Costly Liquidity Provision under Asymmetric Information

Fengfan Xiang*
University of Western Ontario

June 17, 2025

Abstract

I study the asymmetric information problem during financial crises and its implications for monetary policy. Specifically, banks offer liquidity insurance services to households, backed by their asset holdings. A low nominal interest rate policy not only promotes the issuance of bank loans but also reduces the opportunity cost of holding currency, improving banking services. However, I show that the costs associated with asymmetric information, captured by screening costs, can outweigh the benefits of a prosperous financial market. In such a scenario, the Friedman rule is not optimal, and the optimal nominal interest rate policy targets a high rate that shuts down the loan market. Finally, I propose a loan subsidy program to address the asymmetric information problem, under which the Friedman rule becomes optimal.

Key Words: asymmetric information; liquidity; monetary policy
JEL: E4; E5; G2

*Email: fxiang8@uwo.ca.
I am indebted to Stephen Williamson, Baxter Robinson, and Sergio Ocampo Díaz for their invaluable guidance and support. I also want to thank Maria Goltsman, Elizabeth Caucutt, Duhyeong Kim, Yongseok Shin, Shouyong Shi, Bettina Brueggeman, as well as seminar participants at the University of Western Ontario for their helpful comments.

1 Introduction

This paper is primarily concerned with the asymmetric information problem in the loan market during financial crises and its implications for monetary policy. I adopt the costly screening approach, following Wang and Williamson (1998), to capture the welfare loss of asymmetric information, where banks incur an information acquisition cost in lending.[1] The main idea I want to convey through this paper is that the welfare losses caused by asymmetric information can outweigh the benefits of a prosperous loan market in supporting valuable financial intermediation activities. This suggests that central banks should exercise caution in their crisis interventions.

Specifically, I develop a banking model where banks play a liquidity insurance role in the spirit of Diamond and Dybvig (1983), allowing households to withdraw and trade with currency if necessary or hold onto higher-yielding bank deposits. Crucially, banks must pledge assets as collateral to secure their deposit liabilities, similar to the pledgeability constraint in Kiyotaki and Moore (1997). They obtain assets by purchasing safe government bonds or lending against Lucas (1978) trees possessed by households. However, the asymmetric information problem in the loan market, derived from households' private information regarding their valuation of trees, hinders such lending. Banks can pay a fixed cost to screen households who value their assets lowly and are unlikely to make high payments. The screening costs capture the welfare losses associated with asymmetric information during financial crises, and banks incur these costs unless the asymmetric information is severe, shutting down the loan market.

I then study the central bank's nominal interest rate policy, evaluating its effects on the prosperity of the loan market, which is tied to banks' ability to provide liquidity insurance services while also considering the cost of loan issuance under asymmetric

[1] Recent studies on costly information acquisition under asymmetric information include Andolfatto et al. (2014) and Choi and Rocheteau (2024), as well as the literature therein.

information. This generates the key result of this paper: a non-monotonic effect relationship between the nominal interest rate and economic welfare, except in extreme cases where the asymmetric information problem is either so severe that the loan market is always inactive or so mild that it is always active.

An increase in the nominal interest rate impedes banks from providing efficient liquidity insurance services. First, banks request higher loan payments in response to the increased interest rate, thereby reducing households' demand for loans. Consequently, this results in a decrease in the supply of bank assets, limiting banks' ability to provide liquidity insurance services that require the support of assets as collateral. Second, a higher nominal interest rate also prompts banks to shift their portfolio away from the optimal currency level for interest-bearing assets, which further impedes efficient liquidity insurance. The second source of inefficiency can be understood as a violation of the Friedman (1969) rule, which suggests a zero nominal interest to eliminate banks' opportunity cost of holding currency.

Additionally, an increase in the nominal interest rate initially raises banks' screening costs until the rate crosses a cutoff that shuts down the loan market, at which point the screening costs drop to zero. The increased interest rate on safe government bonds induces banks to ask for a disproportionately larger increase in loan payments from households who value Lucas trees lowly and are, therefore, more likely to make smaller payments. In response, these households have a stronger incentive to pretend to value their assets highly to obtain a better payment schedule from banks. This further implies higher screening costs that banks incur. Crucially, once the nominal interest rate exceeds a certain threshold, screening costs become too high, making loans undesirable investments and shutting down the loan market. As a result, banks invest exclusively in safe government bonds.

The two effects mentioned above generate the non-monotonic welfare effect of an increase in the nominal interest rate. Starting at the zero lower bound, an increase in the nominal interest rate reduces welfare by impeding banks' liquidity insurance services and raising screening costs. However, welfare jumps up at the cutoff interest rate when the loan market shuts down, as banks stop suffering screening costs. This suggests a welfare improvement, at least locally. After the cutoff, welfare decreases in the nominal interest rate again, but only because of the reduction in liquidity services. Clearly, when the welfare jump or the local welfare improvement is large, the cost of maintaining a prosperous loan market outweighs its benefits in facilitating banks' liquidity insurance services. In such a scenario, the Friedman rule is not optimal, and the central bank should set a high nominal interest rate that shuts down the loan market entirely.

Finally, I propose a loan subsidy program to address the asymmetric information problem and improve welfare. As discussed earlier, an increase in the nominal interest rate hinders banks from providing liquidity insurance and raises screening costs by exacerbating the incentive problem in the loan market. The subsidy program compensates banks for their opportunity cost of lending, namely the interest rate they earn from safe government bonds. In this way, it works by reducing the effective nominal interest rate that banks face. The optimal subsidy program reduces the effective nominal interest rate to the zero lower bound, allowing banks to fully exploit the loan market as if there were no asymmetric information. Consequently, banks provide as many liquidity insurance services as possible without incurring any screening costs, resulting in a welfare improvement. The Friedman rule is always optimal because the optimal subsidy program also eliminates the welfare jump by removing the screening costs.

Related Literature The banking structure developed here is based on Williamson (2018), who also studies the incentive problem in the financial market. Kang (2019) follows the same framework while incorporating the endogenous asset production process. The incentive problem in these two papers stems from private agents' ability to create counterfeit assets, as in Li et al. (2012). In particular, their incentive problem is severe when the interest rate is low, as this leads to high asset prices and makes counterfeiting profitable. By contrast, I adopt the costly screening approach in Wang and Williamson (1998) to capture the asymmetric information regarding agents' valuations of assets, where the incentive problem is mild when the interest rate is low.

The asymmetric information problem hinders the functioning of financial markets, which is crucial for understanding financial crises, particularly the collapse of financial markets (Dang et al., 2018, 2020).[2] Guerrieri and Shimer (2014) study how asymmetric information reduces asset liquidity, leading to fire sales and flight-to-quality. Geromichalos et al. (2024) examine how asymmetric information hinders the role of assets as means of payment, as does Lu (2024), who also finds a non-monotonic welfare effect. However, neither of their models exhibits market collapse or market shutdown in the language of this paper. Chiu and Koeppl (2016) and Heider et al. (2015) show that asymmetric information can lead to market collapse in the over-the-counter asset markets and the interbank market, respectively. My contribution is to explicitly model the welfare cost of asymmetric information, showing that shutting down the financial market can improve welfare, at least locally, as this cost arises only when the market operates actively. In this way, I provide new insights into the relationship between the prosperity of financial markets and market efficiency during financial crises.

The rest of the paper is organized as follows: I present the environment in section 2 and economic agents' problems in section 3. The definition of the equilibrium is in

[2] Gorton (2008) analyzes the source of asymmetric information and explains how it relates to the market collapse in the 2008 financial crisis. In this crisis, the asymmetric information problem triggers the collapse of the housing segments of the financial market, such as mortgages and mortgage-backed securities, which further leads to the collapse of the non-housing segments of the market, including other asset-backed securities like collateralized loan obligations.

section 4. I then solve the equilibrium and study the optimal nominal interest rate policy in section 5. A loan subsidy program that addresses the asymmetric information problem is proposed in section 6. Section 7 concludes.

2 Environment

Time is discrete and continues forever. There are three types of private agents: a unit measure of households, a unit measure of sellers, and an infinite measure of bankers. They live forever and discount the future across periods with a factor $\beta \in (0,1)$. All private agents have access to a linear production technology that converts labor to consumption goods one-for-one. There is also a government consisting of a fiscal authority and a central bank.

There are three underlying assets: government bonds, currency, and private Lucas (1978) trees. All are one-period assets, yielding payoffs one period after purchase. The fiscal authority issues government bonds and pays an exogenous nominal interest rate of $R-1$. The central bank issues currency, which is a perfectly divisible and portable object that yields no nominal interest. There is a fixed supply of t units of trees every period, traded at an endogenous price of p.[3] I ignore all time subscripts in anticipation of my later focus on stationary equilibria, where real variables are constant across periods, and nominal variables grow at an endogenous inflation rate $\mu - 1$.

In each period, agents engage in two stages of exchange as in Lagos and Wright (2005). In the first stage, all agents trade goods and assets, rebalancing their asset portfolios in a Walrasian *settlement market*. In the second stage, households and sellers randomly match in pairs and trade bilaterally in a *decentralized market* —

[3]The way that I model these trees as one-period assets with an exogenous supply is harmless. Modeling them as long-term assets, following Williamson (2018), or introducing the asset production process with a convex production function, as in Kang (2019), will not alter the main result.

households make a take-it-or-leave-it offer to sellers in exchange for consumption goods. Importantly, private agents are subject to limited commitment such that no one can be forced to repay their debts. Moreover, no record-keeping technology exists, making it impossible to punish those who defaulted in the past. Therefore, agents must acquire assets in advance and use them as a means of payment to settle transactions.

Seller Sellers are risk-neutral and profit-maximizing. They work to produce consumption goods for households in the decentralized market and consume their returns in the next settlement market. Their instantaneous payoff is $C - n$, where C is their consumption and n is the labor supply.[4] There are two types of sellers who accept different means of payments in the decentralized market, as in Williamson (2012, 2018). A fraction $\rho \in (0, 1)$ of sellers only accepts currency, capturing the demand for currency in transactions, while the rest accepts a wide range of means of payments, including deposit claims issued by banks.

Banker Bankers are also risk-neutral and profit-maximizing. They participate only in the settlement market, where they issue deposit claims that can be traded in the decentralized market and secure these liabilities with assets such as government bonds and loans to households. Bankers consume their profits and, when necessary, work to pay off their debts. Their instantaneous payoff is $C^{bk} - N^{bk}$, where C^{bk} and N^{bk} are, respectively, their consumption and labor supply in the settlement market. There is free entry into the banking sector.

Household Households work in the settlement market to buy assets and consumption goods. Their instantaneous utility is $-N + \gamma T + u(c)$, where N is the labor

[4]For convenience, I use uppercase and lowercase letters to distinguish between the utility flows in the settlement and decentralized markets, respectively. I adopt the same notation for other private agents.

supply in the settlement market, γT is their utility flow in the current settlement market from holding T units of Lucas trees purchased in the previous settlement market, and c is their consumption in the decentralized market. Crucially, households differ in their preference for trees, reflected by their preference shock γ that captures heterogeneous hedging needs or personal use of assets (Duffie et al., 2005). Finally, function u is strictly increasing, strictly concave, and twice continuously differentiable with $u(0) = 0$, $u'(0) = \infty$, $u'(\infty) = 0$, and $-cu''(c)/u'(c) < 1$. The last condition implies that the substitution effect dominates the income effect so that the demand for assets increases with their rate of return.

Only households receive direct utility flows from holding Lucas trees. The interpretation is that these trees are untradable (or nonmarketable) privately held assets and businesses, such as sole proprietorships, partnerships, and residential real estate (Longstaff, 2009). For example, Williamson (2018) and Kang (2019) model these trees as houses so that the utility flows come from housing services.

Asymmetric Information Households making asset-purchasing decisions before they know anything about γ, resulting in a degenerate asset distribution every period. However, they learn their type after purchasing their houses, which remains their private information. There are two types of households: an exogenous fraction $\alpha \in (0, 1)$ of households is of good (g) type while the rest is of bad (b) type. Good households are more likely to have a higher value of the preference shock, in the sense that γ among good households has first-order stochastic dominance over that among bad households. Banks do not know the type of households when making loans. They assign a payment schedule $r_i(\cdot)$ to households who report being type $i \in \{g, b\}$, and these households will make a payment $r_i(\gamma)$ under the publicly observable preference shock γ in the next settlement market. They can also verify households' type through a costly screening technology that costs $e > 0$ per household, a real resource cost that captures the welfare loss of informational financial frictions.

Government At the beginning of each period, the fiscal authority issues a fixed amount $\hat{b}$ units of government bonds, and the central bank sets a nominal interest rate on these bonds above the zero lower bound, i.e., $R - 1 \geq 0$.[5] To achieve this interest rate target, the central bank conducts an asset swap, purchasing $\hat{b} - \bar{b}$ units of government bonds with the issuance of the currency $\bar{m}$. Therefore,

$$\hat{b} \ = \ \bar{b} + \bar{m}, \tag{1}$$

which states that the total government bond supply ($\hat{b}$) equals the government bonds circulating in the private sector ($\bar{b}$) plus the bonds held by the central bank ($\hat{b} - \bar{b} = \bar{m}$). All these variables $\hat{b}$, $\bar{b}$, and $\bar{m}$ are real variables in terms of consumption goods in the settlement market.

The fiscal authority has access to lump sum transfers and taxes to balance the government's budget period by period. The budget constraint in steady state is

$$\bar{m} + \bar{b} \ = \ \frac{\bar{m} + R\bar{b}}{\mu} + \tau, \tag{2}$$

where τ is the real quantity of lump-sum transfer (or tax if $\tau < 0$) to the households at the beginning of the settlement market. The left-hand side of (2) represents the government's revenue from issuing new liabilities, which equals to the right-hand side, the payment of its liabilities from the previous period and the transfer to households. Notably, nominal assets from the last period are adjusted by inflation μ.

[5] The zero lower bounds constraint comes from arbitrage. Private agents could short-sell bonds and then invest in zero-interest currency to obtain positive profits if the nominal interest rate were negative. Kim (2024) shows how negative interest rates are implementable in the presence of frictions that inhibit arbitrage.

Timing of Events First, agents trade goods and underlying assets in a Walrasian *settlement market*. In particular, households purchase Lucas threes before knowing their type. They then learn their type, report a type to a bank to apply for loans, and write deposit contracts with the bank. Second, households learn the type of sellers they will meet, figuring out the acceptable means of payment in the incoming decentralized trading. In response, they may withdraw currency or hold onto bank deposits. Third, households match and trade with sellers one-to-one in the *decentralized market*. Fourth, banks may use the screening technology to verify if households are truth-telling at the beginning of the next *settlement market* to ensure households repay their loans based on their true type.[6] Fifth, households' preference shock γ realizes and is publicly observed. Finally, all debts from the previous period, like government bonds and loans, are redeemed. Particularly, households repay their loans based on the realized γ and receive utility flows from trees.

After everything above takes place, a new round starts, beginning with the Walrasian market in the settlement market.

3 Private Agents' Problems

I am now ready to specify private agents' problems, such as households' asset-purchasing and banks' portfolio choice decisions. The crucial part is the banks' lending process. The asymmetric information problem hinders banks from making loans, captured by a screening cost. In particular, the loan market shuts down if this information problem is severe, like the insurance market in Rothschild and Stiglitz (1978). However, private loans are one of the important sources of collateral, supporting useful financial intermediation activities. Here comes the main tradeoff of this paper: a prosperous loan

[6] Assuming the screening process happens one period after signing the loan contract avoids the time discounting β when calculating the screening cost, but does not change any results.

market provides private collateral but at the cost of a welfare loss in dealing with the asymmetric information problem through screening.

3.1 Household's Problem

I start with households' asset-purchasing and loan-taking decisions. Households' quasi-linear utility allows me to isolate these decisions in the settlement market from their trading decisions in the decentralized market.

In the settlement market, each household purchases T units of Lucas trees at a price of p. Their down payment (or out-of-pocket payment) is $-pT + \ell_i^d$, where ℓ_i^d is the loans they obtain from banks, which depends on the type they report $i \in \{g, b\}$. In the subsequent settlement market, households receive a payoff of γT from holding trees and repay $r_i(\gamma)\ell_i^d$ on loans. As will be clear later, banks write incentive-compatible contracts so that households always report their true type with $\Pr(i = g) = \alpha$. Therefore, the ex-ante expected payoff for households with T units of trees is

$$\begin{aligned} &-pT + \alpha\ell_g^d + (1-\alpha)\,\ell_b^d \\ &\qquad + \beta\Big(\big(\alpha\mathbb{E}_g[\gamma] + (1-\alpha)\,\mathbb{E}_b[\gamma]\big)T - \alpha\mathbb{E}[r_g(\gamma)]\,\ell_g^d - (1-\alpha)\,\mathbb{E}[r_b(\gamma)]\,\ell_b^d\Big). \end{aligned} \tag{3}$$

Households use Lucas trees as collateral so that their borrowing of loans satisfies

$$\gamma T \ \geq \ r_i(\gamma)\,\ell_i^d, \quad \forall i \in \{g, b\}\ \forall \gamma. \tag{4}$$

That is, the ex-post payoff from holding trees must exceed their loan payment.

Loan Contract A loan contract consists of pairs of payment schedules $(r_g(\gamma), r_b(\gamma))$ and probabilities (π_g, π_b) that banks use the screening technology to verify if a household is truth-telling. Before delving into details, let me formalize the asymmetric information problem by imposing two regularity conditions regarding the distributions for the preference shock. First, the probability density function g_i for each type is continuous and strictly positive on a common support $[0, \Gamma]$. Second, these distributions satisfy the monotone likelihood ratio property.

Assumption 1. *The distributions for the preference shock satisfy the monotone likelihood ratio property such that* $g_g(x)/g_b(x) < g_g(y)/g_b(y)$, $\forall x, y \in [0, \Gamma]$ *and* $x < y$.

This assumption implies the first-order stochastic dominance of G_b by G_g, i.e., $G_b(\gamma) > G_g(\gamma)$, $\forall \gamma \in [0, \Gamma]$ so that, as mentioned earlier, good households are more likely to have a larger shock than bad ones.

Under Assumption 1, the loan contract shares some features with the insurance contract in Rothschild and Stiglitz (1978). This contract may not exist, capturing the collapse of the structured financial market, such as the collapse of the housing segments of the market like mortgages and mortgage-backed securities during the 2008 Financial Crisis (Benmelech and Bergman, 2018). However, if the contract exists, it is a separating contract, satisfying the following incentive compatibility constraints:

$$\mathbb{E}\left[r_i\left(\gamma\right)\right] \;\leq\; \left(1-\pi_j\right)\int_0^\Gamma r_j\left(\gamma\right)\mathrm{d}G_i\left(\gamma\right) + \pi_j \mathbb{E}_i\left[\gamma\right], \quad \forall i, j \in \{g, b\} \text{ and } i \neq j. \tag{5}$$

These constraints guarantee that households are willing to incur the expected payment $\mathbb{E}\left[r_i\left(\gamma\right)\right]$ with reporting their true type i. Otherwise, they will be detected with probability π_j, incurring a loss of $\mathbb{E}_i\left[\gamma\right]$ ex ante, as the bank will liquidate their assets and deny their access to their trees. They will not be detected with probability $1-\pi_j$ and incur the expected payment $\int_0^\Gamma r_j\left(\gamma\right)\mathrm{d}G_i\left(\gamma\right)$ as if they are type j.

Banks can always choose to hold government bonds, a safe alternative with a gross real interest rate $r = R/\mu$. Consequently, a loan contract must provide banks with an expected payoff greater than the interest on bonds:

$$\mathbb{E}\left[r_i\left(\gamma\right)\right] - \pi_i e \;\geq\; r, \quad \forall i \in \{g, b\}. \tag{6}$$

Moreover, the loan payment should not exceed the service flows such that $0 \leq r_i(\gamma) \leq \gamma$. I also assume the monotonicity condition such that $\gamma_1 \leq \gamma_2 \Rightarrow r_i(\gamma_1) \leq r_i(\gamma_2)$, following Wang and Williamson (1998).

The following lemma displays the properties of optimal loan contracts.

Lemma 1. *(Wang and Williamson, 1998) The optimal loan contract satisfies:*

1. *Good households are screened with a positive probability, while bad ones are not screened, i.e.,* $\pi_g > 0$ *and* $\pi_b = 0$*;*

2. *There exists a unique contract for good households, which is a debt contract, where* $r_g(\gamma) = \gamma$ *for* $\gamma \in [0, \bar{r}_g]$ *and* $r_g(\gamma) = \bar{r}_g$ *for* $\gamma \in [\bar{r}_g, \Gamma]$*;*

3. *There also exists a debt contract for bad households, where* $r_b(\gamma) = \gamma$ *for* $\gamma \in [0, \bar{r}_b]$ *and* $r_b(\gamma) = \bar{r}_b$ *for* $\gamma \in [\bar{r}_b, \Gamma]$*.*

Moreover, π_g*,* $\bar{r}_g$ *and* $\bar{r}_b$ *are determined by the following three equations:*

$$\bar{r}_b - \int_0^{\bar{r}_b} G_b(\gamma)\mathrm{d}\gamma = r, \tag{7}$$

$$\bar{r}_g - \int_0^{\bar{r}_g} G_g(\gamma)\mathrm{d}\gamma = \pi_g e + r, \tag{8}$$

$$(1-\pi_g)\left[\bar{r}_g - \int_0^{\bar{r}_g} G_b(\gamma)\mathrm{d}\gamma\right] + \pi_g \mathbb{E}_b[\gamma] = r. \tag{9}$$

Finally, the loan contract exists if and only if $\bar{r} \geq \bar{r}_g$*, where* $\bar{r}$ *solves*

$$\alpha\left[\bar{r} - \int_0^{\bar{r}} G_g(\gamma)\mathrm{d}\gamma\right] + (1-\alpha)\left[\bar{r} - \int_0^{\bar{r}} G_b(\gamma)\mathrm{d}\gamma\right] = r. \tag{10}$$

Corollary 1. *The payment cutoffs* $(\bar{r}_g, \bar{r}_b)$ *and the screening probability* π_g *are strictly increasing in the real interest rate on government bonds, i.e.,* $\frac{\mathrm{d}\bar{r}_g}{\mathrm{d}r}, \frac{\mathrm{d}\bar{r}_b}{\mathrm{d}r}, \frac{\mathrm{d}\pi_g}{\mathrm{d}r} > 0$*.*

Loans and government bonds are perfect substitutes for risk-neutral banks because, as in (7) and (8), the expected rates of return of these assets are the same. These equations also imply that, in equilibrium, banks must screen good households to induce truth-telling, given that bad households have the incentive to misreport to obtain a more favorable payment schedule (i.e., $\bar{r}_b > \bar{r}_g$). However, using the screening technology with an expected cost of πe on each good household is a pure waste of resources because, in particular, no bad household misreports in equilibrium. In this way, the screening cost captures the welfare loss of the asymmetric information problem.

Characterization of the Household's Problem As discussed below, I will focus on an environment with a scarcity of safe government bonds so that banks are willing to ask for low returns on loans to obtain these assets as collateral. This implies that the quantities of loans ℓ_g^d and ℓ_b^d take the maximum values that satisfy collateral constraints (4). As a result, the payment schedules from Lemma 1 imply the following demands for loans in equilibrium[7]

$$\ell_g^d = T, \quad \ell_b^d = T. \tag{11}$$

Taking these demands into households' objective function (3), the first-order condition with respect to the asset-purchasing decision T gives

$$-p + 1 + \beta\Big(\alpha\mathbb{E}_g[\gamma] + (1-\alpha)\,\mathbb{E}_b[\gamma] - \alpha\mathbb{E}[r_g(\gamma)] - (1-\alpha)\,\mathbb{E}[r_b(\gamma)]\Big) = 0, \tag{12}$$

which does not depend on the quantity of trees, given that households are risk-neutral about the utility flows from holding trees. This further implies that, as in (3), households' ex-ante expected payoff of holding trees is always zero, i.e., the benefits of purchasing trees are fully absorbed by their payments, and this is why the payoff of trees will not show up in the welfare analysis below.[8]

[7] For type i households, the collateral constraint $\gamma T \geq r_i(\gamma)\,\ell_i^d$ can be written as $T \geq \ell_i^d$ when $\gamma \in [0, \bar{r}_i]$ while $\gamma T/\bar{r}_i \geq \ell_i^d$ when $\gamma \in [\bar{r}_i, \Gamma]$. The maximum quantity of loan that satisfies the collateral constraints for all the states γ is $\ell_i^d = T$.

[8] The simplification of the tree market is harmless. The reason is that, instead of the market for Lucas trees, I focus on the loan market and study how policies can balance the cost associated with

3.2 Bank's Problem

Banks maximize profits by taking deposits and investing in financial portfolios. They offer deposit contracts that provide liquidity insurance to households in the spirit of Diamond and Dybvig (1983). Specifically, a deposit contract is a triple (k, m, d): households deposit k units of goods in the settlement market; in return, they can withdraw m units of currency, and they do so if they match with sellers who only accept currency in decentralized transactions; otherwise, they hold onto tradeable claims to d units of goods in the subsequent settlement market. Besides currency for households' withdrawal requests, banks hold loans (ℓ_b^s and ℓ_g^s) and government bonds (b).

Competition among banks drives them to maximize households' expected utility.[9] After paying the required deposits k, a fraction ρ of households withdraw and trade with currency, where they make a take-it-or-leave-it offer that exchanges for $\beta m/\mu$ units of consumption goods from the sellers they meet. The remaining $1-\rho$ of them hold onto deposit claims that exchange for βd units of consumption goods. As a result, households' expected payoffs are

$$-k + \rho u\left(\frac{\beta m}{\mu}\right) + (1-\rho)u\left(\beta d\right). \tag{13}$$

Free entry further drives banks' profits to zero. Their profits come from the return on deposit contracts and investments in government bonds and loans. Therefore,

$$\begin{aligned} & k - \rho m - \beta\left(1-\rho\right)d \\ -\left(b + \alpha\ell_g^s + (1-\alpha)\,\ell_b^s\right) + \beta\frac{Rb}{\mu} + \beta r\left(\alpha\ell_g^s + (1-\alpha)\,\ell_b^s\right) \; &= \; 0, \end{aligned} \tag{14}$$

where $k, m, d, b, \ell_g^s, \ell_b^s \geq 0$.

the asymmetric information problem in the loan market and the benefit of using loans as collateral to support useful intermediation activities.

[9] Banks serve many households, but each household can contact only one bank. Although households cannot diversify across banks, they observe all bank contracts and choose the optimal one.

Banks are also subject to a collateral constraint,

$$\frac{Rb}{\mu} + r\left(\alpha \ell_g^s + (1-\alpha)\,\ell_b^s\right) \;\geq\; (1-\rho)d, \tag{15}$$

so that they prefer paying off their deposit liabilities, i.e., $(1-\rho)d$, rather than defaulting and losing their assets, i.e., $Rb/\mu + r\left(\alpha \ell_g^s + (1-\alpha)\,\ell_b^s\right)$.[10]

Any reduction in loan supply tightens the collateral constraint, hindering banks' ability to provide liquidity insurance services to households. In particular, if the loan market shuts down, banks would rely only on government bonds. A prosperous loan market provides private collateral, allowing banks to offer better liquidity insurance services. However, as mentioned earlier, promoting lending activities is at the cost of wasting resources through screening in the presence of asymmetric information.

Characterization of the Bank's Problem To sum up, banks choose deposit contract (k, m, d) and financial portfolio (b, ℓ_g^s, ℓ_b^s) to maximize households' expected utility (13), subject to the collateral constraint (15), non-negative profit constraint (14), and non-negative constraints $k, m, d, b, \ell_g^s, \ell_b^s \geq 0$. First-order conditions for the bank's problem give the following equilibrium conditions:

$$\frac{\beta}{\mu}u'\left(\frac{\beta m}{\mu}\right) \;=\; 1, \tag{16}$$

$$\beta u'(\beta d) \;=\; \frac{\mu}{R}. \tag{17}$$

The first condition (16) equates households' marginal utility of trading one additional unit of currency to the market price of the currency. This price equals one, the inverse of the gross nominal interest rate on currency. Similarly, the second one (17) equates the marginal utility of trading with an additional unit of deposit claims to the market

[10] As explained earlier, government bonds and loans are perfect substitutes for banks. I use the notations with the nominal interest rate for government bonds and real interest rate for loans to distinguish that these bonds are nominal assets while loans are real assets like deposit claims.

price of collateral, consisting of government bonds and loans, that secures these claims. The price for collateral is the inverse of its gross real interest rate μ/R.

4 Definition of Equilibrium

Definition 1. *Given the total government bond supply $\hat{b}$ and the nominal interest rate R, a stationary equilibrium consists of households' consumptions in the decentralized market $c^m = \beta m/\mu$ and $c^d = \beta d$, their demands for Lucas trees and loans (T, ℓ_g^d, ℓ_b^d), banks' demand for collateral (b, ℓ_g^s, ℓ_b^s), market-determined prices (p, μ), and the screening probability and payment thresholds that characterize the loan contract $(\pi_g, \bar{r}_g, \bar{r}_b)$, satisfying equilibrium conditions for households' and banks' problems ((11), (12), (16) and (17)), the binding collateral constraint (15), the loan contract conditions (7)–(9), and the following market clearing conditions: $\rho m = \bar{m}$ (currency market), $b = \bar{b}$ (bond market), $T = t$ (tree market), and $\ell_i^d = \ell_i^s \; \forall i \in \{g, b\}$ (loan market).*

I define the equilibrium in a way that makes it look like the loan market operates actively. However, the counterpart with an inactive loan market is just imposing zero loan supplies, i.e., $\ell_g^s = \ell_b^s = 0$, by checking the existence condition in Lemma 1.

Assumption 2 (Scaricity of Collateral)**.** *The supply of total government bonds and Lucas trees satisfies $\hat{b} + t < c^\star$ with $u'(c^\star) = 1$.*

I also focus on equilibria such that households' and banks' collateral constraints bind. That is, there does not exist enough collateral that supports a satiated consumption level, i.e., $c^m, c^d < c^\star$. Equilibria, where households achieve the satiated consumption level, are trivial because there would be no change in consumption allocation in response to policy interventions, i.e., households always consume $c^\star$. To ensure these constraints bind, I assume a scarcity of aggregate collateral supply as in Williamson (2018). Specifically, Assumption 2 states that even if banks exhaust all government liabilities and potential loans as collateral, they still cannot support the satiated consumption level for households. Under this assumption, mitigating the asymmetric information problem in the loan market could be beneficial — it facilitates private collateral provision, supporting banks' liquidity insurance services by relaxing their collateral constraints.

5 Equilibrium and Nominal Interest Rate Policy

I pin down the equilibrium with asset markets, equating the demand for bank assets to their supply. The total government bond clearing condition (1), private banks' binding collateral constraint (15), equilibrium conditions from the bank's problem (16) and (17), and asset markets clearing conditions in Definition 1 give

$$\underbrace{\rho c^m u'\left(c^m\right)+\left(1-\rho\right)c^d u'\left(c^d\right)}_{\text{bank asset demand } \mathrm{D}(r,R)} = \underbrace{\hat{b}+\left(\alpha \ell_g^d+\left(1-\alpha\right)\ell_b^d\right)}_{\text{bank asset supply } S(r)}. \tag{18}$$

As it will be clear later, this asset market clearing condition solves the equilibrium in an intuitive way, determining the endogenous gross real interest rate r and helping to show the effects of a change in the exogenous gross nominal interest rate R.

The demand side $D(r,R)$ consists of banks' demand for currency to satisfy households' withdrawal requests $\rho c^m u'\left(c^m\right)$ and their demand for collateral to back deposit claims $\left(1-\rho\right)c^d u'\left(c^d\right)$. From equation (16), the former depends on the nominal interest rate because the rate of return on currency is determined by the inflation rate, i.e., $\mu = R/r$. By contrast, from equation (17), the latter depends only on the real return.

Proposition 1. *Banks' asset demand increases with the real interest rate while decreasing with the nominal interest rate, i.e.,* $\frac{\partial D(r,R)}{\partial r} > 0$ *and* $\frac{\partial D(r,R)}{\partial R} < 0$.

I present all the proofs in Appendix A and discuss the intuition in the main text.

Intuitively, a higher real interest rate r makes it more profitable for banks to hold interest-bearing assets, such as government bonds and loans, increasing their asset demand.[11] By contrast, a higher nominal interest rate R implies a higher inflation rate and, therefore, a lower rate of return on currency. As a result, banks' asset demand decreases because of their decreased demand for currency.

The supply side $S(r)$ consists of the supply of total government bond, $\hat{b}$, and private loans, $\alpha \ell_g^d + (1-\alpha) \ell_b^d$. The total government bond supply $\hat{b}$ can be decomposed into currency $\bar{m}$ and government bonds circulating in the private sector $\bar{b}$. Currency is directly used in transactions that must be settled with currency, while bonds, together with loans, are held by private banks as collateral to support transactions settled with deposit claims. Crucially, *the supply of bank assets only depends on the real interest rate.* The reason is that the fiscal policy exogenously determines the total supply of government bonds $\hat{b}$, which is a constant. Although the supply of private loans is endogenously determined, it is solely determined by the real interest rate because banks anticipate future inflation and only care about real returns when making their portfolio decisions.

The analysis of the supply of bank assets takes two steps. First, I establish an important intermediate result, showing how the severity of the asymmetric information problem determines lending activities in the loan market. This market shuts down when the asymmetric information problem is severe. Second, I show how the real interest rate determines the bank asset supply, which, together with earlier results regarding the bank asset demand (Proposition 1), solves for equilibria. I only need to worry about the gross real interest rate in $(0, 1/\beta)$ because the scarcity of collateral assumption implies a liquidity premium on collateral, resulting in a low real interest rate.

[11] Results in Proposition 1 can be obtained from the bank's problem (16) and (17), which link the consumption quantities to the gross interest rates r and R.

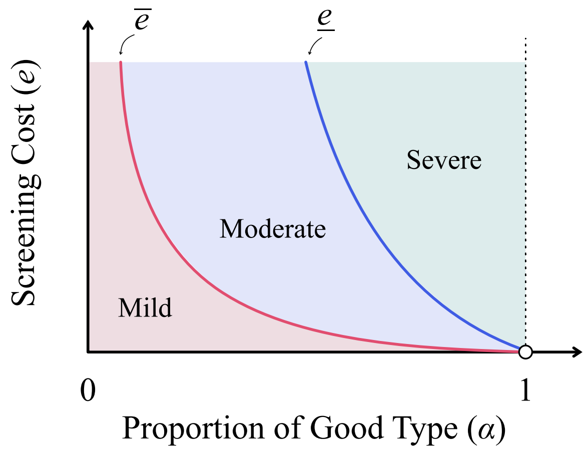

Figure 1: Severity of Asymmetric Information Problem and Equilibrium Type

Proposition 2. *For any fraction of good type households $\alpha \in (0, 1)$, there exit two thresholds of the screening cost $0 < \underline{e} < \bar{e}$, such that*

1. *the loan market operates actively, if the screening cost is low $e \in (0, \underline{e}]$;*
2. *There exists a cutoff gross real interest rate $r^\star \in (0, 1/\beta)$ and the loan market operates actively (shuts down) when the real interest rate is below (above) this cutoff, if the screening cost is between these two thresholds $e \in (\underline{e}, \bar{e}]$;*
3. *the loan market shuts down, if the screening is sufficiently high $e \in (\bar{e}, \infty)$.*

Moreover, these thresholds $\underline{e}$ and $\bar{e}$ are strictly decreasing in α, $\lim_{\alpha\to 0^+} \underline{e} = \lim_{\alpha\to 0^+} \bar{e} = \infty$, and $\lim_{\alpha\to 1^-} \underline{e} = \lim_{\alpha\to 1^-} \bar{e} = 0$.

Figure 1 depicts the results in Proposition 2. A larger proportion of good households α makes it less likely for banks to find bad households if they misreport, while a higher screening cost e makes the screening more costly. Both exacerbate the asymmetric information problem, tightening the incentive constraint (5). The loan market always shuts down when the asymmetric information problem is severe, while it always operates actively when this problem is mild. For the case lies in between, or when the asymmetric information problem is moderate, the market operates actively only

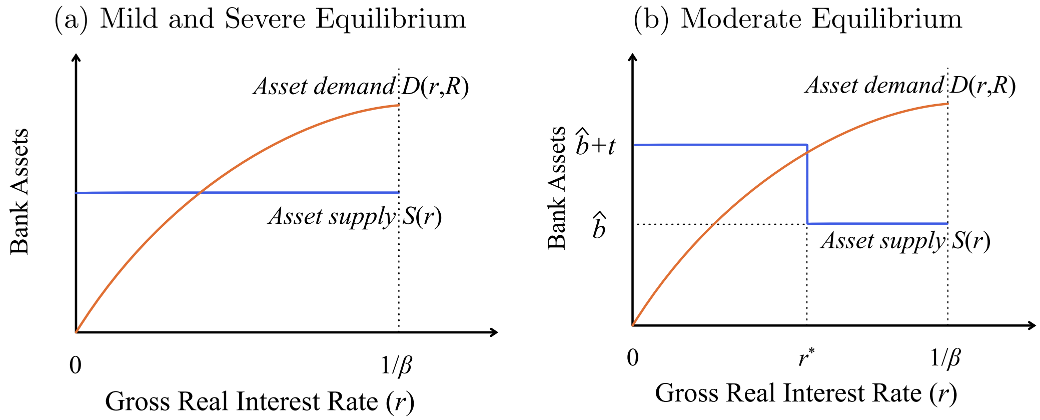

Figure 2: Equilibria under the Asymmetric Information Problem

if the real interest rate is below a cutoff $r^\star$. That is, banks are willing to incur the screening cost to exploit profits from the loan market only when the rate of return on their safe investment alternative, i.e., the real interest rate on government bonds, is low. Otherwise, the cost of switching from bonds to loans outweighs the potential benefits, and the loan market shuts down when this interest rate exceeds the cutoff.

Corollary 2. *The supply of bank assets depends on the severity of the asymmetric information problem, where*

1. *the bank asset supply is inelastic when the asymmetric information problem is mild and severe with* $S(r) = \hat{b} + t$ *and* $S(r) = \hat{b}$ *for* $r \in (0, 1/\beta)$, *respectively;*

2. *the bank asset supply drops off at the cutoff real interest rate* $r^\star$ *that starts shutting down the loan market when the asymmetric information problem is moderate with*

$$S(r) = \begin{cases} \hat{b} + t, & \text{for } r \in (0, r^\star); \\ \left[\hat{b}, \hat{b} + t\right], & \text{for } r = r^\star; \\ \hat{b}, & \text{for } r \in (r^\star, 1/\beta). \end{cases}$$

Different degrees of the severity of the asymmetric information problem give rise to different types of equilibrium. Figure 2a depicts the equilibrium when this information problem is mild or severe, where the supply of bank assets is inelastic in both scenarios. Specifically, when the asymmetric information problem is severe enough to shut the market for private loans, the bank asset supply equals the total supply of government bonds exogenously determined by the fiscal authority, i.e., $S(r) = \hat{b}$. By contrast, when the asymmetric information problem is mild, this supply is $S(r) = \hat{b} + t$. With an active loan market, banks hold both government liabilities and loans.

The supply of bank assets is characterized by a cutoff interest rate $r^\star$ when the asymmetric information problem is moderate, as in Figure 2b, where the loan market operates actively only if the gross real interest is below this cutoff. As a result, when the gross real interest rate is below (above) the cutoff, this asset supply $S(r) = \hat{b}+t$ ($S(r) = \hat{b}$) as in the scenario under mild (severe) asymmetric information problem. However, the bank asset supply is perfectly elastic at the cutoff $r^\star$, as banks are indifferent between making loans or not.

For all these scenarios, a unique equilibrium is determined by the intersection of the bank asset demand $D(r, R)$ and the bank asset supply $S(r)$.

5.1 Nominal Interest Rate Policy

I now study the effects of the central bank's nominal interest rate policy. Central banks often adopt low interest rates to stabilize financial markets and stimulate the economy during financial crises. For example, in the aftermath of the 2008 financial crisis, central banks adopted low interest rates to stabilize financial markets and stimulate the economy. When nominal interest rates were constrained by the zero lower bound, central banks deployed unconventional monetary tools, like quantitative easing, to ease financial conditions (Bernanke, 2020). These tools work like further lowering interest rates. For example, quantitative easing and forward guidance reduce long-term yields. Some central banks, such as the European Central Bank, have even implemented negative nominal interest rates directly.

Define the total welfare as the sum of utilities and disutilities from all economic activities with equally weighted economic agents:

$$\mathcal{W} = \underbrace{\rho\left[u\left(c^m\right) - c^m\right] + (1-\rho)\left[u\left(c^d\right) - c^d\right]}_{\text{aggregate trading surplus}} - \underbrace{\mathbb{I}\left(\text{active loan market}\right)\alpha\pi^g e}_{\text{aggregate screening cost}}. \tag{19}$$

Specifically, the total welfare is captured by two arguments: the aggregate trading surplus and the aggregate screening cost. The former reflects the benefit of banks' liquidity insurance service that is used to support the two types of transactions between households and sellers, while the latter is the cost of this liquidity service during financial crises, reflected by screening costs in issuing loans. As explained earlier, the payoff from holding Lucas trees does not affect welfare because it is fully absorbed by the payment on the trees. In this way, I focus on the key trade off of this paper — the cost-benefit analysis of financial intermediaries' role in liquidity provision.

An increase in the gross nominal interest rate R reduces the aggregate trading surplus in the spirit of the Friedman (1969) rule.[12] This result holds for all three types of equilibrium. Specifically, banks substitute currency for interest-bearing assets, such as government bonds, in response to an increase in R, harming transactions settled with currency, i.e., $\frac{\mathrm{d}c^m}{\mathrm{d}R} < 0$. Although this substitution benefits transactions settled with deposit claims by relaxing banks' collateral constraint, i.e., $\frac{\mathrm{d}c^d}{\mathrm{d}R} \geq 0$, this benefit cannot compensate for the loss in currency transactions.[13] That is because banks move their portfolio away from the optimal currency level in response to the increased

[12]The Friedman rule suggests that the optimal nominal interest rate should be zero or, equivalently, the gross nominal interest rate $R = 1$. Currency bears a nominal interest rate of zero. Following the Friedman rule, the central bank can eliminate the opportunity cost of holding currency, as opposed to other interest-bearing assets, leading to an efficient allocation of assets.

[13]The equality holds when banks' asset supply is perfectly elastic. In that case, the constant real interest rate $r^\star = R/\mu$ implies a constant consumption level for households who trade with deposit claims as in equation (17).

interest rate, leading to an inefficient asset holding and reducing the trading surplus of their depositors as formalized in Proposition 3. In particular, when the supply of bank assets is perfectly elastic, like in the scenario when the asymmetric information problem is moderate with $r = r^{\star}$, an increase in R shifts banks' asset demand $D(r, R)$ downward, reducing their asset holdings in equilibrium.

Proposition 3. *If* $u(c) = \eta \frac{c^{1-\sigma}-1}{1-\sigma}$ *with* $\eta > 0$ *and* $0 < \sigma < 1$*, then a rise in the nominal interest rate reduces the aggregate trading surplus.*

An increase in the gross nominal interest rate R increases the aggregate screening cost, and this result holds only if the loan market operates actively. Again, banks substitute currency for bonds in response to an increase in R. This substitution relaxes banks' collateral constraint, implying a lower price and a higher real interest rate on bank assets. That is, graphically, the increased R pushes banks' asset demand $D(r, R)$ in Figure 2a - Figure 2b downward, resulting in a higher gross real interest rate on the safe government bonds. In response, banks ask for higher loan payments, especially for bad households, who are less likely to make a high payment ex-post. Consequently, loan contracts for good households become relatively more attractive than those for bad households. Banks must increase the screening probability to prevent misreporting (Corollary 1), increasing the aggregate screening cost.

A key finding of this paper is a non-monotonic welfare effect of an increase in the nominal interest rate, as in Figure 3. This striking result arises when the asymmetric information problem is moderate. Starting from the zero lower bound $R = 1$, an increase in the nominal interest rate R reduces welfare because of a lower aggregate trading surplus and a higher aggregate screening cost. Meanwhile, the real interest rate is increasing in R. The welfare jumps up when the nominal rate R increases to the point that the real interest rate r passes through a cutoff, $r^{\star}$, under which the bank asset supply drops off (Corollary 2 and Figure 2b). At the cutoff, the loan market

(a) Friedman Rule is Not Optimal (b) Friedman Rule is Optimal

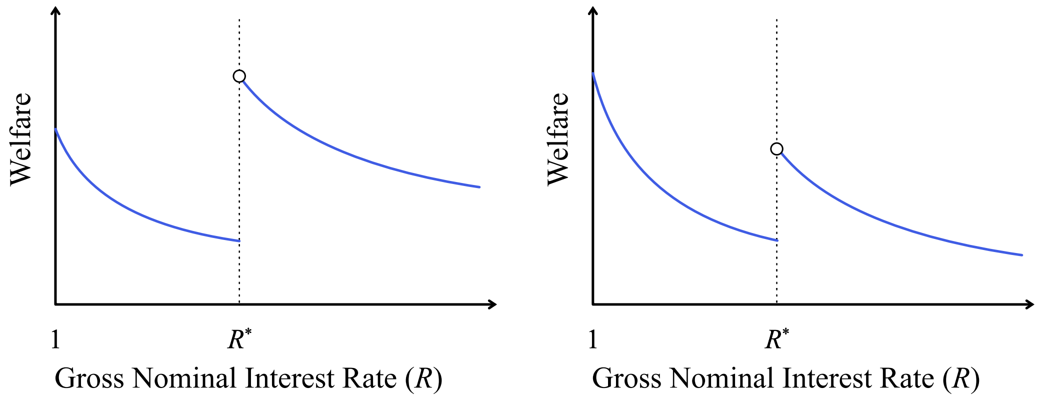

Figure 3: Optimal Interest Rate under Moderate Asymmetric Information Problem

starts shutting down, and banks suddenly stop suffering any screening cost, generating the non-monotonic effect. After the cutoff, the welfare decreases in R again, but only because of a lower aggregate trading surplus.

Crucially, when the welfare jump is large enough, the Friedman rule is not optimal (Figure 3a). Instead, the central bank should set a high nominal interest rate that shuts down the loan market to achieve the optimum. This occurs when the aggregate screening cost exceeds the benefit the loan market provides by creating collateral to support banks' liquidity insurance service, even if the collateral is scarce in aggregate. The Friedman rule can be optimal when this welfare jump is not large, and I provide numerical examples for both cases in Appendix B.

The Friedman rule is always optimal when the asymmetric information problem is mild or severe. The welfare decreases in the nominal interest when this information problem is mild (severe), like the moderate case with the gross real interest rate below (above) the cutoff $r^\star$.

6 Loan Subsidy Program

A low nominal interest rate policy boosts bank asset supply and facilitates more useful intermediation activities. However, the expenses of this policy might outweigh its benefits because banks have to incur screening costs, which is a real resource cost under asymmetric information. In this section, I propose a novel loan subsidy program that policymakers can use to address the asymmetric information problem, which improves welfare by boosting bank asset supply and saving banks' screening costs.[14]

Under the loan subsidy program, the government makes subsidy payments to banks, which are financed through lump-sum taxes in the settlement market. Let s denote the subsidy payment for each unit of loan, regardless of its type. I consider $0 < s < r$, where the former inequality guarantees a subsidy and the latter ensures no arbitrage for banks to issue more loans by short-selling government bonds. Now, instead of the gross real interest on bonds r, banks' after-subsidy opportunity cost of lending becomes $r - s$. As a result, the following equations solve for the payment cutoffs $\bar{r}_g$ and $\bar{r}_b$ and the screening probability π_g:

$$\bar{r}_b - \int_0^{\bar{r}_b} G_b(\gamma)\mathrm{d}\gamma \;=\; r - s, \tag{20}$$

$$\bar{r}_g - \int_0^{\bar{r}_g} G_g(\gamma)\mathrm{d}\gamma \;=\; \pi_g e + r - s, \tag{21}$$

$$(1-\pi_g)\left[\bar{r}_g - \int_0^{\bar{r}_g} G_b(\gamma)\mathrm{d}\gamma\right] + \pi_g \mathbb{E}_b\left[\gamma\right] \;=\; r - s. \tag{22}$$

An increase in the subsidy s reduces the opportunity cost of lending, allowing banks to ask for lower payments on bad households, i.e., $\frac{\mathrm{d}\bar{r}_b}{\mathrm{d}s} < 0$. Consequently, this reduction relaxes the incentive constraint for those bad households, mitigating the

[14] I will not distinguish between the subsidy program as a monetary or fiscal policy, given that the distinction between the two has been blurry during recent crises. For instance, during the COVID-19 crisis, the U.S. Federal Reserve introduced a series of mitigation efforts that often rely on Treasury participation, as documented by Clarida et al. (2021).

asymmetric information problem banks face while lending. Banks are able to use the screening technology less frequently, i.e., $\frac{\mathrm{d}\pi_g}{\mathrm{d}s} < 0$, and allow good households to make lower payments as well, i.e., $\frac{\mathrm{d}\bar{r}_g}{\mathrm{d}s} < 0$. All these results can be easily verified through Corollary 1. Overall, the loan subsidy program mitigates the incentive problem that banks face, reducing the aggregate screening cost.

The government should set the subsidy payment as close as the gross real interest rate r to obtain the optimal effect, i.e., $r \to s$. When optimal, from (20)-(22), the screening probability π_g converges to zero, so there is no screening cost at all. The payment cutoffs $\bar{r}_g$ and $\bar{r}_b$ also converge to zero, reflecting the fact that the government fully compensates banks' opportunity cost of issuing private loans. Consequently, the loan market always operates actively, and banks exploit this market as if there is no asymmetric information problem.[15] In this way, the loan subsidy program creates a prosperous loan market, promoting collateral provision and allowing banks to provide better intermediary services.

Specifically, the supply of bank assets becomes a constant $\hat{b} + t$ under the optimal loan subsidy program for all equilibrium cases, as in the scenario with a mild asymmetric information problem. Figure 4 depicts the general equilibrium effects of the optimal loan subsidy program, where the dashed line denotes the supply of bank assets under subsidy. The demand for bank assets does not change. However, the subsidy program boosts the supply of bank assets, at least for the moderate and severe equilibria, by mitigating the asymmetric information problem in the loan market. Bank assets become less scarce, implying lower asset prices and higher interest rates. Also, the increased bank asset supply allows banks to provide better intermediary services, supporting a larger volume of transactions for households, i.e., higher c^m and c^d.[16]

[15] The condition $\bar{r} \geq \bar{r}_g$ in Lemma 1 always holds when $\bar{r}_g \to 0$, implying an active loan market.

[16] To see this, note that we can rewrite equations (16) and (17) as $u'(c^m) = R/r\beta$ and $u'\left(c^d\right) = 1/r\beta$. For any nominal interest rate R, the subsidy program increases the real interest rate r, promoting transactions for households due to the diminishing marginal utility of consumption.

(a) Moderate Equilibrium under Subsidy (b) Severe Equilibrium under Subsidy

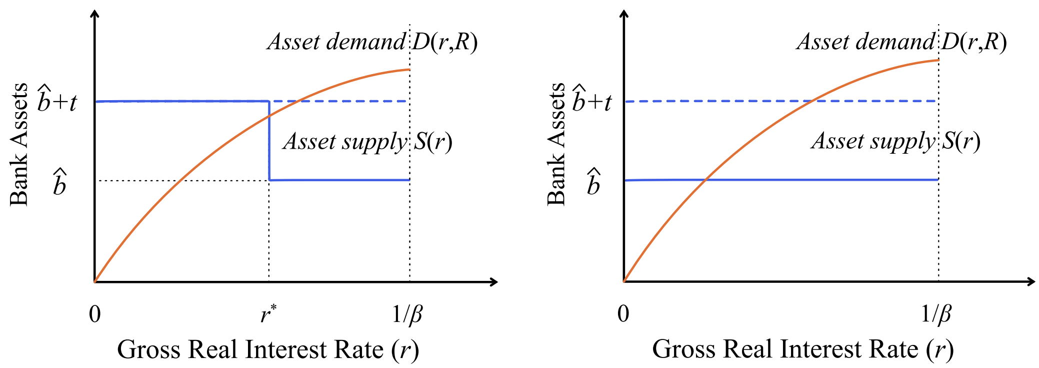

Figure 4: Equilibria under the Optimal loan Subsidy Program

Lastly, the Friedman rule is the optimal nominal interest rate policy under the optimal loan subsidy program. By addressing the asymmetric information problem, banks do not suffer any screening costs. Therefore, reducing the nominal interest rate to the zero lower bound is always optimal because it reduces banks' opportunity cost of holding currency, leading to an efficient allocation of bank assets between currency and interest-bearing assets. This further implies a better liquidity insurance service, increasing the aggregate trading surplus between households and sellers. The Friedman rule is always optimal, as in the case of a mild asymmetric information problem.

7 Conclusion

I develop a model to study the costly liquidity provision under asymmetric information during financial crises. Households have private information regarding the valuations of their assets, and this asymmetric information problem impedes banks' lending against these assets. However, private loans are useful assets for banks, especially when the supply of safe government liabilities is scarce. Consequently, banks are willing to incur an investigation cost to screen households unless the asymmetric information problem is severe, shutting down the loan market.

A key finding of this paper is a non-monotonic effect of an increase in the nominal interest rate on welfare. An increase in the nominal interest rate increases the opportunity cost of holding currency, leading to an inefficient asset allocation between currency and interest-bearing assets in the spirit of the Friedman rule, thereby reducing welfare. However, a sufficiently high interest rate shuts down the private loan market, saving banks from suffering the screening cost, a real resource cost that captures the welfare loss of asymmetric information. These two effects generate the non-monotonic effect. Specifically, welfare jumps up when the loan market starts shutting down, and the zero nominal interest rate policy suggested by the Friedman rule is not optimal when this welfare jump is significant.

I propose a novel subsidy program that improves welfare by addressing the asymmetric information problem. Under the optimal subsidy program, the government fully compensates banks' opportunity cost of lending. Banks exploit the market for private loans at no screening cost and obtain as much collateral as if no such information problem exists. The Friedman rule is always optimal under this program.

References

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

Benmelech, E. and Bergman, N. K. (2018). Credit market freezes. *NBER Macroeconomics Annual*, 32(1):493–526.

Bernanke, B. S. (2020). The new tools of monetary policy. *American Economic Review*, 110(4):943–983.

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

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

Clarida, R., Duygan-Bump, B., and Scotti, C. (2021). The covid-19 crisis and the federal reserve's policy response. *Working Paper*.

Dang, T. V., Gorton, G., and Holmström, B. (2018). Ignorance, debt and financial crises. *Working Paper*. Yale University, New Haven, CT.

Dang, T. V., Gorton, G., and Holmström, B. (2020). The information view of financial crises. *Annual Review of Financial Economics*, 12(1):39–65.

Diamond, D. W. and Dybvig, P. H. (1983). Bank runs, deposit insurance, and liquidity. *Journal of Political Economy*, 91(3):401–419.

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

Friedman, M. (1969). *The Optimum Quantity of Money and Other Essays*. Aldine, Chicago.

Geromichalos, A., Herrenbrueck, L., and Wang, Z. (2024). Asymmetric information, asset markets, and the medium of exchange. *Working Paper*.

Gorton, G. (2008). The panic of 2007. In *Federal Reserve Bank of Kansas City Economic Symposium Conference Proceedings*, pages 131–262. Federal Reserve Bank of Kansas City, Jackson Hole, WY.

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

Heider, F., Hoerova, M., and Holthausen, C. (2015). Liquidity hoarding and interbank market rates: The role of counterparty risk. *Journal of Financial Economics*, 118(2):336–354.

Kang, K.-Y. (2019). Central bank purchases of private assets: An evaluation. *Review of Economic Dynamics*, 31:326–346.

Kim, D. (2024). Negative nominal interest rates and monetary policy. *Working Paper*.

Kiyotaki, N. and Moore, J. (1997). Credit cycles. *Journal of political economy*, 105(2):211–248.

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

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

Longstaff, F. A. (2009). Portfolio claustrophobia: Asset pricing in markets with illiquid assets. *American Economic Review*, 99(4):1119–44.

Lu, X. (2024). Asset liquidity, private information acquisition, and monetary policy. *Working Paper*.

Lucas, R. E. (1978). Asset prices in an exchange economy. *Econometrica: journal of the Econometric Society*, pages 1429–1445.

Rothschild, M. and Stiglitz, J. (1978). Equilibrium in competitive insurance markets: An essay on the economics of imperfect information. In *Uncertainty in economics*, pages 257–280. Elsevier.

Wang, C. and Williamson, S. D. (1998). Debt contracts and financial intermediation with costly screening. *Canadian Journal of Economics*, pages 573–595.

Williamson, S. D. (2012). Liquidity, monetary policy, and the financial crisis: A new monetarist approach. *American Economic Review*, 102(6):2570–2605.

Williamson, S. D. (2018). Low real interest rates, collateral misrepresentation, and monetary policy. *American Economic Journal: Macroeconomics*, 10(4):202–33.

Appendices

A Omitted Proofs

Proof of Proposition 1. Equilibrium conditions from the bank's problem (16) and (17) can be rewritten as

$$\beta u'\left(c^m\right) \;=\; \frac{R}{r}, \tag{A.1}$$

$$R u'\left(c^d\right) \;=\; u'\left(c^m\right). \tag{A.2}$$

Performing comparative statics on this system of equations with respect to an increase in the gross real interest rate r and the gross nominal interest rate R gives, respectively,

$$\frac{\partial c^m}{\partial r} = -R\frac{1}{r^2}\frac{1}{\beta u''\left(c^m\right)} > 0; \quad \frac{\partial c^d}{\partial r} \;=\; -\frac{1}{r^2}\frac{1}{\beta u''\left(c^d\right)} > 0, \tag{A.3}$$

and

$$\frac{\partial c^m}{\partial R} = \frac{1}{r}\frac{1}{\beta u''\left(c^m\right)} < 0; \quad \frac{\partial c^d}{\partial R} \;=\; 0. \tag{A.4}$$

Notice that $D\left(r,R\right) \;=\; \rho c^m u'\left(c^m\right) + \left(1-\rho\right) c^d u'\left(c^d\right)$, where the right-hand side is strictly in each argument because $-cu''(c)/u'(c) < 1$. It is then straightforward to conclude that $\frac{\partial D(r,R)}{\partial r} > 0$ and $\frac{\partial D(r,R)}{\partial R} < 0$. □

Proof of Proposition 2. Define function

$$\Phi\left(x\right) \;=\; \alpha\left[x - \int_0^x G_g\left(\gamma\right)\mathrm{d}\gamma\right] + \left(1-\alpha\right)\left[x - \int_0^x G_b\left(\gamma\right)\mathrm{d}\gamma\right], \tag{A.5}$$

which is strictly increasing in x on $[0,\Gamma]$. Then, the loan contract exists if and only if $\Phi\left(\bar{r}\right) \geq \Phi\left(\bar{r}_g\right)$, given that this condition is equivalent to $\bar{r} \geq \bar{r}_g$. From equations (8)

– (10) in Lemma 1,

$$\begin{aligned}\Phi\left(\bar{r}\right) &= r; &\text{(A.6)}\\ \Phi\left(\bar{r}_g\right) &= r+\pi_g\left\{\alpha e+(1-\alpha)\left[\bar{r}_g-\int_0^{\bar{r}_g}G_b\left(\gamma\right)\mathrm{d}\gamma\right]-(1-\alpha)\,\mathbb{E}_{\mathrm{b}}\left[\gamma\right]\right\}. &\text{(A.7)}\end{aligned}$$

I prove Proposition 2 in two steps. I first prove some useful conditions that characterize the second argument of the right-hand side of the equation (A.7) and then use these conditions to finish the proof.

Step 1 Using integration by parts, $\left[x-\int_0^x G_b\left(\gamma\right)\mathrm{d}\gamma\right]-\mathbb{E}_{\mathrm{b}}\left[\gamma\right]=x+\int_x^\Gamma G_b\left(\gamma\right)\mathrm{d}\gamma-\Gamma<0$. For convenience, define another function $\phi\left(x\right)$, such that

$$\phi\left(x\right) = \alpha e+(1-\alpha)\left[x+\int_x^\Gamma G_b\left(\gamma\right)\mathrm{d}\gamma-\Gamma\right], \tag{A.8}$$

where $\phi'\left(x\right)\geq 0$ on $[0,\Gamma]$, with equality holds when $x=\Gamma$. Then, I can rewrite the existence condition of the loan contract further as $0\geq\phi\left(\bar{r}_g\right)$. Totally differentiating $\phi\left(\bar{r}_g\right)$ with respect to r, α and e, respectively, I obtain the following results:

$$\begin{aligned}\frac{\mathrm{d}\phi\left(\bar{r}_g\right)}{\mathrm{d}r} &= (1-\alpha)\left[1-G_b\left(\bar{r}_g\right)\right]\frac{\mathrm{d}\bar{r}_g}{\mathrm{d}r}>0; &\text{(A.9)}\\ \frac{\mathrm{d}\phi\left(\bar{r}_g\right)}{\mathrm{d}\alpha} &= e-\left[x+\int_x^\Gamma G_b\left(\gamma\right)\mathrm{d}\gamma-\Gamma\right]>0; &\text{(A.10)}\\ \frac{\mathrm{d}\phi\left(\bar{r}_g\right)}{\mathrm{d}e} &= \alpha+(1-\alpha)\left[1-G_b\left(\bar{r}_g\right)\right]\frac{\mathrm{d}\bar{r}_g}{\mathrm{d}e}>0, &\text{(A.11)}\end{aligned}$$

given that $\frac{\mathrm{d}\bar{r}_g}{\mathrm{d}e}>0$ and $\frac{\mathrm{d}\bar{r}_g}{\mathrm{d}r}>0$ from equation (8) and (9).

Step 2 There are three cases given that $\frac{\mathrm{d}\phi(\bar{r}_g)}{\mathrm{d}r}>0$: no loan contract exists for $r\in(0,\frac{1}{\beta})$, loan contracts always exist for $r\in(0,\frac{1}{\beta})$, and there exists a cutoff $r^\star\in(0,\frac{1}{\beta})$ such that loan contracts exist only if $r\leq r^\star$.

Recall that the existence condition of the loan contract is $0\geq\phi\left(\bar{r}_g\right)$. Fix any $\alpha\in(0,1)$, loan contracts alway exist if $0\geq\phi(\bar{r}_g^1)$, where $\bar{r}_g^1$ is the solution to equations (8) and (9) when $r \to \frac{1}{\beta}$, given that $\frac{\mathrm{d}\phi(\bar{r}_g)}{\mathrm{d}r} > 0$. That is,

$$e \;\leq\; -\frac{1-\alpha}{\alpha}\left[\bar{r}_g^1 + \int_{\bar{r}_g^1}^{\Gamma} G_b\left(\gamma\right)\mathrm{d}\gamma - \Gamma\right]. \tag{A.12}$$

Similarly, denote $\bar{r}_g^2$ as the solution to to equations (8) and (9), and no loan contract exists when $r \to 0$ such that

$$e \;>\; -\frac{1-\alpha}{\alpha}\left[\bar{r}_g^2 + \int_{\bar{r}_g^2}^{\Gamma} G_b\left(\gamma\right)\mathrm{d}\gamma - \Gamma\right]. \tag{A.13}$$

Note that $\bar{r}_g^1 > \bar{r}_g^2$, given that $\frac{\mathrm{d}\bar{r}_g}{\mathrm{d}r} > 0$ from (A.9). Also, note that $\bar{r}_g^1 + \int_{\bar{r}_g^1}^{\Gamma} G_b\left(\gamma\right)\mathrm{d}\gamma - \Gamma$ and $\bar{r}_g^2 + \int_{\bar{r}_g^2}^{\Gamma} G_b\left(\gamma\right)\mathrm{d}\gamma - \Gamma$ in equations (A.12) and (A.13) are bounded because $\bar{r}_g^1 \in [0, \Gamma]$ and $\bar{r}_g^2 \in [0, \Gamma]$, which help to obtain later results when I take the limit.

Given that $\frac{\mathrm{d}\phi(\bar{r}_g)}{\mathrm{d}e} > 0$, the loan market is more likely to operate actively with a low screening cost e. Then, define $\underline{e} = \sup E_1$ where all $e \in E_1$ satisfy (A.12) and define $\bar{e} = \inf E_2$ where all $e \in E_2$ satisfy (A.13), which capture the cutoffs such that below $\underline{e}$ the loan market always operate actively and above $\bar{e}$ the loan market always shuts down. From (A.12) and (A.13),

$$\alpha\bar{e} + (1-\alpha)\left[\bar{r}_g^2 + \int_{\bar{r}_g^2}^{\Gamma} G_b\left(\gamma\right)\mathrm{d}\gamma - \Gamma\right] \;\geq\; \alpha\underline{e} + (1-\alpha)\left[\bar{r}_g^1 + \int_{\bar{r}_g^1}^{\Gamma} G_b\left(\gamma\right)\mathrm{d}\gamma - \Gamma\right]. \tag{A.14}$$

This, together with the fact that $\bar{r}_g^1 > \bar{r}_g^2$, implies $\bar{e} > \underline{e} > 0$. Finally, for the case with $e \in (\underline{e}, \bar{e}]$, it is straightforward to show the existence of the cutoff $r^\star$ such that loan contracts exist only if $r \leq r^\star$ because, again, $\frac{\mathrm{d}\phi(\bar{r}_g)}{\mathrm{d}r} > 0$.

For any α, thresholds $\underline{e}$ and $\bar{e}$ can also be viewed as the solution to (A.12) and (A.13) by changing inequalities with equalities. Taking the limit of α, I obtain $\lim_{\alpha\to 0^+}\underline{e} = \lim_{\alpha\to 0^+}\bar{e} = \infty$ and $\lim_{\alpha\to 1^-}\underline{e} = lim_{\alpha\to 1^-}\bar{e} = 0$. These thresholds $\underline{e}$ and $\bar{e}$ are strictly decreasing in α is an immediate result thank to (A.10) and (A.11). □

Proof of Proposition 3. Under $u\left(c\right) = \eta\frac{c^{1-\sigma}-1}{1-\sigma}$, I can rewrite equations (16), (17) and (18) as

$$
\begin{aligned}
c^{m} &= \eta^{\frac{1}{\sigma}} R^{-\frac{1}{\sigma}} (r\beta)^{\frac{1}{\sigma}}, && \text{(A.15)}\\
c^{d} &= \eta^{\frac{1}{\sigma}} (r\beta)^{\frac{1}{\sigma}}. && \text{(A.16)}\\
(r\beta)^{\frac{1}{\sigma}-1} \eta^{\frac{1}{\sigma}} \left[1-\rho+\rho R^{1-\frac{1}{\sigma}}\right] &= S(r). && \text{(A.17)}
\end{aligned}
$$

For any gross nominal interest rate R, these equations solve for the equilibrium gross real interest rate r and consumption allocation c^m and c^d.

Let $\mathcal{TS} = \rho\left[u(c^m) - c^m\right] + (1-\rho)\left[u\left(c^d\right) - c^d\right]$ denote the aggregate trading surplus. The analysis consists of two cases. First, the supply of bank assets is perfectly elastic as in the scenario when the asymmetric information problem is moderate and $r = r^{\star}$. Second, other scenarios such that the supply of bank assets is inelastic with $S'(r) = 0$.

Case 1 The perfect elastic bank asset supply implies that the gross real interest rate is a constant with $r = r^{\star}$. As a result, $\frac{\mathrm{d}c^m}{\mathrm{d}R} < 0$, $\frac{\mathrm{d}c^d}{\mathrm{d}R} = 0$ from equations (A.15) and (A.16). Then, $\frac{\mathrm{d}\mathcal{TS}}{\mathrm{d}R} < 0$ is an immediate result under $c^m < c^{\star}$ with $u'(c^{\star}) = 1$.

Case 2 Totally differentiating (A.15), (A.16) and (A.17) with respect to R gives a system of linear equations of $\frac{\mathrm{d}c^m}{\mathrm{d}R}$, $\frac{\mathrm{d}c^d}{\mathrm{d}R}$ and $\frac{\mathrm{d}r}{\mathrm{d}R}$. Solving this system of equations gives

$$
\begin{aligned}
\frac{\mathrm{d}r}{\mathrm{d}R} &= \frac{\rho r R^{-\frac{1}{\sigma}}}{1-\rho+\rho R^{1-\frac{1}{\sigma}}} > 0; && \text{(A.18)}\\
\frac{\mathrm{d}c^m}{\mathrm{d}R} &= -\frac{1}{\sigma} R^{-\frac{1}{\sigma}-1} (\eta r\beta)^{\frac{1}{\sigma}} \frac{1-\rho}{1-\rho+\rho R^{1-\frac{1}{\sigma}}} < 0; && \text{(A.19)}\\
\frac{\mathrm{d}c^d}{\mathrm{d}R} &= \frac{1}{\sigma} (\eta r\beta)^{\frac{1}{\sigma}} \frac{\rho R^{-\frac{1}{\sigma}}}{1-\rho+\rho R^{1-\frac{1}{\sigma}}} > 0. && \text{(A.20)}
\end{aligned}
$$

Substituting the results into $\frac{\mathrm{d}\mathcal{TS}}{\mathrm{d}R} = \rho\left[u'(c^m) - 1\right] \frac{\mathrm{d}c^m}{\mathrm{d}R} + (1-\rho)\left[u'\left(c^d\right) - 1\right] \frac{\mathrm{d}c^d}{\mathrm{d}R}$ gives

$$
\frac{\mathrm{d}\mathcal{TS}}{\mathrm{d}R} = \frac{\rho(1-\rho)(\eta r\beta)^{\frac{1}{\sigma}} R^{-\frac{1}{\sigma}} \left(-1+R^{-1}\right)}{\sigma\left(1-\rho+\rho R^{1-\frac{1}{\sigma}}\right)} \leq 0, \tag{A.21}
$$

and equality holds at the zero lower bound with the gross nominal interest rate $R = 1$. Therefore, a rise in the nominal interest rate reduces the aggregate trading surplus. □

B Numerical Examples

Let $\hat{b} = 0.1$, $\sigma = 0.17$, $\rho = 0.17$, $\beta = 0.96$, $\eta = 1$, $G_g(x) = x^{80}$ and $G_b(x) = x^2$, where the support of the distributions of the preference shock normalized to $[0, 1]$. These parameter values satisfy all the assumptions in the model. The following are two examples illustrated in Figure 3.

1. Let $e = 1$ and $\alpha = 0.02$. Then, the cutoff real interest rate that shuts down the loan market is $r^* = 0.6731$ and the associated nominal interest rate $R^* = 1.6855$. Now $\mathcal{W}(1) = 0.0410 < \mathcal{W}(R^*) = 0.0563$, which is the case in Figure 3a.

2. Let $e = 0.4$ and $\alpha = 0.001$. Then, the cutoff real interest rate that shuts down the loan market is $r^* = 0.6670$ and the associated nominal interest rate $R^* = 1.2765$. Now $\mathcal{W}(1) = 0.0578 > \mathcal{W}(R^*) = 0.0573$, which is the case in Figure 3b.