Asset Liquidity, Private Information Acquisition, and Monetary Policy

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Abstract

I develop a New-Monetarist framework to study the private information acquisition about the quality of liquid assets in bilateral trades. I investigate the implications of private information acquisition for asset liquidity and discuss welfare and monetary policy implications. The incentives for private information acquisition depend on economic fundamentals and monetary policy. I show that a higher interest rate encourages the incentives to acquire information. As a result, an increase in the nominal interest rate may have a non-monotone effect on asset liquidity. The model is applicable to interpret the 2007-2008 financial crisis.

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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

1 Introduction

The acquisition of private information plays a crucial role in determining 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, prior to the crisis, individual investors held on to MBS based on their confidence in the continued rise of housing prices. However, these investors could not individually analyze and assess the subprime risk due to the complex structure of MBS (Gorton, 2010, p.126). In contrast, financial institutions, such as dealer banks, possessed specialized expertise in asset trading, allowing them to derive private information about the quality of MBS. As housing prices declined in late 2007, MBS became risky with surging defaults and foreclosures. Demand for MBS decreased, and trading became difficult because individual investors feared trading with better-informed dealers (Gorton, 2010, p.8). This illiquidity, tied to private information acquisition, is not unique; it can be observed in other scenarios such as the late 1990s dot-com bubble and recent cryptocurrency trading.

Another objective of this paper is to investigate the importance of monetary policy. In the context of the 2007-2008 financial crisis, cheap money encouraged borrowers to take out new mortgage loans at a lower interest rate and refinance existing ones, contributing to the housing bubble. When interest rates began to rise in 2006-2007, housing prices dropped, leading to higher incentives for private information acquisition (Dang et al., 2020) and subsequently causing liquidity to dry up. Therefore, monetary policy is another critical factor that influences the incentives for private information acquisition and, in turn, its impact on asset liquidity.

In this paper, I develop a New-Monetarist model that formalizes private information acquisition about the asset's dividend.[1] To elaborate on the impacts of private information in asset trading, I adopt Rocheteau (2011), which incorporates a bargaining protocol under asymmetric information. For tractability, the bargaining protocol in this paper entails a screening game structure, assuming that the uninformed households make take-it-or-leave-it offers. In addition, I formalize the acquisition of private information on the dividend 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 assets. 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 by allowing dealers to acquire private information.

The first result shows a unique Nash equilibrium that characterizes the fraction of dealers acquiring private information, stemming from a strategic substitutability among dealers' information acquisition decisions. I show that the value of information, derived from the informational rent of the screening game, (weakly) decreases in the fraction of dealers obtaining private information. Intuitively, when more dealers acquire private information, it intensifies information asymmetries. As a result, uninformed households are incentivized to distort terms of trade to reduce the informational rent. Furthermore, I explore how various economic fundamentals, such as search frictions, average asset quality, and riskiness, influence dealers' decisions regarding the acquisition of private information.

The model sheds light on monetary policy implications on dealers' decisions on private information acquisition. I investigate a money injection, i.e., inflation, which increases the nominal interest rate according to the Fisher effect. I show 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

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

hold. As the real asset and real money balances are substitutes in facilitating trade, the demand for the real asset becomes higher, and the dealers benefit more from possessing private information about the asset's dividend.

Next, I explore how monetary policy affects asset liquidity. I start with discussing two special cases: (i) when the nominal interest rate is sufficiently low, and no dealers acquire private information, and (ii) when the nominal interest rate is sufficiently high, and all dealers acquire private information, i.e., a pure strategy Nash equilibrium. I show that increasing the nominal interest rate has a positive effect on liquidity, given that real money balances and assets are substitutes in facilitating trades. As a result, households shift their demand for real money balances into the real asset. However, in the case when the nominal interest rate is neither too low nor too high, only a fraction of dealers choose to acquire information, i.e., a mixed-strategy Nash equilibrium, an increase in the nominal interest rate may result in a non-monotone effect on asset liquidity. On the one hand, the positive effect persists as in the special cases. On the other hand, an increased nominal interest rate encourages dealers to acquire private information, which intensifies information asymmetries and potentially hinders asset liquidity.

Lastly, I discuss an application of the model to interpret the 2007-2008 financial crisis, aligning with the information view of financial crises spurred by Gorton (2010). I demonstrate the pivotal role 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, asset liquidity, and welfare. Finally, I 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.

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.[2] The closest related study is Lester et al. (2012), which studies the effect of recognizability on asset liquidity and considers endogenous recognizability through information acquisition. To emphasize the role of private information in asset trading, I incorporate a bargaining protocol under asymmetric information in line with Rocheteau (2011).[3] I show that private information acquisition can amplify information asymmetries, potentially hindering the asset's role as a means of payment. This is in contrast to Lester et al. (2012), who suggest that information acquisition strengthens the asset's acceptance as a medium of exchange.

The paper revisits monetary policy and asset prices within the New-Monetarist framework. In line with Geromichalos et al. (2007) and Lagos and Rocheteau (2008), fiat money and real assets compete as a medium of exchange. Therefore, an increased nominal interest rate shifts the demand for fiat money to real assets, positively affecting asset prices. What sets this paper apart is a novel channel for monetary policy effects, specifically 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-monotone impact of monetary policy on asset prices.

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. I show that the Friedman rule is optimal, eliminating incentives for private information acquisition, which is consistent with prior findings. Moreover, this paper illustrates that when deviating from the Friedman rule, the welfare effect of

[2]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 (2022).

[3]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).

asymmetric information is non-monotone.

Regarding the 2007-2008 financial crisis, this paper aligns with literature suggesting incentives for generating private information triggered the crisis, as seen in Gorton and Pennacchi (1990), Gorton (2010), Gorton and Ordoñez (2014), Dang et al. (2015), and Dang et al. (2020). My paper resonates with these prior studies, illustrating how private information acquisition leads to adverse selection problems that impede asset transactions. Moreover, this paper complements the literature in the following two ways. Firstly, it explicitly incorporates an over-the-counter (OTC) market microstructure where dealers purchase assets from households, akin to works by Duffie et al. (2005), Duffie et al. (2007), and Lagos and Rocheteau (2009). Therefore, asset liquidity is determined strategically in bilateral trades, embedding private information within the bargaining process.[4] Secondly, I explore the endogenous determination of private information acquisition, investigating how economic fundamentals and monetary policies impact acquisition incentives, influencing asset liquidity.

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 $\beta \in (0, 1)$. Each period consists of two subperiods: a decentralized market (DM) featuring bilateral matches as in the search theory, followed by a centralized market (CM) where all agents can enter and rebalance portfolio holdings as in the general equilibrium theory. Two goods are divisible and perishable between periods, one produced in the DM and the other in the CM. Furthermore, assume that there is a lack of monitoring or record-keeping technology, such that the agents cannot commit to repaying their debts.

The agents are distinguished by their roles in the DM. There is a unit measure of households, sellers, and dealers. Households only consume the DM good, denoted as q, within a competitive goods market, whereas sellers only produce the DM good. Dealers

[4] 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.

have deep pockets, enabling them to purchase assets from the households and issue liquid IOUs, which are accepted as means of payment by the sellers. The underlying assumption is that the dealers can credibly promise payments to the sellers. In the subsequent subperiod (CM), all agents can consume the CM good (*numéraire*), denoted as X, and supply labor, denoted as H. The production technology in the CM is linear, with labor as the only input. The period utilities for the households, the sellers, and the dealers are given by

$$\mathcal{U}(q, X, H) = u(q) + X - H$$

$$\mathcal{V}(q, X, H) = -q + X - H$$

$$\mathcal{D}(X, H) = X - H$$

I assume that $u(q)$ is twice continuously differentiable, strictly increasing, and strictly concave, with $u(0) = 0, u'(0) = +\infty$, and $u'(\infty) = 0$. The optimum quantity of the DM good traded in bilateral meetings is $q^* \equiv \{q : u'(q) = 1\}$.

There are two assets - fiat money and a real asset. 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 the CM. The real asset is a one-period lived Lucas (1978) tree, with a fixed supply $A > 0$ endowed by households at the beginning of the CM. The real asset price, ϕ_a, is in terms of the CM good (*numéraire*). The asset is subject to an aggregate dividend shock at the beginning of the DM before the matches are formed. 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 $0 \leq \delta_\ell < \delta_h$. Furthermore, I denote the expected dividend as $\delta^e = \pi\delta_h + (1 - \pi)\delta_\ell$. Agents do not realize the value of δ in the DM but understand the stochastic process. The actual δ will be revealed at the beginning of the CM.

In the DM, households can always spend their fiat money holdings on consuming the DM good directly from sellers, assuming fiat money cannot be counterfeited.[5] In

[5]The no counterfeiting assumption guarantees that fiat money is universally accepted by sellers and serves as an outside option for households' means of payment in bilateral trades. Studies on the threat of counterfeiting on asset liquidity include Rocheteau (2009), Li and Rocheteau (2011), and Li et al.

addition, they can search for dealers and liquidate their asset holdings to finance their consumption.[6] See Figure 1 for a graphical illustration. The bilateral matches between a household and a dealer are subject to search frictions, with a meeting probability $\alpha \in (0, 1)$. In addition, the bilateral matches are subject to asymmetric information, with dealers potentially possessing an informational advantage.

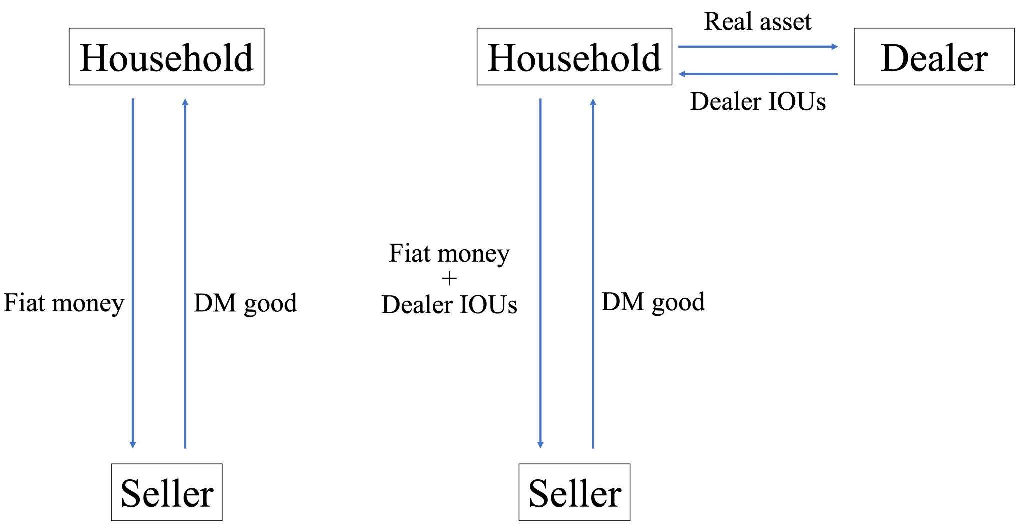

Figure 1: Means of payments in the DM.

Let $\rho \in [0, 1]$ denote the fraction of informed dealers who realize the actual value of the dividend. As a starting point, I treat ρ as an exogenous parameter. In Section 4, ρ is endogenized by allowing dealers to make private information acquisition decisions. Furthermore, assume that dealers' possession of private information about the asset payoff is common knowledge. Therefore, households can distinguish between informed and uninformed dealers. For the simplicity of notation, a household meets with an uninformed dealer in Type I meetings and an informed dealer in Type II meetings. When the bilateral match is formed, I assume that households make a take-it-or-leave-it offer.[7]

(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. However, this paper does not consider the effect of counterfeiting on fiat money's usefulness as a medium of exchange.

[6]On a related point, Geromichalos and Herrenbrueck (2016) formalize the indirect asset liquidity 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).

[7]The assumption guarantees a screening game for the bargaining protocol. It is tractable to solve as we do not rely on refinements of sequential equilibria for a signaling game. In Appendix E, I discuss a

3 Equilibrium

In this section, I describe the agents' problem and define the equilibrium. I start with the value functions of the CM and the DM. 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 and characterize the steady-state equilibrium with exogenous ρ.

3.1 Value Functions

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

$$W(z, a, \delta) = \max_{X,H,z',a'} \{X - H + \beta \mathbb{E} V(z', a', \delta')\} \tag{1}$$

subject to

$$X + \gamma z' + \phi_a a' = H + z + \delta a + \phi_a A + T \tag{2}$$

Variables with a prime denote the future values in the next period. In the CM, households finance their next-period portfolio holdings and the consumption of the CM goods, X, with supplying labor, H, their initial wealth, $z + \delta a$, and their initial endowment of the real asset, $\phi_a A$. In addition, they receive a lump-sum transfer, $T \equiv (\gamma - 1)\phi_m M$, for accomplishing the changes in the fiat money, where ϕ_m is the price of fiat money in terms of CM good. By substituting $X - H$ from (2) into (1),

$$W(z, a, \delta) = z + \delta a + \phi_a A + T + \max_{z' \geq 0, a' \geq 0} \{-\gamma z' - \phi_a a' + \beta \mathbb{E} V(z', a', \delta')\} \tag{3}$$

general setup that allows both households and dealers to make alternating offers à la Rubinstein and Wolinsky (1985). 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, when dealers make offers, the value of private information is non-positive.

the CM 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 DM with portfolio holdings (z', a'). The expectation is taken with respect to δ', which is unknown to the households in the DM. The value function is defined as

$$V(z, a, \delta) = (1-\alpha)[u(q_0(z)) + W(z - q_0(z), a, \delta)] + \alpha[u(q(z, a, \delta)) + W(z - \tau(z, a, \delta), a - d(z, a, \delta), \delta)] \tag{4}$$

The interpretation is as follows. With probability $1 - \alpha$, the household only uses fiat money to consume in the DM, and q_0 denotes the consumption of the DM goods in this case. It is obvious to show that $q_0 = \min\{q^*, z\}$.[8] With probability α, the household meets and bargains with a dealer. In this case, the household gets utility from q and makes payments with real money balances, τ, and the real asset, d, which are the equilibrium contracts characterized in Section 3.2.

3.2 Bargaining Game

I characterize the bargaining protocol between a household and a dealer in the DM. The equilibrium contract consists of the quantities of the DM good traded, denoted as q, the transfer of real money balances, denoted as τ, and the transfer of the real asset, denoted as d. Since the DM good market is competitive with a linear cost, the value of the liquid IOUs issued by dealers is represented by $q - \tau$.

3.2.1 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 real asset. The household solves the following optimization problem

[8] The assumption of the linear cost implies a unit price of the DM goods 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 DM goods.

subject to the dealer's participation constraint and the household's liquidity constraint.

$$\max_{(q_1,\tau_1,d_1)} [u(q_1) - \tau_1 - \delta^e d_1] \tag{5}$$

subject to

$$-(q_1 - \tau_1) + \delta^e d_1 \geq 0 \tag{6}$$

$$0 \leq \tau_1 \leq z, 0 \leq d_1 \leq a \tag{7}$$

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 (5)-(7).

(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 asset are perfect substitutes. The equilibrium contract depends on whether the liquidity wealth, y^e, is sufficient to trade the optimal quantity, q^*.

3.2.2 Type II Meeting

In Type II meetings, a household meets an informed dealer who realizes the true dividend of the real asset, $\delta \in \{\delta_h, \delta_\ell\}$. The bargaining game has a structure of a screening game. 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, incentive-compatible constraints, and the household's liquidity constraints for each state as follows,

$$\max_{\substack{(q_h,\tau_h,d_h)\\(q_\ell,\tau_\ell,d_\ell)}} \{\pi[u(q_h) - \tau_h - \delta_h d_h] + (1-\pi)[u(q_\ell) - \tau_\ell - \delta_\ell d_\ell]\} \tag{8}$$

subject to

$$-(q_h - \tau_h) + \delta_h d_h \geq 0 \tag{9}$$

$$-(q_\ell - \tau_\ell) + \delta_\ell d_\ell \geq 0 \tag{10}$$

$$-(q_h - \tau_h) + \delta_h d_h \geq -(q_\ell - \tau_\ell) + \delta_h d_\ell \tag{11}$$

$$-(q_\ell - \tau_\ell) + \delta_\ell d_\ell \geq -(q_h - \tau_h) + \delta_\ell d_h \tag{12}$$

$$0 \leq \tau_h, \tau_\ell \leq z, 0 \leq d_h, d_\ell \leq a \tag{13}$$

Proposition 1. The constraints (10) and (11) are binding, while (9) and (12) are slack.

$$-(q_\ell - \tau_\ell) + \delta_\ell d_\ell = 0 \tag{14}$$

$$-(q_h - \tau_h) + \delta_h d_h = -(q_\ell - \tau_\ell) + \delta_h d_\ell = (\delta_h - \delta_\ell) d_\ell \tag{15}$$

Proof. See Appendix A. □

The two binding constraints suggest that the household leaves no surplus to the dealers in the low state. However, in the high state, the dealers can extract an informational rent, $(\delta_h - \delta_\ell)d_\ell$, because the informed dealers have incentives to pretend that the dividend is low and issue less liquid bonds. The households must compensate the dealers with the informational rent to prevent them from deviating from the high to the low state.

Lemma 2. 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. □

The intuition of Lemma 2 is similar to that of Lemma 1. Real balances and asset are perfect substitute if the asset pays a high dividend. However, due to adverse selection, the households' liquid wealth becomes the value of their portfolio holdings net the informational rent, $(\delta_h - \delta_\ell)d_\ell$.

Lemma 3. 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

$$u'(q_\ell) = 1 + \frac{\pi}{1-\pi}\frac{\delta_h - \delta_\ell}{\delta_\ell}u'(q_h) \tag{16}$$

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. □

First of all, the equilibrium contract, as suggested by Lemma 3, is unique since $\hat{q}_\ell$ is unique. According to Lemma 2, the right-hand side of (16) is weakly increasing in q_ℓ while the left-hand side is decreasing. There exists a unique q_ℓ that solves (16) denoted as $\hat{q}_\ell$.

Lemma 3 suggests a pecking-order property of payments if the real asset pays 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 real asset to facilitate trade.

An implication of the equilibrium contracts in Lemma 2 and 3 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 $d_\ell \leq d_h$.[9] Intuitively, the households

[9]It is obvious that there are two cases under which $q_\ell = q_h$. First, when $z \geq q^*$, the quantities of the DM good traded achieve the optimal level in both states, i.e. $q_h = q_\ell = q^*$. Second, if $a < a^*(z, \pi, \delta_h, \delta_\ell)$,

attempt to reduce the informational rent of the high dividend state. Furthermore, as the dealers in the high state have incentives to mimic those in the low state, distorting the terms of trade in the low state will reduce those incentives.

3.3 Households' Portfolio Choices

According to the equilibrium contracts characterized in Section 3.2 and the DM value function of a household, (4), the expected value of the household entering the DM is

$$\mathbb{E}V(z,a,\delta) = (1-\alpha)S_0 + \alpha\{(1-\rho)S_1 + \rho[\pi S_h + (1-\pi)S_\ell]\} + z + \delta^e a + W(0,0,\delta) \quad (17)$$

where the trade surpluses from the bilateral matches are

$$S_1 \equiv u[q_1(z,a,\delta)] - q_1(z,a,\delta)$$

$$S_h \equiv u[q_h(z,a,\delta)] - q_h(z,a,\delta) - (\delta_h - \delta_\ell)d_\ell(z,a,\delta)$$

$$S_\ell \equiv u[q_\ell(z,a,\delta)] - q_\ell(z,a,\delta)$$

Intuitively, a household meets a dealer with a probability α and makes a take-it-or-leave-it offer. The household's trade surplus depends on the dealer's possession of private information about the asset quality, measured by ρ. With a probability $1-\alpha$, the household is not matched with a dealer. The payoff of using only real money balances as means of payment is $S_0 \equiv u[q_0(z)] - q_0(z)$.

Iterating (17) one-period forward to obtain $\mathbb{E}V(z', a', \delta')$ and plug it into the CM value function, 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

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 (11) and (12), 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 $d_\ell \leq d_h$.

household j's, $j \in \mathcal{H}$ demand for real money balances and the real asset. Then,

$$[z(j), a(j)] = arg \max_{z,a}\{-iz-(\frac{\phi_a - \phi_a^*}{\beta})a+(1-\alpha)S_0+\alpha[(1-\rho)S_1+\rho[\pi S_h+(1-\pi)S_\ell]]\} \quad (18)$$

where i is the nominal interest rate by applying the stationary monetary equilibrium definition and the Fisher equation $i = (\gamma - \beta)/\beta$. I define $\phi_a^* \equiv \beta\delta^e$, which denotes the fundamental value of the real asset. Lastly, the market clearing conditions suggest that $\int_{j\in\mathcal{H}} z(j)\, dj = Z$ 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.

According to (18), the household's optimal portfolio choices $[z(j), a(j)]$ satisfy the following first-order conditions if $i \geq 0$ and $\phi_a \geq \phi_a^*$,

$$-i + (1-\alpha)S_{0,z} + \alpha\{(1-\rho)S_{1,z} + \rho[\pi S_{h,z} + (1-\pi)S_{\ell,z}]\} \leq 0, \text{ "=" if } z > 0 \quad (19)$$

$$-\frac{\phi_a - \phi_a^*}{\beta} + \alpha\{(1-\rho)S_{1,a} + \rho[\pi S_{h,a} + (1-\pi)S_{\ell,a}]\} \leq 0, \text{ "=" if } a > 0 \quad (20)$$

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 $j \in \{z, a\}$.[10] The intuition is straightforward. At optimum, the marginal benefit has to be equal to the marginal cost of carrying an additional unit of real money balances and assets over to the next-period CM. The nominal interest rate, i, captures the marginal cost for the real balances and $(\phi_a - \phi_a^*)/\beta$ for the real asset. The marginal benefit comes from the real balances and assets serving as mediums of exchange and facilitating the bilateral trades, i.e., a liquidity premium.[11] For the simplicity of notation, the liquidity premium is denoted as $L(q) \equiv u'(q) - 1$. Furthermore, I focus on $L(q)$ being decreasing and convex, i.e., $L'(q) < 0$ and $L''(q) > 0$ for $q < q^*$.

[10] In Appendix B, I show that the objective function of the household's portfolio choice, (18), is jointly concave in (z, a). Hence, the first-order conditions, (19)-(20), are necessary and sufficient for the optimization problem.

[11] Neither the dealers nor the producers have incentives to hold any real balances when they enter the DM 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.

3.4 Steady-State Equilibrium

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

Definition 2. 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;

(3) Market clearing conditions are satisfied.

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

Proof. See Appendix A. □

Now, I summarize the relevant regions of the steady-state equilibrium in Figure 2 as functions of the nominal interest rate, i, and the real asset supply, A.[12] Firstly, the threshold $i^*(A)$ determines whether the low-quality asset are traded in the bilateral meetings. More specifically, Region 1 corresponds to $0 < i < i^*(A)$, then we have $d_\ell = 0$. As Lemma 3 suggests, if the household's real money balance holding is sufficient for consuming $\hat{q}_\ell$, the low-quality asset 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 cost of holding real money balances at the threshold.

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

[12]The relevant region is derived based on Lemma 2 and 3. See Appendix C for more details.

portfolio holdings are scarce. As a result, the households will pay with all their portfolio 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' real asset holdings are abundant, and the equilibrium contract is separating. According to Proposition 2, 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.

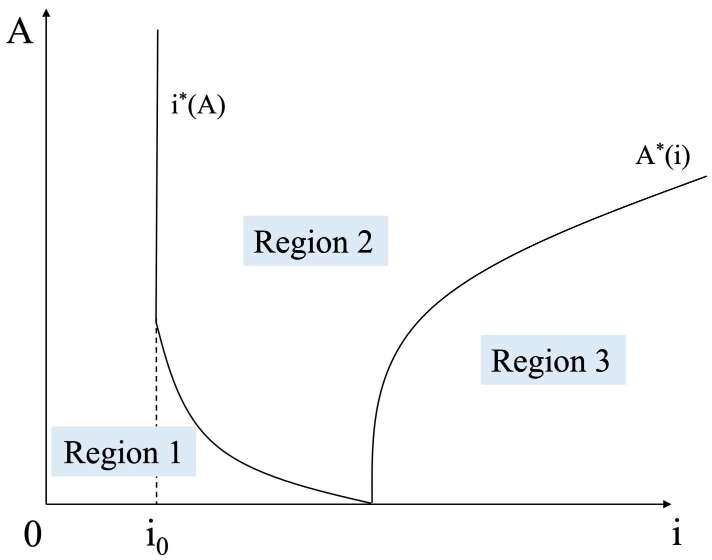

Figure 2: Steady-state equilibrium: relevant regions.

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 1. The proof is relegated to Appendix D.

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	$+$	$+^*$	$+^*$	$+$	?

Table 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.

The results on the effects of monetary policy are very intuitive. As i increases, the households face a higher cost of holding real money balances. Therefore, they lower the demand for real money balances and shift their demand into the real asset, which is a (imperfect) substitute for fiat money. Consequently, the asset price increases as the demand for the real asset 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.

Now, I analyze the effect of the fraction of informed dealers, ρ, on the demand for real money balances, Z. 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 real asset 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.[13] Second, there is a negative general equilibrium effect on the liquidity premium because the households shift their demand for the real asset 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 for a negative direct effect. That is, the marginal benefit for households carrying the real asset into the Type I meetings is higher than that for the Type II meetings. Consequently, a higher fraction of informed dealers impedes the asset liquidity under the following conditions.

Proposition 3. (Information and asset liquidity: Region 1) If $0 < i < i^*(A)$, $\partial \phi_a/\partial \rho < 0$.

Proof. See Appendix D. □

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

First, holding real money balances should be sufficiently inexpensive, i.e., $0 < i < i^*(A)$, such that the steady-state equilibrium lies in Region 1. The intuition is that the households' liquid wealth in the Type II meetings is higher than in the Type I meetings if the dividend is high. Furthermore, according to Lemma 3, households do not use the real asset as a means of payment in the low dividend state. Therefore, the marginal benefit for the households to carry the real asset into the Type II meetings is lower.

Proposition 4. (Information and asset liquidity: Region 3) If $i \geq i^*(A)$ and $A < A^*(i)$, and if $Z(i) + \delta^e A < q^*$ such that $Z(i)$ solves (19), then $\partial \phi_a / \partial \rho < 0$ under the CRRA utility function with the risk-aversion parameter $\sigma < 1$.

Proof. See Appendix D. □

Second, 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, and households' liquid wealth in equilibrium is scarce. Furthermore, I assume the CRRA utility function $u(c) = c^{(1-\sigma)}/(1-\sigma)$ where $\sigma < 1$. Intuitively, households must deplete all their portfolio holdings in all the bilateral meetings. In the Type I meetings, households trade the real asset 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 real asset into the Type II meetings is lower.

3.6 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 expected trade surplus from the bilateral matches in the DM,

$$\mathcal{W} = (1-\alpha)S_0 + \alpha\{(1-\rho)S_1 + \rho[\pi S_h + (1-\pi)S_\ell]\} \tag{21}$$

Firstly, the welfare function (21) 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 real asset 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.

$$\frac{\partial \mathcal{W}}{\partial \rho} = \underbrace{\alpha[\pi S_h + (1-\pi)S_\ell - S_1]}_{\text{direct effect} < 0} + \underbrace{(1-\alpha)\frac{\partial S_0}{\partial \rho} + \alpha\{(1-\rho)\frac{\partial S_1}{\partial \rho} + \rho[\pi\frac{\partial S_h}{\partial \rho} + (1-\pi)\frac{\partial S_\ell}{\partial \rho}]\}}_{\text{general equilibrium effect} > 0} \quad (22)$$

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 real asset into real money balances (Proposition 5). As a result, an increasing ρ leads to higher terms of trade in all the bilateral matches, which is welfare-improving.

To illustrate the two opposing effects on welfare when ρ increases, I consider the following numerical example.[14] 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 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 it is more costly for households to shift their demand of portfolio choices to real money balances.

[14] 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 $\delta_\ell = 0.5$.

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 real assets 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 distort the payment with real assets and save on the informational rent.

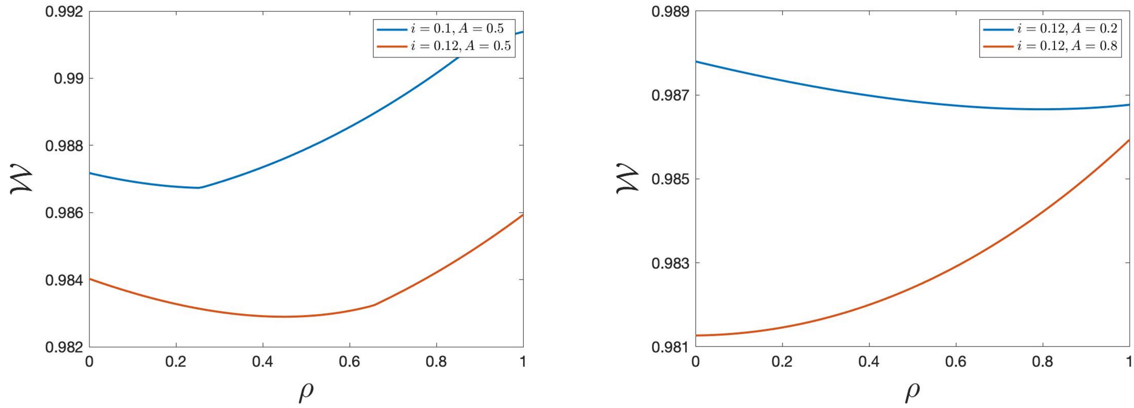

Figure 3: Degree of information asymmetry and welfare. Left: an increase in the nominal interest rate (i); Right: an increase in the real asset supply (A).

4 Private Information Acquisition

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 in the previous section, with exogenous ρ, each relevant region has different implications on the liquidity of the real asset and the equilibrium allocations. Hence, it is important to understand how the two thresholds depend on ρ.

As shown in Figure 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 3, real money balances become more preferable means of payment. Consequently, households' demand for real balances increases, and $i^*(A)$ increases, leading to $d_\ell = 0$ (i.e., Region 2 to Region 1).

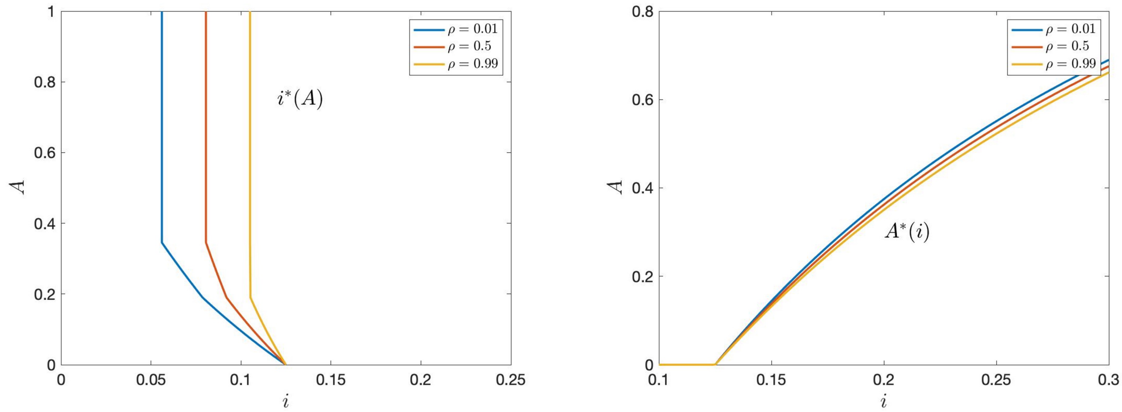

Figure 4: Relevant regions with varying ρ.

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 the DM, 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 have $\Pi(\rho) = \Pi_2(\rho) - \Pi_1(\rho)$. 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 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. However, in the high dividend state, the dealers gain the informational rent. Hence, $\Pi_2(\rho) = \alpha\pi(\delta_h - \delta_\ell)d_\ell(\rho)$, and

$$\Pi(\rho) = \alpha\pi(\delta_h - \delta_\ell)d_\ell(\rho) \tag{23}$$

Intuitively, the value of private information is driven by the informational rent that comes from dealers' possession of private information.[15] The following defines the steady-state equilibrium with endogenous ρ.

Definition 3. The steady-state equilibrium with endogenous fraction of informed dealers is a list $\{\phi_a, Z, q_1, q_h, q_\ell\}$ and the dealers' best response of the information acquisition decision ρ, such that

(1) Given ρ, $\{\phi_a, Z, q_1, q_h, q_\ell\}$ is consistent with the equilibrium in Section 3;

(2) Given $\{\phi_a, Z, q_1, q_h, q_\ell\}$, the measure of informed dealers ρ satisfies one of the following configurations:

(i) When $\Pi(\rho) < K, \forall \rho \in [0, 1]$, a unique pure strategy Nash equilibrium with $\rho = 0$;

(ii) When $\Pi(\rho) > K, \forall \rho \in [0, 1]$, a unique pure strategy Nash equilibrium with $\rho = 1$;

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

The intuition is straightforward. If K is sufficiently small, such that $\Pi(\rho) > K$ for all ρ, the dealer optimally chooses to acquire information. A unique equilibrium exists as all the dealers become informed such that $\rho = 1$. On the other hand, if K is sufficiently big, such that $\Pi(\rho) < K$ for all ρ, there are no dealers acquiring information in equilibrium, $\rho = 0$. Mixed strategy Nash equilibria exist if there exist values for ρ such that $\Pi(\rho) = K$. Thus, any arbitrary $\rho \in [0, 1]$ is a best response.

Lemma 4. Under CRRA utility function, $\Pi(\rho)$ is weakly decreasing in ρ.

Proof. See Appendix A. □

The value of information is independent of ρ in Regions 1 and 3. Intuitively, in Region 1, the real money balance is abundant as the cost of holding real money balances

[15] In Appendix E.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 offer allows us to focus on the highest possible value of private information for the dealers.

is sufficiently low. Therefore, there is no need to use the low-dividend asset as payment in Type II meetings. Hence, the benefit of acquiring information is zero. In Region 3, the value of private information is constant since households must pay informational rent for depleting their asset holdings, A, as payments.

In Region 2, $\Pi(\rho)$ is monotonically decreasing in ρ, i.e., strategic substitutability among the dealers' information acquisition decisions in Region 2. Intuitively, private information acquisition leads to more severe information asymmetries. In addition, by Lemma 3, the low-dividend asset is less desirable to be accepted as means of payment due to households' incentives to reduce informational rent. Consequently, as more dealers acquire private information regarding asset quality, the value of private information will decline.

Proposition 5. (Uniqueness of Nash equilibrium) The best response, ρ^*, that characterizes dealers' decisions to acquire private information is unique.

The proof is omitted as it is directly implied by Lemma 4. More specifically, in Region 1, the unique pure strategy Nash equilibrium is $\rho^* = 0$ since the value of private information is zero. 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, in Region 1, for all dealers, the best response is always not to acquire private information about the asset dividend. In Region 2, there exists a unique mixed-strategy Nash equilibrium, ρ^*, that solves $\Pi(\rho) = K$, where K is the degenerate information cost.[16] In Region 3, the value of information is independent in ρ. Therefore, the unique pure strategy Nash equilibrium satisfies the first two configurations in Definition 3.

4.3 Impacts of Economic Fundamentals

The determination of ρ^* is not structurally invariant. In this section, I investigate the effects of economic fundamentals on the dealers' information acquisition decision.

[16] 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 4 suggests that the Nash equilibrium always exists and is unique. Therefore, I consider a degenerate information cost, $K = \bar{K}$, for all the dealers to keep the analysis as simple as possible.

Proposition 6. **(Search friction and private information acquisition)** As α increases, $\Pi(\rho)$ increases. Hence, $\partial\rho^*/\partial\alpha > 0$.

The proof is omitted given that the value of private information, $\Pi(\rho)$, is monotonically increasing in α by (23). The intuition is straightforward. Lower search friction will increase the probability of dealers being matched and extracting the informational rent. As a result, ρ^* will increase, making the information asymmetries in the economy more severe.

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

Proposition 7. **(Asset fundamentals and private information acquisition)**

(a) As $\pi \to 0$ or $\delta_h - \delta_\ell \to 0$, then $\Pi(\rho) \to 0$. Hence, $\rho^* \to 0$.

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

The proof is as follows. First, according to (23), 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 9 is implied by (16). 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 5, those effects on the determination of ρ^* are non-monotone.[17]

4.4 Monetary Policy Implications

In this section, I study the monetary policy implications on the dealers' decisions to acquire private information and, in turn, on asset liquidity. I consider a money injection,

[17] 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 $\delta_\ell = 0.01$.

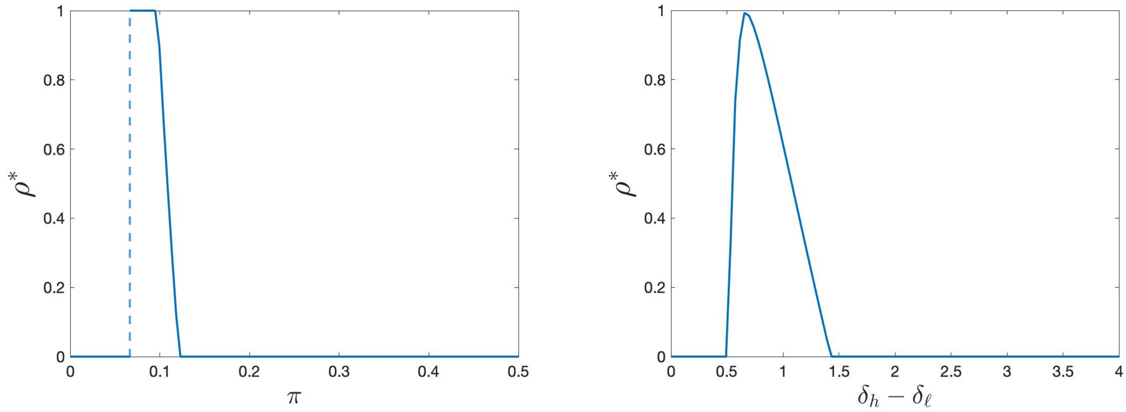

Figure 5: Effects of asset fundamentals on ρ^*. Left: an increase in the average asset quality (π); Right: an increase in the riskiness of assets ($\delta_h - \delta_\ell$).

i.e., inflation, which leads to an increase in the nominal interest rate, i, according to the Fisher effect.

Proposition 8. (Monetary policy and private information acquisition) Under CRRA utility function, if $i \geq i^*(A), A \geq A^*(i)$, $\partial\Pi(\rho)/\partial i > 0$. Hence, $\partial\rho^*/\partial i > 0$.

The proof is similar to the proof of Lemma 4 in Appendix A. In particular, I show that $\partial\hat{q}_\ell/\partial Z < 1$, implying that d_ℓ is decreasing in Z and then, increasing in i. Therefore, the value of private information, monotonically increasing in d_ℓ as in (23), is increasing in i. Consequently, a higher nominal interest rate will encourage private information acquisition. See the left panel of Figure 6 for a graphical illustration.[18] Intuitively, for a sufficiently low nominal interest rate, the equilibrium falls in Region 1, in which the value of information is zero. No dealers will acquire information, i.e., $\rho^* = 0$, and the economy will save on the information cost. As the nominal interest rate increases, the equilibrium switches from Region 1 to Region 2 or 3. The real asset becomes useful as a means of payment, and the value of private information increases. Hence, the dealers have more incentives to acquire information.

With private information acquisition, I investigate monetary policy implications for asset liquidity. I start with two special cases with the pure strategy Nash equilibrium. First, for a sufficiently small nominal interest rate in Region 1, $\rho^* = 0$ since the value

[18]The parameter values for Figure 6 are the same as those for the left panel of Figure 5.

of private information, $\Pi(\rho) = 0$. Hence, by D.2, $\phi_a = \phi_a^* + \beta\alpha\delta^e L(q_1)$. Second, we have $\rho^* = 1$ for a sufficiently large nominal interest rate in Region 3, assuming $\Pi(\rho) = \alpha\pi(\delta_h - \delta_\ell)A > K$. By D.6, $\phi_a = \phi_a^* + \beta\alpha[\delta_\ell L(q_2) - \pi(\delta_h - \delta_\ell)]$. Therefore, for both cases, increasing the nominal interest rate leads households to shift their demand to the real asset. The results in Table 1 still hold.

For the nominal interest rate not too small nor too large, there exists a mixed-strategy Nash equilibrium in Region 2. An increase in the nominal interest rate may have a non-monotone effect on asset liquidity. See the right panel of Figure 6 for a numerical example. Intuitively, the effect of monetary policy on asset liquidity can be separated into two opposing forces. On the one hand, money injection positively affects asset liquidity due to fiat money and the real asset competing as the medium of exchange. On the other hand, with endogenous private information acquisition, the dealers are more willing 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 Propositions 3 and 4.

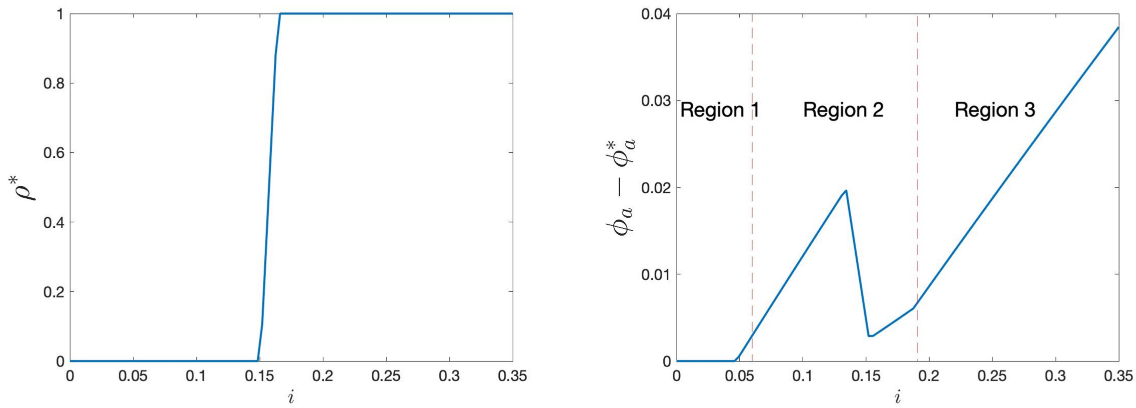

Figure 6: Effects of monetary policy. Left: on dealers' incentives for private information acquisition (ρ^*); Right: on the liquidity premium ($\phi_a - \phi_a^*$).

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.[19]

5.1 Information Sensitivity, Liquidity, and Monetary Policy

Gorton (2010) suggests that a crisis is an event where "information-insensitive" assets become "information-sensitive," i.e., a *regime switch*. Specifically, some agents find it profitable to learn private information to speculate on the value of the assets. Private information acquisition is associated with the *regime switch*, as the information is only accessible to the expertise due to the complexity of the security chain. According to Gorton (2010), the *regime switch* is devastating, causing assets to become highly illiquid. The asset market is subject to an endogenous adverse selection problem that hinders asset liquidity.

The model formalizes the *regime switch*, resulting in liquidity drying up during the crisis in the existing literature (Dang et al., 2017; Dang et al., 2020; Gorton, 2010; Gorton and Ordoñez, 2014). The *information insensitivity* of assets corresponds to $\rho^* = 0$ in my model, such that dealers have no incentives to acquire private information on the asset's dividend. 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. Both fiat money and real asset circulate as mediums of exchange and are perfect substitutes for facilitating trade.

With higher incentives for dealers to acquire private information regarding the asset's dividend, more bilateral trades happen in the Type II meetings. By Lemma 3, I show a drying-up in liquidity for the low-quality asset, i.e., $d_\ell = 0$, due to a more severe adverse selection problem when the holdings of real balances are sufficient. Therefore, the model provides an important monetary policy implication. The monetary authority

[19] 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).

should keep the nominal interest rate low to the extent that bilateral trades are facilitated by fiat money, which is always information-insensitive.

5.2 The Launch of the ABX Index

To illustrate the *regime switch* of the information sensitivity, Gorton (2010) describes an example as follows. The AAA-rate tranches of MBS were traded extensively in the U.S. repo market prior to the crisis. The securities were "information insensitive," as house prices were always supposed to go up. Participants of the MBS market had no incentives to acquire information about the security's value until the introduction of the ABX index. Therefore, Gorton (2010) documented that the launch of the ABX index triggered the *regime switch*, leading to the drying-up of liquidity in the MBS market.

The ABX index was launched by dealer banks and began trading in 2006.[20] During the 2007-2008 financial crisis, the introduction of the ABX index revealed that subprime-related securities were falling rapidly in value, which triggered agents to acquire private information (if they could) on the value of the collateral. Through the lens of my model, the introduction of the ABX index can be viewed as a decline in the cost of information acquisition.

The effect of a declining information cost, K, is demonstrated in Figure 7.[21] First of all, it is straightforward that dealers are more willing to acquire private information because they are facing a lower information cost. Hence, the adverse selection problem in the asset market is more severe, leading to a falling liquidity premium. Furthermore, the low-quality assets, such as the MBS backed by subprime mortgages, became highly illiquid, and welfare decreased.[22]

[20] The ABX index is a credit derivative linked to twenty equally weighted subprime residential mortgage-backed securities; see Gorton (2009).

[21] The parameter values are the same as those for the left panel of Figure 5.

[22] On a related point, the arrival of (adverse) news impacts the liquidity of the asset. See Andolfatto et al. (2014) and Gu et al. (2020). In this paper, households distort the payments using the real asset when the dealers are informed about the low dividend, d_ℓ, to save on informational rent.

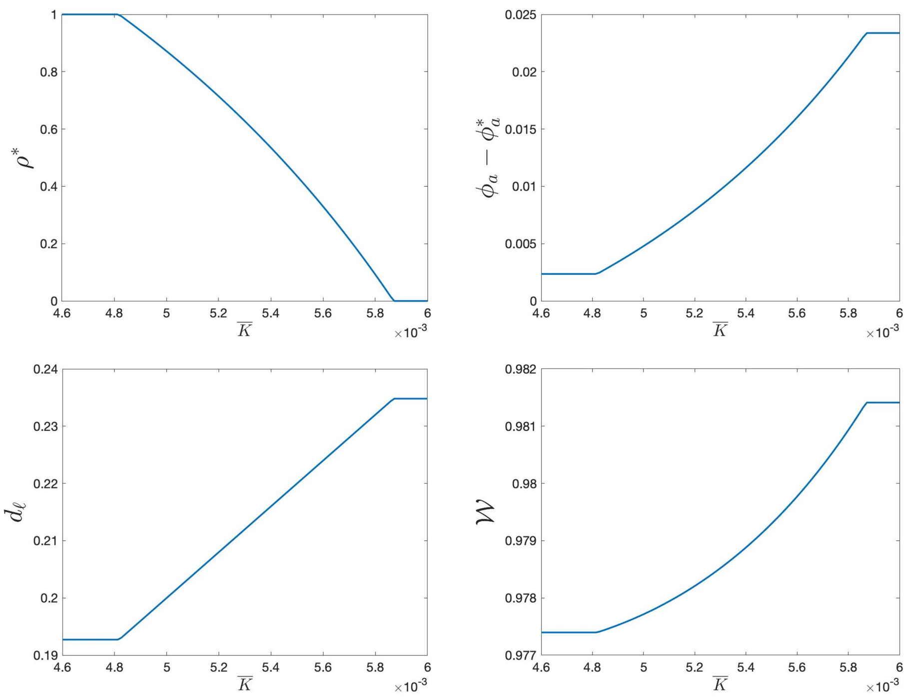

Figure 7: Effects of the information cost.

5.3 Maintaining Information Insensitivity

Following the information view of the crisis explained in Section 5.1, it is critical to maintain the "information insensitivity"of assets in order to preserve asset liquidity. In particular, I discuss two mechanisms: (i) reduce the macroeconomic uncertainty, and (ii) reduce the supply of the real asset through a government asset purchasing program.

5.3.1 A Decrease in Macroeconomic Uncertainty

The uncertainty is measured by an increase in the mean-preserving spread over asset dividends across states, $\delta_h - \delta_\ell$. According to Proposition 7, 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 can also increase the liquidity premium and the welfare. However, the adverse selection problem becomes too severe, and the low-quality asset becomes illiquid, i.e., $d_\ell = 0$. See Figure 8 for a numerical illustration.[23]

[23]The parameter values for Figure 8 are the same as those for the left panel of Figure 5.

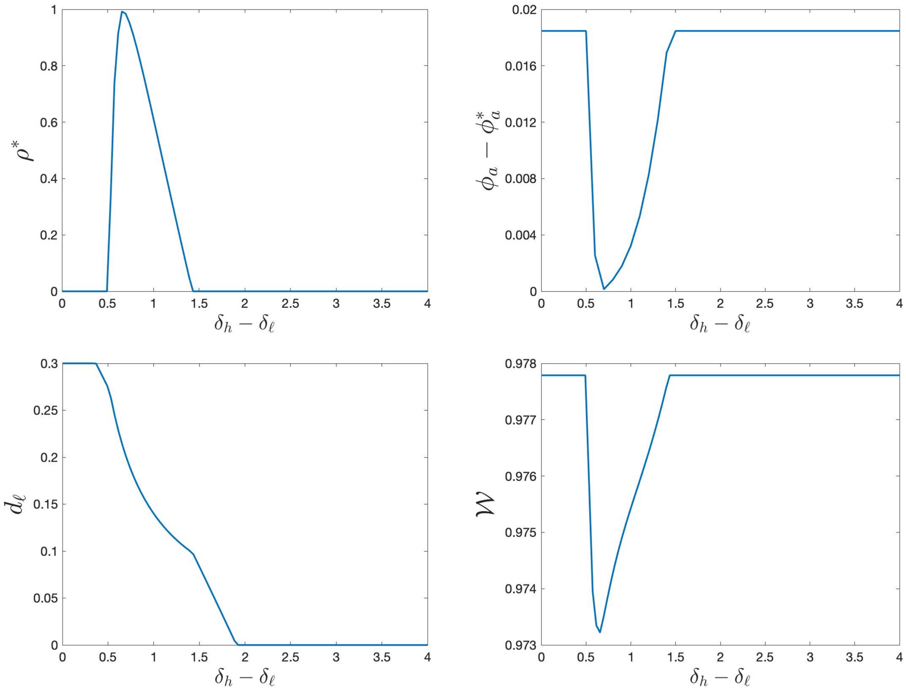

Figure 8: Effects of dispersion of dividends across states.

5.3.2 Government Asset Purchasing Program

The Federal Reserve made a series of large-scale asset purchases (LSAPs) between late 2008 and October 2014. The Fed's purchasing of long-term securities reduced the supply of securities in the market. Through the lens of my model, the LSAPs correspond to the supply of the real asset, A, declines. The model suggests that when the nominal interest rate is high, reducing asset supply in the market discourages private information acquisition and increases the liquidity premium. The LSAPs are welfare-improving. However, the transactions of low-quality assets declined. See Figure 9 for a numerical illustration.[24]

6 Conclusion

I develop a New-Monetarist model to study the implications of private information acquisition for asset liquidity. I elaborate on the impacts of private information in asset trading by incorporating a bargaining protocol under asymmetric information as in Rocheteau (2011). Furthermore, based on Lester et al. (2012), I formalize the acquisition of private

[24]The parameter values for Figure 9 are the same as those for the left panel of Figure 5.

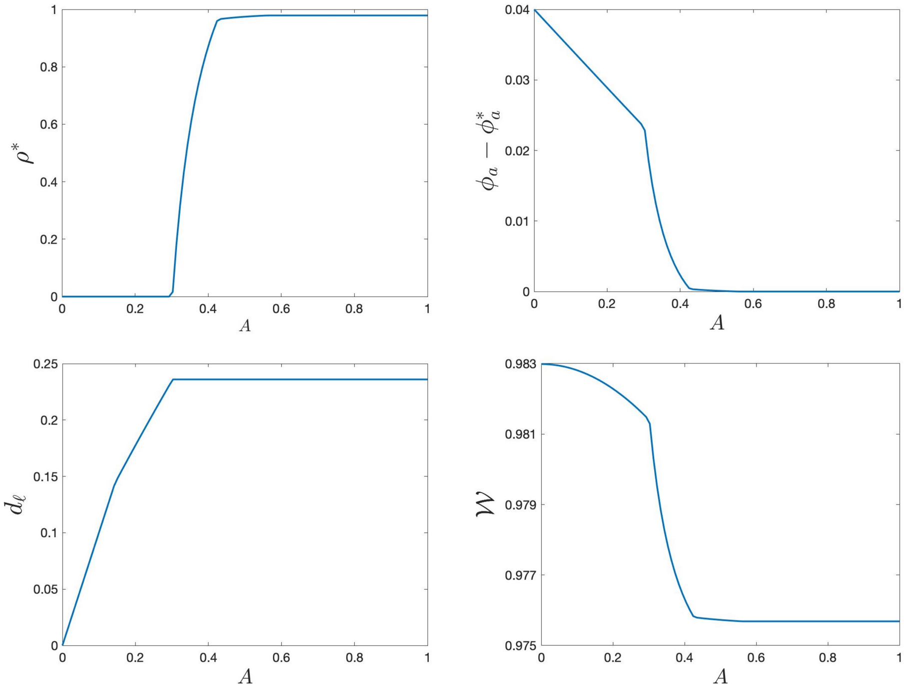

Figure 9: Effects of the real asset supply.

information on the real asset's dividends.

I start the analysis with an exogenous fraction of informed dealers who purchase assets. I characterize the steady-state equilibrium and investigate the effects of monetary policy and private information on asset liquidity and welfare. Next, I endogenize the fraction of informed dealers and study the dealers' decisions to acquire private information. I prove the uniqueness of the steady-state equilibrium in the presence of private information acquisition.

The main message of this paper is that dealers' private information acquisition 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 of the real asset, exhibit non-monotonic impacts on the fraction of informed dealers. Moreover, an increased nominal interest rate results in an increase in the fraction of informed dealers, amplifying the adverse selection problem in asset trading.

The model sheds light on the monetary policy implications for asset liquidity. When the nominal interest rate is sufficiently small or large, the model suggests a pure-strategy Nash equilibrium characterizing the dealers' private information acquisition. That is, no dealers acquire private information with a sufficiently small nominal interest rate, and all dealers acquire private information when the nominal interest rate is larger. In these scenarios, increasing the nominal interest rate has a positive effect on liquidity, given that real money balances and assets are substitutes in facilitating trade. On the other hand, when the nominal interest rate is neither too small nor too large, there exists a mixed-strategy Nash equilibrium such that only a fraction of dealers acquire private information. In this case, an increase in the nominal interest rate may have a non-monotone effect on asset liquidity.

Lastly, I discuss an application of the model to interpret the 2007-2008 financial crisis, aligning with the information view of financial crises spurred by Gorton (2010). I demonstrate the pivotal role of private information acquisition in causing illiquidity during the crisis. Furthermore, I apply the model to understand the impacts of the launch of the ABX index, reducing the macroeconomic uncertainty and reducing the asset supply through a government asset purchasing program.

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A Omitted Proofs

Proof of Proposition 1. First, (9) and (11) cannot both be binding. If this were the case, the household could raise her expected surplus by increasing q_h and keeping $(q_\ell, \tau_\ell, d_\ell)$ unchanged without upsetting (9)-(12). Similarly, (10) and (12) cannot both be binding as well.

Now, we can proof that (11) is binding by contradiction. Assume that (11) holds with a strict inequality. Then (9) and (11) 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 (11) holds with a strict inequality, then so does (9), which contradicts to our first point. Hence, (11) must be binding. Similarly, by contradiction, (10) must be binding as well. □

Proof of Lemma 2 and 3. The Lagrangian for the optimization problem is

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

where λ_1 and λ_2 are the Lagrangian multipliers with respect to the two binding constraints, (14) and (15), 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

$$\frac{\partial \mathcal{L}}{\partial q_h} = \pi u'(q_h) - \lambda_2 = 0 \quad \text{(A.2)}$$

$$\frac{\partial \mathcal{L}}{\partial \tau_h} = -\pi + \lambda_2 + (\mu_1^h - \mu_2^h) = 0 \quad \text{(A.3)}$$

$$\frac{\partial \mathcal{L}}{\partial d_h} = -\pi\delta_h + \lambda_2\delta_h + (\nu_1^h - \nu_2^h) = 0 \tag{A.4}$$

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 that the solution in Lemma 2 satisfies the necessary and sufficient conditions for the optimization problem.

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

$$\frac{\partial \mathcal{L}}{\partial q_\ell} = (1-\pi)u'(q_\ell) - \lambda_1 = 0 \tag{A.5}$$

$$\frac{\partial \mathcal{L}}{\partial \tau_\ell} = -(1-\pi) + \lambda_1 + (\mu_1^\ell - \mu_2^\ell) = 0 \tag{A.6}$$

$$\frac{\partial \mathcal{L}}{\partial d_\ell} = -(1-\pi)\delta_\ell + \lambda_1\delta_\ell - \lambda_2(\delta_h - \delta_\ell) + (\nu_1^\ell - \nu_2^\ell) = 0 \tag{A.7}$$

I discuss three possible cases as follows.

Case 1: $\mu_1^\ell = \mu_2^\ell = 0$. By (A.7), $\nu_1^\ell - \nu_2^\ell > 0$, so $d_\ell = 0$. By (A.6), $\lambda_1 = 1 - \pi$, then $q_\ell = q^*$. By (14), $\tau_\ell = q^* < z$ 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.2), (A.5) and (A.7), q_ℓ solves (16). Denote the solution as $\hat{q}_\ell$. By (14), $d_\ell = [\hat{q}_\ell - z]/\delta_\ell$, 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 (14), $q_\ell = z + \delta_\ell a$. By (A.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 (14), $q_\ell = z$. By (A.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.7), $\nu_1^\ell - \nu_2^\ell > 0$, so $d_\ell = 0$. However, by (A.5), $\lambda_1 < 1 - \pi$, thus $q_\ell > q^*$ which is infeasible when $\tau_\ell = 0$ and $d_\ell = 0$. □

Proof of Proposition 2. 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 Lemma 1-3. 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, (19), 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

$$A^d(\phi_a) \equiv \{\int_{j\in[0,1]} a(j)\, dj : a(j) \text{ solves } (20)\}$$

The proof consists of three parts.

Part I. I first focus on $A^d(\phi_a) = \{a\}, a > 0$. Hence, (20) hold with equality,

$$\phi_a - \phi_a^* = \beta\alpha\{(1-\rho)S_{1,a} + \rho[\pi S_{h,a} + (1-\pi)S_{l,a}]\} \tag{A.8}$$

According to Section B, 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 (19)-(20), $q_1 = q_h = q^*$, 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 3, $q_\ell = \min\{Z(i), \tilde{q}_\ell\}$, where $\tilde{q}_\ell$ solves (16) with $q_h = q^*$, and $Z(i)$ solves

$$i = (1-\alpha)L(z) + \alpha\rho(1-\pi)L(q_\ell) \tag{A.9}$$

which is (19) 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 (19)-(20) with $a = 0$.

I summarize the aggregate asset demand correspondence in Figure 10, 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. $\square$

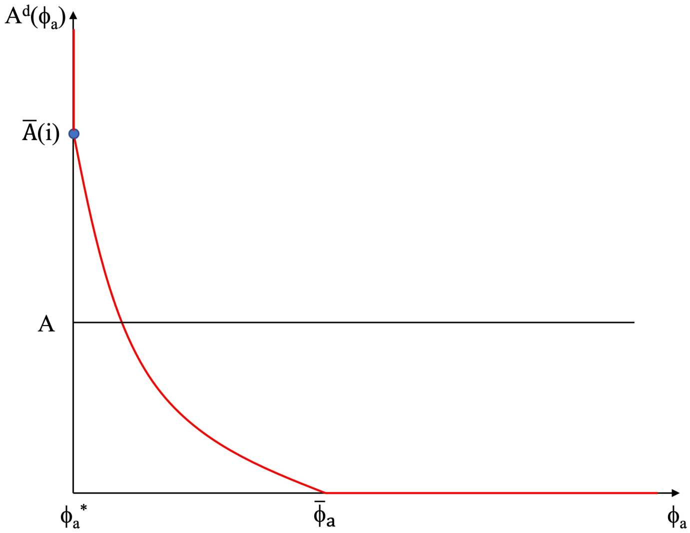

Figure 10: Aggregate Asset Demand Correspondence

Proof of Lemma 4. According to Lemma 2 and 3, the characterization of the benefit from acquiring private information is as follows for each relevant region when $b = 1$.

$$\Pi(\rho) = \begin{cases} 0, & \text{if } 0 < i < i^*(A) \\ \alpha\pi\frac{\delta_h-\delta_\ell}{\delta_\ell}[\hat{q}_\ell(\rho) - Z(\rho)], & \text{if } i \geq i^*(A), A \geq A^*(i) \\ \alpha\pi(\delta_h - \delta_\ell)A, & \text{if } i \geq i^*(A), A < A^*(i) \end{cases} \tag{A.10}$$

The value of information is independent of ρ in Region 1 and 3.

For Region 2, according to (A.10), if $i \geq i^*(A)$ and $A \geq A^*(i)$,

$$\frac{\partial\Pi(\rho)}{\partial\rho} = \alpha\pi\frac{\delta_h - \delta_\ell}{\delta_\ell}(\frac{\partial\hat{q}_\ell}{\partial Z} - 1)\frac{\partial Z}{\partial\rho} \tag{A.11}$$

where

$$\frac{\partial\hat{q}_\ell}{\partial Z} = \frac{\frac{\pi}{1-\pi}\frac{\delta_h-\delta_\ell}{\delta_\ell}\frac{\delta_h}{\delta_\ell}\frac{L'(q_h)}{L'(\hat{q}_\ell)}}{1 + \frac{\pi}{1-\pi}(\frac{\delta_h-\delta_\ell}{\delta_\ell})^2\frac{L'(q_h)}{L'(\hat{q}_\ell)}} \tag{A.12}$$

Under CRRA utility function, $\partial Z/\partial\rho > 0$. Then, the sign of $\partial\Pi(\rho)/\partial\rho$ depends on the sign of $\partial\hat{q}_\ell/\partial Z - 1$. That is,

$$\frac{\partial\Pi(\rho)}{\partial\rho}\begin{cases} > 0 & \text{if } \frac{\pi}{1-\pi}\frac{\delta_h-\delta_\ell}{\delta_\ell}\frac{L'(q_h)}{L'(\hat{q}_\ell)} > 1 \\ < 0 & \text{if } \frac{\pi}{1-\pi}\frac{\delta_h-\delta_\ell}{\delta_\ell}\frac{L'(q_h)}{L'(\hat{q}_\ell)} < 1 \end{cases} \tag{A.13}$$

With CRRA utility function, we have $L'(q) = -\sigma q^{-\sigma-1}$, then

$$\frac{L'(q_h)}{L'(\hat{q}_\ell)} = (\frac{q_h}{\hat{q}_\ell})^{-\sigma-1} \tag{A.14}$$

Furthermore, according to the bargaining solutions, $\hat{q}_\ell$ solves (16), which becomes

$$(q_\ell)^{-\sigma} = 1 + \frac{\pi}{1-\pi}\frac{\delta_h-\delta_\ell}{\delta_\ell}(q_h)^{-\sigma} \tag{A.15}$$

Combine (A.14) and (A.15), we have

$$\frac{\pi}{1-\pi}\frac{\delta_h-\delta_\ell}{\delta_\ell}\frac{L'(q_h)}{L'(\hat{q}_\ell)} = \frac{\hat{q}_\ell}{q_h} - \frac{(\hat{q}_\ell)^{\sigma+1}}{q_h} < 1 \tag{A.16}$$

since the first term is strictly smaller than 1 and the second term is weakly positive. As a result, $\partial\Pi(\rho)/\partial\rho < 0$ for Region 2. $\square$

B 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 (18) is jointly concave in (z, a). Therefore, the first-order conditions (19)-(20) 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 Lemma 2 and 3, 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 (16). 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 $|H_3| = a_3 d_3 - b_3 c_3 > 0$.

C Relevant Regions

In this section, I characterize the two critical thresholds in Figure 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 3. 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 (16). 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.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 4. Furthermore, I show that π cannot be too large to have $A^*(i)$ exist. According to Proposition 2, $q_\ell \leq q_h$. 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, (16) becomes

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

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 $i^*(A)$.

D Proof of Results in Table 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 Lemma 1-3, the first-order conditions for households' optimal portfolio choices, (19)-(20), and the market clearing conditions, the steady-state equilibrium (Z, ϕ_a) satisfies

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

$$\phi_a^* = \phi_a - \beta\alpha[(1-\rho)\delta^e L(q_1) + \rho\pi\delta_h L(q_h)] \tag{D.2}$$

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

$$i = (1-\alpha)L(Z) + \alpha\{(1-\rho)L(q_1) + \rho[\pi\frac{\delta_h}{\delta_\ell}L(q_h) + \pi\frac{\delta_h - \delta_\ell}{\delta_\ell}]\} \tag{D.3}$$

$$\phi_a^* = \phi_a - \beta\alpha\{(1-\rho)\delta^e L(q_1) + \rho\pi\delta_h L(q_h)\} \tag{D.4}$$

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 (16).

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

$$i = (1-\alpha)L(Z) + \alpha[(1-\rho)L(q_1) + \rho L(q_2)] \tag{D.5}$$

$$\phi_a^* = \phi_a - \beta\alpha\{(1-\rho)\delta^e L(q_1) + \rho[\delta_\ell L(q_2) - \pi(\delta_h - \delta_\ell)]\} \tag{D.6}$$

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 (D.1), (D.3), and (D.5). 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 (D.2), (D.4), and (D.6), 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.

$$\frac{\partial Z}{\partial \rho} = \frac{\alpha\{L(q_1) - [\pi L(q_h) + (1-\pi)L(q_\ell)]\}}{(1-\alpha)L'(Z) + \alpha\{(1-\rho)L'(q_1) + \rho[\pi L'(q_h) + (1-\pi)L'(q_\ell)]\}} \tag{D.7}$$

$$\frac{\partial \phi_a}{\partial \rho} = \beta\alpha\{[\pi\delta_h L(q_h) - \delta^e L(q_1)] + [(1-\rho)\delta^e L'(q_1) + \rho\pi\delta_h L'(q_h)]\frac{\partial Z}{\partial \rho}\} \tag{D.8}$$

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

$$\frac{\partial Z}{\partial \rho} = \frac{\alpha\{L(q_1) - [\pi\frac{\delta_h}{\delta_\ell}L(q_h) + \pi\frac{\delta_h - \delta_\ell}{\delta_\ell}]\}}{(1-\alpha)L'(Z) + \alpha[(1-\rho)L'(q_1) + \rho\pi\frac{\delta_h}{\delta_\ell}\mathcal{C}]} \tag{D.9}$$

$$\frac{\partial \phi_a}{\partial \rho} = \beta\alpha\{[\pi\delta_h L(q_h) - \delta^e L(q_1)] + [(1-\rho)\delta^e L'(q_1) + \rho\pi\delta_h\mathcal{C}]\frac{\partial Z}{\partial \rho}\} \tag{D.10}$$

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

$$\frac{\partial Z}{\partial \rho} = \frac{\alpha[L(q_1) - L(q_2)]}{(1-\alpha)L'(Z) + \alpha[(1-\rho)L'(q_1) + \rho L'(q_2)]} \tag{D.11}$$

$$\frac{\partial \phi_a}{\partial \rho} = \beta\alpha\{[\delta_\ell L(q_2) - \pi(\delta_h - \delta_\ell) - \delta^e L(q_1)] + [(1-\rho)\delta^e L'(q_1) + \rho\delta_\ell L'(q_2)]\frac{\partial Z}{\partial \rho}\} \tag{D.12}$$

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 real assets is ambiguous. Hence, I focus on showing the following sufficient conditions for a (weakly) negative direct effect.

Proof of Proposition 3. 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 $\partial\phi_a/\partial\rho < 0$.

Proof of Proposition 4. For Region 3, suppose $Z(i) + \delta^e A < q^*$, where $Z(i)$ satisfies (D.5). 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.

E 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 DM goods market. As a result, the equilibrium contract offered by the household is characterized in Section 3.2. Now, I solve the equilibrium contract when the dealer makes the offer, denoted as $\{(q_1^D, \tau_1^D, d_1^D), (q_h^D, \tau_h^D, d_h^D), (q_\ell^D, \tau_\ell^D, d_\ell^D)\}$.

E.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

$$\max_{(q_1^D, \tau_1^D, d_1^D)} [-q_1^D + \tau_1^D + \delta^e d_1^D] \tag{E.1}$$

s.t.

$$u(q_1^D) - \tau_1^D - \delta^e d_1^D \geq S_0 \tag{E.2}$$

$$0 \leq \tau_1^D \leq z, 0 \leq d_1^D \leq a \tag{E.3}$$

Define $y^e \equiv z + \delta^e a$. The equilibrium contract offered by the dealer solves (E.1)-(E.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, q^*.

E.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

$$\max_{(q^D,\tau^D,d^D)\in\mathcal{F}} \{[-q^D + \tau^D + \delta d^D]\mathbb{1}_{\mathcal{A}}(q^D, \tau^D, d^D)\} \tag{E.4}$$

The household's payoff is

$$\begin{aligned}
&[u(q^D)+W(z-\tau^D, a-d^D, \delta)]\mathbb{1}_{\mathcal{A}}(q^D, \tau^D, d^D)+[u(q_0)+W(z-q_0, a, \delta)][1-\mathbb{1}_{\mathcal{A}}(q^D, \tau^D, d^D)] \\
&= [u(q^D) - \tau^D - \delta d^D]\mathbb{1}_{\mathcal{A}}(q^D, \tau^D, d^D) + S_0[1 - \mathbb{1}_{\mathcal{A}}(q^D, \tau^D, d^D)] + W(z, a, \delta) \qquad \text{(E.5)}
\end{aligned}$$

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

After receiving the offer, the household forms expectations about the quality of the real asset, 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

$$\mathcal{A}(\lambda) = \{(q^D, \tau^D, d^D) \in \mathcal{F} : u(q^D) - \tau^D - \mathbb{E}_\lambda[\delta]d^D \geq S_0\} \tag{E.6}$$

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 (E.4), with $\delta \in \{\delta_h, \delta_\ell\}$; the set of acceptable offers for a household $\mathcal{A}$ is defined by (E.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.[25] Therefore, as shown in Rocheteau (2011), there is no pooling offer with $d^D > 0$ in equilibrium since 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 real asset 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 state $\chi \in \{h, \ell\}$ as $(q_\chi^D, \tau_\chi^D, d_\chi^D)$. First, if the dealers are informed that the asset dividend is high, the equilibrium contract solves

$$\max_{(q_h^D, \tau_h^D, d_h^d)} \{-q_h^D + \tau_h^D + \delta_h d_h^D\} \tag{E.7}$$

s.t.

$$u(q_h^D) - \tau_h^D - \delta_h d_h^D \geq S_0 \tag{E.8}$$

$$0 \leq \tau_h^D \leq z, 0 \leq d_h^D \leq a \tag{E.9}$$

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

$$\max_{(q_\ell^D, \tau_\ell^D, d_\ell^d)} \{-q_\ell^D + \tau_\ell^D + \delta_\ell d_\ell^D\} \tag{E.10}$$

s.t.

$$u(q_\ell^D) - \tau_\ell^D - \delta_\ell d_\ell^D \geq S_0 \tag{E.11}$$

$$-q_\ell^D + \tau_\ell^D + \delta_h d_\ell^D \leq -q_h^D + \tau_h^D + \delta_h d_h^D = u(q_h^D) - q_h^D - S_0 \tag{E.12}$$

$$0 \leq \tau_\ell^D \leq z, 0 \leq d_\ell^D \leq a \tag{E.13}$$

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

[25] One could consider the undefeated equilibrium as an alternative refinement. See Bajaj (2018), Wang (2020), and Madison (2022). As shown in Rocheteau (2011), with a sufficiently low nominal interest rate, the separating equilibrium by the Intuitive Criterion is robust.

(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

$$d_\ell^D = \frac{u(q_\ell^D) - \tau_\ell^D - S_0}{\delta_\ell} \tag{E.14}$$

$$u(q_\ell^D) - q_\ell^D + (\frac{\delta_h}{\delta_\ell} - 1)[u(q_\ell^D) - \tau_\ell^D - S_0] = u(q_h^D) - q_h^D \tag{E.15}$$

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

$$\mathcal{L} = [-q_\ell^D + \tau_\ell^D + \delta_\ell d_\ell^D] + \lambda_1[u(q_\ell^D) - \tau_\ell^D - \delta_\ell d_\ell^D - S_0] + \lambda_2[(u(q_h^D) - q_h^D) - (u(q_\ell^D) - q_\ell^D) - (\delta_h - \delta_\ell)d_\ell^D]$$
$$+ \mu_1 \tau_\ell^D + \mu_2(z - \tau_\ell^D) + \nu_1 d_\ell^D + \nu_2(a - d_\ell^D) \tag{E.16}$$

where λ_1 and λ_2 are the Lagrangian multipliers with respect to the two constraints, (E.11) and (E.12). μ_i and ν_i for $i = \{1, 2\}$ are the Lagrangian multipliers with respect to the liquidity constraints, E.13.

The optimal contract satisfies the following first-order conditions

$$\frac{\partial \mathcal{L}}{\partial q_\ell^D} = -1 + \lambda_1 u'(q_\ell^D) - \lambda_2[u'(q_\ell^D) - 1] = 0 \tag{E.17}$$

$$\frac{\partial \mathcal{L}}{\partial \tau_\ell^D} = 1 - \lambda_1 + (\mu_1 - \mu_2) = 0 \tag{E.18}$$

$$\frac{\partial \mathcal{L}}{\partial d_\ell^D} = \delta_\ell - \lambda_1 \delta_\ell - \lambda_2(\delta_h - \delta_\ell) + (\nu_1 - \nu_2) = 0 \tag{E.19}$$

To begin with, I show that both (E.11) and (E.12) are binding. Firstly, Consider (E.11) is binding and (E.12) is slack. (i.e., $\lambda_1 > 0, \lambda_2 = 0$) Then, $q_\ell^D = \min\{q^*, u^{-1}(\bar{y} +$

$S_0)\} \leq q_h^D$, and (E.12) becomes

$$u(q_\ell^D) - q_\ell^D + (\delta_h - \delta_\ell) d_\ell^D \leq u(q_h^D) - q_h^D \tag{E.20}$$

If $\underline{y} \geq u(q^*) - S_0$, then $q_h^D = q_\ell^D = q^*$. (E.20) implies that $d_\ell^D = 0$ and (E.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, (E.12) becomes

$$-q_\ell^D + z + \delta_h a + S_0 = \bar{y} + S_0 - q_h^D + (q_h^D - q_\ell^D) \leq u(q_h^D) - q_h^D \tag{E.21}$$

which implies $q_h^D - q_\ell^D \leq 0$, i.e., a contradiction. Next, if (E.12) is binding and (E.11) is slack. (i.e., $\lambda_1 = 0, \lambda_2 > 0$) By (E.17), $u'(q_\ell^D) - 1 < 0$, which is infeasible. Therefore, both (E.11) and (E.12) are binding.

The optimal contract solves (E.17)-(E.19) wth $\lambda_1 > 0$ and $\lambda_2 > 0$. Combining (E.18) and (E.19), we have

$$1 - \lambda_1 = \mu_2 - \mu_1 = \frac{\nu_2 - \nu_1}{\delta_\ell} + \lambda_2 \frac{\delta_h - \delta_\ell}{\delta_\ell} \tag{E.22}$$

Similar to the proof for Lemma 2 and 3, 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 (E.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, (E.14)-(E.15). Furthermore, the left-hand side of (E.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 (E.15), and a unique $d_\ell^D \in [0, a]$ that solves (E.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.

Signaling v.s. Screening. Compared to the equilibrium contracts proposed by the households in Section 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 of the real asset, 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.

E.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

$$[z(j), a(j)] = arg \max_{z,a} \{-iz - (\frac{\phi_a - \phi_a^*}{\beta})a + [(1-\alpha) + \alpha(1-b)]S_0 + \alpha b[(1-\rho)S_1 + \rho[\pi S_h + (1-\pi)S_\ell]]\} \tag{E.23}$$

The difference from (18) 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 (E.7)-(E.13). Furthermore, if $b = 0$, the liquidity premium is eliminated.

Following Appendix B, we can show that the objective function, (E.23), is jointly concave in (z, a). Hence, the following first-order conditions are necessary and sufficient for the optimization problem.

$$-i + [(1-\alpha) + \alpha(1-b)]S_{0,z} + \alpha b\{(1-\rho)S_{1,z} + \rho[\pi S_{h,z} + (1-\pi)S_{\ell,z}]\} \leq 0, \text{ "=" if } z > 0 \tag{E.24}$$

$$-\frac{\phi_a - \phi_a^*}{\beta} + \alpha b\{(1-\rho)S_{1,a} + \rho[\pi S_{h,a} + (1-\pi)S_{\ell,a}]\} \leq 0, \text{ "=" if } a > 0 \tag{E.25}$$

As a result, with exogenous ρ, the comparative statics in Table 1 still hold.

E.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 3.2. Thus, the value of private information becomes

$$\begin{aligned}\Pi(\rho) = {} & \alpha b\pi(\delta_h - \delta_\ell)d_\ell^H(\rho) \\ & + \alpha(1-b)\{\pi[u(q_h^D) - q_h^D] + (1-\pi)[u(q_\ell^D) - q_\ell^D] - [u(q_1^D) - q_1^D]\}\end{aligned} \tag{E.26}$$

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 (E.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 $b \in (0, 1)$.[26] 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 4. 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 4 remain.

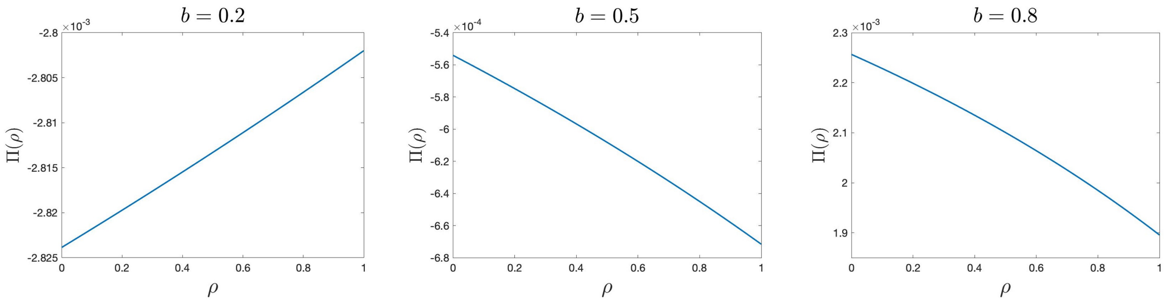

Figure 11: Value of Private Information.

[26]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 $A = 0.2$.