# Costly Liquidity Provision under Asymmetric Information

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**Abstract**

I study asymmetric information in bank lending and its implications for monetary policy. Banks incur screening costs in lending because households possess private information about collateral values. While costly, loans are useful collateral that supports banking services. A higher nominal interest rate discourages lending and weakens banking services, but also saves on screening costs. I show how these savings can outweigh the losses from reduced banking services, at least locally, when the interest rate rises to the point that shuts down the loan market and eliminates screening. When screening is sufficiently costly, such a high rate can be globally optimal, implying that the Friedman rule is not necessarily optimal. A loan subsidy that removes screening costs restores the optimality of the Friedman rule.

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

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# 1 Introduction

This paper is primarily concerned with the asymmetric information problem in bank lending and its implications for monetary policy. I adopt the costly screening approach, following Wang and Williamson (1998), to capture the welfare losses associated with asymmetric information, where banks incur real resource costs to acquire information about households' collateral values in lending.[1] Despite involving screening costs, loans are useful collateral that help sustain bank services. The main idea I want to convey through this paper is that the welfare losses caused by asymmetric information can outweigh the benefits of an active loan market, suggesting that central banks should exercise caution in their crisis interventions.

Specifically, I develop a banking model in which banks play a liquidity insurance role in the spirit of Diamond and Dybvig (1983), allowing households to withdraw and trade with currency when necessary or to hold higher-yielding bank deposits. Crucially, banks must pledge assets as collateral to secure their deposit liabilities. They obtain assets by purchasing safe government bonds or by lending against households' assets that take the form of Lucas (1978) trees. However, an asymmetric information problem arises in the loan market from households' private information about the valuation of their trees. Banks can pay a fixed cost to screen households whose trees are more likely to yield low payoffs, making them less likely to make high payments. These screening costs are real resource costs that capture the welfare loss associated with asymmetric information. In equilibrium, banks incur these costs whenever the loan market is active.

I study the central bank's nominal interest rate policy, evaluating its effects on the loan market, which is tied to banks' ability to provide liquidity insurance services while also considering the cost of loan issuance under asymmetric information. A key result of the paper is a non-monotonic welfare effect of the nominal interest rate, except in cases

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

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 on safe government bonds hinders banks' ability to provide liquidity-insurance services for two reasons. First, a higher interest rate induces banks to shift their portfolio away from the optimal currency level toward interest-bearing assets. This first reason can be understood as a violation of the Friedman (1969) rule, which proposes a zero nominal interest to eliminate banks' opportunity cost of holding currency. Second, banks raise loan payments in response to the increased interest rate, which in turn reduces households' demand for loans. Consequently, the supply of bank assets decreases, limiting banks' ability to issue deposit liabilities.

Additionally, an increase in the nominal interest rate raises banks' screening costs until the rate crosses a cutoff that shuts down the loan market, at which point the screening costs also drop to zero. A higher interest rate on safe government bonds induces banks to demand disproportionately higher loan payments from households whose Lucas trees are more likely to yield low payoffs, compensating for the greater risk of receiving low payments. This exacerbates the incentive problem in the loan market because, in response, such households have a stronger incentive to misreport the quality of their assets to obtain more favorable loan terms. Thus, banks incur higher screening costs. Crucially, once the nominal interest rate exceeds a certain threshold, screening costs become prohibitively expensive, making loans undesirable investments and shutting down the loan market. From that point, banks invest exclusively in government bonds.

The two effects discussed 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 due to the reduced liquidity insurance services and the increased screening costs. However, welfare jumps up at the cutoff rate when the loan market shuts down, as banks stop paying 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 insurance services. Particularly, when the welfare jump or the local welfare improvement is large, the cost of maintaining an active loan market can outweigh its benefit in supporting banks' liquidity insurance services. In such a case, the Friedman rule is not optimal, and the central bank should set the nominal interest rate high enough to shut down the loan market.

Finally, I propose a loan subsidy program that addresses the asymmetric information problem and improves welfare.[2] As discussed earlier, an increase in the nominal interest rate hinders banks from providing liquidity insurance services 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 zero, allowing banks to fully exploit the loan market as if there were no asymmetric information. Consequently, banks offer as many liquidity insurance services as possible without incurring any screening costs, leading to a welfare improvement. When paired with the loan subsidy program, the Friedman rule is always optimal because the subsidy eliminates screening costs and thus removes the welfare jump described above.

**Related Literature** The banking structure developed here is based on Williamson (2018), who also studies incentive problems in the financial market. Kang (2019) follows the same framework while incorporating an endogenous asset production process. The incentive problems in these two papers stem from private agents' ability to create counterfeit assets, as in Li, Rocheteau, and Weill (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. I adopt instead the costly screening approach in Wang and Williamson

[2]For example, the U.S. government conducts subsidy programs through its Troubled Asset Relief Program during the 2008 Financial Crisis and the Paycheck Protection Program Liquidity Facility during the COVID-19 Pandemic.

(1998) to capture the cost of asymmetric information regarding agents' asset valuations, where the incentive problem is (instead of severe) mild when the interest rate is low.

The damaging effects of asymmetric information in financial markets were once more highlighted by recent financial crises, during which information-sensitive assets ceased to trade and market activity collapsed (Dang, Gorton, & Holmström, 2018, 2020). This might be the case of the 2008 financial crisis (Gorton, 2008): asymmetric information triggered a collapse in the housing segments of the financial market, including mortgages and mortgage-backed securities, which in turn propagated to other asset-backed securities, such as collateralized debt obligations. Guerrieri and Shimer (2014) study how asymmetric information reduces asset liquidity, leading to fire sales and flight-to-quality. Geromichalos, Herrenbrueck, and Wang (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, Hoerova, and Holthausen (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, to show its implications for monetary policy, and to provide remedies to the underlying informational frictions. I show 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 section 4. I then solve the equilibrium and study the optimal nominal interest rate policy in sections 5 and 6. A loan subsidy program that addresses the asymmetric information problem is proposed in section 7. Section 8 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 $\beta \in (0,1)$. Private agents have access to a linear production technology that converts labor into 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. The fiscal authority issues government bonds and pays an exogenous nominal interest rate of $R-1$. The central bank issues currency, 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 $p$. I omit all time subscripts, anticipating my later focus on stationary equilibria, where real variables are constant 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* — 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 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. I use uppercase and lowercase letters to distinguish between utility flows in the settlement and decentralized markets, respectively, and apply the same notation for other private agents. There are two types of sellers who accept different means of payment in the decentralized market, as in Williamson (2012, 2018). A fraction $\rho \in (0,1)$ of sellers accept only currency, capturing the demand for currency in transactions, while the rest accept a wide range of means of payment, including bank deposits.

**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 cannot consume in the settlement market but work there to buy assets. They do not purchase consumption goods in this market and carry them to the decentralized market because all goods, including those in the settlement market, are perishable. Their instantaneous utility is $-N + \gamma T + u(c)$, where $N$ is labor supply in the settlement market, $T$ is the quantity of Lucas trees purchased in the previous settlement market, $\gamma$ is a payoff shock that determines the fruits (or dividends) each tree yields and is discussed in more details below, and $c$ is consumption in the decentralized market. The 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 asset demand increases with the rate of return.

Only households receive payoffs 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 derive from housing services. Crucially, households receive different payoffs from trees, reflected in their payoff shock $\gamma$, which captures their heterogeneous hedging needs or personal use of assets. There are two types of households — good ($g$) and bad ($b$) — that differ in the payoff shock distribution. The distributions satisfy two regularity conditions. First, for each type $i \in \{g, b\}$, the probability density function $g_i$ is continuous and strictly positive on a common support $[0, \Gamma]$. Second, these distributions satisfy the monotone likelihood ratio property.

**Assumption 1.** *The distributions of the payoff 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 the cumulative distribution function $G_b$ by $G_g$, i.e., $\forall \gamma \in [0, \Gamma]$, $G_b(\gamma) > G_g(\gamma)$. Therefore, good households are more likely to draw higher shocks and thus earn higher payoffs than bad households.

**Asymmetric Information** Households make asset-purchasing decisions before they know anything about the payoff shock $\gamma$, resulting in a degenerate asset distribution every period. However, they learn their type after purchasing Lucas trees, with an exogenous fraction $\alpha \in (0, 1)$ of households being good while the rest being bad, and the type remains households' private information. Although good households are more likely to receive a higher payoff from their assets, banks do not know the type of households when making loans. In response, banks assign a payment schedule $r_i(\cdot)$ to households reporting type $i \in \{g, b\}$, who then make payment $r_i(\gamma)$ under the publicly observable shock $\gamma$ in the next settlement market. Banks can also assess household 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 bonds above the zero lower bound, i.e., $R - 1 \geq 0$.[3] To support 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 the steady state is

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

where $\tau$ 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 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 $\mu$.

**Timing of Events** First, agents trade goods and assets in a Walrasian *settlement market*. In particular, households purchase Lucas threes before knowing their own type. They then learn their type, report a type to a bank to apply for loans, and write deposit contracts with the same bank. Second, households learn the type of seller they will meet

[3]The zero lower bounds constraint comes from arbitrage. Agents could short-sell bonds and then invest in zero-interest currency to obtain positive profits if the nominal interest rate were negative. Kim (2025) shows how negative interest rates are implementable in the presence of frictions that inhibit arbitrage.

and figure out the acceptable means of payment in the decentralized market. 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.[4] Fifth, households' payoff shock $\gamma$ 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 $\gamma$ 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 purchases and banks' portfolio choices. The key part of the model is the market for bank loans to households. The asymmetric information problem hinders banks from making loans. In particular, the loan market shuts down if this problem is severe, as in the insurance market of Rothschild and Stiglitz (1978). However, private loans are an important source of collateral, facilitating valuable intermediation activities. Here comes the main tradeoff of this paper: an active loan market provides private collateral for banks, but at the cost of more 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

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

trading decisions in the decentralized market.

In the settlement market, each household purchases $T$ units of Lucas trees at a price of $p$. Their out-of-pocket payment (or down payment) is $-pT + \ell_i^d$, where $\ell_i^d$ is the loans they obtain from banks, which depends on the type, $i \in \{g, b\}$, they report. In the subsequent settlement market, households receive a payoff of $\gamma T$ from holding trees and repay $r_i(\gamma)\ell_i^d$ on loans. As will be clear below, banks write incentive-compatible contracts so that households always report their true type with $\Pr(i = g) = \alpha$. Therefore, each household's ex-ante expected payoff with $T$ units of trees is

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

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

$$\gamma T \;\geq\; r_i(\gamma)\,\ell_i^d, \quad \forall\, i \in \{g, b\}, \gamma \in [0, \Gamma]. \tag{4}$$

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

**Loan Contract** As mentioned earlier, a loan contract consists of pairs of payment schedules $(r_g(\gamma), r_b(\gamma))$ and probabilities $(\pi_g, \pi_b)$ that banks use the screening technology to verify if a household is truth-telling.

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

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

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 $\pi_j$, 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, households' loan payment should not exceed their payoff from holding Lucas trees, 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 the optimal loan contract that satisfy the conditions above.

**Lemma 1.** *(Wang & 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, $\pi_g$, $\bar{r}_g$ 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*

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

*Otherwise, the loan market collapses.*

**Corollary 1.** *The payment cutoffs $(\bar{r}_g, \bar{r}_b)$ and the screening probability $\pi_g$ 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 $\pi e$ on each good household is a pure waste of resources because, in particular, no 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 focus on an environment where collateral is scarce in aggregate (Assumption 2), so that banks are willing to accept low rates of return on loans, which is useful collateral for banks. As a result, the quantities of loans $\ell_g^d$ and $\ell_b^d$ take the maximum values that satisfy collateral constraints (4), which are

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

given the payment schedules in Lemma 1.[5] 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.[6]

## 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 deposit claims to $d$ units of goods in the subsequent settlement market. Besides currency for households' withdrawal

[5]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 $\gamma$ is $\ell_i^d = T$.

[6]The simplification of the tree market is harmless. The reason is that, instead of focusing on the Lucas tree market, I concentrate on the loan market and examine how policies can balance the costs associated with the asymmetric information problem in the loan market and the benefits of using loans as collateral to support useful intermediation activities.

requests, banks hold loans ($\ell_b^s$ and $\ell_g^s$) and government bonds ($b$).

Competition among banks drives them to offer deposit contracts that maximize households' expected utility.[7] After paying the required deposits $k$, a fraction $\rho$ 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 $\beta d$ 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,

$$\underbrace{k - \rho m - \beta\left(1-\rho\right)d}_{\text{return from deposit contracts}} \overbrace{- \left(b + \alpha\ell_g^s + (1-\alpha)\,\ell_b^s\right) + \beta\frac{Rb}{\mu} + \beta r\left(\alpha\ell_g^s + (1-\alpha)\,\ell_b^s\right)}^{\text{return from financial portfolios}} \;=\; 0, \tag{14}$$

where $k, m, d, b, \ell_g^s, \ell_b^s \geq 0$.[8]

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., $Rb/\mu + r\left(\alpha\ell_g^s + (1-\alpha)\,\ell_b^s\right)$.

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 solely on government bonds. An active loan market provides

[7] 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.

[8] 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 the real interest rate for loans to distinguish between these two types of assets: bonds are nominal assets, while loans are real assets.

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 $(b, \ell_g^s, \ell_b^s)$ 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 always equals one. Similarly, the second condition (17) equates the marginal utility of trading an additional unit of deposit claims with the market price of collateral, which consists of government bonds and loans that secure these claims. The price for collateral is the inverse of its gross real interest rate $\mu/R$.

# 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 $(T, \ell_g^d, \ell_b^d)$, banks' demand for collateral $(b, \ell_g^s, \ell_b^s)$, market-determined prices $(p, \mu)$, 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 bind-*

*ing 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 markets).*

I define equilibrium as the state in which the loan market operates actively. However, the counterpart with an inactive loan market is equivalent, which imposes zero loan supplies, i.e., $\ell_g^s = \ell_b^s = 0$, with 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 focus on equilibria where households' and banks' collateral constraints are binding. 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.

**Remark** Under Assumption 2, mitigating the asymmetric information problem in the loan market can be beneficial — it facilitates private loan provision and supports banks' liquidity insurance services by relaxing their collateral constraints. The key idea of this paper is to trade off the benefit from relaxed collateral constraints against the screening costs, especially during financial crises, when the asymmetric information problem is severe. As in (17), Assumption 2 also implies a low real interest rate, $r < 1/\beta$, given that households always consume below the satiated consumption level. This low-interest-rate environment is related to Rajan (2006), who argue that low interest rates can exacerbate incentive problems in financial markets, leading to financial instability. Also see Akinci, Benigno, Del Negro, and Queralto (2023) and the references therein for recent work on how low interest rates can create financial instability risks.

# 5 Functioning of the Loan Market and Equilibrium

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

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

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 $(1-\rho)\, c^d u'\left(c^d\right)$. 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 and decreases 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, thereby increasing their asset demand.[9] By contrast, a higher nominal interest rate $R$ implies a higher inflation

[9] 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 $R$.

rate and, therefore, a lower rate of return on currency. As a result, banks' asset demand decreases in $R$ due to their reduced 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 depends only 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. The supply of private loans is endogenously determined by the real interest rate alone, as banks anticipate future inflation and only consider 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 that 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), pins down the equilibrium. 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.

**Proposition 2.** *For any fraction of good type households* $\alpha \in (0,1)$, *there exist 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* $e \in (\underline{e}, \bar{e}]$;

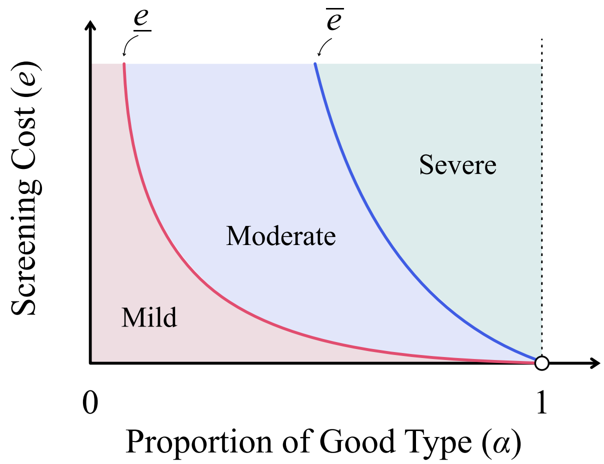


Figure 1: Severity of Asymmetric Information Problem and Equilibrium Type

*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* $\alpha$*,* $\lim_{\alpha \to 0^+} \underline{e} = \lim_{\alpha \to 0^+} \bar{e} = \infty$*, 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 $\alpha$ 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 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*

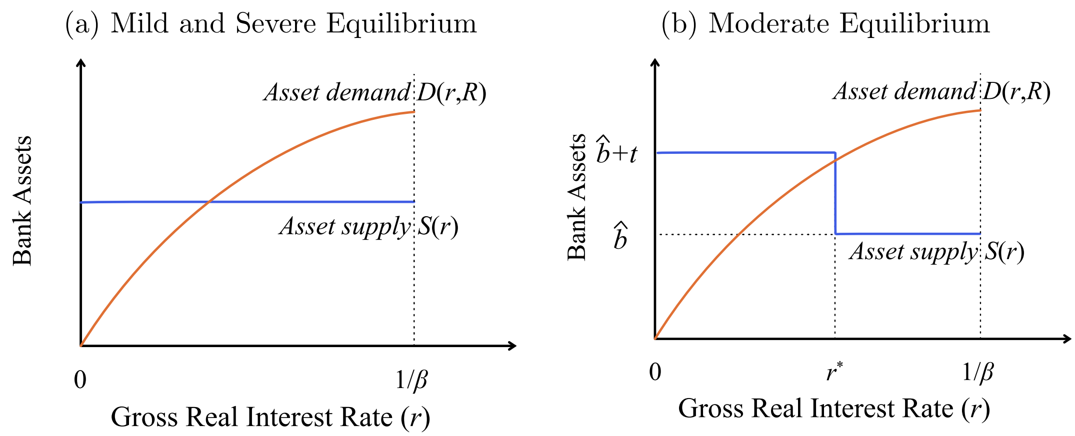


Figure 2: Equilibria under the Asymmetric Information Problem

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. When the asymmetric information problem is severe enough to shut down the market for private loans, the bank's asset supply equals the total supply of government bonds, which is 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 and not making loans.

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 $S(r)$.

# 6 Nominal Interest Rate Policy

I now study the effects of the central bank's nominal interest rate policy. Central banks typically lower interest rates to stabilize markets and support economic activity, as was the case after the 2008 financial crisis. When nominal interest rates are constrained by the zero lower bound, central banks adopt unconventional monetary tools that operate as extensions of conventional rate cuts to ease financial conditions (Bernanke, 2020). For example, central banks use quantitative easing and forward guidance to reduce long-term yields, and some, such as the European Central Bank, have even implemented negative nominal interest rates.

To evaluate central bank interventions, define total welfare as the sum of utilities and disutilities from all economic activities with equally weighted economic agents:

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

In net, this welfare measure is captured by two arguments: the aggregate trading surplus and the aggregate screening cost. The former reflects the benefit of banks' liquidity insurance services, which are used to support transactions between households and sellers, while the latter is the cost of these services, reflected in the screening costs associated with loan issuance. 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.[10] 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.[11] That is because banks adjust their portfolio away from the optimal currency level in response to the increased interest rate, leading to 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, as in the scenario when the asymmetric information problem is moderate with $r = r^\star$, an increase in $R$ also shifts banks' asset demand $D(r, R)$ downward, reducing their asset holdings in equilibrium.

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

An increase in the gross nominal interest rate $R$ increases the aggregate screening cost when the loan market is active. Again, banks substitute currency for bonds in response to an increase in $R$. This substitution relaxes banks' collateral constraint, implying a lower

[10]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.

[11]The equality holds when the 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).

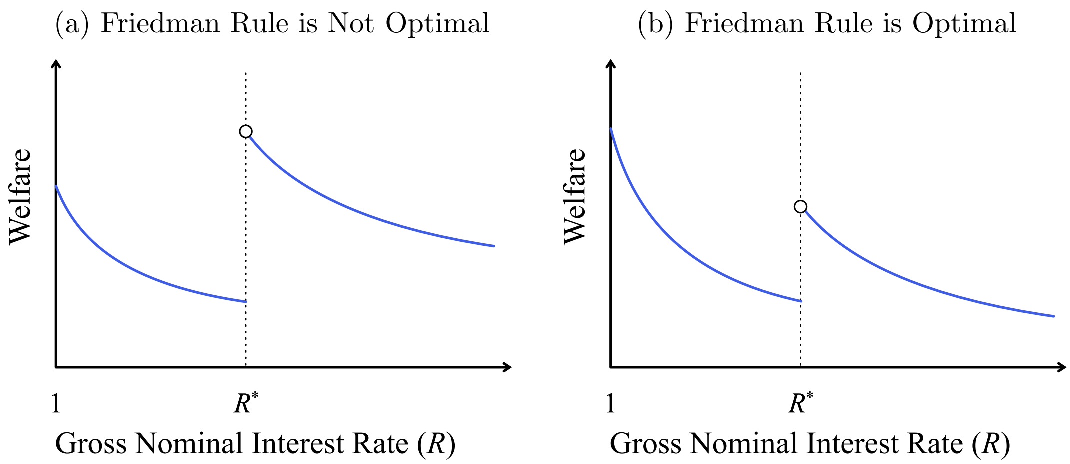


Figure 3: Optimal Interest Rate under Moderate Asymmetric Information Problem

price, or equivalently, a higher real interest rate on bank assets. That is, graphically, the increased $R$ pushes banks' asset demand $D(r, R)$ in Figure 2 downward, resulting in a higher real interest rate, i.e., higher $r$, on safe government bonds. In response, banks request higher loan payments, especially from bad households, who are less likely to make high payments ex-post. As a result, 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 that the deadweight loss from screening induces a non-monotonic welfare effect of an increase in the nominal interest rate. This result, characterized by a welfare jump, arises when the asymmetric information problem is moderate.

As shown in Figure 3, starting from the zero lower bound $R = 1$, raising the nominal interest rate on safe government bonds, $R$, reduces welfare. This is because, first, it increases screening costs, thereby discouraging bank lending and reducing the supply of bank assets. Second, raising this nominal rate also increases banks' opportunity cost of holding currency, shifting their portfolios away from the optimal currency level. Both effects weaken banks' liquidity insurance services and lower the aggregate trading surplus. As a result, raising $R$ reduces welfare because of lower trading surpluses and higher screening costs. However, welfare jumps up when the nominal rate $R$ increases to the point where the real interest rate $r$ passes the cutoff $r^{\star}$, at which the supply of bank assets drops (Corollary 2 and Figure 2b). At this cutoff, the loan market begins to shut down, and banks suddenly stop incurring screening costs, resulting in the non-monotonic welfare pattern. After the cutoff, the welfare decreases in $R$ again, but only because of lower trading surpluses.

Crucially, when the welfare jump is large enough, the Friedman rule is not optimal (Figure 3a). Instead, the central bank should set a sufficiently 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 services. The Friedman rule remains optimal when this welfare jump is not large, and I provide numerical examples for both cases in Appendix B. However, as shown in Figure 3, regardless of whether the Friedman rule is globally optimal, shutting down the loan market is always locally optimal.

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

# 7 Loan Subsidy Program

A low nominal interest rate policy boosts bank asset supply and facilitates useful intermediation activities. However, the costs of such a policy may outweigh its benefits due to the screening costs, which are a real resource cost under asymmetric information. In this section, I propose a loan subsidy program that policymakers can use to alleviate the asymmetric information problem, which improves welfare by boosting bank asset supply and saving banks' screening costs.[12] Practice examples include the U.S. government's Troubled Asset Relief Program during the 2008 Financial Crisis and the Paycheck Protection Program Liquidity Facility during the COVID-19 Pandemic.

The government makes subsidy payments to banks through the loan subsidy program, which is 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 loans and short-sell government bonds. Now, instead of the gross real interest on bonds $r$, the 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 $\pi_g$:

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

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

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

An increase in the subsidy $s$ reduces the opportunity cost of lending, allowing banks to charge lower payments to bad households, i.e., $\frac{\mathrm{d}\bar{r}_b}{\mathrm{d}s} < 0$. This reduction in payments relaxes the incentive constraint for bad households, thereby mitigating the asymmetric information problem banks face while lending. Banks then rely less on the screening technology, i.e., $\frac{\mathrm{d}\pi_g}{\mathrm{d}s} < 0$, and allow good households to make lower payments, 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 and lowers the aggregate screening cost.

The welfare-maximizing policy should set the subsidy payment as close as possible to

[12] 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, Duygan-Bump, and Scotti (2021).

the gross real interest rate $r$ to obtain the optimal effect, i.e., $s \to r$. In this limit situation, from (20)-(22), the screening probability $\pi_g$ converges to zero, eliminating screening costs. The payment cutoffs $\bar{r}_g$ and $\bar{r}_b$ also converge to zero, indicating that the government fully compensates banks for their opportunity cost of issuing private loans. Consequently, the loan market always operates actively, and banks exploit this market as if there were no asymmetric information.[13] In this way, the loan subsidy program creates a prosperous loan market, facilitating collateral provision and enabling banks to provide more efficient intermediation services.

Figure 4 depicts the effects of the optimal loan subsidy program, with the dashed line denoting the supply of bank assets under subsidy. 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. The demand for bank assets remains unchanged. By boosting the supply of bank assets, the subsidy program lowers asset prices and raises the real interest rate, i.e., a higher real rate $r$. The increased bank asset supply, as well as the increased interest rate $r$, relaxes banks' collateral constraint (15), allowing them to provide better intermediation services and supporting a larger volume of transactions for households, i.e., higher $c^m$ and $c^d$.[14]

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. There is no such welfare jump as in Figure 3. Thus, reducing the nominal interest rate to zero 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 better liquidity insurance services, increasing the aggregate trading surplus between households and sellers. The Friedman rule is always

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

[14] 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.

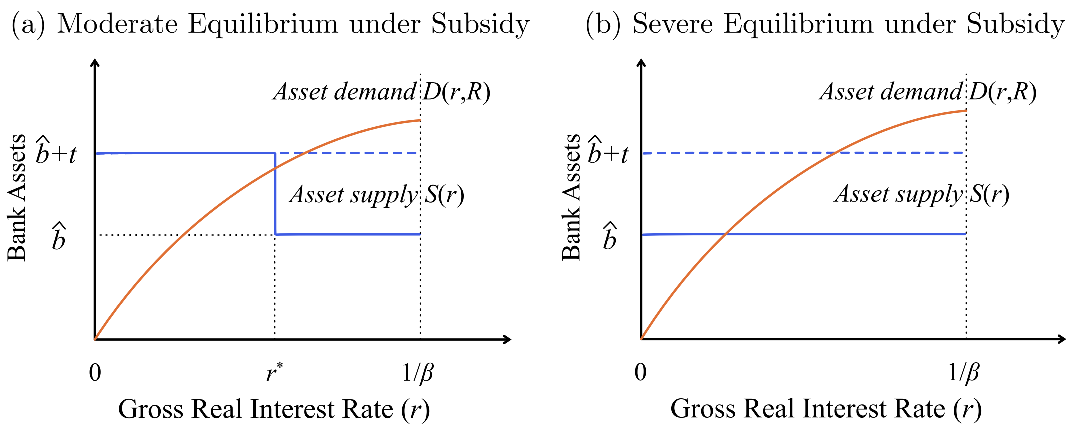


Figure 4: Equilibria under the Optimal loan Subsidy Program

optimal, as in the case of a mild asymmetric information problem.

# 8 Conclusion

I develop a model to study costly liquidity provision under asymmetric information. Households have private information regarding the valuations of their assets, and this asymmetric information impedes banks' lending against these assets. However, private loans are useful assets for banks, especially when the supply of safe government debt is scarce. Consequently, banks are willing to incur investigation costs to screen households unless the asymmetric information problem is severe, shutting down the 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 on safe government bonds discourages the issuance of bank loans. It also increases banks' opportunity cost of holding currency, leading to an inefficient allocation of assets between currency and interest-bearing assets, in line with the Friedman rule. These two effects imply a decrease in welfare. However, a sufficiently high interest rate shuts down the private loan market, saving banks from incurring the costs of screening. 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 large.

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

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# Appendix

## 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,

$$\Phi(\bar{r}) = r; \tag{A.6}$$

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

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

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

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

$$\frac{\mathrm{d}\phi(\bar{r}_g)}{\mathrm{d}r} = (1-\alpha)\left[1 - G_b(\bar{r}_g)\right]\frac{\mathrm{d}\bar{r}_g}{\mathrm{d}r} > 0; \tag{A.9}$$

$$\frac{\mathrm{d}\phi(\bar{r}_g)}{\mathrm{d}\alpha} = e - \left[x + \int_x^\Gamma G_b(\gamma)\,\mathrm{d}\gamma - \Gamma\right] > 0; \tag{A.10}$$

$$\frac{\mathrm{d}\phi(\bar{r}_g)}{\mathrm{d}e} = \alpha + (1-\alpha)\left[1 - G_b(\bar{r}_g)\right]\frac{\mathrm{d}\bar{r}_g}{\mathrm{d}e} > 0, \tag{A.11}$$

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 $0 \geq \phi(\bar{r}_g)$. 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,

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

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

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

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 $\bar{r}_g^1 + \int_{\bar{r}_g^1}^{\Gamma} G_b(\gamma)\,\mathrm{d}\gamma - \Gamma$ and $\bar{r}_g^2 + \int_{\bar{r}_g^2}^{\Gamma} G_b(\gamma)\,\mathrm{d}\gamma - \Gamma$ 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),

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

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 $\alpha$, 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 $\alpha$, 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 $\alpha$ is an immediate result thank to (A.10) and (A.11). $\square$

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

$$c^m = \eta^{\frac{1}{\sigma}} R^{-\frac{1}{\sigma}} (r\beta)^{\frac{1}{\sigma}}, \tag{A.15}$$

$$c^d = \eta^{\frac{1}{\sigma}} (r\beta)^{\frac{1}{\sigma}}. \tag{A.16}$$

$$(r\beta)^{\frac{1}{\sigma}-1} \eta^{\frac{1}{\sigma}} \left[1-\rho+\rho R^{1-\frac{1}{\sigma}}\right] = S(r). \tag{A.17}$$

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

$$\frac{\mathrm{d}r}{\mathrm{d}R} = \frac{\rho r R^{-\frac{1}{\sigma}}}{1-\rho+\rho R^{1-\frac{1}{\sigma}}} > 0; \tag{A.18}$$

$$\frac{\mathrm{d}c^m}{\mathrm{d}R} = -\frac{1}{\sigma} R^{-\frac{1}{\sigma}-1} (\eta r\beta)^{\frac{1}{\sigma}} \frac{1-\rho}{1-\rho+\rho R^{1-\frac{1}{\sigma}}} < 0; \tag{A.19}$$

$$\frac{\mathrm{d}c^d}{\mathrm{d}R} = \frac{1}{\sigma} (\eta r\beta)^{\frac{1}{\sigma}} \frac{\rho R^{-\frac{1}{\sigma}}}{1-\rho+\rho R^{1-\frac{1}{\sigma}}} > 0. \tag{A.20}$$

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. $\square$

# 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 payoff 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.