasing. There exists a unique q_ℓ that solves (2.8) denoted as $\hat{q}_\ell$. In addition, Lemma 4 suggests a pecking-order property of payments if the trees pay a low dividend. If the household holds a sufficient amount of real money balances, i.e., $z > z^*(a, \pi, \delta_h, \delta_\ell)$, then the real balances serve as the only means of payment, i.e., $d_\ell = 0$. Otherwise, the household will first deplete the real money balances, i.e., $\tau_\ell = z$, and then use the trees to facilitate trade.

An implication of the equilibrium contracts is that bargaining under asymmetric information leads to a distortion of the terms of trade and asset transactions in the low dividend state. That is, $q_\ell \leq q_h$ and $d_\ell \leq d_h$.[10] The intuition is straightforward. According to (2.7), the informational rent is increasing in d_ℓ, since the more low-dividend trees being transacted, the higher incentives the high-state dealers mimic those in the low-state and take advantage of the informational advantage. Therefore, by distorting the terms of trade in the low-dividend state, households reduce those incentives and effectively save on the informational rent.

2.3.3 Households' Portfolio Choices

According to the equilibrium contracts characterized in Section 2.3.2 and the value function, (2.3), the expected value of the household entering Stage 1 becomes

$$\mathbb{E}V(z, a, \delta) = (1-\alpha)S_0 + \alpha\{(1-\rho)S_1 + \rho[\pi S_h + (1-\pi)S_\ell]\} + z + \delta^e a + W(0, 0, \delta) \quad (2.9)$$

[10] It is obvious that there are two cases under which $q_\ell = q_h$. First, when $z \geq q^*$, the quantities of the special good traded achieve the optimal level in both states, i.e. $q_h = q_\ell = q^*$. Second, if $a < a^*(z, \pi, \delta_h, \delta_\ell)$, we have $q_h = q_\ell = z + \delta_\ell a$. For the rest of the cases, if $z^*(a, \pi, \delta_h, \delta_\ell) < z < q^*$, then $q_\ell = z$ and $q_h = min\{q^*, \bar{y}\}$. If $0 \leq z \leq z^*(a, \pi, \delta_h, \delta_\ell)$ and $a \geq a^*(z, \pi, \delta_h, \delta_\ell)$, then $q_\ell \leq \underline{y} \leq \bar{y} - (\delta_h - \delta_\ell)d_\ell = q_h$ as $d_\ell \leq a$. Next, by the dealers' two incentive-compatible constraints, we have $(\tau_h - \tau_\ell) + \delta_\ell(d_h - d_\ell) \leq q_h - q_\ell \leq (\tau_h - \tau_\ell) + \delta_h(d_h - d_\ell)$, which implies $d_\ell \leq d_h$.

and S_i, where $i \in \{0, 1, h, \ell\}$, denotes the trade surplus from different types (i) of bilateral matches. For example, with probability $1 - \alpha$, the household is not matched with a dealer and uses real money balances as the only means of payment. In this case, the trade surplus is defined as $S_0 \equiv u[q_0(z)] - q_0(z)$. With a probability α, a household meets a dealer and forms a Type I meeting with a probability $1 - \rho$, in which the trade surplus is $S_1 \equiv u[q_1(z, a, \delta)] - q_1(z, a, \delta)$. With the complementary probability ρ, they form a Type II meeting, in which the trade surplus is $S_h \equiv u[q_h(z, a, \delta)] - q_h(z, a, \delta) - (\delta_h - \delta_\ell)d_\ell(z, a, \delta)$ for the high-dividend state, and $S_\ell \equiv u[q_\ell(z, a, \delta)] - q_\ell(z, a, \delta)$ for the low-dividend state.

Now, we can derive the objective function for the household's optimal portfolio choices. Let the set of all households, $\mathcal{H}$ be the interval $[0, 1]$, and let $[z(j), a(j)]$ be the household j's, $j \in \mathcal{H}$ demand for real money balances and the trees. Then,

$$[z(j), a(j)] = arg \max_{z,a}\{-iz-(\frac{\phi_a - \phi_a^*}{\beta})a+(1-\alpha)S_0+\alpha[(1-\rho)S_1+\rho[\pi S_h+(1-\pi)S_\ell]]\} \quad (2.10)$$

where i is the nominal interest rate by applying the stationary monetary equilibrium definition and the Fisher equation $i = (\gamma - \beta)/\beta$, and $\phi_a^* \equiv \beta\delta^e$ denote the fundamental value of the trees.

According to (2.10), the household's optimal portfolio choices $[z(j), a(j)]$ satisfy the following first-order conditions if $i \geq 0$ and $\phi_a \geq \phi_a^*$,

$$-i + (1-\alpha)S_{0,z} + \alpha\{(1-\rho)S_{1,z} + \rho[\pi S_{h,z} + (1-\pi)S_{\ell,z}]\} \leq 0, \text{ "=" if } z > 0 \quad (2.11)$$

$$-\frac{\phi_a - \phi_a^*}{\beta} + \alpha\{(1-\rho)S_{1,a} + \rho[\pi S_{h,a} + (1-\pi)S_{\ell,a}]\} \leq 0, \text{ "=" if } a > 0 \quad (2.12)$$

where $S_{i,j} \equiv \partial S_i / \partial j$ denotes the first-order partial derivatives of the trade surpluses, $i \in \{0, 1, h, \ell\}$, with respect to the holdings of the asset $j \in \{z, a\}$.[11] Intuitively, at optimum, the marginal benefit has to be equal to the marginal cost of carrying an additional unit of asset over to the next-period Stage 1. The nominal interest rate, i, captures the marginal cost for the real balances and $(\phi_a - \phi_a^*)/\beta$ for the trees. The marginal benefit comes from the real balances and trees serving as mediums of exchange and facilitating the bilateral trades, i.e., a liquidity premium.[12] For the simplicity of notation, let $L(q) = u'(q) - 1$. Furthermore, I focus on $L(q)$ being decreasing and convex, i.e., $L'(q) < 0$ and $L''(q) > 0$ for $q < q^*$.

2.3.4 Steady-State Equilibrium

In this section, I characterize the steady-state equilibrium. The definition of the steady-state equilibrium is as follows.

Definition 1. The steady-state equilibrium consists of a list of quantities traded $\{(q_1, \tau_1, d_1), (q_h, \tau_h, d_h), (q_\ell, \tau_\ell, d_\ell)\}$, the real asset price ϕ_a, and portfolio holdings (z, a), such that

(1) Given the nominal interest rate (i) and the real asset price (ϕ_a), $(z, a) \in \mathbb{R}_+^2$ solves the household's optimal portfolio choice problem;

(2) $\{(q_1, \tau_1, d_1), (q_h, \tau_h, d_h), (q_\ell, \tau_\ell, d_\ell)\} \in \mathbb{R}_+^3 \times \mathbb{R}_+^3 \times \mathbb{R}_+^3$ solves the bargaining problems;

[11] In Appendix A.2, I show that the objective function of the household's portfolio choice, (2.10), is jointly concave in (z, a). Hence, the first-order conditions, (2.11)-(2.12), are necessary and sufficient for the optimization problem.

[12] Neither the dealers nor the producers have incentives to hold any real balances when they enter Stage 1 since there is an opportunity cost, $i \geq 0$, and they do not benefit from the liquidity value of the real balances. Hence, I only focus on the households' portfolio choice problem.

(3) Market clearing conditions are satisfied: $\int_{j\in\mathcal{H}} z(j)\,dj = Z$ and $\int_{j\in\mathcal{H}} a(j)\,dj = A$, where $Z \equiv \phi_m M = \phi'_m M'$ denotes the aggregate real balances for the steady state.

Proposition 1. A steady-state equilibrium exists and is unique.

Proof. See Appendix A.1. □

Now, I summarize the relevant regions of the steady-state equilibrium in Figure 2.2 as functions of the nominal interest rate, i, and the real asset supply, A.[13] Firstly, the threshold $i^*(A)$ determines whether the low-quality asset are traded in the Type II meetings, i.e. $Z(i^*) = \hat{q}_\ell$. More specifically, Region 1 corresponds to $0 < i < i^*(A)$, then we have $d_\ell = 0$. As Lemma 4 suggests, if the household's real money balance holding is sufficient for consuming $\hat{q}_\ell$, the low-dividend trees will not serve as a means of payment due to adverse selection. In this case, the cost of holding real money balances, i, has to be sufficiently low. Furthermore, the threshold, $i^*(A)$, is decreasing in A when A is sufficiently low. Intuitively, the households would demand more real money balances to facilitate trade, increasing the nominal interest rate at the threshold. When A is abundant, holding more real money balances does not bring more liquidity, making the nominal interest rate threshold constant.

The second threshold, $A^*(i)$, determines whether households distort the terms of trade in the low dividend state. For example, in Region 3, where $i > i^*(A)$ and $A < A^*(i)$, no distortion occurs, and the equilibrium contract is pooling, i.e., $q_h = q_\ell$, $\tau_h = \tau_\ell$, and $d_h = d_\ell$. Intuitively, households have no incentives to distort the terms of trade since their portfolio holdings are scarce. As a result, the households will pay with all their portfolio

[13]The relevant region is derived based on Lemmas 3 and 4. See Appendix A.3 for more details.

holdings in the bilateral meetings even though they have to compensate the dealers with the informational rent when the asset dividend is high. On the other hand, in Regions 1 and 2, the households' holdings of trees are abundant, and the equilibrium contract is separating. According to Lemmas 3 and 4, the households will distort the terms of trade in the low dividend state, i.e., $q_\ell < q_h$ and $d_\ell < d_h$, to save on the informational rent.

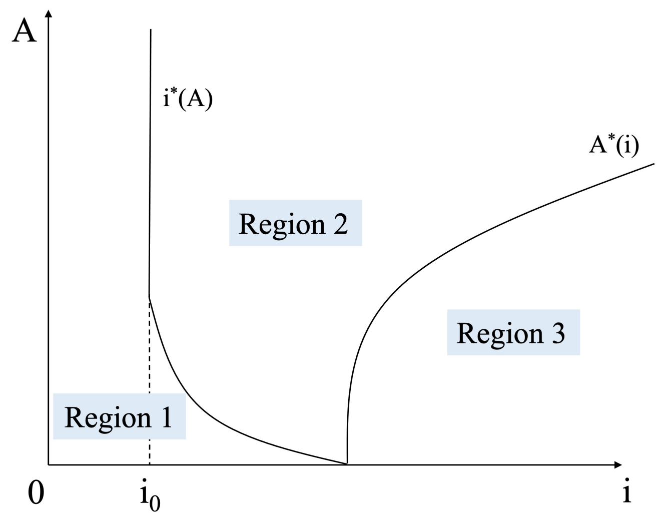

Figure 2.2: Steady-state equilibrium: relevant regions.

2.3.5 Asset Liquidity, Private Information, and Monetary Policy

In this section, I study the role of the nominal interest rate and the fraction of informed dealers on the steady-state equilibrium. The results are summarized in Table 2.1. The proof is relegated to Appendix A.4.

The results on the effects of monetary policy are very intuitive. As the nominal interest rate increases, the households face a higher cost of holding real money balances.

ζ	$\frac{\partial Z}{\partial \zeta}$	$\frac{\partial q_1}{\partial \zeta}$	$\frac{\partial q_h}{\partial \zeta}$	$\frac{\partial q_\ell}{\partial \zeta}$	$\frac{\partial \phi_a}{\partial \zeta}$
i	$-$	$-^*$	$-^*$	$-$	$+^*$
ρ	$+$	$+^*$	$+^*$	$+$	$-^\dagger$

Table 2.1: Effects of monetary policy and private information ($i > 0$). Note: * means no change when q_1 and q_h achieve the optimal level q^* in equilibrium. † means the relationship holds under certain conditions specified in Lemma 5.

Therefore, they lower the demand for real money balances and shift their demand into the trees, which is a (imperfect) substitute for fiat money in facilitating bilateral trades. Consequently, the asset price increases as the demand for the trees increases. Furthermore, since the equilibrium allocations, (q_1, q_h, q_ℓ), all increase in the real balance holdings, they all decrease in the nominal interest rate.

Then, I analyze the effect of the fraction of informed dealers on the demand for real money balances. Intuitively, when ρ increases, information asymmetry is more severe because there is a higher probability of meeting an informed dealer and trading in the Type II meeting. As a result, the marginal benefit of holding real money balances, i.e., $(1-\rho)S_{1,z} + \rho[\pi S_{h,z} + (1-\pi)S_{\ell,z}]$, is higher since $L(q)$ is decreasing and convex. Therefore, the demand for real money balances increases, and the equilibrium allocations, (q_1, q_h, q_ℓ), also increase.

Next, I turn to the impact of the fraction of informed dealers on asset liquidity. First, there is a direct effect on the marginal benefit of holding an additional unit of the tree when the probability of a household trading with an informed dealer is higher. However, the sign of the direct effect is ambiguous, which depends on the equilibrium allocations, (q_1, q_h, q_ℓ), for each region.[14] Second, there is a negative general equilibrium effect on the

[14]That is, the sign of $\pi S_{h,a} + (1-\pi)S_{\ell,a} - S_{1,a}$ is indeterminate. See Appendix A.4.

liquidity premium because the households shift their demand for the trees to real balances, i.e., $\partial Z/\partial \rho > 0$. Therefore, the sign of $\partial \phi_a/\partial \rho$ is not apparent because of the direct effect.

I investigate two sufficient conditions as follows for a negative direct effect. That is, the marginal benefit for households carrying the trees into the Type I meetings is higher than that for the Type II meetings. Consequently, these conditions imply that a higher fraction of informed dealers impedes the asset liquidity.

Lemma 5. The sufficient conditions for $\partial \phi_a/\partial \rho < 0$ are:

(a) The nominal interest rate is sufficiently low, i.e., $0 < i < i^*(A)$.

(b) Under the CRRA utility function with the risk-aversion parameter $\sigma < 1$, the nominal interest rate is sufficiently high and households' liquid wealth is scarce, i.e., $i \geq i^*(A)$ and $A < A^*(i)$.

Proof. See Appendix A.4. □

The first condition suggests that holding real money balances should be sufficiently inexpensive, such that the steady-state equilibrium lies in Region 1. According to Lemma 4, households do not use the trees as a means of payment in the low dividend state. Therefore, the marginal benefit of carrying the low-dividend asset into Type II meetings is zero, i.e., $S_{\ell,a} = 0$. If the trees' dividend is high, the households' liquid wealth in the Type II meetings is higher than in the Type I meetings, i.e., $z + \delta_h a > z + \delta^e a$. In this case, the marginal benefit for the households to carry the high-dividend asset into the Type II meetings is lower because the households' liquidity constraint is less binding than that in the Type I meeting. Therefore, the expression in footnote 13 is negative, suggesting that the households' demand for the trees is higher in the Type I meetings.

The second condition suggests that the nominal interest rate should be sufficiently high, and asset supply should be sufficiently low, such that the steady-state equilibrium lies in Region 3. Furthermore, households' liquid wealth in equilibrium must be scarce. That is, $Z(i) + \delta^e A < q^*$, where $Z(i)$ solves (2.11). As a result, households must deplete all their portfolio holdings in all the bilateral meetings. In the Type I meetings, households trade the trees based on the expected dividend because both the households and the dealers are uninformed about the actual dividend. In the Type II meetings, households incur the informational rent on their asset holdings and cannot save on it by distorting the asset payments. As a result, the marginal benefit for the households carrying the trees into the Type II meetings is lower. Again, the expression in footnote 13 is negative.

2.3.6 Monetary Policy, Information, and Equilibrium Welfare

In this section, I turn to the normative properties of the steady-state equilibrium and analyze the effect of information friction on welfare. I define the welfare as the households' expected trade surplus from the bilateral matches in Stage 1,

$$\mathcal{W} = (1-\alpha)S_0 + \alpha\{(1-\rho)S_1 + \rho[\pi S_h + (1-\pi)S_\ell]\} \tag{2.13}$$

Firstly, the welfare function (2.13) suggests that the economy is in Pareto efficiency where $i = 0$. That is, the optimal monetary policy implements the Friedman rule. Since the real money balance holding is abundant, the agent uses the real money balances as the only medium of exchange and trades the first-best output level, q^*, in all the bilateral meetings. Since it is costless to hold real money balances, the trees possesses zero liquidity premium, and the asset price is equal to the fundamental value, $\phi_a = \phi_a^*$.

Next, when deviating from the Friedman rule, i.e., $i > 0$, I find that the severity of information asymmetries affects the welfare through two opposing forces.

$$\frac{\partial \mathcal{W}}{\partial \rho} = \underbrace{\alpha[\pi S_h + (1-\pi)S_\ell - S_1]}_{\text{direct effect} < 0}$$
$$+ \underbrace{(1-\alpha)\frac{\partial S_0}{\partial \rho} + \alpha\{(1-\rho)\frac{\partial S_1}{\partial \rho} + \rho[\pi\frac{\partial S_h}{\partial \rho} + (1-\pi)\frac{\partial S_\ell}{\partial \rho}]\}}_{\text{general equilibrium effect} > 0} \quad (2.14)$$

On the one hand, there is a direct effect from an increase in ρ. Welfare decreases since the households are risk-averse, and the trade surplus functions are concave. On the other hand, there is a positive general equilibrium effect. An increase in ρ leads the households to shift their demand for the trees into real money balances, i.e., $\partial Z/\partial \rho > 0$ (see Table 1). As a result, an increasing ρ leads to higher terms of trade in all the bilateral matches, which is welfare-improving.

The following numerical example illustrates the two opposing effects on welfare when ρ increases. As shown in Figure 2.3, welfare first decreases in ρ, then increases.[15] Also, I use the example to study the comparative statics for a change in the nominal interest rate, i, and in the asset supply, A, which are essential for characterizing the relevant regions and determining asset liquidity and the trade surplus. On the left panel, I fix $A = 0.5$ and increase i from 0.1 to 0.12. Graphically, welfare declines for all $\rho \in [0, 1]$ due to inflation. The cost of holding real balances is more expensive, and the terms of trade are low in all bilateral meetings. In addition, the general equilibrium effect is attenuated because

[15] I adopt the CRRA utility function, $u(q) = 2\sqrt{q}$. Other parameter values are $\beta = 0.97$, $\alpha = 0.5$, $\pi = 0.1$, $\delta_h = 1$, and $\delta_\ell = 0.5$.

it is more costly for households to shift their demand of portfolio choices to real money balances. On the right panel, I fix $i = 0.12$ and increase A from 0.2 to 0.8. Firstly, when the asset supply is more abundant, households tend to pay with the trees that incur higher informational rent. Hence, the trade surplus in the high dividend state of the Type II meeting decreases. Therefore, welfare declines for all $\rho \in [0, 1]$ as A increases. Secondly, the general equilibrium effect is strengthened when the asset supply is larger. Intuitively, households have more incentives to shift their demand to real money balances to save on the informational rent by distorting the payment with trees.

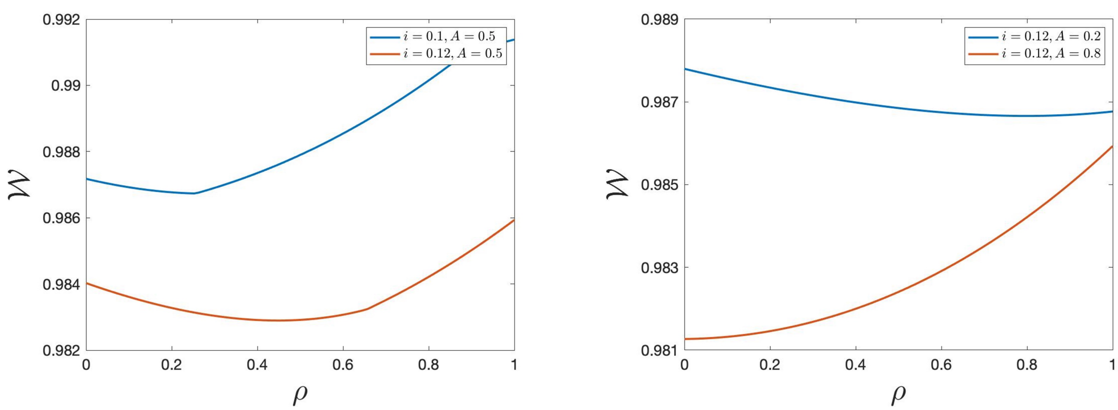

Figure 2.3: Degree of information asymmetry and welfare. Left: an increase in the nominal interest rate (i); Right: an increase in the real asset supply (A).

2.4 Private Information Acquisition

2.4.1 Relevant Regions with Varying ρ

Before I characterize the steady-state equilibrium with endogenous ρ, I start with a graphical illustration of the relevant regions when ρ varies. According to the relevant regions described in Figure 2.2 in the previous section, with exogenous ρ, each relevant region has different implications on asset liquidity and equilibrium allocations. In this section, I show that the two thresholds that determine the relevant regions depend on ρ.

As shown in Figure 2.4, when ρ increases, the two thresholds both shift to the right. Consequently, an equilibrium would move from Region 3 to Region 2 to Region 1. Intuitively, as information asymmetry is more severe, households have more incentives to distort the terms of trade in the low dividend state to save on informational rent (i.e., Region 3 to Region 2). Furthermore, according to Lemma 4, real money balances become more preferable means of payment. Consequently, households' demand for real balances increases, and $i^*(A)$ increases as ρ increases, leading to $d_\ell = 0$ (i.e., Region 2 to Region 1).

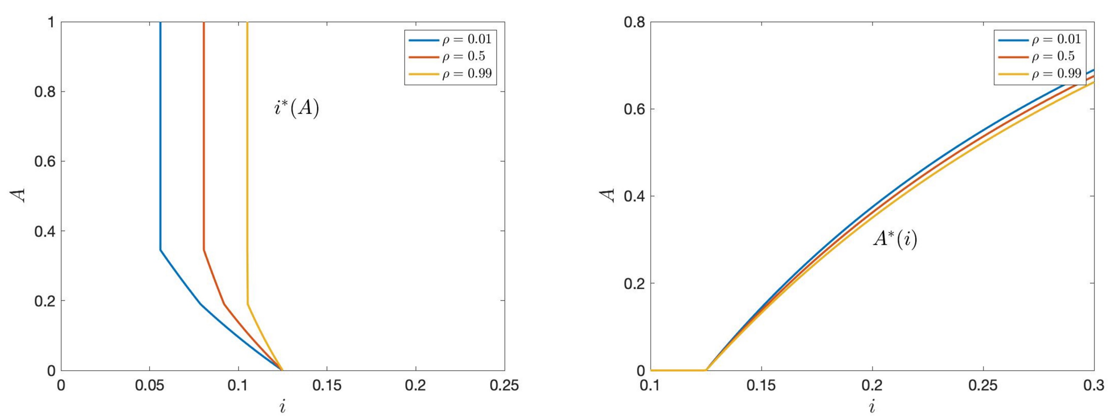

Figure 2.4: Relevant regions with varying ρ.

2.4.2 Steady-State Equilibrium

In this section, I endogenize the severity of information asymmetries by allowing the dealers to acquire private information regarding the asset dividends. The information acquisition decisions are made before matches are formed in Stage 1, associated with a flow cost, K. Furthermore, the assumption that whether a dealer has acquired private information is common knowledge remains.

The dealers make information acquisition decisions by comparing the value of private information with the cost. Conditional on a fraction $\rho \in [0,1]$ of other dealers being informed, let $\Pi(\rho)$ denote the dealer's benefit to become informed and denote $\Pi_1(\rho)$ and $\Pi_2(\rho)$ as the dealer's trade surplus in the Type I and Type II meetings. We define $\Pi(\rho) = \Pi_2(\rho) - \Pi_1(\rho)$. That is, the value of private information is the gain from being informed net the opportunity cost of not being informed. Given the bargaining protocol discussed in Section 2.3.2, $\Pi_1(\rho) = 0$ as the households extract all the trade surplus from the take-it-or-leave-it offer in the Type I meeting. In the Type II meeting, the households leave no surplus to the dealers in the low dividend state according to (2.6). However, in the high dividend state, the dealers benefit from the informational rent as shown in (2.7). Hence, $\Pi_2(\rho) = \alpha\pi(\delta_h - \delta_\ell)d_\ell(\rho)$, and

$$\Pi(\rho) = \alpha\pi(\delta_h - \delta_\ell)d_\ell(\rho) \tag{2.15}$$

Intuitively, the value of private information is driven by the informational rent that comes from dealers' possession of private information.[16] According to Lemmas 3 and 4, I express

[16] In Appendix A.5.4, I show that, when the dealers are chosen to make a take-it-or-leave-it offer, the value of private information is non-positive. Therefore, the assumption that the households making the take-it-or-leave-it offer allows us to focus on the upper bound of the dealers' private information acquisition.

the value of private information for each relevant region in Figure 2.2 as follows,

$$\Pi(\rho) = \begin{cases} 0, & \text{if } 0 \leq i < i^*(A) \\ \alpha\pi\frac{\delta_h - \delta_\ell}{\delta_\ell}[\hat{q}_\ell(\rho) - Z(\rho)], & \text{if } i \geq i^*(A), A \geq A^*(i) \\ \alpha\pi(\delta_h - \delta_\ell)A, & \text{if } i \geq i^*(A), A < A^*(i) \end{cases} \tag{2.16}$$

First, the value of information is independent of ρ in Regions 1 and 3. Intuitively, in Region 1, the real money balance holdings are sufficient as the cost of holding real money balances is sufficiently low. Therefore, the households will not use the low-dividend asset as payment in Type II meetings, i.e., $d_\ell = 0$, according to Lemma 4. Therefore, the benefit for the dealers to acquire private information is zero. In Region 3, the households' liquid wealth is scarce. Therefore, the households will deplete their entire portfolio wealth in facilitating the bilateral trades. The value of private information is constant since households must pay informational rent for depleting their asset holdings as payments, i.e., $d_\ell = A$.

Lemma 6. $\Pi(\rho)$ is weakly decreasing in ρ.

Proof. See Appendix A.1. □

Lemma 6 suggests that, in Region 2, $\Pi(\rho)$ is monotonically decreasing in ρ. This implies a strategic substitutability among the dealers' information acquisition decisions in Region 2. Intuitively, private information acquisition leads to more severe information asymmetries in the bilateral trades. Therefore, as shown in Figure 2.4, the steady-state equilibrium with endogenous ρ will switch from Region 3 to Region 2 to Region 1, implying a distortion on the terms of trade in the low dividend state in order to save on the households' informational rent. Consequently, the value of private information, directly driven by the informational rent, will be reduced when there are more informed dealers, i.e., a strategic substitutability among the dealers' information acquisition decisions.

Proposition 2. (Characterization of Nash equilibrium)

(a) The equilibrium value of ρ^* satisfies one of the following configurations:

(i) If $\Pi(0) < K$, there exists a unique pure strategy Nash equilibrium with $\rho = 0$;

(ii) If $\Pi(1) > K$, there exists a unique pure strategy Nash equilibrium with $\rho = 1$;

(iii) If $\exists \rho \in [0, 1]$ s.t. $\Pi(\rho) = K$, then these values are mixed-strategy Nash equilibria.

(b) There exists a unique Nash equilibrium ρ^* that characterizes the dealers' optimal decision for private information acquisition.

Part (a) is straightforward. If the cost of acquiring information is sufficiently high, such that $\Pi(0) < K$, where $\Pi(0)$ is the maximum value of private information the dealers can extract, then there are no dealers acquiring information in equilibrium, i.e., $\rho = 0$. On the other hand, if the information cost is sufficiently low, such that $\Pi(1) > K$, where $\Pi(1)$ is the minimum value of private information, dealers optimally choose to acquire information. A unique equilibrium exists as all the dealers become informed, i.e., $\rho = 1$. Mixed strategy Nash equilibria exist if the information cost is neither too high nor too low. Therefore, The values for ρ that satisfy $\Pi(\rho) = K$ constitute a best response for the dealers' information acquisition decision.

Furthermore, Part (b) of Proposition 2 is directly implied by Lemma 6. Moreover, if the nominal interest rate is sufficiently small (i.e., $0 \leq i < i^*(A)$), the unique pure strategy Nash equilibrium is $\rho^* = 0$ since the value of private information is zero by Lemma

4. Intuitively, the cost of holding real money balances is sufficiently low, and there is no need to use the low-dividend asset as payment. Hence, for all dealers, the best response is always not to acquire private information about the asset dividend. If $i \geq i^*(A)$ and $A \geq A^*(i)$, there exists a unique mixed-strategy Nash equilibrium, ρ^*, that solves $\Pi(\rho) = K$, where $K = \bar{K}$ is the degenerate information cost.[17] Lastly, if $i \geq i^*(A)$ and $A < A^*(i)$, the value of information is independent in ρ. Therefore, we have a unique pure strategy Nash equilibrium depends on whether the information cost exceeds the value of private information or not.

Discussion. The strategic substitutability among dealers' information acquisition decisions is crucial for the uniqueness of the Nash equilibrium and for the future analysis of the economic fundamentals that affect the information acquisition decisions. In this paper, the underlying mechanism is that information acquisition can intensify information asymmetries, potentially hindering the tree's role as a means of payment. Therefore, when more dealers acquire private information regarding the dividend of the Lucas trees, the value of private information declines as the transactions of the trees are distorted. In contrast, information acquisition may lead to strategic complementarity and multiple equilibria as it mitigates information asymmetries. For example, in Lester et al. (2012), Rocheteau et al. (2018) and Geromichalos et al. (2021), sellers invest in information that increases their acceptance of the Lucas trees (or bonds). Additionally, in Choi and Rocheteau (2024), sellers acquire an informative signal about consumers' privately-known preferences.

[17] Lester et al. (2012) assume an increasing information cost in ρ to construct stable mixed-strategy Nash equilibria. In contrast, the strategic substitutability by Lemma 6 suggests that the Nash equilibrium always exists and is unique. Therefore, I consider a degenerate information cost for all the dealers to keep the analysis tractable.

2.4.3 Monetary Policy Implications

Once we have characterized the unique Nash equilibrium for the dealers' information acquisition decisions, it becomes obvious that the decision, ρ^*, depends on the model parameters. Therefore, as a starting point, I explore the monetary policy implications on the dealers' decisions to acquire private information and, in turn, on asset liquidity. I consider a money injection, i.e., inflation, which leads to an increase in the nominal interest rate (i) according to the Fisher effect.

I start with two special cases with the pure strategy Nash equilibrium. First, for a sufficiently small nominal interest rate such that the steady-state equilibrium lies in Region 1, $\rho^* = 0$ since the value of private information is zero. Hence, by (A.4.2), $\phi_a = \phi_a^* + \beta\alpha\delta^e L(q_1)$. Second, we have $\rho^* = 1$ for a sufficiently large nominal interest rate such that the steady-state equilibrium lies in Region 3, assuming $\Pi(\rho) = \alpha\pi(\delta_h - \delta_\ell)A > \bar{K}$. By (B.2.12), $\phi_a = \phi_a^* + \beta\alpha[\delta_\ell L(q_2) - \pi(\delta_h - \delta_\ell)]$. Therefore, for both cases, increasing the nominal interest rate has no effect on the dealers' information acquisition decisions, and the results in Table 2.1 still hold. Intuitively, real money balances and the trees serve as competing mediums of exchange. With higher inflation, the return of money is lower, and the households shift their portfolio holdings from real money balances to the trees.

The rest of the analysis focuses on Region 2 where the nominal interest rate is neither too small nor too large, in which we have a mixed-strategy Nash equilibrium, $\rho^* \in (0, 1)$, characterizing the fraction of informed dealers.

Proposition 3. (Monetary policy and private information acquisition) If $i \geq i^*(A)$ and $A \geq A^*(i)$, low-dividend asset transactions (d_ℓ) is weakly increasing in the nominal interest rate (i). Therefore, the value of private information (Π) and information acquisition (ρ^*) increases with higher nominal interest rate.

The proof is omitted as it is implied by Lemma 6. Focusing on Region 2, I show that $\partial \hat{q}_\ell / \partial Z < 1$ in the proof of Lemma 6, implying that d_ℓ is decreasing in Z and then, increasing in i. Intuitively, the households will increase their use of trees as payments in the bilateral trades since it is more costly to hold real money balances. Therefore, the value of private information (2.15) is increasing in the nominal interest rate. Consequently, private information acquisition is encouraged as the trees becomes more useful as a means of payment, i.e., $\partial \rho^* / \partial i \geq 0$.

Monetary policy and asset liquidity. An implication of Proposition 3 is that an increase in the nominal interest rate may have a non-monotonic effect on asset liquidity. More specifically, the effect of monetary policy on asset liquidity can be separated into two opposing forces. First, money injection positively affects asset liquidity because real money balances and the trees are competing as mediums of exchange. Second, according to Proposition 3, a higher fraction of dealers choose to acquire private information as the value of private information increases in the nominal interest rate. Therefore, asymmetric information becomes more severe, which impedes asset liquidity under certain conditions suggested by Lemma 5.

I consider a numerical example as illustrated in Figure 2.5.[18] On the left panel, for sufficiently low interest rate (i.e., Region 1) and sufficiently high interest rate (i.e., Region 3), the model suggests a pure-strategy Nash equilibrium such that $\rho^* = 0$ and $\rho^* = 1$,

[18] The parameter values are the same as for Figure 2.3 (see footnote 14), and $A = 0.3$ and $\bar{K} = 0.005$. Furthermore, those parameter values satisfy the sufficient conditions suggested by Lemma 5.

respectively. Therefore, the dealers' information acquisition decisions do not depend on the nominal interest rate, and only the first channel plays a role through which a money injection increases the asset liquidity. However, when the interest rate is neither too high nor too low (i.e., Region 2), we may have a mixed-strategy Nash equilibrium, ρ^*, that depends on the nominal interest rate following Proposition 3. As illustrated in the right panel of Figure 2.5, when taking endogenous information acquisition into account, monetary policy can have a negative effect on the liquidity premium through the mixed-strategy Nash equilibrium. According to Lemma 5 and Proposition 3, a higher nominal interest rate will encourage private information acquisition that leads to more severe information asymmetries and, in turn, impedes asset liquidity.

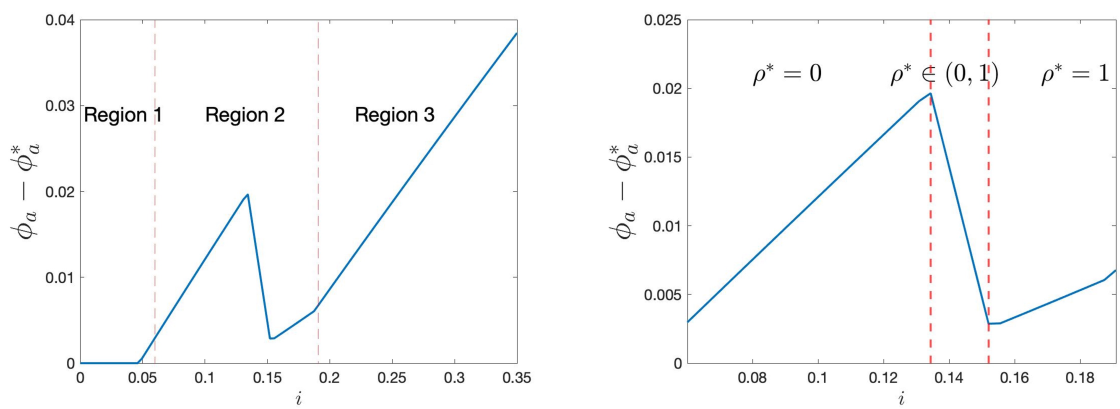

Figure 2.5: Effects of monetary policy (i) on the liquidity premium ($\phi_a - \phi_a^*$). Left: for each relevant regions; Right: for Region 2, where a mixed-strategy Nash equilibrium appears.

Welfare cost of inflation. In the conventional wisdom in monetary economics, inflation incurs a welfare cost, making real money balances more costly to hold and the households' liquidity constraints more binding.[19] Now, I explore the welfare implications of monetary

[19] See Lucas (2000) for a survey. Recent studies on the welfare cost of inflation in the New-Monetarist

policy with the presence of private information acquisition. As illustrated in Figure 2.6, the welfare cost of inflation is intensified as inflation increases.[20] The intuition follows Proposition 3. When the nominal interest rate is sufficiently low, no dealers acquire private information. In this case, the bilateral trades are not subject to information asymmetries since both the households and the dealers are symmetrically uninformed. Therefore, the welfare cost of inflation is equivalent to treating $\rho = 0$ to be exogenous. However, increased inflation will make real money balances less valuable, and the bilateral trades will be facilitated with the trees as a means of payment. Therefore, the value of private information rises, which encourages private information acquisition, i.e., ρ^* increases. As more dealers choose to acquire information, information asymmetries become more severe, worsening the social welfare of the risk-averse households.

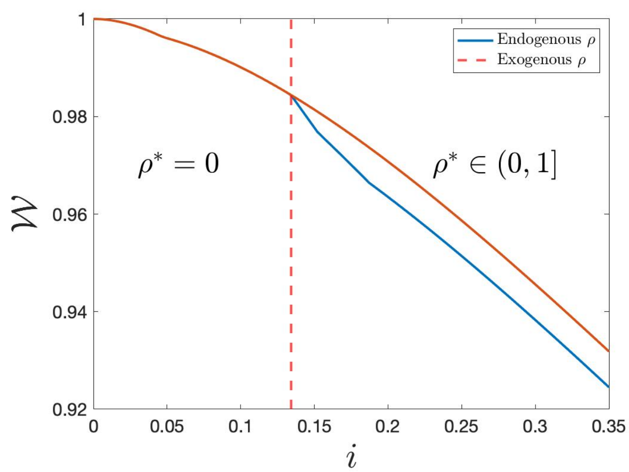

Figure 2.6: Effects of monetary policy (i) on equilibrium welfare ($\mathcal{W}$).

literature include Lagos and Wright (2005), Craig and Rocheteau (2008), Chiu and Molico (2010), and Rocheteau (2012).

[20]The parameter values are the same as for Figure 2.3 (see footnote 14), and $A = 0.3$ and $\bar{K} = 0.005$. For the exogenous ρ case, I set $\rho = 0$.

2.4.4 Impacts of Other Economic Fundamentals

The determination of ρ^* is not structurally invariant. According to (2.15), the benefit for the dealers to acquire private information is affected by the search frictions (α), the average quality of the trees (π), and the riskiness of the trees ($\delta_h - \delta_\ell$). In this section, I investigate the effects of these economic fundamentals on the dealers' decisions for private information acquisition.

Proposition 4. (Search friction and private information acquisition) When the degree of search friction is less severe (i.e., α increases), low-dividend asset transactions (d_ℓ) is weakly increasing, then the value of private information (Π) increases. Hence, acquisition of private information (ρ^*) increases.

Proof. See Appendix A.1. $\square$

The intuition is straightforward. Lower search friction will increase the probability of dealers being matched and extracting the informational rent. Furthermore, households have a higher chance of liquidating their asset holdings with dealers. As a result, private information regarding the asset's dividend is more valuable to the dealers. Therefore, a higher fraction of dealers acquire private information, making the information asymmetries in the economy more severe, i.e., $\partial\rho^*/\partial\alpha \geq 0$.

Next, I study the impacts of asset fundamentals on the dealers' private information acquisition decisions. I investigate the effects of the average quality, determined by π, and the riskiness of the trees, represented by a mean-preserving spread over the dividends, i.e., $\delta_h - \delta_\ell$.

Proposition 5. (Asset fundamentals and private information acquisition)

(a) The effects of asset fundamentals on the value of private information (Π):

(i) As $\pi \to 0$ or $\delta_h - \delta_\ell \to 0$, then $\Pi(\rho) \to 0$;

(ii) As $\pi \to 1$ or $\delta_h - \delta_\ell \to \infty$, then $d_\ell(\rho) \to 0$ and $\Pi(\rho) \to 0$.

(b) The effects of an increase in the average quality or riskiness of the trees on private information acquisition is non-monotonic.

The proof is as follows. First, according to (2.15), the value of private information approaches 0 if π or $\delta_h - \delta_\ell$ approach 0. With a positive information cost, K, dealers will not acquire private information, i.e., $\rho^* = 0$, as $\Pi(\rho) < K$ for all ρ. The second part of Proposition 5(a) is implied by (2.8). As $\pi \to 1$ or $\delta_h - \delta_\ell \to \infty$, then $\hat{q}_\ell \to Z$ and households distort the informational rent to zero, i.e., $d_\ell \to 0$. The dealers become reluctant to acquire private information. As shown in Figure 2.7, those effects on the determination of ρ^* are non-monotonic.[21]

2.5 Application: The 2007-2008 Financial Crisis

In this section, I discuss an application of the model to explain the recent financial crisis in 2007-2008. Gorton (2010) suggests that a crisis is an event where information-insensitive securities become information-sensitive, i.e., a regime switch. Specifically, only some agents obtained private information to speculate on the value of the securities due to

[21] I consider the CRRA utility function, $u(q) = 2\sqrt{q}$, and $\beta = 0.97$, $\alpha = 0.5$, $i = 0.15$, and $A = 0.3$. For the left panel, I set $\delta_h = 1$, $\delta_\ell = 0.5$, and $\bar{K} = 0.005$. For the right panel, $\pi = 0.1$, $\bar{K} = 0.007$, and I normalize $\delta^e = 1$. The increase in the mean-preserving spread is accomplished by decreasing δ_ℓ by 0.01 starting from $\delta_\ell = 1$ until $\delta_\ell = 0.01$.

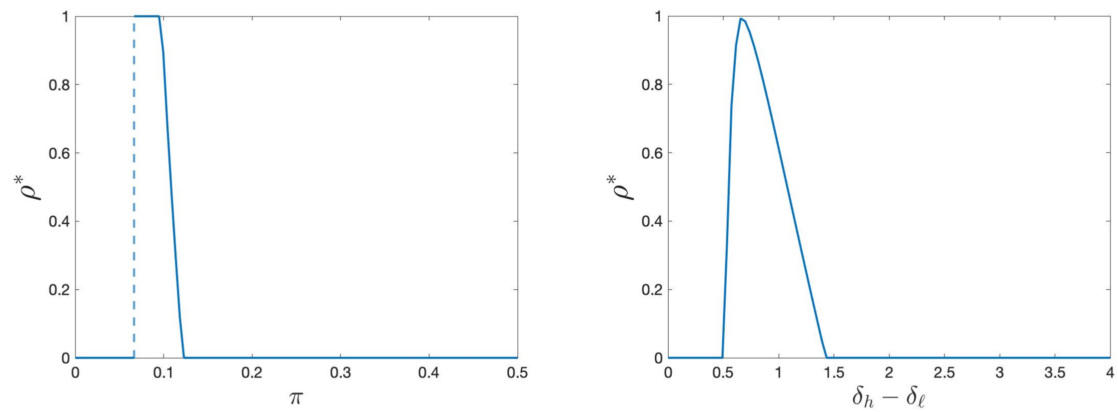

Figure 2.7: Effects of asset fundamentals on ρ^*. Left: an increase in the average asset quality (π); Right: an increase in the riskiness of assets ($\delta_h - \delta_\ell$).

the complexity of the security chain. As Gorton (2010) describes, the "regime switch" was devastating, causing the securties to become highly illiquid.[22]

2.5.1 Information Sensitivity and Information Acquisition

The model formalizes the "regime switch" - an endogenous adverse selection problem generated by private information acquisition. The information insensitivity corresponds to $\rho^* = 0$, so the dealers do not produce private information. In this case, all the bilateral trades happen in the Type I meetings, in which the households and the dealers are symmetrically uninformed about the dividend. In this case, the model suggests that the securities can circulate as mediums of exchange or collaterals and are perfect substitutes for real money balances in facilitating bilateral trades.

With higher incentives for dealers to acquire information regarding the dividend, more bilateral trades are subject to asymmetric information in the Type II meetings. Trans-

[22] Gorton (2009) and Gorton and Metrick (2012) document a jump in the repo market haircuts for different collaterals during the crisis, implying a massive deleveraging and an absence of buyers for these securities. For more empirical evidence, see Covitz et al. (2013), Kacperczyk and Schnabl (2010), and Dang et al. (2020).

actions of the low-quality assets are stopped, i.e., $d_\ell = 0$, due to a more severe adverse selection problem when the holdings of real balances are sufficient. Therefore, the model implies that the monetary authority should keep the nominal interest rate low to the extent that bilateral trades are facilitated by real money balances, which are always information-insensitive and, in turn, lower the benefit of producing private information.

2.5.2 The Launch of the ABX Index

Gorton (2009) and Gorton (2010) discuss that the launch of the ABX index to some extent triggered the regime switch, leading to the drying-up of liquidity in the mortgage-backed securities (MBS) market. Prior to the crisis, the AAA-rate tranches of MBS were traded extensively in the U.S. repo market. The securities were information insensitive as house prices were always supposed to go up, and the participants of the MBS market had no incentives to acquire information about the security's value. However, with the introduction of the ABX index in 2006, agents were revealed that subprime-related securities were falling rapidly in value, resulting in the information acquisition.

Through the lens of my model, the introduction of the ABX index is viewed as a technological innovation that makes information more available to access, i.e., a lower cost of information, $\bar{K}$. Then, a higher fraction of dealers is willing to acquire private information, and the adverse selection problem in the asset market is more severe. Therefore, the low-quality assets, such as the MBS backed by subprime mortgages, became highly illiquid, and a financial crisis was triggered.[23]

[23] Andolfatto et al. (2014) adopt the same interpretation of the launch of the ABX index. Therefore, agents are more incentivized to inspect the trees' dividend types. Furthermore, the arrival of adverse news can lead to financial crises and a drying up in asset liquidity.

2.5.3 Maintaining Information Insensitivity

Lastly, I discuss two methods suggested by the model to maintain the information insensitivity of assets in order to preserve asset liquidity.

Reducing the macroeconomic uncertainty. The macroeconomic uncertainty can be measured by the mean-preserving spread over the dividends across the types, i.e., $\delta_h - \delta_\ell$. According to Proposition 5, an increase in $\delta_h - \delta_\ell$ will incentivize dealers to invest in private information when the dispersion of dividends is initially small. Therefore, reducing the dispersion will mitigate the adverse selection problem, restore asset liquidity, and improve welfare. On the other hand, increasing the dispersion of dividends to a sufficiently high level can also discourage the dealers' private information acquisition. However, in this case, the adverse selection problem is too severe, and the low-quality assets become illiquid, i.e., $d_\ell = 0$.

Government asset purchasing program. The model is also applicable to explain the effects of a change in the aggregate asset supply, A. In practice, the Federal Reserve made a series of large-scale asset purchases (LSAPs) between late 2008 and October 2014. Therefore, the Fed's purchasing of long-term securities reduced the supply of securities in the market. Through the lens of my model, the LSAPs can be interpreted as a decline in the supply of the real asset, A. The market clearing conditions suggest that the asset transactions in the bilateral trades are impeded, implying a lower value of private information and information acquisition regarding the dividends. As a result, the adverse selection problem is less severe, the liquidity premium of assets increases, and the LSAPs are welfare-improving. However, the transactions of low-quality assets decline.

2.6 Conclusion

The objective of this paper is to study the implications of private information acquisition for asset liquidity. I develop a New-Monetarist model incorporating a bargaining protocol with private information as in Rocheteau (2011) and strategic information acquisition decisions in bilateral meetings based on Lester et al. (2012).

In this first part of the paper, with an exogenous information asymmetry, I characterize the steady-state equilibrium and investigate the effects of monetary policy and private information on asset liquidity and welfare. In the second part of the paper, I endogenize the information asymmetry and study the decisions for private information acquisition.

The decisions to acquire private information depend on economic fundamentals and monetary policy. Reduced search frictions tend to encourage information acquisition, while asset fundamentals, such as the average quality and the riskiness, exhibit non-monotonic impacts on the information acquisition decisions. Moreover, an increased nominal interest rate encourages the acquisition of private information, amplifying the adverse selection problem in asset trading.

The main result of this paper highlights a novel channel for monetary policy affecting asset liquidity through the decisions for private information acquisition. When the nominal interest rate is sufficiently low or high, increasing the nominal interest rate positively affects asset liquidity, given that real money balances and the trees are substitutes in facilitating trade, consistent with the conventional wisdom of the New-Monetarist literature. However, when the nominal interest rate is neither too high nor too low, an increase in the nominal interest rate encourages dealers to acquire private information regarding the dividends of the assets, resulting in a non-monotonic effect on asset liquidity. For the normative analysis, the welfare cost of inflation is intensified with the presence of private information acquisition.

Lastly, I discuss an application of the model to demonstrate the importance of private information acquisition in causing illiquidity during the 2008 financial crisis and to understand the impacts of the launch of the ABX index, reducing the macroeconomic uncertainty and through a government asset purchasing program.

Chapter 3

Asset Liquidity and Information Acquisition with Hidden Information Status

3.1 Introduction

Private information acquisition plays an important role in asset trading as it endogenously generates information asymmetries. As formalized in Chapter 2, the decisions to acquire private information suggests an important channel through which monetary policy can transmit non-monotonically to asset liquidity. The framework assumes that agents acquire private information in a transparent manner, with their actions being common knowledge. However, real-world markets often operate in environments where the acquisition of private information is shrouded in opacity, leading to a hidden information status.

Considering the application in Chapter 2, Gorton (2010) explains that during the financial crisis in 2007-2008, the mortgage-backed security (MBS) market became highly illiquidity due to a production of private information. Specifically, some agents, such as financial institutions, dealer banks, and government entities, possessed specialized expertise in asset trading, allowing them to derive information about the quality of MBS. However, in practice, participants in the MBS market typically do not have direct knowledge about the counterparties' information asymmetries. This could be the result of the anonymous trade in the over-the-counter market, data protection or regulatory constraints, and the complexity of the traders' base, which includes a wide range of institutional investors, asset managers, hedge funds, and government-sponsored enterprises, making it difficult to observe the agents' possession of private information.

To fill in this gap, this paper seeks to explore the implications of hidden information status for private information acquisition in asset trading. I develop a New-Monetarist model to study asset liquidity embedding private information acquisition, assuming hidden information status.[1] Two assets - fiat money and a one-period lived Lucas (1978) tree - are valued for liquidity depending on their usefulness in facilitating bilateral trades as means of payments (or collateral). Fiat money is universally accepted, whereas using the tree as means of payment is subject to asymmetric information. Specifically, the tree pays a stochastic dividend at the beginning of each period before bilateral meetings are formed. Households holding the trees are not informed about the dividend. With some probability, they match with better-informed buyers of the trees who are dealers with private information about the dividend. However, the hidden information status restricts the households to

[1] A literature review can be found in Chapter 2.

distinguish between the informed and uninformed buyers. Extending the framework in Chapter 2, this paper incorporates a bargaining protocol with asymmetric information and formalizes private information acquisition based on Lester et al. (2012).

The first part of the paper characterizes the steady-state equilibrium with an exogenous fraction of the informed dealers who purchase the trees. The bargaining protocol entails a screening game structure such that households screen three types of dealers: (i) dealers are informed about high dividend (high-type), (ii) dealers are informed about low dividend (low-type), and (iii) uninformed dealers (uninformed type). In contrast to Chapter 2, the hidden information status allows the uninformed dealers to have incentives to mimic the low-type dealers and to extract informational rent. Focusing on the steady state, I show that the equilibrium contract can be separating, semi-pooling, and pooling, depending on the households' demand for real money balances, which is determined by the nominal interest rate.

Furthermore, a change in the fraction of informed dealers can lead to a switch in between the separating, semi-pooling, and pooling equilibrium. Specifically, with low fraction of informed dealers in the economy, the uninformed dealers tend to pool with the high-type dealers, and the low-type dealers are distorted. On the contrary, as the fraction of informed dealers is high, the uninformed dealers tend to pool with the low-type ones, and the terms of trade for the high type depend on the nominal interest rate. In addition, I investigate the effect of the fraction of informed dealers on the demand for real money balances and welfare and compare the results with those in Chapter 2.

The second part of the paper endogenize the fraction of informed dealers by allowing the dealers to make information acquisition decisions. The analysis taking the fraction of the informed dealers as exogenous explains the value of private information for the dealers. In particular, the dealers' benefit from acquiring private information and becoming informed is driven by the difference in between the information rents extracted by the high-type dealers and the uninformed ones. Furthermore, the low-types dealers do not extract any informational rents. The model shows a strategic substitutability among dealers' information acquisition decisions, suggesting a unique Nash equilibrium that characterizes the fraction of dealers acquiring private information.

By assuming hidden information status, this paper provides new insights about monetary policy implications for private information acquisition in contrast to Chapter 2. When information status is common knowledge, Chapter 2 suggests that inflation encourages private information acquisition. However, with hidden information status, this paper shows that the effect of inflation on the dealers' information acquisition decisions is non-monotonic. The dealers choose not to acquire information when the nominal interest rate is either high or low. When the nominal interest rate is low, the intuition follows Chapter 2. However, when the nominal interest rate is high, the households' portfolio wealth is scarce, and they have to deplete all their portfolio holdings for consumption across all states. However, the hidden information status prevent the households from inferring the types of dealers, eliminating the dealers' incentives to become informed.

The rest of the paper is organized as follows. Section 3.2 describes the model environment. Section 3.3 characterizes the steady-state equilibrium, taking the fraction of informed dealers as exogenous. Section 3.4 endogenize this fraction by formalizing the dealers' information acquisition decisions. Lastly, Section 3.5 concludes the paper.

3.2 Environment

The environment is extending the model in Chapter 2. Time is discrete, starts at $t = 0$, and continues forever. Agents are infinitely-lived and discount the future between periods with a discount factor $\beta \in (0, 1)$. Stage 1 features bilateral matches as in the search theory and information frictions. Stage 2 is a Walrasian settlement market in which all agents can enter and rebalance their portfolio holdings. Agents, period utilities, types of goods, and financial assets are formalized exactly the same as the model in Chapter 2.

Fiat money cannot be counterfeited, making it universally accepted by the sellers as a medium of exchange. However, liquidating the trees is subject to information frictions due to the aggregate dividend shock. In particular, the dividend can be a high type, $\delta = \delta_h$, with probability $\pi \in (0, 1)$, or a low type, $\delta = \delta_\ell$, with complementary probability $1 - \pi$, where $0 < \delta_\ell < \delta_h$. Therefore, the presence of dealers is necessary. The dealers function the same as in Chapter 2. The bilateral matches between a household and a dealer are subject to search frictions, with a meeting probability $\alpha \in (0, 1)$, and asymmetric information, with dealers potentially possessing an informational advantage regarding the dividend.

The key deviation from the model in Chapter 2 is that the dealers' information status is hidden. Therefore, households cannot distinguish between informed and uninformed dealers. However, letting $\rho \in [0, 1]$ denote the fraction of informed dealers who can realize the actual value of the dividend, households still understand the distribution of ρ.

Therefore, to the households' point of view, the dealers can be three types - informed about the dividend is high δ_h (henceforth, "high" type), informed about the dividend is low δ_ℓ (henceforce, "low" type), and uninformed about the dividend (henceforce, "uninformed" type). As a starting point, I treat ρ as exogenous. In Section 3.4, ρ is endogenized by allowing dealers to make private information acquisition decisions.

3.3 Equilibrium

In this section, I describe the agents' problem and define the steady-state equilibrium with exogenous ρ. I start with the value functions of the two stages. Then, I characterize the equilibrium contracts of the bargaining games for the bilateral matches. Lastly, given the equilibrium contracts, I solve the households' optimal portfolio choices.

3.3.1 Value Functions

Let z and a denote the household's holding of real money balances and the trees. The value function of a household entering Stage 2 with portfolio holdings (z, a) and the realized dividend of the trees $\delta \in \{\delta_h, \delta_\ell\}$ is

$$W(z, a, \delta) = \max_{X,H,z',a'} \{X - H + \beta \mathbb{E} V(z', a', \delta')\} \tag{3.1}$$

$$\text{s.t. } X + \gamma z' + \phi_a a' = H + z + \delta a + \phi_a A + T \tag{3.2}$$

which is the same as Chapter 2. Similarly, let$\mathbb{E}V(z', a', \delta')$ denote the value function of a household who enters the next-period Stage 1 with portfolio holdings (z', a'). The expectation is taken with respect to δ', which is unknown to the households in Stage 1. The value function is defined as

$$V(z,a,\delta) = (1-\alpha)[u(q_0(z)) + W(z-q_0(z),a,\delta)] \\ + \alpha[u(q(z,a,\delta)) + W(z-\tau(z,a,\delta),a-d(z,a,\delta),\delta)] \quad (3.3)$$

3.3.2 Bargaining Game

In this section, I characterize the bargaining protocol between a household and a dealer in Stage 1. The equilibrium contract consists of the quantities of the special good traded, q, the transfer of real money balances as payment, τ, and the transfer of the trees, d. Then, the value of the liquid IOUs issued by dealers is represented by $q-\tau$. For tractability reasons, I assume that the households make a take-it-or-leave-it offer when the bilateral match is formed.

More specifically, the household with portfolio holdings (z,a) offers a menu of contracts, $\{(q_h,\tau_h,d_h),(q_\ell,\tau_\ell,d_\ell),(q_u,\tau_u,d_u)\}$, where the subscript denotes the type of the dealers. The household maximizes the expected payoff from the bilateral trade subject to the dealer's participation constraints and incentive-compatible constraints for each dividend state $\chi \in \{h,\ell,u\}$ as follows,

$$\max_{(q_\chi,\tau_\chi,d_\chi)} \{\rho\pi[u(q_h)-\tau_h-\delta_h d_h] \\ + \rho(1-\pi)[u(q_\ell)-\tau_\ell-\delta_\ell d_\ell] + (1-\rho)[u(q_u)-\tau_u-\delta^e d_u]\} \quad (3.4)$$

$$\text{s.t.} \quad -(q_\chi - \tau_\chi) + \delta_\chi d_\chi \geq 0 \text{ and } -(q_\chi - \tau_\chi) + \delta_\chi d_\chi \geq -(q_{-\chi} - \tau_{-\chi}) + \delta_\chi d_{-\chi}$$

and the feasibility constraints $0 \leq \tau_\chi \leq z$ and $0 \leq d_\chi \leq a$.

Lemma 1. The following participation constraint and the incentive-compatible constraints are binding.

$$-q_\ell + \tau_\ell + \delta_\ell d_\ell = 0 \tag{3.5}$$

$$-q_h + \tau_h + \delta_h d_h = (\delta_h - \delta^e) d_u + (\delta^e - \delta_\ell) d_\ell \tag{3.6}$$

$$-q_u + \tau_u + \delta^e d_u = (\delta^e - \delta_\ell) d_\ell \tag{3.7}$$

The incentive-compatible contraints imply the ranking of the terms of trade as follows.

$$0 \leq d_\ell \leq d_u \leq d_h \leq a \tag{3.8}$$

$$q_\ell \leq q_u \leq q_h \tag{3.9}$$

Proof. See Appendix B.1. □

The three binding constraints (3.5)-3.7 suggest that the household leaves no surplus to the dealer in the low state, whereas in the high state, the dealer can extract an informational rent, $(\delta_h - \delta^e)d_u + (\delta^e - \delta_\ell)d_\ell$, and in the uninformed state, the dealer can also extract an informational rent, $(\delta^e - \delta_\ell)d_\ell$. Intuitively, the dealers in the high state have incentives to pretend the ones in the uninformed or low states. In this case, the high-state dealers benefit from issuing less IOUs. Similarly, the uninformed dealers have incentives to mimic the low-state dealers, whereas the low-state dealers do not have incentives to mimic those in the other states. Therefore, the households only need to make sure the low-state dealers participate in the trade and leave no trade surplus to those dealers. Lemmas 2-4 characterize the equilibrium contracts.

Lemma 2. The equilibrium contract for the high-dividend state, taken d_u and d_ℓ as given, is

(a) If $q^* + (\delta_h - \delta^e)d_u + (\delta^e - \delta_\ell)d_\ell \leq z + \delta_h a$, then $q_h = q^*$ and $\tau_h + \delta_h d_h = q^* + (\delta_h - \delta^e)d_u + (\delta^e - \delta_\ell)d_\ell$;

(b) If $q^* + (\delta_h - \delta^e)d_u + (\delta^e - \delta_\ell)d_\ell > z + \delta_h a$, then $q_h = z + \delta_h a - (\delta_h - \delta^e)d_u - (\delta^e - \delta_\ell)d_\ell$, $\tau_h = z$, and $d_h = a$.

Proof. See Appendix B.1. □

Real balances and the trees are perfect substitutes as means of payment if the trees pay a high dividend. However, due to adverse selection, the households' liquid wealth becomes the value of their portfolio holdings net the informational rent, $(\delta_h - \delta^e)d_u + (\delta^e - \delta_\ell)d_\ell$, that they have to compensate the dealers.

Lemma 3. Denote $z_u^*(a, \pi, \rho, \delta_h, \delta_\ell)$ s.t. $z = \hat{q}_u(z, a, \pi, \rho, \delta_h, \delta_\ell) - \delta_\ell d_\ell$ and $z_1^*(a, \pi, \rho, \delta_h, \delta_\ell)$ s.t. $z = \hat{q}_u(z, a, \pi, \rho, \delta_h, \delta_\ell) - \delta^e d_h(z, a, \pi, \rho, \delta_h, \delta_\ell) + (\delta^e - \delta_\ell)d_\ell$, where $\hat{q}_u$ solves

$$u'(q_u) = 1 + \frac{\rho\pi}{1-\rho}\frac{\delta_h - \delta^e}{\delta^e}u'(q_h) \tag{3.10}$$

The equilibrium contract for the uninformed state, taken d_ℓ as given, is

(a) If $z \geq q^* + \delta_\ell d_\ell$, then $q_u = q^*$, $\tau_u = q^* + \delta_\ell d_\ell$, and $d_u = d_\ell$;

(b) If $z_u^*(a, \pi, \rho, \delta_h, \delta_\ell) \leq z < q^* + \delta_\ell d_\ell$, then $q_u = z + \delta_\ell d_\ell$, $\tau_u = z$, and $d_u = d_\ell$;

(c) If $z_1^*(a,\pi,\rho,\delta_h,\delta_\ell) \leq z < z_u^*(a,\pi,\rho,\delta_h,\delta_\ell)$, then $q_u = \hat{q}_u$, $\tau_u = z$, and $d_u = [\hat{q}_u - z + (\delta^e - \delta_\ell)d_\ell]/\delta^e$;

(d) If $0 \leq z < z_1^*(a,\pi,\rho,\delta_h,\delta_\ell)$, then $q_u = z + \delta^e d_h - (\delta^e - \delta_\ell)d_\ell$, $\tau_u = z$, and $d_u = d_h = a$.

Lemma 4. Denote $z_\ell^*(a,\pi,\rho,\delta_h,\delta_\ell)$ s.t. $z = \hat{q}_\ell(z,a,\pi,\rho,\delta_h,\delta_\ell)$ and $z_2^*(a,\pi,\rho,\delta_h,\delta_\ell)$ s.t. $z = \hat{q}_\ell(z,a,\pi,\rho,\delta_h,\delta_\ell) - \delta_\ell d_u(z,a,\pi,\rho,\delta_h,\delta_\ell)$, where $\hat{q}_\ell$ solves

$$u'(q_\ell) = 1 + \frac{\rho\pi u'(q_h) + (1-\rho)u'(q_u)}{\rho(1-\pi)} \frac{\delta^e - \delta_\ell}{\delta_\ell} \tag{3.11}$$

The equilibrium contract for the low-dividend state is

(a) If $z \geq q^*$, then $q_\ell = q^*$, $\tau_\ell = q^*$, and $d_\ell = 0$;

(b) If $z_\ell^*(a,\pi,\rho,\delta_h,\delta_\ell) \leq z < q^*$, then $q_\ell = z$, $\tau_\ell = z$, and $d_\ell = 0$;

(c) If $z_2^*(a,\pi,\rho,\delta_h,\delta_\ell) \leq z < z_\ell^*(a,\pi,\rho,\delta_h,\delta_\ell)$, then $q_\ell = \hat{q}_\ell$, $\tau_\ell = z$, and $d_\ell = (\hat{q}_\ell - z)/\delta_\ell$;

(d) If $0 \leq z < z_2^*(a,\pi,\rho,\delta_h,\delta_\ell)$, then $q_\ell = z + \delta_\ell d_\ell$, $\tau_\ell = z$, and $d_\ell = d_u = a$.

Proof. See Appendix B.1. $\square$

Lemmas 3 and 4 suggest a pecking-order property of payments if the dealers are uninformed or low types. If the household holds a sufficient amount of real money balances, i.e., $z \geq z_u^*(a,\pi,\rho,\delta_h,\delta_\ell)$ or $z \geq z_\ell^*(a,\pi,\rho,\delta_h,\delta_\ell)$, then the real balances serve as the only means of payment, i.e., $d_u = d_\ell = 0$. Otherwise, the household will first deplete the real money balances, i.e., $\tau_\ell = z$, and then use the trees to facilitate trade. This is consistent with (3.8) and (3.9) such that bargaining under asymmetric information leads to a distortion of the terms of trade and asset transactions in the low dividend state and the uninformed state. Intuitively, the distortions allow the households to save on the informational rent and reduce the incentives of the high-state and uninformed dealers to lie about their types.

Proposition 1. The equilibrium contracts can be separating, semi-pooling, or pooling, depending on the households' real money balances. Denote $z^*_{max} \equiv \max\{z^*_u, z^*_\ell\}$ and $z^*_{min} \equiv \min\{z^*_u, z^*_\ell\}$.

(a) If $z^*_{max} \leq z < q^*$, then the equilibrium contract is a semi-pooling contract such that $q_u = q_\ell = \tau_u = \tau_\ell = z$, and $d_u = d_\ell = 0$; also, $q_h = \min\{q^*, z + \delta_h a\}$;

(b) If $z^*_{min} \leq z < z^*_{max}$, there are two possible cases depending on the model parameter:

(i) If $z^*_u \geq z^*_\ell$, the equilibrium contract is a separating contract where $q_h = \min\{q^*, z + d_h a - (\delta_h - \delta^e)d_u\} = \min\{q^*, \hat{q}_u + \delta_h(a - d_u)\}$ for the high state, $q_u = \hat{q}_u$, $\tau_u = z$, and $d_u = (\hat{q}_u - z)/\delta^e$ for the uninformed state, and $q_\ell = z$, $\tau_\ell = z$, and $d_\ell = 0$ for the low state;

(ii) If $z^*_u < z^*_\ell$, then the equilibrium contract is a semi-pooling contract such that $q_u = \hat{q}_\ell$, and $d_u = d_\ell = (\hat{q}_\ell - z)/\delta_\ell$; for the high state, $q_h = \min\{q^*, z + d_h a - (\delta_h - \delta_\ell)d_\ell\}$;

(c) If $z^*_1 \leq z < z^*_{min}$, then the equilibrium contract is a separating contract where $q_h = \min\{q^*, z + d_h a - (\delta_h - \delta^e)d_u - (\delta^e - \delta_\ell)d_\ell\}$ for the high state, $q_u = \hat{q}_u$, $\tau_u = z$, and $d_u = (\hat{q}_u - z)/\delta^e$ for the uninformed state, and $q_\ell = \hat{q}_\ell$, $\tau_\ell = z$, and $d_\ell = (\hat{q}_\ell - z)/\delta_\ell$ for the low state;

(d) If $z^*_2 \leq z < z^*_1$, then the equilibrium contract is a semi-pooling contract where

$q_h = q_u = z + \delta^e d_h - (\delta^e - \delta_\ell)d_\ell$, $\tau_u = \tau_h = z$, and $d_u = d_h = a$, and $q_\ell = \hat{q}_\ell$, $\tau_\ell = z$, and $d_\ell = (\hat{q}_\ell - z)/\delta_\ell$ for the low state;

(e) If $0 \leq z < z_2^*$, then the equilibrium contract is a pooling contract such that $q_h = q_u = q_\ell = z + \delta_\ell a$, $\tau_h = \tau_u = \tau_\ell = z$, and $d_h = d_u = d_\ell = a$.

3.3.3 Households' Portfolio Choices

According to the equilibrium contracts characterized in Section 3.3.2 and the value function, (3.3), the expected value of the household entering Stage 1 becomes

$$\mathbb{E}V(z, a, \delta) = (1-\alpha)S_0 + \alpha\{(1-\rho)S_u + \rho[\pi S_h + (1-\pi)S_\ell]\} + z + \delta^e a + W(0,0,\delta) \quad (3.12)$$

and S_i, where $i \in \{0, h, \ell, u\}$, denotes the trade surplus from different types (i) of bilateral matches. For example, with probability $1-\alpha$, the household is not matched with a dealer and uses real money balances as the only means of payment. In this case, the trade surplus is defined as $S_0 \equiv u[q_0(z)] - q_0(z)$. With a probability α, a household meets a dealer and with a probability $1-\rho$, the dealer is uninformed. The trade surplus is $S_u \equiv u[q_u(a, \pi, \delta_h, \delta_\ell)] - q_u(a, \pi, \delta_h, \delta_\ell) - (\delta^e - \delta_\ell)d_\ell(a, \pi, \delta_h, \delta_\ell)$. With the complementary probability ρ, the dealer is informed about the dividend, in which the trade surplus is $S_h \equiv u[q_h(a, \pi, \delta_h, \delta_\ell)] - q_h(a, \pi, \delta_h, \delta_\ell) - (\delta_h - \delta^e)d_u(a, \pi, \delta_h, \delta_\ell) - (\delta^e - \delta_\ell)d_\ell(a, \pi, \delta_h, \delta_\ell)$ for the high-dividend state, and $S_\ell \equiv u[q_\ell(a, \pi, \delta_h, \delta_\ell)] - q_\ell(a, \pi, \delta_h, \delta_\ell)$ for the low-dividend state.

Now, we can derive the objective function for the household's optimal portfolio choices. Let the set of all households, $\mathcal{H}$ be the interval $[0, 1]$, and let $[z(j), a(j)]$ be the household j's, $j \in \mathcal{H}$ demand for real money balances and the trees. Then,

$$[z(j), a(j)] = arg \max_{z,a}\{-iz-(\frac{\phi_a - \phi_a^*}{\beta})a+(1-\alpha)S_0+\alpha[(1-\rho)S_u+\rho[\pi S_h+(1-\pi)S_\ell]]\} \quad (3.13)$$

where i is the nominal interest rate by applying the stationary monetary equilibrium definition and the Fisher equation $i = (\gamma - \beta)/\beta$, and $\phi_a^* \equiv \beta\delta^e$ denote the fundamental value of the trees.

According to (3.13), the household's optimal portfolio choices $[z(j), a(j)]$ satisfy the following first-order conditions if $i \geq 0$ and $\phi_a \geq \phi_a^*$,

$$-i + (1-\alpha)S_{0,z} + \alpha\{(1-\rho)S_{u,z} + \rho[\pi S_{h,z} + (1-\pi)S_{\ell,z}]\} \leq 0, \text{ "=" if } z > 0 \quad (3.14)$$

$$-\frac{\phi_a - \phi_a^*}{\beta} + \alpha\{(1-\rho)S_{u,a} + \rho[\pi S_{h,a} + (1-\pi)S_{\ell,a}]\} \leq 0, \text{ "=" if } a > 0 \quad (3.15)$$

where $S_{i,j} \equiv \partial S_i/\partial j$ denotes the first-order partial derivatives of the trade surpluses, $i \in \{0, 1, h, \ell\}$, with respect to the holdings of the asset $j \in \{z, a\}$.[2] Intuitively, at optimum, the marginal benefit, i.e., the liquidity premium, has to be equal to the marginal cost of carrying an additional unit of asset over to the next-period Stage 1.

3.3.4 Steady-State Equilibrium

In this section, I characterize the steady-state equilibrium. The definition of the steady-state equilibrium is as follows.

[2]Similar to Chapter 2, the objective function, (3.13), is jointly concave in (z, a). Hence, the first-order conditions, (3.14)-(3.15), are necessary and sufficient for the optimization problem.

Definition 1. The steady-state equilibrium consists of a list of quantities traded $\{(q_h, \tau_h, d_h), (q_\ell, \tau_\ell, d_\ell), (q_u, \tau_u, d_u)\}$, the real asset price ϕ_a, and portfolio holdings (z, a), such that

(1) Given the nominal interest rate (i) and the real asset price (ϕ_a), $(z, a) \in \mathbb{R}^2_+$ solves the household's optimal portfolio choice problem;

(2) $\{(q_h, \tau_h, d_h), (q_\ell, \tau_\ell, d_\ell), (q_u, \tau_u, d_u)\} \in \mathbb{R}^3_+ \times \mathbb{R}^3_+ \times \mathbb{R}^3_+$ solves the bargaining problems;

(3) Market clearing conditions are satisfied: $\int_{j\in\mathcal{H}} z(j)\, dj = Z$ and $\int_{j\in\mathcal{H}} a(j)\, dj = A$, where $Z \equiv \phi_m M = \phi'_m M'$ denotes the aggregate real balances for the steady state.

Proposition 2. A steady-state equilibrium exists and is unique.

According to Proposition 1, there are five relevant regions depending on the nominal interest rate, i, under which the equilibrium contract can be separating, semi-pooling, or pooling.[3] The full characterization of the relevant regions is relegated to Appendix B.2. Then, Table 3.1 summarizes the comparative statics with respect to the nominal interest rate.

$\frac{\partial Z}{\partial \zeta}$	$\frac{\partial q_1}{\partial \zeta}$	$\frac{\partial q_h}{\partial \zeta}$	$\frac{\partial q_\ell}{\partial \zeta}$	$\frac{\partial \phi_a}{\partial \zeta}$
$-$	$-^*$	$-^*$	$-$	$+^*$

Table 3.1: Comparative static with respect to the nominal interest rate $(i > 0)$. Note: * means no change when q_1 and q_h achieve the optimal level q^* in equilibrium.

Asset liquidity and monetary policy. The conventional wisdom of the effect of monetary policy on asset liquidity still holds. As the nominal interest rate increases, the house-

[3] According to the thresholds for the real money balances, $(z^*_u, z^*_\ell, z^*_1, z^*_2)$, as defined in Proposition 1, the thresholds for the nominal interest rate that determines the relevant regions, $(i^*_u, i^*_\ell, i^*_1, i^*_2)$, is pinned down accordingly by 3.14.

holds face a higher cost of holding real money balances. Therefore, they lower the demand for real money balances and shift their demand into the trees, which is a (imperfect) substitute for fiat money in facilitating bilateral trades. Consequently, the asset price increases as the demand for the trees increases.

Furthermore, the model with exogenous ρ suggests that the optimal monetary policy implements the Friedman rule. Since the real money balance holding is abundant, the agent uses the real money balances as the only medium of exchange and trades the first-best output level, q^*, in all the bilateral meetings. Since it is costless to hold real money balances, the trees possesses zero liquidity premium, and the asset price is equal to the fundamental value, $\phi_a = \phi_a^*$.

3.3.5 Relevant Regions with Varying ρ

In this section, I investigate the switch in between relevant regions when ρ varies, as illustrated by Figure 3.1. According to Section 3.3.4, each relevant region has different implications on asset liquidity and equilibrium allocations.

In Figure 3.1, the terms of trade for each type, (q_h, q_u, q_ℓ), depict a switch in between a separating, semi-pooling, and pooling equilibrium, according to Proposition 1, as ρ varies.[4] The intuition follows (3.10), which characterizes the incentive-compatible constraints to restrict the high-type dealers mimicking the uninformed ones. As $\rho \to 0$, the fraction of informed dealers is low, the households do not need to distort the uninformed state too much to reduce the incentives of the high-type dealers deviating. Hence, we have

[4] I adopt the CRRA utility function, $u(q) = 2\sqrt{q}$. Other parameter values are $\beta = 0.97$, $\alpha = 0.5$, $\pi = 0.1$, $\delta_h = 1$, $\delta_\ell = 0.5$, and $A = 0.3$.

a semi-pooling equilibrium where $d_u \to d_h$ and $q_u \to q_h$. On the contrary, as $\rho \to 1$, the households have to distort the uninformed state, $q_u \to q_\ell$ and $d_u \to d_\ell$.

Similarly, according to (3.11), the equilibrium contract prevent the high-type and uninformed dealers mimicking the low-type ones. As $\rho \to 0$, the fraction of uninformed dealers is high, the households have to distort the low-type state to reduce the incentives of the uninformed dealers deviating. Hence, $d_\ell \to 0$ and $q_\ell \to Z$. On the contrary, as $\rho \to 1$, the low-type dealers is not distorted much and can pool with the uninformed dealers, $q_\ell \to q_u$ and $d_\ell \to d_u$.

Furthermore, the presence of the separating, semi-pooling, and pooling equilibrium depends on the nominal interest rate, which determines the households' liquid wealth. Therefore, Figure 3.1 shows the following two cases: (i) a relatively large nominal interest rate, $i = 0.12$, and (ii) a relatively small nominal interest rate, $i = 0.05$. When the nominal interest rate is high (left panel), the households' liquid wealth is scarce.[5] The households start with distorting only the low state contract, so we have a semi-pooling equilibrium such that the uninformed dealers pool with the high type dealers. As ρ increases, the uninformed dealers are distorted and pool with the low-type dealers. However, when the nominal interest rate is low, the liquid wealth is relatively more abundant. Even when ρ is small, the households distort both the uninformed and low states to save on the informational rent, since they have more sufficient real balances to facilitate trade. Therefore, a separating equilibrium exists when ρ is small. As ρ increases, the uninformed dealers tends to pool with the low-type dealers, and, according to (3.11), d_u and d_ℓ are increasing in ρ. As the

[5] I adopt the CRRA utility function, $u(q) = 2\sqrt{q}$. Other parameter values are $\beta = 0.97$, $\alpha = 0.5$, $\pi = 0.1$, $\delta_h = 1$, $\delta_\ell = 0.5$, and $A = 0.3$.

distortion on the uninformed and low state is lower, the demand for real money balances, Z, is decreasing in ρ in the case of a semi-pooling equilibrium for the uninformed and low types. Therefore, as ρ increases, households' liquid wealth declines. For a relatively large nominal interest rate, the liquid wealth for the households is scarce such that q_h declines and eventually, the high-type dealers pool with the other types. On the contrary, if the nominal interest rate is relatively low, the households' liquid wealth is more abundant, and, in the high state, the terms of trade is at the optimal quantity, $q_h = q^*$ as suggested by Lemma 2, despite the real money balances are declining.

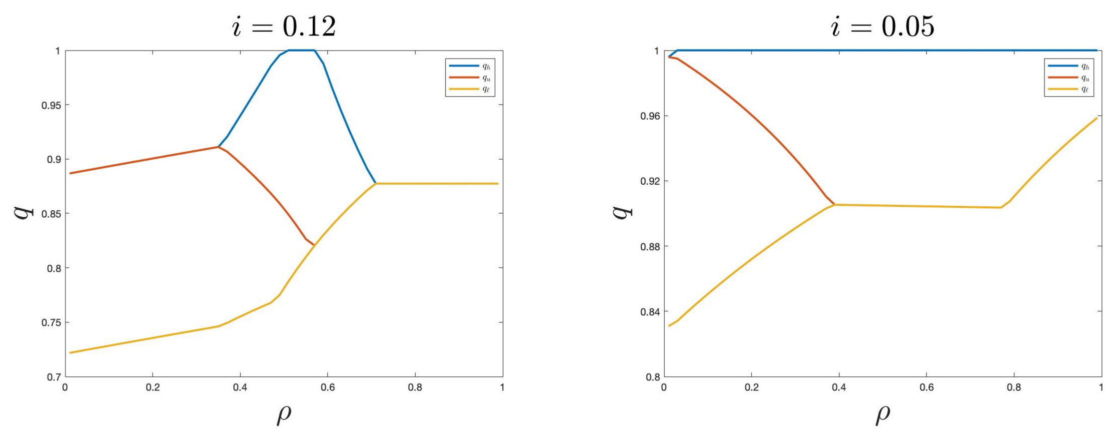

Figure 3.1: Switch in between a separating, semi-pooling, and pooling equilibrium with varying ρ. Left: a large nominal interest rate ($i = 0.12$); Right: a small nominal interest rate ($i = 0.05$).

Demand for real money balances. I investigate the effect of ρ on the demand on real money balances as depicted by Figure 3.2.[6] In general, the effect is non-monotonic and depends on each relevant region. Starting with sufficiently small ρ where the equilibrium is semi-pooling as the uninformed dealers pool with the high-type dealers, the effect is positive.

[6]Same parameter values are taken as in Figure 3.1 with $i = 0.12$. See footnote 5.

More specifically, the optimality condition that determines the households' optimal holdings for real money balances (3.14) becomes $i = (1-\alpha)L(Z)+\alpha\{[1-\rho(1-\pi)]L(q_u)+\rho(1-\pi)L(q_\ell)\}$ as $q_h = q_u$. Therefore, the direct effect from an increased ρ leads to a higher probability to meet with the low-type dealers whose asset valuation is also low. Therefore, households demand for more real balances to facilitate trade.

In contrast to Chapter 2, the demand for real money balances can decrease in ρ when we have a semi-pooling equilibrium such that the uninformed dealers pool with the low-type dealers, i.e., $q_u = q_\ell$. Then, (3.14) becomes $i = (1-\alpha)L(Z) + \alpha[\rho\pi L(q_h) + (1-\rho\pi)L(q_u)]$. A higher ρ makes the right-hand side lower because the probability to meet with the high-type dealers who have high valuation for the tree is higher, implying that the marginal benefit from holding real money balances decreases. For relatively large ρ, we have a pooling equilibrium where all types of dealers behave the same. Therefore, the equilibrium outcomes do not depend on ρ.

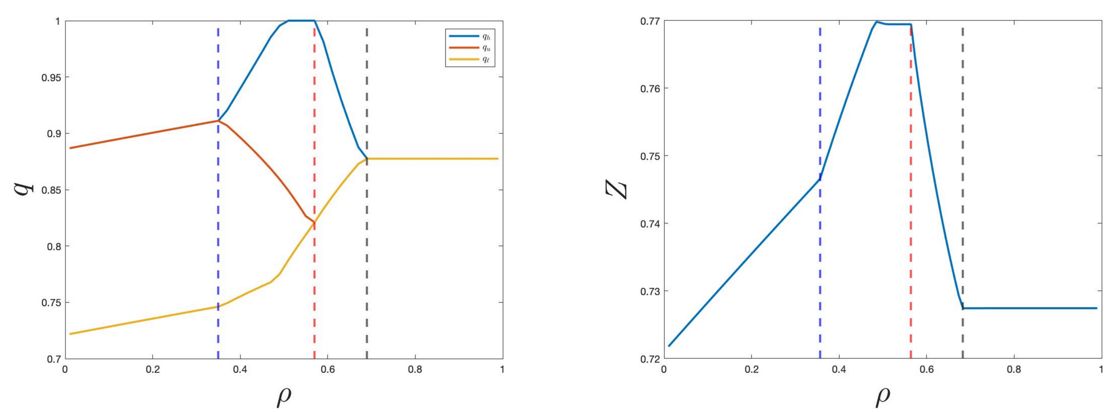

Figure 3.2: Effect of ρ on the demand for real money balances (Z).

Welfare implications. For the normative properties of the steady-state equilibrium, I define the welfare as the households' expected trade surplus from the bilateral matches in Stage 1,

$$\mathcal{W} = (1-\alpha)S_0 + \alpha\{(1-\rho)S_u + \rho[\pi S_h + (1-\pi)S_\ell]\} \tag{3.16}$$

Then, when deviating from the Friedman rule, i.e., $i > 0$, I find that the severity of information asymmetries affects the welfare through two opposing forces.

$$\begin{aligned}\frac{\partial \mathcal{W}}{\partial \rho} = &\underbrace{\alpha[\pi S_h + (1-\pi)S_\ell - S_u]}_{\text{direct effect} < 0} \\ &+ \underbrace{(1-\alpha)\frac{\partial S_0}{\partial \rho} + \alpha\{(1-\rho)\frac{\partial S_u}{\partial \rho} + \rho[\pi\frac{\partial S_h}{\partial \rho} + (1-\pi)\frac{\partial S_\ell}{\partial \rho}]\}}_{\text{general equilibrium effect}}\end{aligned} \tag{3.17}$$

In general, the effect of the degree of information asymmetries is non-monotonic on the welfare. Firstly, the negative direct effect suggests that the welfare decreases since the households are risk-averse, and the trade surplus functions are concave. Secondly, following the results from Figure 3.2, the general equilibrium effect is non-monotonic as it depends on the change in the demand for real money balances. Specifically, Figure 3.3 provides a numerical example and compares the welfare effect of ρ when information status is hidden (i.e., left panel) and when information status is common knowledge (i.e., right panel).[7] When information status is hidden, a higher degree of information asymmetries is (weakly) welfare-worsening for relatively small and relatively large ρ. These ranges for ρ correspond to the cases where the equilibrium is semi-pooling or pooling. Otherwise, when ρ is neither too small nor too big, the equilibrium is separating, and the welfare effect is non-monotonic.

[7] Same parameter values are taken as in Figure 3.1 with $i = 0.12$. See footnote 5.

However, when information status is observed, the numerical example suggests a positive effect on the welfare. Intuitively, with higher ρ, the households will have a higher chance to meet with an informed dealer, and they are able to distinguish that the dealer is informed. Therefore, a higher ρ will encourage the households to carry more real money balances to save on the information rent, which is welfare-improving.

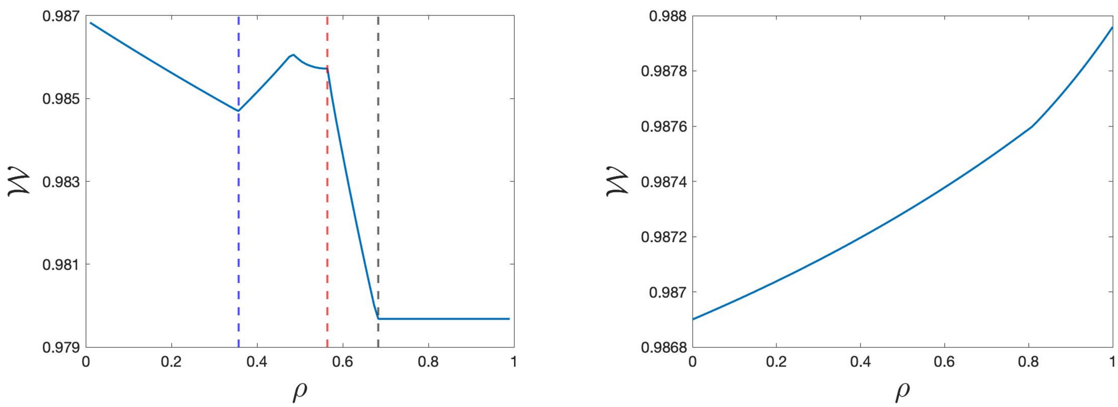

Figure 3.3: Effect of ρ on the welfare ($\mathcal{W}$). Left: information status is hidden (Chapter 3); Right: information status is common knowledge (Chapter 2).

3.4 Private Information Acquisition

3.4.1 Steady-State Equilibrium

In this section, I endogenize the degree of information asymmetries by allowing the dealers to acquire private information regarding the asset dividends. The information acquisition decisions are made before matches are formed in Stage 1, associated with a flow cost, K. The dealers make information acquisition decisions by comparing the value of private information with the cost. Conditional on a fraction $\rho \in [0, 1]$ of other dealers being informed, let $\Pi^i(\rho)$ denote the dealer's benefit to become informed and $\Pi^u(\rho)$ for staying uninformed. We define the value of private information as $\Pi(\rho) = \Pi^i(\rho) - \Pi^u(\rho)$. That is, the value of private information is the gain from being informed net the opportunity cost of not being informed. Intuitively, the value of private information is driven by the informational rent that comes from dealers' possession of private information. Given the bargaining protocol discussed in Section 3.3.2, the uninformed dealers can extract informational rent since the household tends to prevent them from mimicking the low-state dealers. Therefore,

$$\Pi^u(\rho) = \alpha(\delta^e - \delta_\ell)d_\ell(\rho) \tag{3.18}$$

If the dealers become informed, the dealers can extract informational rent in the high-dividend state, since the households tend to prevent them mimicking the uninformed and the low type dealers. Hence,

$$\Pi^i(\rho) = \alpha\pi[(\delta_h - \delta^e)d_u(\rho) + (\delta^e - \delta_\ell)d_\ell(\rho)] \tag{3.19}$$

Therefore, the value of private information is expressed as

$$\Pi(\rho) = \alpha\pi(1-\pi)(\delta_h - \delta_\ell)[d_u(\rho) - d_\ell(\rho)] \tag{3.20}$$

Proposition 2. (Characterization of Nash equilibrium)

(a) The equilibrium value of ρ^* satisfies one of the following configurations:

(i) If $\Pi(0) < K$, there exists a unique pure strategy Nash equilibrium with $\rho = 0$;

(ii) If $\Pi(1) > K$, there exists a unique pure strategy Nash equilibrium with $\rho = 1$;

(iii) If $\exists \rho \in [0, 1]$ s.t. $\Pi(\rho) = K$, then these values are mixed-strategy Nash equilibria.

(b) There exists a unique Nash equilibrium ρ^* that characterizes the dealers' optimal decision for private information acquisition.

Similar to Chapter 2, the strategic substitutability still holds in this case when information status is hidden, i.e., $\Pi(\rho)$ is weakly decreasing in ρ. This result is shown by Figure 3.1. As $\rho \to 0$, the uninformed dealers tend to pool with the high-type ones. As ρ increases, there is a higher fraction of informed dealers. To prevent the high-type dealers mimicking the uninformed dealers, the households are more willing to distort d_u, making the uninformed dealers to pool with the low-type ones. Therefore, d_u is decreasing in ρ for relatively small ρ. As the semi-pooling equilibrium is achieved, i.e., $d_u = d_\ell$, then they both increase in ρ as implied by (3.11). See Figure 3.4 for a graphical illustration.[8]

Part (a) of Proposition 2 is straightforward. If the cost of acquiring information is sufficiently high, such that $\Pi(0) < K$, where $\Pi(0)$ is the maximum value of private information the dealers can extract, then there are no dealers acquiring information in equilibrium, i.e., $\rho^* = 0$. On the other hand, if the information cost is sufficiently low, such that $\Pi(1) > K$, where $\Pi(1)$ is the minimum value of private information, dealers optimally choose to acquire information. A unique equilibrium exists as all the dealers become informed, i.e., $\rho^* = 1$. Mixed strategy Nash equilibria exist if the information cost is neither too high nor too low. Therefore, The values for ρ that satisfy $\Pi(\rho) = K$

[8]The parameter values are the same as for Figure 3.1, and $i = 0.12$. See footnote 5.

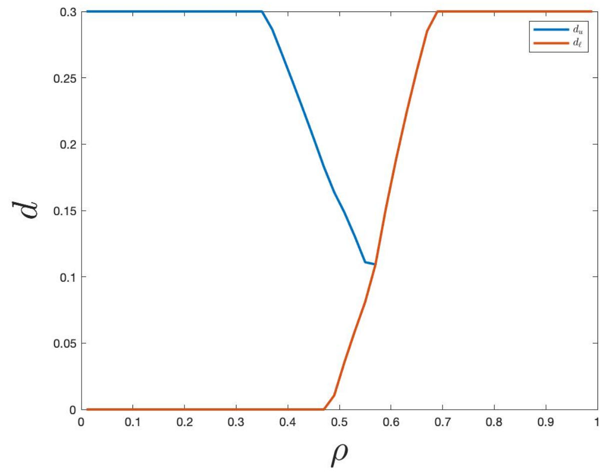

Figure 3.4: Strategic substitutability among dealers' information acquisition decisions.

constitute a best response for the dealers' information acquisition decision. Furthermore, Part (b) of Proposition 2 is directly implied by the strategic substitutability among the dealers' information acquisition decisions.

3.4.2 Monetary Policy Implications

In this section, I explore the monetary policy implications on the dealers' decisions to acquire private information. I consider a money injection, i.e., inflation, which leads to an increase in the nominal interest rate (i) according to the Fisher effect.

In general, the effect of a money injection on the value of information is non-monotonic as illustrated by Figure (3.5).[9] The intuitive follows Proposition 1 and the relevant regions. For relatively small nominal interest rate, real balance holding is abundant. Therefore, the households can distort both the uninformed and low state in order to save on the informational rent, implying a semi-pooling equilibrium where $d_u = d_\ell$ for all ρ, and the

[9] I adopt the CRRA utility function, $u(q) = 2\sqrt{q}$. Other parameter values are $\beta = 0.97$, $\alpha = 0.5$, $\pi = 0.1$, $\delta_h = 1$, $\delta_\ell = 0.5$, and $A = 0.15$. For the right panel, $K = 0.003$.

value of private information is zero. Consequently, for low interest rate, no dealers acquire private information, i.e., $\rho^* = 0$.

As the nominal interest rate increases, the households' liquid wealth becomes scarce, and there will be less distortion in the uninformed state. Then, the value of private information increases. As the nominal interest rate keep increasing, the households' do not hold sufficient portfolio to distort either the uninformed or the low state to save on the informational rent. Instead, they have to deplete all their portfolio holdings in the bilateral trades. Therefore, a pooling equilibrium is achieved such that $d_u = d_\ell = A$ for all ρ, leading to a zero value of private information. Therefore, for a relatively high nominal interest rate, no dealers will acquire private information, i.e., $\rho^* = 0$. Consequently, inflation has a non-monotonic effect on the dealers' information acquisition decisions.

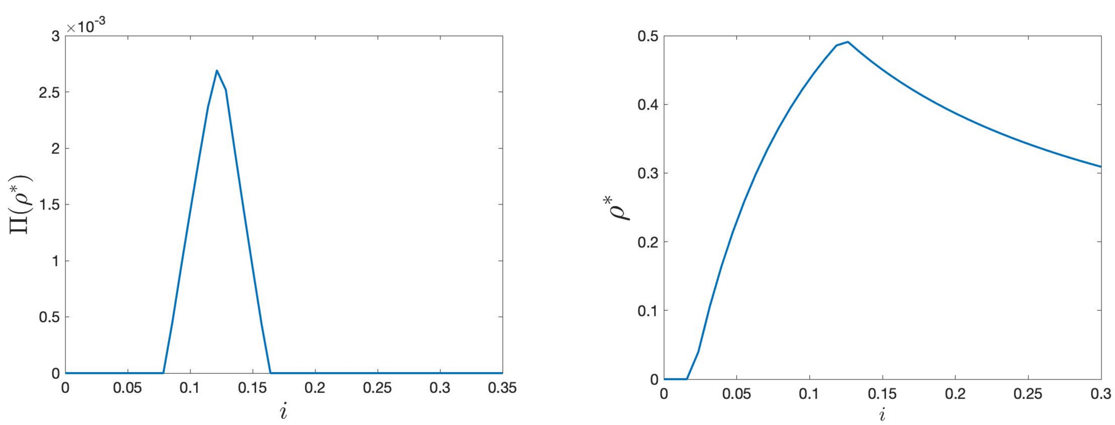

Figure 3.5: Effects of monetary policy (i). Left: on value of private information ($\Pi(\rho)$); Right: information acquisition decision (ρ^*).

Hidden information status. By assuming hidden information status, this paper provides new insights about monetary policy implications, comparing to Chapter 2. When information status is common knowledge, Chapter 2 suggests that inflation consistently encourages dealers to acquire private information, as higher inflation erodes the value of real money balances, incentivizing the use of the trees as means of payment. However, with hidden information status, the effect of inflation is non-monotonic. The dealers choose not to acquire private information when nominal interest rates are either high or low.

The key reason behind the non-monotonic effect of inflation is the inability of households to distinguish between informed and uninformed dealers. This hidden information status allows uninformed dealers to extract informational rent by mimicking the low-type dealers. In addition, the high-type dealers have incentives to mimic the uninformed and low-type dealers. Consequently, households distort both uninformed and low states to save on the cost of informational rent.

In scenarios where the nominal interest rate is low, the intuition follows Chapter 2 assuming common knowledge. Abundant real money balances reduce the need for asset-based transactions, leading to diminished incentives for dealers to acquire private information. Conversely, when nominal interest rates are high, households must deplete their portfolio holdings for consumption across all states. However, the hidden information status prevent the households from inferring the types of the dealers. This eliminates the dealers' incentives to become informed, as their behavior are the same across different types.

3.5 Conclusion

In conclusion, this paper investigate the implications of hidden information status for private information acquisition in asset trading within the framework of New-Monetarist economics. By comparing models with common knowledge (Chapter 2) and hidden information status, this paper provides new insights about equilibrium outcomes and monetary policy implications.

In this first part of the paper, with an exogenous information asymmetry, I characterize the steady-state equilibrium and investigate the effects of monetary policy and private information on equilibrium outcomes. In particular, the paper suggests that hidden information status leads to strategic behavior among dealers, resulting in equilibrium configurations characterized by separating, semi-pooling, and pooling equilibria. The presence of these equilibrium outcomes highly depend on monetary policy and information asymmetries in the economy. Furthermore, for different types of equilibrium, I investigate the effect of the degree of information asymmetries on the demand for real money balances and welfare and compare the results with those in Chapter 2.

In the second part of the paper, I endogenize the fraction of informed dealers and formalize their decisions for private information acquisition, which is characterized by a unique Nash equilibrium. A key finding of this paper is the non-monotonic effect of inflation on dealers' private information acquisition decisions in the presence of hidden information status. While with information status being common knowledge, higher inflation consistently encourages private information acquisition. Instead, this paper suggests that dealers choose not to acquire information when nominal interest rates are either high or low. When the nominal interest rate is low, the intuition follows Chapter 2. However, when the nominal interest rate is high, the households' portfolio wealth is scarce, and they have to deplete all their portfolio holdings for consumption across all states. However, the hidden information status prevent the households from inferring the types of dealers, eliminating the dealers' incentives to become informed. Eventually, the effect of inflation on asset liquidity is non-monotonic.

Chapter 4

Asset Liquidity, Portfolio Management, and the Home Bias Puzzle

4.1 Introduction

The home bias puzzle in equities has been a long-lasting feature of international capital markets. Seminal works by French and Poterba (1991) and Tesar and Werner (1995) demonstrate the tendency of investors to disproportionately allocate their portfolio holdings to domestic equities, forgoing the full advantages of international diversification, significantly contradicting the predictions of standard finance theories. Despite advancements in financial integration over the past decades, the degree of home bias has not decreased significantly. As of 2007, U.S. investors retained over 80 percent of domestic equities, significantly surpassing the global market portfolio share of U.S. equities as suggested by the standard finance theory. This trend is not exclusive to the United States and persists across various nations.

The existing literature has a focus on information-based explanations to explain the home bias puzzle.[1] Intuitively, the literature assumes exogenous information asymmetries among investors. That is, investors receive less precise signals on the future payoff of the foreign stocks, and, consequently, perceive the foreign stock as being riskier. However, in order to quantitatively match the home bias, these models have to assume an implausibly high initial information asymmetry. Therefore, more recent literature incorporates endogenous information acquisition. More specifically, investors can choose what home or foreign information to acquire and allocate portfolio based on information acquisition. As a result, initially small information advantage is amplified by information acquisition, leading to the specialization in holding domestic stock.

As the landscape of investment management evolved, with a significant portion of international investments now overseen by institutional portfolio managers, traditional information-based rationales for home bias appear increasingly inadequate.[2] With mutual funds, pension funds, and other financial intermediaries commanding a substantial stake in equity markets, the informational advantage once attributed to individual investors diminishes. Professional fund managers, presumed to be well-informed about the benefits of diversification, is critical for understanding international portfolio allocation strategies.

[1] See the related literature in Section 4.3.

[2] According to Commission on Corporate Governance of the New York Stock Exchange (July 23, 2010), Dziuda and Mondria (2012) point out an increasing trend away from individual stock ownership towards institutional ownership. By 2009, mutual funds, pension funds, other financial intermediaries had control of about 75% of the U.S. equity market.

In this paper, I aim to fill a gap of the existing literature with a particular focus on the portfolio managers who are delegated to make international investment for the individual investors. The paper is organized as follows. In Section 4.2, I summarize the empirical facts from the recent literature that I aim to explain. In Section 4.3, I discuss future research agenda and the development of the existing literature. Section 4.4 concludes the paper.

4.2 Stylized Facts

In this section, I review the empirical evidence from the recent literature.

#1. The presence and declining trend of the degree of home bias in equities. The degree of the home bias in equities is measured as the disparity between the share of foreign equities in a country's portfolio relative to their representation in the global market.

$$\text{Home Bias} = 1 - \frac{\text{Share of Foreign Equities in Country's Equity Holdings}}{\text{Share of Foreign Equities in World Market Portfolio}}$$

A degree of home bias of one signifies full equity bias towards domestic assets, while zero suggests optimal diversification based on the International Capital Asset Pricing Model (CAPM).

As shown by Coeurdacier and Rey (2012), the trend of home bias in developed countries across regions of the world has decreased over the past decades although the process of financial globalization remains high in most countries. See Figure 4.1. Following Lane and Milesi-Ferretti (2018), the time series of the degree of home bias in equities has been extended for the G7 countries.[3] The presence and declining trade of the home bias

[3]The time series has been extended up to 2020 for the United States, Canada, Japan, and Germany, up

is robust. Up to 2020, the home bias for the United States was 0.73, and for Canada, the home bias was 0.53. The home bias for the European countries is relatively weaker.

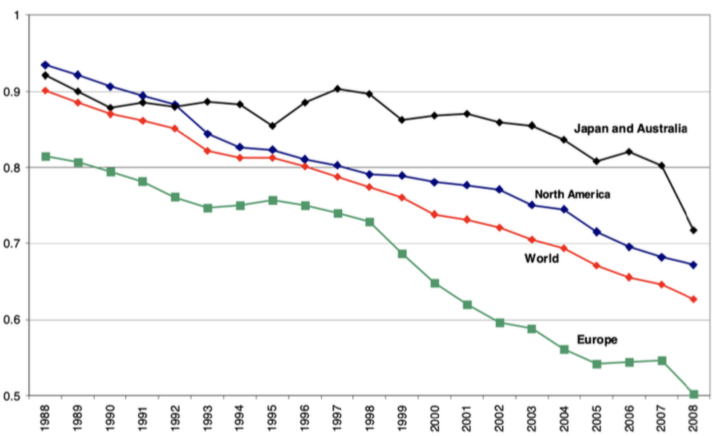

Figure 4.1: The declining trend of the degree of home bias. Source: Coeurdacier and Rey (2012).

#2. Home bias at the fund level. Empirical observations at the fund level provide further insights into the home bias puzzle in equities. Hau and Rey (2008b) employ a fund-level dataset created by Thomson Financial Securities (TFS), which reveals the mutual fund equity holdings worldwide. I report the summary statistics of the dataset in Table 4.1.

Fund in:	US	CA	UK	EU	SWZ
No. of funds	5,123	643	1,186	3,804	373
Positions	800,339	57,003	140,523	310,726	40,302
Value	2,851	111	252	353	80

Table 4.1: Summary statistics on fund holdings in 1998-2002 (in billions of dollars). Source: Hau and Rey (2008b).

to 2018 for France, and up to 2014 for the United Kingdom and Italy. The home bias degree in 1998 for France and Italy is missing.

Another work by Chan et al. (2005) employ the same data focusing on the degree of home bias in equities in 26 countries, including advanced economies and emerging markets. The paper shows that, during 1999-2000, the share of mutual fund holdings in the domestic market is much larger than their market capitalization weight in the world's portfolio. Furthermore, Chan et al. (2005) investigate the plausible factors that affect the international portfolio allocations, such as economic development, capital controls, stock market development, familiarity, and investor protection.

Hau and Rey (2008b) estimate the degree of home bias in equities at the fund level using the total market capitalization of the domestic assets in which funds invest divided by the total investment portfolio. I report the statistics in Table 4.2. Consistent with Figure 4.1, the United States and Canada exhibit a higher degree of home bias at the fund level, and the European countries exhibit relatively less home bias.

Fund in:	US	CA	UK	EU	SWZ
Mean	0.68	0.55	0.32	0.29	0.35

Table 4.2: Summary statistics on fund-level home bias in equities in 1998-2002. Source: Hau and Rey (2008b).

Comparing the fund-level home bias in equities with the aggregate level, Hau and Rey (2008b) find that, on average, equity mutual funds were less home biased than other investors during 2001-2002. The measure of the aggregate-level home bias in the paper is to estimate the total investment in the domestic market by domestic agents divided by total domestic market capitalization using the CPIS and the Fédération Internationale des Bourses de Valeurs (FIBV) data. I report the statistics in Table 4.3. Furthermore, another paper by Hau and Rey (2008b) demonstrates the declining trend in the degree of home bias for all countries between 2001 and 2002.

Fund in:	US	CA	UK	EU	SWZ
Aggregate level	0.92	0.84	0.65	0.55	0.65
Fund level	0.85	0.71	0.23	0.44	0.20

Table 4.3: Measures of home bias in equities at aggregate level and fund level in 2001-2002. Source: Hau and Rey (2008b).

#3. Fund size and the degree of home bias in equities. Based on the fund-level measures, Hau and Rey (2008b) find that the degree of home bias exhibits a positive correlation with the size of funds (except the UK and Switzerland). More specifically, funds with a home bias greater than 80 percent have a mean market capitalization of \$4.33 billion, whereas funds with a home bias of less than 20 percent have a mean market capitalization of only \$0.67 billion. Additionally, for intermediate degrees of home bias (i.e., between 20 and 80 percent), there is a positive correlation between the degree of home bias and the size of the funds.

Additionally, Hau and Rey (2008b) demonstrate a strong positive correlation between the size of the fund and the number of sectors and the number of foreign countries the fund invests in (expect for Switzerland). For the United States, Hau and Rey (2008b) find a correlation coefficient of 0.11 regressing the (log) fund size on the (log) number of countries, and 0.07, on the (log) number of sectors, respectively.

#4. Heterogeneity in investment strategies. Hau and Rey (2008b) find a strong heterogeneity in the degree of home bias at the fund level. As illustrated by Figure 4.2, the distribution of the degree of home bias at the fund level is bimodal, suggesting heterogeneity in the funds' investment strategies. The distribution peaks at 0 percent and 100 percent of home bias, indicating substantial specialization of funds into either fully domestic or fully international investment.

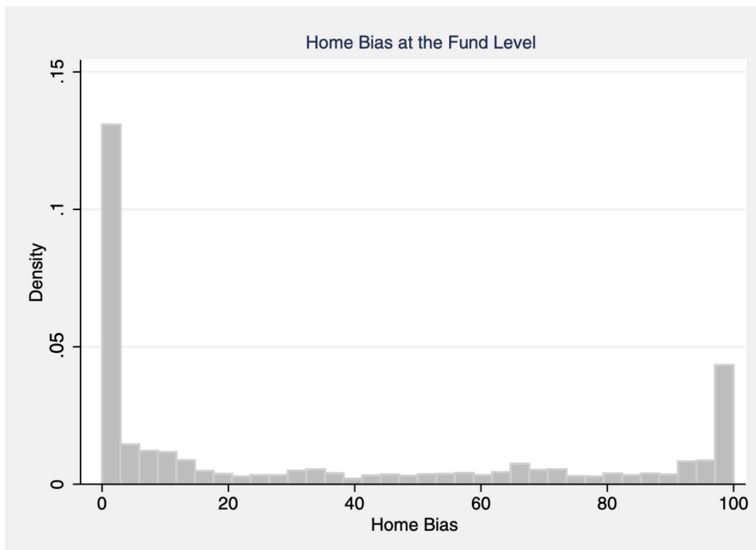

Figure 4.2: Heterogeneity in investment strategies. Source: Hau and Rey (2008b).

#5. Dynamics of international portfolio allocation. Employing the TFS dataset, Hau and Rey (2008a) study the institutional investors' portfolio rebalancing strategies over 1997 to 2002. Importantly, the comprehensive fund-level dataset enables the authors to accurately estimate the portfolio adjustments made by fund managers in response to fluctuations in equity values and exchange rates. The dataset also allows them to compute the time series of the marginal risk contribution of individual stocks to a specific fund's portfolio, providing insight into the reallocation decisions of fund managers in reaction to these variations.

Firstly, Hau and Rey (2008a) justifies the significant heterogeneity in the compositions of institutional investors' portfolios, particularly in the varying degrees of home bias (i.e., Stylized fact #4). Secondly, the paper studies the dynamics of the foreign shares of the fund's portfolio. The main finding suggests that portfolio managers adjust their foreign portfolio share to counteract the valuation effects of asset price changes. When the foreign portfolio share yields higher returns than the domestic share, it leads to capital repatriation. Conversely, underperformance of foreign assets leads to capital expatriation. Lastly, portfolio rebalancing strategies also aim to mitigate fluctuations in portfolio weights caused by changes in total equity risk and foreign exchange rate risk.

4.3 Future Research and Related Literature

The primary objective of my future research is to further elucidate the mechanisms underlying the home bias puzzle in equities, with a particular focus on the role of delegated portfolio managers. This aspect has been largely overlooked in the existing international finance literature. This research aims to develop a comprehensive theoretical framework that explains the stylized facts summarized in the previous section, incorporating key components such as asset liquidity, information asymmetries, and the implications of delegated portfolio management.

Asset liquidity is a crucial factor in portfolio management and investment decisions. In the context of home bias, understanding how liquidity preferences differ between domestic and foreign assets can shed light on why investors might prefer local equities. The importance of the liquidity of assets has been emphasized by Geromichalos and Simonovska

(2014) to reconcile the home bias puzzles in equities and in consumption, coupled with higher turnover rates of foreign equities. Asset liquidity is formalized based on the New-Monetarist framework, in which certain assets facilitate trades in the home and foreign goods market with imperfect credit. Therefore, the assets function as mediums of exchange, as is standard in monetary theory. Furthermore, they represents claims to future consumption, as is standard in finance theory.

The main assumption in Geromichalos and Simonovska (2014) in order to reconcile the international puzzles is that the net dividend from foreign assets is lower due to policy frictions, information frictions, or transaction costs. Therefore, the domestic assets entail superior stores of value. Considering the equilibrium regime where domestic assets facilitate trade in the domestic goods market and foreign assets in the foreign market, the model generates home bias in equities and consumption since domestic assets provide higher dividends, provided that trading opportunities abroad are not significantly more frequent than those at home. On the other hand, foreign assets turn over faster than domestic assets because they can facilitate trade in the foreign goods market but represent inferior stores of value.

The importance of information asymmetries has been highlighted in finance and open economy financial macroeconomics studies. There is a vast literature incorporating the information-based explanation to understand the empirical observations of the home bias in equities. Early models in finance literature, such as those by Gehrig (1993) and Brennan and Cao (1997), assume exogenous information asymmetry as a key determinant of home bias. These models assume that agents receive signals on the future performance of stocks, with signals on foreign assets being less precise. Consequently, domestic investors perceive foreign stocks as riskier, leading to a reduction in foreign stock holdings that results in equity home bias.

Empirical support for the information-based explanations can be found in the existing literature. Coval and Moskowitz (1999) focus on the preference for geographic proximity, a proxy for the informational differences between foreign and domestic investors. More specifically, the paper finds that the U.S. investment managers have a strong preference for locally headquartered firms, particularly smaller, highly leveraged companies involved in non-traded goods production. Ahearne et al. (2004) demonstrates an indicator for the reduction in information asymmetries, which is the portion of a country's market that has a public U.S. listing. The paper justifies the information-based explanations as foreign firms, which do not have a public U.S. listing, are subject to higher information cost and are significantly underweighted in the U.S. equity portfolios. Using the fund-level dataset, Chan et al. (2005) argue that stock market development and familiarity indicators have significant effects on the degree of home bias. Similar to Coval and Moskowitz (1999), Portes and Rey (2005) adopts a gravity model and suggests that the geography of information has crucial effects on cross-border equity flows.

Moving to the recent literature in the open economy financial macroeconomics, Hatchondo (2008) introduces a two-country model with two assets per country. Firstly, local investors possess informational advantage about local assets, allowing them to favor local investments. Secondly, due to high short selling costs and informative signals, investors are less willing to short sell the low-quality local asset. Instead, they reduce their foreign asset holdings, leading to the equity home bias in equilibrium. Similarly, Gordon and Bovenberg (1996) highlight that information asymmetries lead to diminished returns on the foreign capital investment for domestic investors. Tille and van Wincoop (2009) introduce information dispersion across investors following Gehrig (1993) and Brennan and Cao (1997). Each investor receives a private signal on the future fundamentals of domestic and foreign stock, and the signal on the domestic stock is more precise, which generates portfolio shifts away from foreign assets.

More recent literature allows for endogenous information acquisition in order to address the limitations of exogenous information asymmetry assumptions. That is, the papers have to assume implausibly high information asymmetries in order to match with the degree of home bias quantitatively. To generate endogenous information asymmetries, Van Nieuwerburgh and Veldkamp (2009) incorporate the rational inattention model by Sims (2003) to demonstrate a small initial informational advantage can drive significant home bias when investors face capacity constraints in processing information. In this setup, investors are assumed to possess a minor informational advantage regarding local assets to reduce the perceived risk. Consequently, investors tend to allocate more capital to local assets. Moreover, this incentivizes investors to endogenously choose to acquire further information about local assets, eventually magnifying the initial slight advantage and generating a significant home bias in equities. Mondria (2010) extends this framework by allowing investors to determine both the precision and structure of the information they process, leading to specialization in local stocks. Moreover, Mondria and Wu (2010) utilize a similar approach to explain the declining trend of the degree of home bias over time, highlighting the interaction between capital openness and learning strategies in shaping international portfolio investment behavior.

Lastly, with an increasing proportion of capital flows intermediated through institutional investors, studies by Chan et al. (2005), Hau and Rey (2008a), and Hau and Rey (2008b) utilize fund-level datasets to estimate home bias, providing empirical evidence on the importance of delegated portfolio investment behavior on understanding the home bias puzzle in equity. Additionally, Dziuda and Mondria (2012) explicitly formalize delegated portfolio management strategies, demonstrating how information asymmetry at the household level can influence fund managers' decisions to operate in domestic markets. Given that domestic households possess informational advantage about local assets, they can effectively assess the performance of managers investing in these assets. Consequently, highly skilled managers, benefiting from transparency, tend to operate in the domestic market. Thus, following Van Nieuwerburgh and Veldkamp (2009), a small initial informational advantage at the household level can amplify home bias through the decision of skilled fund managers to focus on domestic investments. However, this framework does not account for the diverse array of investment strategies observed at the fund level (i.e., Stylized fact #3).

To sum up, my future research aims to integrate the concept of delegated portfolio management into models addressing the home bias puzzle in equities, with a focus on information asymmetries. Delegated portfolio management, characterized by a principal-agent relationship, involves an investor (the principal) delegating portfolio investment decisions to a portfolio manager (the agent). The vast literature on this topic highlights peculiar features of such contracts, particularly the issues of adverse selection and moral hazard.

See Stracca (2006) for a comprehensive survey. Before the contract is signed, the agent typically possesses better information about their own quality, which constitutes adverse selection. After the contract is signed, the agent can acquire superior information through costly effort, which is unobservable to the principal, leading to moral hazard.

Additionally, my research will focus on the interactions between information asymmetries and asset liquidity, as both are crucial in explaining the home bias puzzle. Existing literature suggests that professional portfolio managers can mitigate investors' information asymmetries concerning domestic and foreign assets, which can be a potential explanation of the observed decline in home bias over time, considering declining search frictions to look for portfolio managers in the advanced economies. However, the persistence of home bias can be attributed to the information asymmetries between investors and portfolio managers, resulting in the pecking-order theory of payments similar as in Chapters 2 and 3. My future research agenda aims to elucidate these mechanisms by developing a model that captures how managers' professionalism and enhanced information acquisition capabilities impact portfolio choices and liquidity considerations. This paper aims to answer why home bias is declining but still remains prevalent despite advancements in information technology and financial integration, offering insights into how asset liquidity and information asymmetries in delegated management shape international portfolio allocations.

4.4 Conclusion

The home bias puzzle in equities, highlighted by seminal works by French and Poterba (1991) and Tesar and Werner (1995), underscores a significant phenomenon that contradicts to the international capital asset pricing model. Investors persistently exhibit a tendency to overweight domestic equities, thereby forgoing the potential benefits of international diversification.

The existing literature has explored information-based explanations to interpret this puzzle. Initially, models assume exogenous information asymmetries, and more recent studies incorporate endogenous information acquisition, wherein investors endogenously choose to acquire information and adjust their portfolio allocations accordingly, leading to a specialization in domestic stock holdings.

With portfolio managers playing a more important role in making international portfolio allocations for individual investors, traditional information-based explanation for the home bias puzzle in equities become more inadequate. The rise of mutual funds, pension funds, and other financial intermediaries implies the diminishing informational asymmetries between the home and foreign assets. Professional fund managers, presumed to be well-informed about the benefits of diversification, appear to be crucial in understanding the dynamics of international portfolio allocation strategies and the home bias puzzle in equities.

In this paper, I first summarize the stylized facts on the degree of home bias at the fund level in the existing literature, and I discuss my future research agenda to match with the stylized facts and the related literature. The existing literature suggests that asset liquidity is critical in determining portfolio allocation strategies. Furthermore, the delegated portfolio management between investors and portfolio managers is subject to both adverse selection and moral hazard. Therefore, I argue that the increasing proportion of international investment executed by portfolio managers might be a plausible reason for the declining trend of the degree of the home bias. My future research aims to incorporate key components such as asset liquidity, information asymmetries, and the implications of delegated portfolio management and to study why home bias is declining but still remains prevalent despite advancements in information technology and financial integration.

Chapter 5

Conclusions

This dissertation consists of three essays that study asset liquidity and information. By adopting the New-Monetarist framework, this dissertation investigates the impacts of the presence and acquisition of private information acquisition on asset liquidity.

In Chapter 2, I explore the implications of private information acquisition for asset liquidity. The model incorporates a bargaining protocol with private information and strategic information acquisition decisions, revealing how economic fundamentals and monetary policy influence private information acquisition. This chapter identifies a non-monotonic effect of nominal interest rates and providing insights into the role of private information in exacerbating adverse selection problems. An application of the model is discussed to interpret the financial crisis in 2007-2008.

Building upon the findings of Chapter 2, Chapter 3 extended the analysis to account for hidden information status, which is a relevant feature in the asset market in practice. By uncovering strategic behaviors among dealers under hidden information status, this chapter suggests a non-monotonic effect of monetary policy on private information acquisition. Furthermore, the paper investigates the effects of hiding information status by comparing the equilibrium outcomes and welfare implications between Chapters **??** and **??**.

Lastly, Chapter 4 addressed the long-lasting puzzle of home bias in equities in international finance literature. With a significant portion of international investments now overseen by portfolio managers, traditional information-based explanations for home bias appear inadequate. I summarize the stylized facts on the degree of home bias at the fund level and discuss my future research agenda aiming to further investigate the implications of delegated portfolio management for the dynamics of the home bias in equities, incorporating key components such as asset liquidity, information asymmetries, and the role of portfolio managers in the international portfolio allocations.

Bibliography

Ahearne, A. G., Griever, W. L., and Warnock, F. E. (2004). Information costs and home bias: an analysis of us holdings of foreign equities. *Journal of international economics*, 62(2):313–336.

Akerlof, G. A. (1970). The market for "lemons": Quality uncertainty and the market mechanism. *The Quarterly Journal of Economics*, 84(3):448–500.

Andolfatto, D., Berentsen, A., and Waller, C. (2014). Optimal disclosure policy and undue diligence. *Journal of Economic Theory*, 149:128–152.

Andolfatto, D. and Martin, F. M. (2013). Information disclosure and exchange media. *Review of Economic Dynamics*, 16(3):527–539.

Bajaj, A. (2018). Undefeated equilibria of the Shi–Trejos–Wright model under adverse selection. *Journal of Economic Theory*, 176:957–986.

Banerjee, A. V. and Maskin, E. S. (1996). A Walrasian theory of money and barter. *The Quarterly Journal of Economics*, 111(4):955–1005.

Berentsen, A. and Rocheteau, G. (2004). Money and information. *The Review of Economic Studies*, 71(4):915–944.

Brennan, M. J. and Cao, H. H. (1997). International portfolio investment flows. *The Journal of Finance*, 52(5):1851–1880.

Camargo, B. and Lester, B. (2014). Trading dynamics in decentralized markets with adverse selection. *Journal of Economic Theory*, 153:534–568.

Chan, K., Covrig, V., and Ng, L. (2005). What determines the domestic bias and foreign bias? evidence from mutual fund equity allocations worldwide. *The Journal of Finance*, 60(3):1495–1534.

Chiu, J. and Koeppl, T. V. (2016). Trading dynamics with adverse selection and search: Market freeze, intervention and recovery. *The Review of Economic Studies*, 83(3):969–1000.

Chiu, J. and Molico, M. (2010). Liquidity, redistribution, and the welfare cost of inflation. *Journal of Monetary Economics*, 57(4):428–438.

Cho, I.-K. and Kreps, D. M. (1987). Signaling games and stable equilibria. *The Quarterly Journal of Economics*, 102(2):179–221.

Choi, M. (2018). Imperfect information transmission and adverse selection in asset markets. *Journal of Economic Theory*, 176:619–649.

Choi, M. and Liang, F. (2023). Learning and money adoption. *Journal of Political Economy*, 131(7):000–000.

Choi, M. and Rocheteau, G. (2024). Information acquisition and price discrimination in dynamic, decentralized markets. *Review of Economic Dynamics*, 53:1–46.

Coeurdacier, N. and Rey, H. (2012). Home bias in open economy financial macroeconomics. *Journal of Economic Literature*, 51(1):63–115.

Coval, J. D. and Moskowitz, T. J. (1999). Home bias at home: Local equity preference in domestic portfolios. *The Journal of Finance*, 54(6):2045–2073.

Covitz, D., Liang, N., and Suarez, G. A. (2013). The evolution of a financial crisis: Collapse of the asset-backed commercial paper market. *The Journal of Finance*, 68(3):815–848.

Craig, B. and Rocheteau, G. (2008). Inflation and welfare: A search approach. *Journal of Money, Credit and Banking*, 40(1):89–119.

Dang, T. V., Gorton, G., and Holmström, B. (2015). The information sensitivity of a security. Mimeo.

Dang, T. V., Gorton, G., and Holmström, B. (2020). Ignorance, debt and financial crises. Mimeo.

Dang, T. V., Gorton, G., Holmström, B., and Ordonez, G. (2017). Banks as secret keepers. *American Economic Review*, 107(4):1005–1029.

Duffie, D., Gârleanu, N., and Pedersen, L. H. (2005). Over-the-counter markets. *Econometrica*, 73(6):1815–1847.

Duffie, D., Gârleanu, N., and Pedersen, L. H. (2007). Valuation in over-the-counter markets. *The Review of Financial Studies*, 20(6):1865–1900.

Dziuda, W. and Mondria, J. (2012). Asymmetric information, portfolio managers, and home bias. *The Review of Financial Studies*, 25(7):2109–2154.

French, K. R. and Poterba, J. M. (1991). Investor diversification and international equity markets. *The American Economic Review*, 81:222–226.

Gehrig, T. (1993). An information based explanation of the domestic bias in international equity investment. *The Scandinavian Journal of Economics*, pages 97–109.

Geromichalos, A. and Herrenbrueck, L. (2016). Monetary policy, asset prices, and liquidity in over-the-counter markets. *Journal of Money, Credit and Banking*, 48(1):35–79.

Geromichalos, A., Herrenbrueck, L., and Wang, Z. (2022). Asymmetric information and the liquidity role of assets. *Available at SSRN*.

Geromichalos, A., Jung, K. M., Lee, S., and Carlos, D. (2021). A model of endogenous direct and indirect asset liquidity. *European Economic Review*, 132:103627.

Geromichalos, A., Licari, J. M., and Suárez-Lledó, J. (2007). Monetary policy and asset prices. *Review of Economic Dynamics*, 10(4):761–779.

Geromichalos, A. and Simonovska, I. (2014). Asset liquidity and international portfolio choice. *Journal of Economic Theory*, 151:342–380.

Gordon, R. H. and Bovenberg, A. (1996). Why is capital so immobile internationally? possible explanations and implications for capital income taxation. *The American Economic Review*, 86(5):1057–1075.

Gorton, G. (2009). Information, liquidity, and the (ongoing) panic of 2007. *American Economic Review*, 99(2):567–572.

Gorton, G. (2010). *Slapped by the invisible hand: The panic of 2007*. Oxford University Press.

Gorton, G. and Metrick, A. (2012). Securitized banking and the run on repo. *Journal of Financial Economics*, 104(3):425–451.

Gorton, G. and Ordonez, G. (2014). Collateral crises. *American Economic Review*, 104(2):343–378.

Gorton, G. and Pennacchi, G. (1990). Financial intermediaries and liquidity creation. *The Journal of Finance*, 45(1):49–71.

Gu, C., Han, H., and Wright, R. (2020). The effects of news when liquidity matters. *International Economic Review*, 61(4):1411–1435.

Gu, C., Menzio, G., Wright, R., and Zhu, Y. (2021). Market freezes. Working Paper.

Guerrieri, V. and Shimer, R. (2014). Dynamic adverse selection: A theory of illiquidity, fire sales, and flight to quality. *American Economic Review*, 104(7):1875–1908.

Guerrieri, V., Shimer, R., and Wright, R. (2010). Adverse selection in competitive search equilibrium. *Econometrica*, 78(6):1823–1862.

Hatchondo, J. C. (2008). Asymmetric information and the lack of portfolio diversification. *International Economic Review*, 49(4):1297–1330.

Hau, H. and Rey, H. (2008a). Global portfolio rebalancing under the microscope. Technical report, National Bureau of Economic Research.

Hau, H. and Rey, H. (2008b). Home bias at the fund level. *American Economic Review*, 98(2):333–338.

Hirshleifer, J. (1971). The private and social value of information and the reward to inventive activity. In *American Economic Review*, volume 61, pages 561–574. Elsevier.

Hu, T.-W. and Rocheteau, G. (2015). Monetary policy and asset prices: A mechanism design approach. *Journal of Money, Credit and Banking*, 47(S2):39–76.

Kacperczyk, M. and Schnabl, P. (2010). When safe proved risky: commercial paper during the financial crisis of 2007–2009. *Journal of Economic Perspectives*, 24(1):29–50.

Kurlat, P. (2013). Lemons markets and the transmission of aggregate shocks. *American Economic Review*, 103(4):1463–1489.

Kurlat, P. (2016). Asset markets with heterogeneous information. *Econometrica*, 84(1):33–85.

Lagos, R. (2011). Asset prices, liquidity, and monetary policy in an exchange economy. *Journal of Money, Credit and Banking*, 43:521–552.

Lagos, R. and Rocheteau, G. (2008). Money and capital as competing media of exchange. *Journal of Economic theory*, 142(1):247–258.

Lagos, R. and Rocheteau, G. (2009). Liquidity in asset markets with search frictions. *Econometrica*, 77(2):403–426.

Lagos, R., Rocheteau, G., and Wright, R. (2017). Liquidity: A new monetarist perspective. *Journal of Economic Literature*, 55(2):371–440.

Lagos, R. and Wright, R. (2005). A unified framework for monetary theory and policy analysis. *Journal of Political Economy*, 113(3):463–484.

Lagos, R. and Zhang, S. (2015). Monetary exchange in over-the-counter markets: A theory of speculative bubbles, the fed model, and self-fulfilling liquidity crises. Working Paper.

Lagos, R. and Zhang, S. (2020). Turnover liquidity and the transmission of monetary policy. *American Economic Review*, 110(6):1635–1672.

Lane, P. R. and Milesi-Ferretti, G. M. (2018). The external wealth of nations revisited: international financial integration in the aftermath of the global financial crisis. *IMF Economic Review*, 66:189–222.

Lester, B., Postlewaite, A., and Wright, R. (2012). Information, liquidity, asset prices, and monetary policy. *The Review of Economic Studies*, 79(3):1209–1238.

Lester, B., Shourideh, A., Venkateswaran, V., and Zetlin-Jones, A. (2019). Screening and adverse selection in frictional markets. *Journal of Political Economy*, 127(1):338–377.

Lewis, M. (2011). *The big short: Inside the doomsday machine.* W.W. Norton and Company.

Li, Y. and Rocheteau, G. (2011). On the threat of counterfeiting. *Macroeconomic Dynamics*, 15(S1):10–41.

Li, Y., Rocheteau, G., and Weill, P.-O. (2012). Liquidity and the threat of fraudulent assets. *Journal of Political Economy*, 120(5):815–846.

Lucas, Jr, R. E. (2000). Inflation and welfare. *Econometrica*, 68(2):247–274.

Lucas Jr, R. E. (1978). Asset prices in an exchange economy. *Econometrica*, pages 1429–1445.

Madison, F. (2019). Frictional asset reallocation under adverse selection. *Journal of Economic Dynamics and Control*, 100:115–130.

Madison, F. (2024). Asymmetric information in frictional markets for liquidity: Collateralized credit vs asset sale. *Journal of Economic Dynamics and Control*, 159:104808.

Mailath, G. J., Okuno-Fujiwara, M., and Postlewaite, A. (1993). Belief-based refinements in signalling games. *Journal of Economic Theory*, 60(2):241–276.

Mondria, J. (2010). Portfolio choice, attention allocation, and price comovement. *Journal of Economic Theory*, 145(5):1837–1864.

Mondria, J. and Wu, T. (2010). The puzzling evolution of the home bias, information processing and financial openness. *Journal of Economic Dynamics and Control*, 34(5):875–896.

Nosal, E. and Rocheteau, G. (2013). Pairwise trade, asset prices, and monetary policy. *Journal of Economic Dynamics and Control*, 37(1):1–17.

Portes, R. and Rey, H. (2005). The determinants of cross-border equity flows. *Journal of international Economics*, 65(2):269–296.

Rocheteau, G. (2009). Information and liquidity: A discussion. FRB of Cleveland Working Paper No. 09-02.

Rocheteau, G. (2011). Payments and liquidity under adverse selection. *Journal of Monetary Economics*, 58(3):191–205.

Rocheteau, G. (2012). The cost of inflation: A mechanism design approach. *Journal of Economic Theory*, 147(3):1261–1279.

Rocheteau, G. and Nosal, E. (2017). *Money, payments, and liquidity.* MIT Press.

Rocheteau, G. and Wright, R. (2005). Money in search equilibrium, in competitive equilibrium, and in competitive search equilibrium. *Econometrica*, 73(1):175–202.

Rocheteau, G. and Wright, R. (2013). Liquidity and asset-market dynamics. *Journal of Monetary Economics*, 60(2):275–294.

Rocheteau, G., Wright, R., and Xiao, S. X. (2018). Open market operations. *Journal of Monetary Economics*, 98:114–128.

Rubinstein, A. and Wolinsky, A. (1985). Equilibrium in a market with sequential bargaining. *Econometrica: Journal of the Econometric Society*, pages 1133–1150.

Sims, C. A. (2003). Implications of rational inattention. *Journal of monetary Economics*, 50(3):665–690.

Stracca, L. (2006). Delegated portfolio management: A survey of the theoretical literature. *Journal of Economic surveys*, 20(5):823–848.

Tesar, L. L. and Werner, I. M. (1995). Home bias and high turnover. *Journal of international Money and Finance*, 14(4):467–492.

Tille, C. and van Wincoop, E. (2009). *Disconnect and Information Content of International Capital Flows: Evidence and Theory*. SSRN.

Van Nieuwerburgh, S. and Veldkamp, L. (2009). Information immobility and the home bias puzzle. *The Journal of Finance*, 64(3):1187–1215.

Wang, Z. (2020). Liquidity and private information in asset markets: To signal or not to signal. *Journal of Economic Theory*, 190:105122.

Williamson, S. and Wright, R. (1994). Barter and monetary exchange under private information. *The American Economic Review*, pages 104–123.

Zhang, C. (2014). An information-based theory of international currency. *Journal of International Economics*, 93(2):286–301.

Appendix A

Appendix for Chapter 2

A.1 Omitted Proofs

Proof of Lemma 2. First, the participation constraint and the incentive-compatible constraint for the same state cannot both be binding. If this were the case, taking the high-dividend state as an example, the household could raise her expected surplus by increasing q_h and keeping $(q_\ell, \tau_\ell, d_\ell)$ unchanged without upsetting the participation constraints and the incentive-compatible constraints.

Now, we can prove that (2.7) is binding by contradiction. Assume that the constraint holds with a strict inequality. Then the participation constraint and the incentive-compatible constraint for the high-dividend state imply that

$$-(q_h - \tau_h) + \delta_h d_h > -(q_\ell - \tau_\ell) + \delta_h d_\ell \geq 0$$

This set of inequalities implies that if (2.7) holds with a strict inequality, then so does the participation constraint, which contradicts to our first point. Hence, (2.7) must be binding. Similarly, by contradiction, (2.6) must be binding as well. □

Proof of Lemmas 3 and 4. The Lagrangian for the optimization problem is

$$\begin{aligned}\mathcal{L} = \pi[u(q_h) - \tau_h - \delta_h d_h] + (1-\pi)[u(q_\ell) - \tau_\ell - \delta_\ell d_\ell] \\ + \lambda_1[-(q_\ell - \tau_\ell) + \delta_\ell d_\ell] + \lambda_2[-(q_h - \tau_h) + \delta_h d_h - (\delta_h - \delta_\ell) d_\ell] \\ + \mu_1^h \tau_h + \mu_2^h [z - \tau_h] + \mu_1^\ell \tau_\ell + \mu_2^\ell [z - \tau_\ell] \\ + \nu_1^h d_h + \nu_2^h [a - d_h] + \nu_1^\ell d_\ell + \nu_2^\ell [a - d_\ell]\end{aligned} \quad \text{(A.1.1)}$$

where λ_1 and λ_2 are the Lagrangian multipliers with respect to the two binding constraints, (2.6) and (2.7), hence $\lambda_1 > 0$ and $\lambda_2 > 0$. μ and ν are the Lagrangian multipliers with respect to the liquidity constraints. Theses multipliers are positive if the corresponding constraint binds; otherwise, they are zero.

High Dividend State. The first-order conditions are

$$\frac{\partial \mathcal{L}}{\partial q_h} = \pi u'(q_h) - \lambda_2 = 0 \quad \text{(A.1.2)}$$

$$\frac{\partial \mathcal{L}}{\partial \tau_h} = -\pi + \lambda_2 + (\mu_1^h - \mu_2^h) = 0 \quad \text{(A.1.3)}$$

$$\frac{\partial \mathcal{L}}{\partial d_h} = -\pi \delta_h + \lambda_2 \delta_h + (\nu_1^h - \nu_2^h) = 0 \quad \text{(A.1.4)}$$

Two cases are relevant: either $\mu_1^h = \mu_2^h = \nu_1^h = \nu_2^h = 0$ or $\mu_1^h > 0, \nu_1^h > 0$. Therefore, it can be easily verified the optimal solutions in Lemma 3.

Low Dividend State. The solution for the low dividend state, $(q_\ell, \tau_\ell, d_\ell)$, satisfies the first-order conditions

$$\frac{\partial \mathcal{L}}{\partial q_\ell} = (1-\pi)u'(q_\ell) - \lambda_1 = 0 \tag{A.1.5}$$

$$\frac{\partial \mathcal{L}}{\partial \tau_\ell} = -(1-\pi) + \lambda_1 + (\mu_1^\ell - \mu_2^\ell) = 0 \tag{A.1.6}$$

$$\frac{\partial \mathcal{L}}{\partial d_\ell} = -(1-\pi)\delta_\ell + \lambda_1\delta_\ell - \lambda_2(\delta_h - \delta_\ell) + (\nu_1^\ell - \nu_2^\ell) = 0 \tag{A.1.7}$$

I discuss three possible cases as follows.

Case 1: $\mu_1^\ell = \mu_2^\ell = 0$. By (A.1.7), $\nu_1^\ell - \nu_2^\ell > 0$, so $d_\ell = 0$. By (A.1.6), $\lambda_1 = 1 - \pi$, then $q_\ell = q^*$. By (2.6), $\tau_\ell = q^* < z$ needs to be satisfied, i.e., Case (a).

Case 2: $\mu_1^\ell = 0, \mu_2^\ell > 0$. Thus, $\tau_\ell = z$ and $\lambda_1 > 1 - \pi$, which implies that $q_\ell < q^*$. Firstly, if $\nu_1^\ell = \nu_2^\ell = 0$, we have $0 < d_\ell < a$. By (A.1.2), (A.1.5) and (A.1.7), q_ℓ solves (2.8). Denote the solution as $\hat{q}_\ell$. By (2.6), $d_\ell = [\hat{q}_\ell - z]/\delta_\ell$, which lies between 0 and a. Thus, $z \leq \hat{q}_\ell$ and $z + \delta_\ell a \geq \hat{q}_\ell$ need to be satisfied, i.e., Case (c).

Then, we consider $\nu_1^\ell = 0, \nu_2^\ell > 0$ such that $\tau_\ell = z$ and $d_\ell = a$. By (2.6), $q_\ell = z + \delta_\ell a$. By (A.1.7), we have $q_\ell < \hat{q}_\ell$ under this case. Thus, $z + \delta_\ell a < \hat{q}_\ell$ needs to be satisfied, i.e., Case (d).

Lastly, we consider $\nu_1^\ell > 0, \nu_2^\ell = 0$ such that $\tau_\ell = z$ and $d_\ell = 0$. By (2.6), $q_\ell = z$. By (A.1.7), we have $q_\ell > \hat{q}_\ell$. Thus, $z > \hat{q}_\ell$ needs to be satisfied, i.e., Case (b).

Case 3: $\mu_1^\ell > 0, \mu_2^\ell = 0$. Hence, $\tau_\ell = 0$. By (A.1.7), $\nu_1^\ell - \nu_2^\ell > 0$, so $d_\ell = 0$. By (A.1.5), $\lambda_1 < 1 - \pi$, thus $q_\ell > q^*$ which is infeasible when $\tau_\ell = 0$ and $d_\ell = 0$. $\square$

Proof of Proposition 1. According to Definition 1, the steady-state equilibrium can be expressed as a pair, (Z, ϕ_a), where ϕ_a is the equilibrium price and the equilibrium allocations, (q_1, q_h, q_ℓ), only depend on Z as suggested by the equilibrium contracts (Lemmas 1, 3 and 4). Hence, the proof focuses on the determination of (Z, ϕ_a).

The uniqueness of Z is obvious. From the households' optimal portfolio choices, for all $i > 0$, $Z(i)$ is uniquely determined by the first-order condition, (2.11), with the equality holds and asset market clears, $a = A$. When $i = 0$, $Z \geq q^*$ is not unique but is payoff irrelevant, i.e. $q_1 = q_h = q_\ell = q^*$.

Now, I show the existence and uniqueness of ϕ_a. First, define the aggregate asset demand correspondence

$$A^d(\phi_a) \equiv \{\int_{j\in[0,1]} a(j)\, dj : a(j) \text{ solves } (2.12)\}$$

The proof consists of three parts.

Part I. I first focus on $A^d(\phi_a) = \{a\}, a > 0$. Hence, (2.12) hold with equality,

$$\phi_a - \phi_a^* = \beta\alpha\{(1-\rho)S_{1,a} + \rho[\pi S_{h,a} + (1-\pi)S_{l,a}]\} \tag{A.1.8}$$

According to Section A.2, as a increases, $S_{1,a}$, $S_{h,a}$ and $S_{\ell,a}$ decrease. Then, ϕ_a decreases. Therefore, $A^d(\phi_a)$ is decreasing in ϕ_a for $\phi_a > \phi_a^*$.

Part II. Now I consider $\phi_a = \phi_a^*$ and I focus on $i > 0$. Thus, by (2.11)-(2.12), $q_1 = q_h = q^*$, which implies that $z + \delta^e a \geq q^*$ and $z + \delta_h a - (\delta_h - \delta_\ell)(q_\ell - z)/\delta_\ell \geq q^*$ according to the bargaining solutions. Hence, the aggregate asset demand correspondence suggests that $A^d(\phi_a^*) \in [\bar{A}(i), \infty)$ where

$$\bar{A}(i) = \max\{\frac{q^* - Z(i)}{\delta^e}, \frac{q^* - Z(i)}{\delta_h} + \frac{\delta_h - \delta_\ell}{\delta_h}[q_\ell - Z(i)]/\delta_\ell\}$$

By Lemma 4, $q_\ell = \min\{Z(i), \tilde{q}_\ell\}$, where $\tilde{q}_\ell$ solves (2.8) with $q_h = q^*$, and $Z(i)$ solves

$$i = (1-\alpha)L(z) + \alpha\rho(1-\pi)L(q_\ell) \tag{A.1.9}$$

which is (2.11) with $q_1 = q_h = q^*$.

Part III. Lastly, as $A^d(\phi_a)$ is decreasing in ϕ_a, there exists a threshold, $\bar{\phi}_a$, such that $A^d(\phi_a) = 0$ for all $\phi_a \geq \bar{\phi}_a$. In addition, $\bar{\phi}_a$ has to satisfy (2.11)-(2.12) with $a = 0$.

I summarize the aggregate asset demand correspondence in Figure A.1, taken i as given. Given fixed asset supply A and market clearing condition, the equilibrium asset price, ϕ_a, is unique such that $A \in A^d(\phi_a)$. Furthermore, with unique determination of Z, the equilibrium allocations, (q_1, q_h, q_ℓ), are unique. □

Proof of Lemma 6. According to (2.16), the value of information is independent of ρ in Region 1 and 3. Therefore, the objective is to show $\partial\Pi(\rho)/\partial\rho < 0$ for Region 2.

If $i \geq i^*(A)$ and $A \geq A^*(i)$,

$$\frac{\partial\Pi(\rho)}{\partial\rho} = \alpha\pi\frac{\delta_h - \delta_\ell}{\delta_\ell}(\frac{\partial\hat{q}_\ell}{\partial Z} - 1)\frac{\partial Z}{\partial\rho} \tag{A.1.10}$$

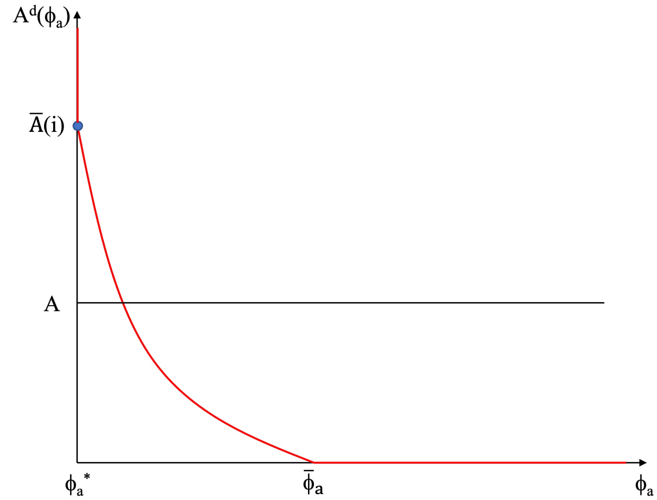

Figure A.1: Aggregate Asset Demand Correspondence

where

$$\frac{\partial \hat{q}_\ell}{\partial Z} = \frac{\frac{\pi}{1-\pi}\frac{\delta_h-\delta_\ell}{\delta_\ell}\frac{\delta_h}{\delta_\ell}\frac{L'(q_h)}{L'(\hat{q}_\ell)}}{1+\frac{\pi}{1-\pi}(\frac{\delta_h-\delta_\ell}{\delta_\ell})^2\frac{L'(q_h)}{L'(\hat{q}_\ell)}} \tag{A.1.11}$$

According to the results in Table 2.1, we have $\partial Z/\partial\rho > 0$. Then, the sign of $\partial\Pi(\rho)/\partial\rho$ depends on the sign of $\partial\hat{q}_\ell/\partial Z - 1$, which is equivalent to compare $\frac{\pi}{1-\pi}\frac{\delta_h-\delta_\ell}{\delta_\ell}\frac{L'(q_h)}{L'(\hat{q}_\ell)}$ with 1.

I claim that $\frac{\pi}{1-\pi}\frac{\delta_h-\delta_\ell}{\delta_\ell}\frac{L'(q_h)}{L'(\hat{q}_\ell)} < 1$. First, according to Appendix A.3, we have $\frac{\pi}{1-\pi}\frac{\delta_h-\delta_\ell}{\delta_\ell} < 1$ to guarantee the existence of the threshold $A^*(i)$. Then, since $L(q)$ is decreasing and convex, i.e., $L'(q) < 0$ and $L''(q) > 0$ for $q < q^*$, it directly implies $\frac{L'(q_h)}{L'(\hat{q}_\ell)} < 1$ with $\hat{q}_\ell < q_h$. As a result, $\partial\Pi(\rho)/\partial\rho < 0$ for Region 2. □

Proof of Proposition 4. According to (2.15), α affects the value of private information $\Pi(\rho)$ through the following two channels,

$$\frac{\partial\Pi(\rho)}{\partial\alpha} = \underbrace{\pi(\delta_h-\delta_\ell)d_\ell(\rho)}_{\text{direct effect} > 0} + \underbrace{\alpha\pi(\delta_h-\delta_\ell)\frac{\partial d_\ell(\rho)}{\partial\alpha}}_{\text{indirect effect}} \tag{A.1.12}$$

Then, we need to determine the sign of $\partial d_\ell / \partial \alpha$. According to (2.16), d_ℓ is independent of α for Regions 1 and 3. Therefore, $\partial \Pi(\rho)/\partial \alpha > 0$, and the indirect effect does not play a role. Now, focusing on Region 2, we have

$$\frac{\partial d_\ell}{\partial \alpha} = \frac{\partial d_\ell}{\partial Z}\frac{\partial Z}{\partial \alpha} \tag{A.1.13}$$

where $\partial d_\ell / \partial Z < 0$ implied by Lemma 6. Furthermore, by (2.11),

$$\frac{\partial Z}{\partial \alpha} = \frac{L(Z) - \{(1-\rho)L(q_1) + \rho[\pi L(q_h) + (1-\pi)L(q_\ell)]\}}{(1-\alpha)L'(Z) + \alpha\{(1-\rho)L'(q_1) + \rho[\pi L'(q_h) + (1-\pi)L'(q_\ell)]\}} < 0 \tag{A.1.14}$$

since q_1, q_h and q_ℓ are all greater than Z. Therefore, the indirect effect is positive since $\partial d_\ell / \partial \alpha > 0$, and $\partial \Pi(\rho)/\partial \alpha > 0$ for Region 2. $\square$

A.2 Objective Function of Portfolio Choices

I aim to show that $(1-\alpha)S_0 + \alpha\{(1-\rho)S_1 + \rho[\pi S_h + (1-\pi)S_\ell]\}$ in (2.10) is jointly concave in (z, a). Therefore, the first-order conditions (2.11)-(2.12) are necessary and sufficient to pin down the households' optimal portfolio choices given $i \geq 0$ and $\phi_a \geq \phi_a^*$. According to the bargaining solutions, I discuss the following cases.

Case 1: If $i = 0$, then $z \geq q^*$ and $q_0 = q_1 = q_h = q_\ell = q^*$. the first-order conditions are satisfied automatically, and $\phi_a = \phi_a^*$.

Case 2: If $z^*(a, \pi, \delta_h, \delta_\ell) < z < q^*$, then $S_{i,zz} = L'(q_i)$ where $q_1 = min\{q^*, z + \delta^e a\}$, $q_h = min\{q^*, z + \delta_h a\}$ and $q_\ell = z$. Then, $S_{1,aa} = (\delta^e)^2 L'(q_1)$, $S_{h,aa} = (\delta_h)^2 L'(q_h)$, $S_{1,za} = \delta^e L'(q_1)$, $S_{h,za} = \delta_h L'(q_h)$, and $S_{0,za} = S_{0,aa} = S_{\ell,za} = S_{\ell,aa} = 0$. Therefore, the

Hessian matrix is defined as

$$H_1 = \begin{bmatrix} a_1 & b_1 \\ c_1 & d_1 \end{bmatrix}$$

where

$$a_1 = [(1-\alpha) + \alpha\rho(1-\pi)]L'(z) + \alpha[(1-\rho)L'(q_1) + \rho\pi L'(q_h)]$$

$$b_1 = c_1 = \alpha[(1-\rho)\delta^e L'(q_1) + \rho\pi\delta_h L'(q_h)]$$

$$d_1 = \alpha[(1-\rho)(\delta^e)^2 L'(q_1) + \rho\pi(\delta_h)^2 L'(q_h)]$$

We have $a_1 < 0$ since $L'(\cdot) < 0$. The determinant of the Hessian matrix is $|H_1| = a_1 d_1 - b_1 c_1 > 0$ if $q_1 < q^*$. That is, $z + \delta^e a < q^*$.

Case 3: If $z < z^*(a, \pi, \delta_h, \delta_\ell)$ and $a \geq a^*(z, \pi, \delta_h, \delta_\ell)$, then $S_{0,zz} = L'(q_0)$, $S_{1,zz} = L'(q_1)$, $S_{1,za} = \delta^e L'(q_1)$, and $S_{1,aa} = (\delta^e)^2 L'(q_1)$ where $q_1 = min\{q^*, z + \delta^e a\}$. According to Lemmas 3 and 4, we have $q_h = \min\{q^*, z + \delta_h a - \frac{\delta_h - \delta_\ell}{\delta_\ell}(q_\ell - z)\}$ and $q_\ell = \hat{q}_\ell$ that solves (2.8). Then, we can derive $\pi S_{h,zz} + (1-\pi)S_{\ell,zz} = \pi\frac{\delta_h}{\delta_\ell}L'(q_h)\frac{\partial q_h}{\partial z}$, $\pi S_{h,za} + (1-\pi)S_{\ell,za} = \pi\frac{\delta_h}{\delta_\ell}L'(q_h)\frac{\partial q_h}{\partial a}$, and $\pi S_{h,aa} + (1-\pi)S_{\ell,aa} = \pi\delta_h L'(q_h)\frac{\partial q_h}{\partial a}$, and we can solve for

$$\frac{\partial q_h}{\partial a} = \delta_\ell\frac{\partial q_h}{\partial z} = \delta_h/(1 + \frac{\pi}{1-\pi}(\frac{\delta_h - \delta_\ell}{\delta_\ell})^2\frac{L'(q_h)}{L'(\hat{q}_\ell)}) > 0$$

Let $\mathcal{C} \equiv L'(q_h)\frac{\partial q_h}{\partial z}$. Therefore, the Hessian matrix is defined as

$$H_2 = \begin{bmatrix} a_2 & b_2 \\ c_2 & d_2 \end{bmatrix}$$

where

$$a_2 = (1-\alpha)L'(z) + \alpha[(1-\rho)L'(q_1) + \rho\pi\frac{\delta_h}{\delta_\ell}\mathcal{C}]$$

$$b_2 = c_2 = \alpha[(1-\rho)\delta^e L'(q_1) + \rho\pi\delta_h\mathcal{C}]$$

$$d_2 = \alpha[(1-\rho)(\delta^e)^2 L'(q_1) + \rho\pi\delta_h\delta_\ell\mathcal{C}]$$

Thus, we have $a_2 < 0$ since $L'(\cdot) < 0$ and $\mathcal{C} < 0$. The determinant of the Hessian matrix is $|H_2| = a_2 d_2 - b_2 c_2 > 0$ if $q_1 < q^*$ or $q_h < q^*$, which implies that $z + \delta^e a < q^*$ or $z + \delta_h a - (\delta_h - \delta_\ell)d_\ell < q^*$.

Case 4: If $z < z^*(a, \pi, \delta_h, \delta_\ell)$ and $a < a^*(z, \pi, \delta_h, \delta_\ell)$, then $S_{i,zz} = L'(q_i)$ where $q_1 = \min\{q^*, z+\delta^e a\}$ and $q_h = q_\ell = z+\delta_\ell a \equiv q_2$. Then, $S_{1,aa} = (\delta^e)^2 L'(q_1)$, $S_{h,aa} = S_{\ell,aa} = (\delta_\ell)^2 L'(q_2)$, $S_{1,za} = \delta^e L'(q_1)$, $S_{h,za} = S_{\ell,za} = \delta_\ell L'(q_2)$. Therefore, the Hessian matrix is defined as

$$H_3 = \begin{bmatrix} a_3 & b_3 \\ c_3 & d_3 \end{bmatrix}$$

where

$$a_3 = (1-\alpha)L'(z) + \alpha[(1-\rho)L'(q_1) + \rho L'(q_2)]$$

$$b_3 = c_3 = \alpha[(1-\rho)\delta^e L'(q_1) + \rho\delta_\ell L'(q_2)]$$

$$d_3 = \alpha[(1-\rho)(\delta^e)^2 L'(q_1) + \rho(\delta_\ell)^2 L'(q_2)]$$

We have $a_3 < 0$ since $L'(\cdot) < 0$. The determinant of the Hessian matrix is $|H_3| = a_3 d_3 - b_3 c_3 > 0$.

A.3 Relevant Regions

In this section, I characterize the two critical thresholds in Figure 2.2. First, $i^*(A)$ solves $Z(i) = \hat{q}_\ell$. In Region 1, i.e., $0 < i < i^*(A)$, we have $d_\ell = 0$ by Lemma 4. As the asset supply becomes sufficiently larger, that is, $A \geq [q^* - Z(i_0)]/\delta_h$, then $q_1 = q_h = q^*$, and $\tilde{q}_\ell = L^{-1}(\frac{\pi}{1-\pi}\frac{\delta_h - \delta_\ell}{\delta_\ell})$ that solves (2.8). Therefore, $i^*(A) = i_0$ is independent of A, where $i_0 = (1-\alpha)\frac{\pi}{1-\pi}\frac{\delta_h-\delta_\ell}{\delta_\ell} + \alpha\rho\pi\frac{\delta_h-\delta_\ell}{\delta_\ell}$, which is (A.1.9) with $L(z) = L(\tilde{q}_\ell) = \frac{\pi}{1-\pi}\frac{\delta_h-\delta_\ell}{\delta_\ell}$. On the contrary, if $A < [q^* - Z(i_0)]/\delta_h$, then $\hat{q}_\ell = Z(i^*)$ is increasing in A, and $i^*(A)$ is decreasing in A.

The second threshold, $A^*(i) = [\hat{q}_\ell - Z(i)]/\delta_\ell$, is monotonically increasing in i, which is implied by the proof for Lemma 6. Furthermore, I show that π cannot be too large to have $A^*(i)$ exist. According to Lemmas 3 and 4, $q_\ell \leq q_h$. As the constraint $a \geq a^*(z, \pi, \delta_h, \delta_\ell)$ becomes more and more binding, the optimal contract approaches to a pooling offer such that $q_h = q_\ell$. Then, (2.8) becomes

$$(1 - \frac{\pi}{1-\pi}\frac{\delta_h - \delta_\ell}{\delta_\ell})u'(q_\ell) = 1 \tag{A.3.1}$$

Hence, $(1-\pi)\delta_\ell > \pi(\delta_h - \delta_\ell)$ guarantees the existence of the threshold $A^*(i)$.

Lastly, given the definitions of the two critical thresholds for the relevant regions, it is straightforward to show that $A^*(i)$ and $i^*(A)$ intersect on the horizontal axis. Since $i^*(A)$ solves $\hat{q}_\ell = Z(i)$, we have $A^*(i^*) = (\hat{q}_\ell - Z)/\delta_\ell = 0$, which implies that the point, $(i^*(0), 0)$ lies on both $A^*(i)$ and $i^*(A)$.

A.4 Proof of Results in Table 2.1

In this section, I first characterize the steady-state equilibrium (Z, ϕ_a) according to Definition 2 for each relevant region.

Region 1: $0 < i < i^*(A)$. According to Lemmas 1, 3 and 4, the first-order conditions for households' optimal portfolio choices, (2.11)-(2.12), and the market clearing conditions, the steady-state equilibrium (Z, ϕ_a) satisfies

$$i = (1-\alpha)L(Z) + \alpha\{(1-\rho)L(q_1) + \rho[\pi L(q_h) + (1-\pi)L(q_\ell)]\} \tag{A.4.1}$$

$$\phi_a^* = \phi_a - \beta\alpha[(1-\rho)\delta^e L(q_1) + \rho\pi\delta_h L(q_h)] \tag{A.4.2}$$

where $q_1 = \min\{q^*, Z + \delta^e A\}$, $q_h = \min\{q^*, Z + \delta_h A\}$, and $q_\ell = Z$.

Region 2: $i \geq i^*(A)$ and $A \geq A^*(i)$. The equilibrium (Z, ϕ_a) satisfies

$$i = (1-\alpha)L(Z) + \alpha\{(1-\rho)L(q_1) + \rho[\pi\frac{\delta_h}{\delta_\ell}L(q_h) + \pi\frac{\delta_h - \delta_\ell}{\delta_\ell}]\} \tag{A.4.3}$$

$$\phi_a^* = \phi_a - \beta\alpha\{(1-\rho)\delta^e L(q_1) + \rho\pi\delta_h L(q_h)\} \tag{A.4.4}$$

where $q_1 = \min\{q^*, Z + \delta^e A\}$, $q_h = \min\{q^*, Z + \delta_h A - \frac{\delta_h - \delta_\ell}{\delta_\ell}(\hat{q}_\ell - Z)\}$, and $q_\ell = \hat{q}_\ell$ that solves (2.8).

Region 3: $i \geq i^*(A)$ and $A < A^*(i)$. The equilibrium (Z, ϕ_a) satisfies

$$i = (1-\alpha)L(Z) + \alpha[(1-\rho)L(q_1) + \rho L(q_2)] \tag{A.4.5}$$

$$\phi_a^* = \phi_a - \beta\alpha\{(1-\rho)\delta^e L(q_1) + \rho[\delta_\ell L(q_2) - \pi(\delta_h - \delta_\ell)]\} \tag{A.4.6}$$

where $q_1 = \min\{q^*, Z + \delta^e A\}$ and $q_2 = Z + \delta_\ell A$.

First, if i is sufficiently low or A is sufficiently high, the households' liquid wealth in equilibrium can be abundant. Then, the terms of trade q_1 and q_h can achieve the optimal level, q^*, and are independent on model parameters. From now on, I focus on the interior solutions, i.e., $q_1 < q^*$ and $q_h < q^*$, when the parameters (i, A) make the households' liquid wealth in equilibrium scarce.

The effects of the nominal interest rate on the demand for real balances and the equilibrium allocations are implied by (A.4.1), (B.2.7), and (B.2.11). As i increases, the liquidity premiums on the right-hand sides, $L(q_1)$, $L(q_h)$ and $L(q_\ell)$, will increase. Then, the equilibrium allocations, (q_1, q_h, q_ℓ), all decrease, and the demand of real money balances, Z, decreases. By (A.4.2), (B.2.8), and (B.2.12), as the liquidity premiums increase when i increases, ϕ_a also increases.

Next, I investigate the impact of the fraction of informed dealers, ρ, on the steady-state equilibrium, (Z, ϕ_a).

Region 1: $0 < i < i^*(A)$. I derive the partial derivatives as follows.

$$\frac{\partial Z}{\partial \rho} = \frac{\alpha\{L(q_1) - [\pi L(q_h) + (1-\pi)L(q_\ell)]\}}{(1-\alpha)L'(Z) + \alpha\{(1-\rho)L'(q_1) + \rho[\pi L'(q_h) + (1-\pi)L'(q_\ell)]\}} \tag{A.4.7}$$

$$\frac{\partial \phi_a}{\partial \rho} = \beta\alpha\{[\pi\delta_h L(q_h) - \delta^e L(q_1)] + [(1-\rho)\delta^e L'(q_1) + \rho\pi\delta_h L'(q_h)]\frac{\partial Z}{\partial \rho}\} \tag{A.4.8}$$

Region 2: $i \geq i^*(A)$ and $A \geq A^*(i)$. Again, let $\mathcal{C} \equiv L'(q_h)\frac{\partial q_h}{\partial z}$. Then, we have

$$\frac{\partial Z}{\partial \rho} = \frac{\alpha\{L(q_1) - [\pi\frac{\delta_h}{\delta_\ell}L(q_h) + \pi\frac{\delta_h - \delta_\ell}{\delta_\ell}]\}}{(1-\alpha)L'(Z) + \alpha[(1-\rho)L'(q_1) + \rho\pi\frac{\delta_h}{\delta_\ell}\mathcal{C}]} \tag{A.4.9}$$

$$\frac{\partial \phi_a}{\partial \rho} = \beta\alpha\{[\pi\delta_h L(q_h) - \delta^e L(q_1)] + [(1-\rho)\delta^e L'(q_1) + \rho\pi\delta_h\mathcal{C}]\frac{\partial Z}{\partial \rho}\} \tag{A.4.10}$$

Region 3: $i \geq i^*(A)$ and $A < A^*(i)$. Similarly, we solve for

$$\frac{\partial Z}{\partial \rho} = \frac{\alpha[L(q_1) - L(q_2)]}{(1-\alpha)L'(Z) + \alpha[(1-\rho)L'(q_1) + \rho L'(q_2)]} \tag{A.4.11}$$

$$\frac{\partial \phi_a}{\partial \rho} = \beta\alpha\{[\delta_\ell L(q_2) - \pi(\delta_h - \delta_\ell) - \delta^e L(q_1)] + [(1-\rho)\delta^e L'(q_1) + \rho\delta_\ell L'(q_2)]\frac{\partial Z}{\partial \rho}\} \tag{A.4.12}$$

Now, I show that $\partial Z/\partial \rho > 0$ for all three regions. First, the denominators are all negative as $L'(\cdot) < 0$ and $\mathcal{C} < 0$. For Regions 1 and 2, we have $q_1 > \pi q_h + (1-\pi)q_\ell$ according to the bargaining solutions. Since $L(q)$ is decreasing and convex, by Jensen's inequality, $L(q_1) < L(\pi q_h + (1-\pi)q_\ell) \leq \pi L(q_h) + (1-\pi)L(q_\ell)$. For Region 3, since $q_1 > q_2$, $L(q_1) < L(q_2)$. Then, the numerators are all negative, and we can conclude that $\partial Z/\partial \rho > 0$.

Lastly, I investigate the sign of $\partial \phi_a/\partial \rho$ for each relevant region. Since $L'(q) < 0$ and $\partial Z/\partial \rho > 0$, the indirect effect of changing ρ on asset liquidity through changing Z is negative for all three regions. However, the sign of the direct effect on the marginal benefit of carrying the trees is ambiguous. Hence, I focus on showing the following sufficient conditions for a (weakly) negative direct effect.

Proof of Lemma 5. For Region 1, the direct effect, $\pi\delta_h L(q_h) - \delta^e L(q_1) \leq 0$ since $\pi\delta_h < \delta^e$ and $L(q_h) \leq L(q_1)$. Therefore, $0 < i < i^*(A)$ is a sufficient condition for $\partial \phi_a/\partial \rho < 0$.

For Region 3, suppose $Z(i) + \delta^e A < q^*$, where $Z(i)$ satisfies (B.2.11). Then, with CRRA utility function, the sufficient condition for a negative direct effect becomes $\delta_\ell (q_2)^{-\sigma} < \delta^e (q_1)^{-\sigma}$. Equivalently, we should have $(\delta_\ell/\delta^e)^{1/\sigma} < q_2/q_1 = (Z + \delta_\ell A)/(Z + \delta^e A)$. After cross-multiplication, it becomes $(Z + \delta^e A)(\delta_\ell)^{1/\sigma} < (Z + \delta_\ell A)(\delta^e)^{1/\sigma}$. That is, $\delta^e \delta_\ell[(\delta_\ell)^{1/\sigma - 1} - (\delta^e)^{1/\sigma - 1}]A < [(\delta^e)^{1/\sigma} - (\delta_\ell)^{1/\sigma}]Z$. Hence, when the risk-aversion parameter $\sigma < 1$, the inequality is satisfied automatically as the left-hand side is negative and the right-hand side is positive.

A.5 Alternating offers

In this section, I follow Rubinstein and Wolinsky (1985) and discuss a more general setup of the bargaining protocol. When a bilateral match is formed in each period, the household and the dealer are chosen randomly to offer a contract. More specifically, with probability $b \in [0, 1]$, the household makes a take-it-or-leave-it offer, and with complementary probability $1 - b$, the dealer makes a take-it-or-leave-it offer. The household's outside option, $S_0 \equiv u(q_0) - q_0$, is the trade surplus only paying with real money balances in the competitive special goods market. As a result, the equilibrium contract offered by the household is characterized in Section 2.3.2. Now, I solve the equilibrium contract when the dealer makes the offer, denoted as $\{(q_1^D, \tau_1^D, d_1^D), (q_h^D, \tau_h^D, d_h^D), (q_\ell^D, \tau_\ell^D, d_\ell^D)\}$.

A.5.1 Type I Meeting

A household matches with an uninformed dealer in Type I meetings. Therefore, the household and the dealer are symmetrically uninformed about the asset dividend. The dealer's problem is

$$\max_{(q_1^D,\tau_1^D,d_1^D)} [-q_1^D + \tau_1^D + \delta^e d_1^D] \tag{A.5.1}$$

s.t.

$$u(q_1^D) - \tau_1^D - \delta^e d_1^D \geq S_0 \tag{A.5.2}$$

$$0 \leq \tau_1^D \leq z, 0 \leq d_1^D \leq a \tag{A.5.3}$$

Define $y^e \equiv z + \delta^e a$. The equilibrium contract offered by the dealer solves (A.5.1)-(A.5.3).

(a) If $u(q^*) - S_0 \leq y^e$, then $q_1^D = q^*$ and $\tau_1^D + \delta^e d_1^D = u(q^*) - S_0$;

(b) If $u(q^*) - S_0 > y^e$, then $q_1^D = u^{-1}(y^e + S_0)$, $\tau_1^D = z$, and $d_1^D = a$.

The proof is omitted, and the intuition is straightforward. The bargaining solution depends on whether the household's liquidity wealth, y^e, is sufficient to trade the optimal quantity.

A.5.2 Type II Meeting: A Signaling Game

In Type II meetings, a household matches with an uninformed dealer. Hence, the bargaining protocol has a structure of a signaling game. The dealer offers a contract $(q^D, \tau^D, d^D) \in \mathcal{F} \equiv \mathbb{R}_+ \times [0, z] \times [0, a]$, as a function of the dealer's private information about $\delta \in \{\delta_h, \delta_\ell\}$, and the household accepts or rejects the offer. A strategy for the household is an acceptance rule such that $\mathcal{A} \in \mathcal{F}$ is a set of acceptable offers.

Define an indicator function $\mathbb{1}_{\mathcal{A}}(q^D, \tau^D, d^D)$ such that it equals to one if $(q^D, \tau^D, d^D) \in \mathcal{A}$ and zero otherwise. The dealer's problem in the dividend state $\delta \in \{\delta_h, \delta_\ell\}$ is

$$\max_{(q^D,\tau^D,d^D)\in\mathcal{F}} \{[-q^D + \tau^D + \delta d^D] \mathbb{1}_{\mathcal{A}}(q^D, \tau^D, d^D)\} \tag{A.5.4}$$

The household's payoff is

$$[u(q^D)+W(z-\tau^D,a-d^D,\delta)]\mathbb{1}_{\mathcal{A}}(q^D,\tau^D,d^D)+[u(q_0)+W(z-q_0,a,\delta)][1-\mathbb{1}_{\mathcal{A}}(q^D,\tau^D,d^D)]$$
$$=[u(q^D)-\tau^D-\delta d^D]\mathbb{1}_{\mathcal{A}}(q^D,\tau^D,d^D)+S_0[1-\mathbb{1}_{\mathcal{A}}(q^D,\tau^D,d^D)]+W(z,a,\delta) \quad \text{(A.5.5)}$$

by the linearity of $W(z,a,\delta)$.

After receiving the offer, the household forms expectations about the dividend, δ. Let $\lambda(q^D,\tau^D,d^D)\in[0,1]$ be the updated belief such that the asset quality is high, $\delta=\delta_h$. Then, $\mathbb{E}_\lambda[\delta]=\lambda(q^D,\tau^D,d^D)\delta_h+(1-\lambda(q^D,\tau^D,d^D))\delta_\ell$. For a given belief system, the set of acceptable offers is

$$\mathcal{A}(\lambda)=\{(q^D,\tau^D,d^D)\in\mathcal{F}:u(q^D)-\tau^D-\mathbb{E}_\lambda[\delta]d^D\geq S_0\} \quad \text{(A.5.6)}$$

Also, I assume a tie-breaking rule according to which households accept the offers whenever they are indifferent between accepting or rejecting them.

The equilibrium contract made by the dealers is a perfect Bayesian equilibrium (PBE) that consists of a pair of strategies and a belief system such that (q^D,τ^D,d^D) solves (A.5.4), with $\delta\in\{\delta_h,\delta_\ell\}$; the set of acceptable offers for a household $\mathcal{A}$ is defined by (A.5.6); the belief system $\lambda:\mathcal{F}\to[0,1]$ satisfies the Bayes' rule. Furthermore, I use the Intuitive Criterion of Cho and Kreps (1987) to refine the equilibrium concept.[1] Therefore, as shown in Rocheteau (2011), there is no pooling offer with $d^D>0$ in equilibrium since

[1] One could consider the undefeated equilibrium as an alternative refinement following Mailath et al. (1993). See Bajaj (2018), Wang (2020), and Madison (2024). As shown in Rocheteau (2011), with a sufficiently low nominal interest rate, the separating equilibrium by the Intuitive Criterion is robust.

a pooling contract violates the Intuitive Criterion. Intuitively, the dealers who know the asset dividend is low have incentives to deviate from the pooling contract by decreasing the transfer of the trees by a small amount, $\epsilon > 0$, and the issuance of liquid IOUs by a value between $\delta_\ell \epsilon$ and $\delta_h \epsilon$. Such an offer would raise the payoff of the dealers in the low dividend state but hurt those in the high dividend state, and the household should attribute this offer to the low dividend state.

Now, I focus on separating PBE and denote the equilibrium contracts for each dividend state $\chi \in \{h, \ell\}$ as $(q_\chi^D, \tau_\chi^D, d_\chi^D)$. First, if the dealers are informed that the dividend is high, the equilibrium contract solves

$$\max_{(q_h^D, \tau_h^D, d_h^d)} \{-q_h^D + \tau_h^D + \delta_h d_h^D\} \tag{A.5.7}$$

s.t.

$$u(q_h^D) - \tau_h^D - \delta_h d_h^D \geq S_0 \tag{A.5.8}$$

$$0 \leq \tau_h^D \leq z, 0 \leq d_h^D \leq a \tag{A.5.9}$$

Next, for the dealers who are informed that the dividend is low, the equilibrium contract solves

$$\max_{(q_\ell^D, \tau_\ell^D, d_\ell^d)} \{-q_\ell^D + \tau_\ell^D + \delta_\ell d_\ell^D\} \tag{A.5.10}$$

s.t.

$$u(q_\ell^D) - \tau_\ell^D - \delta_\ell d_\ell^D \geq S_0 \tag{A.5.11}$$

$$-q_\ell^D + \tau_\ell^D + \delta_h d_\ell^D \leq -q_h^D + \tau_h^D + \delta_h d_h^D = u(q_h^D) - q_h^D - S_0 \tag{A.5.12}$$

$$0 \leq \tau_\ell^D \leq z, 0 \leq d_\ell^D \leq a \tag{A.5.13}$$

Lemma E.1. The equilibrium contract for the high dividend state ($\delta = \delta_h$) is

(a) If $u(q^*) - S_0 \leq \bar{y}$, then $q_h^D = q^*$ and $\tau_h^D + \delta_h d_h^D = u(q^*) - S_0$;

(b) If $u(q^*) - S_0 > \bar{y}$, then $q_h^D = u^{-1}(\bar{y} + S_0)$, $\tau_h^D = z$, and $d_h^D = a$.

The equilibrium contract for the low dividend state ($\delta = \delta_\ell$) is

(c) If $z \geq u(q^*) - S_0$, then $q_\ell^D = q^*$, $\tau_\ell^D = u(q^*) - S_0$, and $d_\ell^D = 0$;

(d) If $z < u(q^*) - S_0$, then $\tau_\ell^D = z$, and $(q_\ell^D, d_\ell^D) \in [0, q_h^D] \times [0, a]$ solves

$$d_\ell^D = \frac{u(q_\ell^D) - \tau_\ell^D - S_0}{\delta_\ell} \tag{A.5.14}$$

$$u(q_\ell^D) - q_\ell^D + (\frac{\delta_h}{\delta_\ell} - 1)[u(q_\ell^D) - \tau_\ell^D - S_0] = u(q_h^D) - q_h^D \tag{A.5.15}$$

where $q_h^D = \min\{q^*, u^{-1}(\bar{y} + S_0)\}$.

Proof. The proof for the high dividend state is omitted as the equilibrium contract is the complete-information offer. For the low dividend state, the Lagrangian for the optimization problem is

$$\mathcal{L} = [-q_\ell^D + \tau_\ell^D + \delta_\ell d_\ell^D] + \lambda_1[u(q_\ell^D) - \tau_\ell^D - \delta_\ell d_\ell^D - S_0] + \lambda_2[(u(q_h^D) - q_h^D) - (u(q_\ell^D) - q_\ell^D) - (\delta_h - \delta_\ell) d_\ell^D]$$
$$+ \mu_1 \tau_\ell^D + \mu_2(z - \tau_\ell^D) + \nu_1 d_\ell^D + \nu_2(a - d_\ell^D) \tag{A.5.16}$$

where λ_1 and λ_2 are the Lagrangian multipliers with respect to the two constraints, (A.5.11) and (A.5.12). μ_i and ν_i for $i = \{1, 2\}$ are the Lagrangian multipliers with respect to the liquidity constraints, A.5.13. The optimal contract satisfies the following first-order conditions

$$\frac{\partial \mathcal{L}}{\partial q_\ell^D} = -1 + \lambda_1 u'(q_\ell^D) - \lambda_2[u'(q_\ell^D) - 1] = 0 \tag{A.5.17}$$

$$\frac{\partial \mathcal{L}}{\partial \tau_\ell^D} = 1 - \lambda_1 + (\mu_1 - \mu_2) = 0 \tag{A.5.18}$$

$$\frac{\partial \mathcal{L}}{\partial d_\ell^D} = \delta_\ell - \lambda_1\delta_\ell - \lambda_2(\delta_h - \delta_\ell) + (\nu_1 - \nu_2) = 0 \tag{A.5.19}$$

To begin with, I show that both (A.5.11) and (A.5.12) are binding. Firstly, Consider (A.5.11) is binding and (A.5.12) is slack. (i.e., $\lambda_1 > 0, \lambda_2 = 0$) Then, $q_\ell^D = \min\{q^*, u^{-1}(\bar{y} + S_0)\} \le q_h^D$, and (A.5.12) becomes

$$u(q_\ell^D) - q_\ell^D + (\delta_h - \delta_\ell)d_\ell^D \le u(q_h^D) - q_h^D \tag{A.5.20}$$

If $\underline{y} \ge u(q^*) - S_0$, then $q_h^D = q_\ell^D = q^*$. (A.5.20) implies that $d_\ell^D = 0$ and (A.5.12) is binding, i.e., a contradiction. If $\underline{y} < u(q^*) - S_0$, we have $\tau_\ell^D = z$ and $d_\ell^D = a$. Then, (A.5.12) becomes

$$-q_\ell^D + z + \delta_h a + S_0 = \bar{y} + S_0 - q_h^D + (q_h^D - q_\ell^D) \le u(q_h^D) - q_h^D \tag{A.5.21}$$

which implies $q_h^D - q_\ell^D \le 0$, i.e., a contradiction. Next, if (A.5.12) is binding and (A.5.11) is slack. (i.e., $\lambda_1 = 0, \lambda_2 > 0$) By (A.5.17), $u'(q_\ell^D) - 1 < 0$, which is infeasible. Therefore, both (A.5.11) and (A.5.12) are binding. The optimal contract solves (A.5.17)-(A.5.19) wth $\lambda_1 > 0$ and $\lambda_2 > 0$. Combining (A.5.18) and (A.5.19), we have

$$1 - \lambda_1 = \mu_2 - \mu_1 = \frac{\nu_2 - \nu_1}{\delta_\ell} + \lambda_2\frac{\delta_h - \delta_\ell}{\delta_\ell} \tag{A.5.22}$$

Similar to the proof for Lemmas 3 and 4, I consider the following relevant cases.

Case 1: $\mu_1 = \mu_2 = 0$ and $\nu_1 > \nu_2$, which implies $0 \leq \tau_\ell^D \leq z$ and $d_\ell^D = 0$. By (A.5.22), $\lambda_1 = 1$. Then, $q_\ell^D = q^*$ and $\tau_\ell^D = u(q^*) - S_0 \leq z$.

Case 2: $\mu_1 < \mu_2$ and hence, $\tau_\ell^D = z$. Then, q_ℓ^D and d_ℓ^D solves the two binding constraints, (A.5.14)-(A.5.15). Furthermore, the left-hand side of (A.5.15) is monotonically increasing in q_ℓ^D. When $q_\ell^D = 0$, the left-hand side is negative. When $q_\ell^D = q_h^D$, the left-hand side is greater than the right-hand side. Therefore, there exists a unique $q_\ell^D \in [0, q_h^D]$ that solves (A.5.15), and a unique $d_\ell^D \in [0, a]$ that solves (A.5.14). $\square$

Belief system. The equilibrium consists of a belief system that generates the acceptance rule for households. According to Bayes' rule, a belief system that is consistent with (q^D, τ^D, d^D) is

$$\lambda(q_h^D, \tau_h^D, d_h^D) = 1$$

$$\lambda(q_\ell^D, \tau_\ell^D, d_\ell^D) = 0$$

For all other out-of-equilibrium offers, by construction, the following belief system satisfies the Intuitive Criterion.

$$\lambda(q^D, \tau^D, d^D) = 1, \forall (q^D, \tau^D, d^D) \notin \mathcal{O} \text{ s.t. } -q^D + \tau^D + \delta_h d^D > u(q_h^D) - q_h^D - S_0$$

$$\lambda(q^D, \tau^D, d^D) = 0, \forall (q^D, \tau^D, d^D) \notin \mathcal{O} \text{ s.t. } -q^D + \tau^D + \delta_h d^D \leq u(q_h^D) - q_h^D - S_0$$

where $\mathcal{O}$ is the set of the offers on the equilibrium path. That is, the out-of-equilibrium offers that would better off the dealers in the high dividend state are attribute to those dealers, and the rest offers are attribute to the dealers in the low dividend state. Now, I conclude the setup of the signaling game.

Signaling v.s. Screening. Compared to the equilibrium contracts proposed by the households in Section 2.3.2, the *pecking-order property of payments* still holds for the low dividend state. That is, when the dealer is informed about the low dividend, there is a strict preference for using real money balances to trade. Furthermore, $q_\ell^D \leq q_h^D$ and $d_\ell^D \leq d_h^D$ also hold when the dealer makes the take-it-or-leave-it offer.

A.5.3 Households' Portfolio Choices

Once the dealers are allowed to make take-it-or-leave-it offers, the objective function for the households' optimal portfolio choices becomes

$$[z(j), a(j)] = arg \max_{z,a}\{-iz-(\frac{\phi_a - \phi_a^*}{\beta})a+[(1-\alpha)+\alpha(1-b)]S_0+\alpha b[(1-\rho)S_1+\rho[\pi S_h+(1-\pi)S_\ell]]\} \tag{A.5.23}$$

The difference from (2.10) is that when the dealers make the offers, with a probability $1-b$, the households' trade surplus from the bilateral meetings is S_0. The surplus is the same as that from the households' outside option since the dealers will extract all surplus according to the signaling game (A.5.7)-(A.5.13). Furthermore, if $b = 0$, the liquidity premium is eliminated.

Following Appendix A.2, the objective function, (A.5.23), is jointly concave in (z, a). Hence, the first-order conditions are:

$$-i+[(1-\alpha)+\alpha(1-b)]S_{0,z}+\alpha b\{(1-\rho)S_{1,z}+\rho[\pi S_{h,z}+(1-\pi)S_{\ell,z}]\} \leq 0, \text{ "=" if } z > 0 \tag{A.5.24}$$

$$-\frac{\phi_a - \phi_a^*}{\beta} + \alpha b\{(1-\rho)S_{1,a} + \rho[\pi S_{h,a} + (1-\pi)S_{\ell,a}]\} \leq 0, \text{ ''='' if } a > 0 \tag{A.5.25}$$

As a result, with exogenous ρ, the comparative statics in Table 2.1 still hold.

A.5.4 Value of Private Information and Information Acquisition

Now, the dealers can extract trade surplus when they make take-it-or-leave-it offers, with a probability of $1-b$. Given the equilibrium contracts discussed above, in the Type I meetings, the dealers can extract a trade surplus $\Pi_1(\rho) = \alpha(1-b)[u(q_1^D) - q_1^D]$. In the Type II meetings, the dealers can extract a trade surplus plus the informational rent in the high dividend state when the households make the offer. Hence, $\Pi_2(\rho) = \alpha b\pi(\delta_h - \delta_\ell)d_\ell(\rho) + \alpha(1-b)\{\pi[u(q_h^D) - q_h^D] + (1-\pi)[u(q_\ell^D) - q_\ell^D]\}$, where $d_\ell(\rho)$ is the equilibrium contract characterized in Section 2.3.2. Thus, the value of private information becomes

$$\begin{aligned}\Pi(\rho) = \alpha b\pi(\delta_h - \delta_\ell)d_\ell^H(\rho) \\ + \alpha(1-b)\{\pi[u(q_h^D) - q_h^D] + (1-\pi)[u(q_\ell^D) - q_\ell^D] - [u(q_1^D) - q_1^D]\}\end{aligned} \tag{A.5.26}$$

Lemma E.2. When the dealers are making the equilibrium offer (i.e., $b = 0$), the value of private information is non-positive.

The proof is as follows. By the equilibrium contract (q^D, τ^D, d^D), we have $\pi q_h^D + (1-\pi)q_\ell^D \leq q_1^D$. Denote $S^D(q) \equiv u(q) - q$, then $S^D(q)$ is increasing and concave, and we have $\pi S^D(q_h^D) + (1-\pi)S^D(q_\ell^D) \leq S^D(q_1^D)$. Hence, the second line of (A.5.26) is non-positive. Intuitively, dealers signal low-quality assets by distorting the terms of trade. In other words, dealers becoming privately informed about the asset quality will diminish their trade surpluses. Furthermore, this Lemma implies that dealers have no incentives to acquire private information, i.e., $\rho^* = 0$, if the dealers make take-it-or-leave-it offers.

I consider the following numerical examples to further illustrate the value of private information with $b \in (0,1)$.[2] As b is small, the dealers have a higher chance to make a take-it-or-leave-it offer. As shown in the left panel, the value of private information is negative, following Lemma E.2, and increasing in ρ, i.e., a strategic complementarity. As b increases, the households have a higher chance to make the offers, leading to an increasing value of private information for dealers and a strategic substitutability, following Lemma 6. As a result, the following numerical examples illustrate a unique Nash equilibrium, ρ^*, that characterizes the dealers' decisions for private information acquisition. More specifically, as shown in the left and middle panels, with sufficiently small b, the value of private information is negative. Then, there exists a unique pure-strategy Nash equilibrium, $\rho^* = 0$, stating that no dealers will acquire private information. With sufficiently large b, as shown in the right panel, a unique mixed-strategy Nash equilibrium exists, ρ^*, such that $\Pi(\rho^*) = K$. Furthermore, the results in Section 2.4 remain.

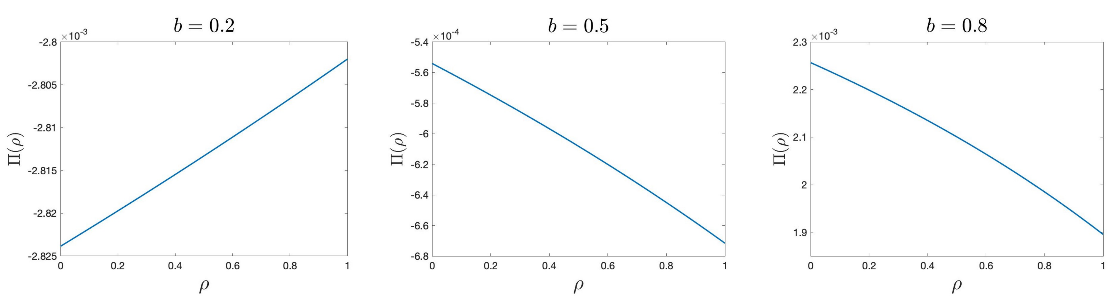

Figure A.2: Value of Private Information.

[2]I consider the CRRA utility function, $u(q) = 2\sqrt{q}$, and $\beta = 0.97$, $\alpha = 0.5$, $\delta_h = 1$, $\delta_\ell = 0.5$, $\pi = 0.1$, $i = 0.15$, and $A = 0.2$.

Appendix B

Appendix for Chapter 3

B.1 Omitted Proofs

Proof of Lemma 1. I first reduce the numbers of the participation constraints. It is obvious to show that the participation constraint for the low type dealers must be binding, and those for the high type and uninformed type dealers will be automatically satisfied. By applying the incentive-compatible constraints and $\delta_\ell \leq \delta^e \leq \delta_h$, we have

$$-q_h + \tau_h + \delta_h d_h \geq -q_\ell + \tau_\ell + \delta_h d_\ell \geq -q_\ell + \tau_\ell + \delta_\ell d_\ell \geq 0 \tag{B.1.1}$$

$$-q_u + \tau_u + \delta^e d_u \geq -q_\ell + \tau_\ell + \delta^e d_\ell \geq -q_\ell + \tau_\ell + \delta_\ell d_\ell \geq 0 \tag{B.1.2}$$

Then, I aim to reduce the numbers of the incentive-compatible constraints, and I claim that we only need the dealers to be indifferent from deviating from the high to the uninformed type and from the uninformed to the low type, and the rest of the incentive-compatible constraints will be automatically satisfied. The proof consists of four parts.

Part 1. This part of the proof shows that (3.6) and (3.7) are binding at the optimum. By contradiction, suppose (3.7) is slack. The household could raise the expected payoff for the bilateral trade by increasing q_h so as to make the constraint binding without affecting (3.6) while improving maximand. The same argument applies if (3.6) is not binding at the optimum.

Part 2. This part of the proof shows that the incentive-compatible constraint that guarantees the high type dealers not mimicking the low type is automatically satisfied when (3.6) and (3.7) are satisfied.

$$\delta^e(d_u - d_\ell) \geq q_u - q_\ell - \tau_u + \tau_\ell \tag{B.1.3}$$

With $\delta_h \geq \delta^e$,

$$\delta_h(d_u - d_\ell) \geq q_u - q_\ell - \tau_u + \tau_\ell \tag{B.1.4}$$

Applying (3.6), I show that this incentive-compatible constraint is automatically satisfied.

Part 3. This part of the proof shows that the incentive-compatible constraints that guarantee the low type dealers not mimicking the uninformed type dealers, and the uninformed type dealers not mimicking the high type dealers are automatically satisfied when (3.6) and (3.7) are binding. First, with (3.6) binding,

$$q_h - q_u - \tau_h + \tau_u = \delta_h(d_h - d_u) \geq \delta^e(d_h - d_u) \tag{B.1.5}$$

Similarly, with (3.7) binding,

$$q_u - q_\ell - \tau_u + \tau_\ell = \delta^e(d_h - d_u) \geq \delta_\ell(d_h - d_u) \tag{B.1.6}$$

Hence, the two incentive-compatible constraints are automatically satisfied.

Part 4. Following Part 3, this part of the proof shows that the incentive-compatible constraints that guarantee the low type dealers not mimicking the high type dealers is automatically satisfied. From (B.1.5),

$$q_h - q_u - \tau_h + \tau_u \geq \delta^e(d_h - d_u) \geq \delta_\ell(d_h - d_u) \tag{B.1.7}$$

Applying the incentive-compatible constraints from Part 3, I show that the above incentive-compatible constraint is satisfied.

Lastly, (3.8) is implied by the incentive-compatible constraints. For instance, the two incentive-compatible constraints for the high type and uninformed types of dealers do not mimic each other suggest that $(\delta_h - \delta^e)(d_h - d_u) \geq 0$. Hence, $d_h \geq d_u$. Furthermore, (3.9) is implied by (3.8), which is shown later for Lemmas 2-4. □

Proof of Lemmas 2-4. The Lagrangian for the optimization problem is

$$\mathcal{L} = \{\rho\pi[u(q_h) - \tau_h - \delta_h d_h] + \rho(1-\pi)[u(q_\ell) - \tau_\ell - \delta_\ell d_\ell] + (1-\rho)[u(q_u) - \tau_u - \delta^e d_u]\}$$
$$+\lambda^h[-q_h+\tau_h+\delta_h d_h-(\delta_h-\delta^e)d_u-(\delta^e-\delta_\ell)d_\ell]+\lambda^l(-q_\ell+\tau_\ell+\delta_\ell d_\ell)+\lambda^u[-q_u+\tau_u+\delta^e d_u-(\delta^e-\delta_\ell)d_\ell]$$
$$+\mu_1^h(z-\tau_h)+\mu_2^h\tau_h+\mu_1^l(z-\tau_\ell)+\mu_2^l\tau_\ell+\mu_1^u(z-\tau_u)+\mu_2^u\tau_u$$
$$+\nu_1(a-d_h)+\nu_2(d_h-d_u)+\nu_3(d_u-d_\ell]+\nu_4 d_\ell \quad \text{(B.1.8)}$$

where the Lagrangian multipliers are positive if the corresponding constraint binds; otherwise, they are zero.

High Dividend State. First, I focus on the solution for the high state, (q_h, τ_h, d_h). The first-order conditions are

$$\frac{\partial \mathcal{L}}{\partial q_h} = \rho\pi u'(q_h) - \lambda^h = 0 \quad \text{(B.1.9)}$$

$$\frac{\partial \mathcal{L}}{\partial \tau_h} = -\rho\pi + \lambda^h - \mu_1^h + \mu_2^h = 0 \quad \text{(B.1.10)}$$

$$\frac{\partial \mathcal{L}}{\partial d_h} = (-\rho\pi + \lambda^h)\delta_h - \nu_1^h + \nu_2^h = 0 \quad \text{(B.1.11)}$$

Two cases are relevant: either $\mu_1^h = \mu_2^h = \nu_1 = \nu_2 = 0$ or $\mu_1^h > \mu_2^h, \nu_1 > \nu_2$. Therefore, it can be easily verified that, taken d_ℓ and d_u as given, the contract suggested by Lemma 2 is optimal.

Uninformed State. The solution for the uninformed state, (q_u, τ_u, d_u), given d_ℓ, satisfies the first-order conditions

$$\frac{\partial \mathcal{L}}{\partial q_u} = (1-\rho)u'(q_u) - \lambda^u = 0 \quad \text{(B.1.12)}$$

$$\frac{\partial \mathcal{L}}{\partial \tau_u} = -(1-\rho) + \lambda^u - \mu_1^u + \mu_2^u = 0 \tag{B.1.13}$$

$$\frac{\partial \mathcal{L}}{\partial d_u} = [-(1-\rho) + \lambda_u]\delta^e - \lambda_h(\delta_h - \delta^e) - \nu_2 + \nu_3 = 0 \tag{B.1.14}$$

We discuss three possible cases as follows.

Case 1. $\mu_1^u = \mu_2^u = 0$. By (B.1.14), $0 = \nu_2 < \nu_3$, so $d_u = d_\ell$. By (B.1.13), $\lambda^u = 1-\rho$, then $q_u = q^*$. By (3.7), $\tau_u = q^* - \delta_\ell d_u = q^* - \delta_\ell d_\ell \leq z$ needs to be satisfied.

Case 2. $\mu_1^u > 0, \mu_2^u = 0$. Thus, $\tau_u = z$ and $\lambda^u > 1-\rho$, which implies that $q_u < q^*$. Firstly, if $\nu_2 = \nu_3 = 0$, we have $d_\ell \leq d_u \leq d_h$. By (B.1.9), (B.1.12) and (B.1.14), $\hat{q}_u$ solves (3.10). Since the left hand side is decreasing in q_u while the right hand side is increasing, there exists a unique solution, $\hat{q}^u$. By (3.7), $d_u = [\hat{q}_u - z + (\delta^e - \delta_\ell)d_\ell]/\delta^e$, which lies between d_ℓ and d_h. Thus, we have $\hat{q}_u - \delta^e d_h + (\delta^e - \delta_\ell)d_\ell \leq z \leq \hat{q}_u - \delta_\ell d_\ell$.

Then, we consider $\nu_2 > 0, \nu_3 = 0$ such that $\tau_u = z$ and $d_u = d_h$. By (3.7), $q_u = z + \delta^e d_h - (\delta^e - \delta_\ell)d_\ell$. In this case, we have $q_u < \hat{q}_u$. Thus, $0 \leq z < \hat{q}_u - \delta^e d_h + (\delta^e - \delta_\ell)d_\ell$ needs to be satisfied.

Lastly, we consider $\nu_2 = 0, \nu_3 > 0$ such that $\tau_u = z$ and $d_u = d_\ell$. By (3.7), $q_u = z + \delta^e d_\ell - (\delta^e - \delta_\ell)d_\ell = z + \delta_\ell d_\ell$. By (B.1.14), we have $q_u > \hat{q}^u$. Thus, $z > \hat{q}^u - \delta_\ell d_\ell$ needs to be satisfied.

Case 3. $\mu_1^u = 0, \mu_2^u > 0$. Hence, $\tau_u = 0$. By (B.1.14), $\nu_2 < \nu_3$, so $d_u = d_\ell$. However, by (B.1.12), $\lambda^u < 1-\rho$, thus $q_u > q^*$ which is infeasible when $\tau_u = 0$ and $d_u = d_\ell$.

Low Dividend State. The solution for the low state, $(q_\ell, \tau_\ell, d_\ell)$, satisfies the first-order conditions

$$\frac{\partial \mathcal{L}}{\partial q_\ell} = \rho(1-\pi)u'(q_\ell) - \lambda^l = 0 \tag{B.1.15}$$

$$\frac{\partial \mathcal{L}}{\partial \tau_\ell} = -\rho(1-\pi) + \lambda^l - \mu_1^l + \mu_2^l = 0 \tag{B.1.16}$$

$$\frac{\partial \mathcal{L}}{\partial d_\ell} = [-\rho(1-\pi) + \lambda^l]\delta_\ell - (\lambda^h + \lambda^u)(\delta^e - \delta_\ell) - \nu_3 + \nu_4 = 0 \tag{B.1.17}$$

Similar to the U-state solution, three possible cases are discussed.

Case 1. $\mu_1^l = \mu_2^l = 0$. By (B.1.17), $0 = \nu_3 < \nu_4$, so $d_\ell = 0$. By (B.1.16), $\lambda^l = \rho(1-\pi)$, then $q_\ell = q^*$. By (3.5), $\tau_\ell = q^* \leq z$ needs to be satisfied.

Case 2. $\mu_1^l > 0, \mu_2^l = 0$. Thus, $\tau_\ell = z$ and $\lambda^l > \rho(1-\pi)$, which implies that $q_\ell < q^*$. Firstly, if $\nu_3 = \nu_4 = 0$, we have $0 < d_\ell < d_u$. By (B.1.9), (B.1.12), (B.1.15) and (B.1.17), $\hat{q}_\ell$ solves 3.11. Since the left hand side is decreasing in q_ℓ while the right hand side is increasing, there exists a unique solution, $\hat{q}^l$. By (3.5), $d_\ell = (q_\ell - z)/\delta_\ell$, which lies between 0 and d_u. Thus, $\hat{q}_\ell - \delta_\ell d_u \leq z \leq \hat{q}_\ell$.

Then, we consider $\nu_3 > 0, \nu_4 = 0$ such that $\tau_\ell = z$ and $d_\ell = d_u$. By (3.5), $q_\ell = z + \delta_\ell d_u$. In this case, we have $q_\ell < \hat{q}^l$. Thus, $0 \leq z < \hat{q}_\ell - \delta_\ell d_u$ needs to be satisfied.

Lastly, we consider $\nu_3 = 0, \nu_4 > 0$ such that $\tau_\ell = z$ and $d_\ell = 0$. By (3.5), $q_\ell = z$. By (B.1.17), we have $q_\ell > \hat{q}^l$. Thus, $\hat{q}^l < z < q^*$ needs to be satisfied.

Case 3. $\mu_1^l = 0, \mu_2^l > 0$. Hence, $\tau_\ell = 0$. By (B.1.17), $\nu_3 < \nu_4$, so $d_\ell = 0$. However, by (B.1.15), $\lambda^l < \rho(1-\pi)$, thus $q_\ell > q^*$ which is infeasible when $\tau_\ell = 0$ and $d_\ell = 0$. □

B.2 Characterization of the Steady-State Equilibrium with Exogenous ρ

In this section, I characterize the steady-state equilibrium (Z, ϕ_a) according to Definition 1 for each relevant region. According to the thresholds for the real money balances, $(z_u^*, z_\ell^*, z_1^*, z_2^*)$, as defined in Proposition 1, the thresholds for the nominal interest rate that determines the relevant regions, $(i_u^*, i_\ell^*, i_1^*, i_2^*)$, is pinned down accordingly by 3.14.

Region 1: $0 < i \leq \min\{i_u^*, i_\ell^*\}$. According to Lemmas 2-4, the equilibrium contract is a semi-pooling contract such that the uninformed dealers pool with the low type dealers. The first-order conditions for households' optimal portfolio choices, (3.14)-(3.15), and the market clearing conditions, the steady-state equilibrium (Z, ϕ_a) satisfies

$$i = (1-\alpha)L(Z) + \alpha\{(1-\rho)L(q_u) + \rho[\pi L(q_h) + (1-\pi)L(q_\ell)]\} \tag{B.2.1}$$

$$\phi_a - \phi_a^* = \beta\alpha\rho\pi\delta_h L(q_h) \tag{B.2.2}$$

where $q_h = \min\{q^*, Z + \delta_h A\}$, $q_u = q_\ell = Z$, and $d_u = d_\ell = 0$.

Region 2: *Case 1:* If $i_u^* < i \leq i_\ell^*$. The equilibrium contract is separating. The equilibrium (Z, ϕ_a) satisfies

$$i = [(1-\alpha) + \alpha\rho(1-\pi)]L(Z) + \alpha\rho\pi[\frac{\delta_h}{\delta^e}L(q_h) + \frac{\delta_h - \delta^e}{\delta^e}] \tag{B.2.3}$$

$$\phi_a - \phi_a^* = \beta\alpha\rho\pi\delta_h L(q_h) \tag{B.2.4}$$

where $q_h = \min\{q^*, Z + \delta_h A - (\delta_h - \delta^e)d_u\}$, and $q_u = \hat{q}_u$ that solves (3.10), $q_\ell = Z$, $d_u = (\hat{q}_u - Z)/\delta^e$, and $d_\ell = 0$.

Case 2: If $i_\ell^* < i \leq i_u^*$. The equilibrium contract is a semi-pooling contract such that the uninformed dealers pool with the low type dealers. The equilibrium (Z, ϕ_a) satisfies

$$i = (1-\alpha)L(Z) + \alpha\{\rho\pi L(q_h) + [1-\rho+\rho(1-\pi)]L(q_\ell)\} \tag{B.2.5}$$

$$\phi_a - \phi_a^* = \beta\alpha[\delta_\ell\rho\pi L(q_h) + \delta_\ell(1-\rho\pi)L(q_\ell) - (\delta^e - \delta_\ell)] \tag{B.2.6}$$

where $q_h = \min\{q^*, Z + \delta_h A - (\delta_h - \delta_\ell)d_\ell\}$, and $q_u = \hat{q}_\ell$ that solves (3.11), and $d_u = d_\ell = (\hat{q}_\ell - Z)/\delta_\ell$.

Region 3: $\max\{i_u^*, i_\ell^*\} < i \leq i_1^*$. The equilibrium contract is separating. The equilibrium (Z, ϕ_a) satisfies

$$i = (1-\alpha)L(Z) + \alpha[\rho\pi\frac{\delta_h}{\delta_\ell}L(q_h) + \frac{\delta^e - \delta_\ell}{\delta_\ell}] \tag{B.2.7}$$

$$\phi_a - \phi_a^* = \beta\alpha\rho\pi\delta_h L(q_h) \tag{B.2.8}$$

where $q_h = \min\{q^*, Z + \delta_h A - (\delta_h - \delta^e)d_u - (\delta^e - \delta_\ell)d_\ell\}$, and $q_u = \hat{q}_u$ that solves (3.10), $q_\ell = \hat{q}_\ell$ that solves (3.11), $d_u = [\hat{q}_u - Z + (\delta^e - \delta_\ell)d_\ell]/\delta^e$, and $d_\ell = (\hat{q}_\ell - Z)/\delta_\ell$.

Region 4: $i_1^* < i \leq i_2^*$. The equilibrium contract is a semi-pooling contract such that the uninformed dealers pool with the high type dealers. The equilibrium (Z, ϕ_a) satisfies

$$i = (1-\alpha)L(Z) + \alpha(1-\rho+\rho\pi)[\frac{\delta^e}{\delta_\ell}L(q_h) + \frac{\delta^e - \delta_\ell}{\delta_\ell}] \tag{B.2.9}$$

$$\phi_a - \phi_a^* = \beta\alpha[(1-\rho+\rho\pi)\delta^e L(q_h) - \rho\pi(\delta_h - \delta^e)] \tag{B.2.10}$$

where $q_h = q_u = Z + \delta^e A - (\delta^e - \delta_\ell)d_\ell$, $q_\ell = \hat{q}_\ell$ that solves (3.11), $d_h = d_u = A$ and $d_\ell = (\hat{q}_\ell - Z)/\delta_\ell$.

Region 5: $i > i_2^*$. The equilibrium contract is a pooling contract where $q_h = q_u = q_\ell \equiv q_p$. The equilibrium (Z, ϕ_a) satisfies

$$i = (1-\alpha)L(Z) + \alpha L(q_p) \tag{B.2.11}$$

$$\phi_a - \phi_a^* = \beta\alpha[\delta_\ell L(q_p) - (\delta^e - \delta_\ell)] \tag{B.2.12}$$

where $q_p = Z + \delta_\ell A$.

Numerical Illustrations. Figure B.1 shows some numerical examples to illustrate how the separating, semi-pooling, and pooling equilibra emerge.[1] On the vertical axis, I plot the quantities of special goods traded to represent the equilibrium contract for each type. According to (3.8)-(3.9), the rankings for q will imply the ranking for d.

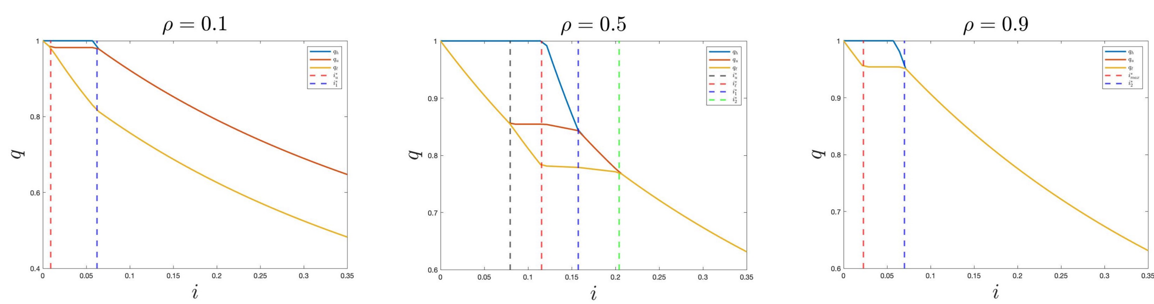

Figure B.1: Relevant regions: numerical illustrations for $\rho = \{0.1, 0.5, 0.9\}$.

Starting with $\rho = 0.1$, the equilibrium is semi-pooling where $q_u = q_\ell = Z(i)$ and $d_u = d_\ell = 0$ when $0 < i \leq i_u^*$. When $i_u^* < i \leq i_1^*$, the equilibrium is separating where d_ℓ

[1] I adopt the CRRA utility function, $u(q) = 2\sqrt{q}$. Other parameter values are $\beta = 0.97$, $\alpha = 0.5$, $\pi = 0.1$, $\delta_h = 1$, $\delta_\ell = 0.5$, and $A = 0.3$.

stays at zero and $d_u > 0$; at the same time, $q_\ell = Z(i)$ and $q_u = \hat{q}_u$ that solves (3.10). As $i > i_1^*$, $d_u = d_h = A$ and $d_\ell = 0$; then, $q_u = q_h = Z((i) + \delta^e A$ and $q_\ell = Z(i)$. Therefore, the equilibrium is semi-pooling where the uninformed dealers pool with the high-type ones. It is worth mentioning that, for small ρ, d_ℓ is always distorted to zero, as the fraction of uninformed dealers is large, and they have incentives to deviate to the low state. Therefore, the households have to distort the terms of trade for the low state.

The middle panel depicts the relevant regions when $\rho = 0.5$. These five regions correspond to the ones as defined in Proposition 1. When $0 < i \leq i_u^*$, the equilibrium is semi-pooling where $q_u = q_\ell = Z(i)$ and $d_u = d_\ell = 0$. When $i_u^* < i \leq i_\ell^*$, d_ℓ stays at zero and $d_u > 0$; at the same time, $q_\ell = Z(i)$ and $q_u = \hat{q}_u$ that solves (3.10). When $i_\ell^* < i \leq i_1^*$, d_ℓ increases above zero. The equilibrium is still separating as $q_u = \hat{q}_u$ that solves (3.10), and $q_\ell = \hat{q}_\ell$ that solves (3.11); then $d_u > d_\ell > 0$. When $i_1^* < i \leq i_2^*$, d_u keeps increasing and reaches $d_u = d_h = A > d_\ell$; then, $q_u = q_h = Z(i) + \delta^e A - (\delta^e - \delta_\ell)d_\ell$, and and $q_\ell = \hat{q}_\ell$ that solves (3.11). Therefore, the equilibrium is semi-pooling where the uninformed dealers pool with the high-type ones. Lastly, when $i > i_2^*$, d_ℓ keeps increasing and reaches $d_\ell = d_u = d_h = A$ and $q_\ell = q_u = q_h = Z(i) + \delta_\ell A$. The equilibrium is pooling.

Lastly, for $\rho = 0.9$, we can observe that the uninformed dealers pool with the low-types dealers for all i. The intuition comes from (3.10) and (3.11). According to (3.10), when ρ is large, there is a high fraction of informed dealers, and those in the high state have incentives to mimic the uninformed ones. Therefore, the households distort the terms of trade in the uninformed state such that $d_u \to d_\ell$. Similarly, for (3.11), when ρ is large, there is a low fraction of uninformed dealers who would mimic the low-type dealers; therefore, the households do not need to distort the low state and $d_\ell \to d_u$. Now, the relevant regions would be either semi-pooling where the uninformed dealers pool with the low-state dealers or pooling where all three types pool altogether. More specifically, when $0 < i \leq i^*_{max}$, $d_u = d_\ell = 0$ and $q_u = q_\ell = Z(i)$. When $i^*_{max} < i \leq i^*_2$, $0 < d_u = d_\ell < A$ and $q_u = \hat{q}_\ell$ that solves (3.11). When $i > i^*_2$, the equilibrium becomes pooling where $d_h = d_u = d_\ell = A$ and $q_h = q_u = q_\ell = Z(i) + \delta_\ell A$.