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Shadow Banking, Capital Requirements and Monetary Policy

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Abstract

I construct a model of the ABCP market to capture the trade-offs between traditional and shadow banks. While traditional banks are better equipped in collecting private information, shadow banks can finance more entrepreneurs' projects since the capital requirements for loans to shadow banks are laxer than those for regular loans. First, the credit risk diminishes the lending capacity of shadow banks, yet it does not activate traditional loans. An increase in the monitoring cost of shadow banks might shift credit from shadow to traditional banks; however, traditional banks cannot restore credit to a level consistent with that initially achieved by shadow banks. Second, the central bank's private asset purchases transfer credit from traditional to shadow banks and increase the size of funded projects when frictions are moderate in the shadow banking sector. Third, in the case of highly information-sensitive shadow loans, a decrease in the interest rate on reserves improves the lending capacity of shadow banks more than that of traditional banks.

Keywords: Shadow banking; asset-backed commercial paper; capital requirements; monetary policy.
JEL Classification: E40, E50

1. Introduction

It is important to understand the unregulated banking sector—known as *shadow banking system*—to shed light on the global financial crisis in 2008. In contrast to the Great Depression, the recent financial crisis did not stem from

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the disruption of retail payment activity in the commercial banking sector. As discussed in Gorton (2009), the financial crisis appears to have originated from disruption in the unregulated banking sector. So-called shadow banks are unregulated or lightly regulated, yet they potentially enhance credit and alleviate the liquidity constraints in the financial sector. However, shadow banking activity can be highly information-sensitive and this creates incentive problems. The financial crisis in the shadow banking system has led to a decline in the transactions of traditional banks and real economic activity. The recovery has been very slow after the collapse in shadow banking activity as new loans have, to a certain extent, been originated in the traditional banking sector. However, it has been argued that traditional banks cannot fulfill the role that shadow banks had played in providing credit to the economy.

This paper focuses on some essential features of shadow banking, namely the *asset-backed commercial paper* (ABCP) market. A special purpose entity (SPE)—referred to as conduit in the context of ABCP program—is formed by sponsoring financial institutions, a majority of which are commercial banks. In fact, the securitization turns the illiquid assets on the balance sheet of these banks into liquid assets. That is, sponsoring banks generally find it useful to conduct off-balance sheet financing through the transfer of the assets to their conduits. Hence, the motivation of this paper is to (i) capture the trade-offs between on-balance sheet loans and off-balance sheet financing in the ABCP market, (ii) assess the effects of credit risk and information-sensitivity of shadow loans on the relative use of shadow funded credit, and (iii) analyze how a set of monetary policy tools addresses these problems. Under what conditions does a shadow funded credit increase welfare? How effectively do traditional banks fulfill the role of providing credit that shadow banks had played before the crisis? How do the conventional and unconventional monetary policies affect the competition between traditional and shadow banks as liquidity providers?

My central findings can be summarized as follows: (i) When the shadow banks take over funding entrepreneurs, the credit risk shrinks the lending capacity of shadow banks, decreases the asset-backed security (ABS) outstanding, and increases the nominal interest rate spread between the ABSs and the government bonds, but loans do not flee to traditional banks; however, an increase in monitoring costs of shadow banks might shift credit from shadow to traditional banks. Further, the credit erosion in the shadow banking sector might not be fully recovered by the traditional banks. (ii) The central bank's purchases of ABSs increase welfare by reinforcing the shadow funded credit when the monitoring costs of shadow banks are moderate. (iii) When the shadow funded credit is sufficiently information-sensitive, lowering the interest rates improves the loan creation capacity of shadow banks more than that of traditional banks.

This paper models both traditional and shadow banks. In the spirit of Diamond and Dybvig (1983), the traditional banking sector is modeled as a risk-sharing framework of banking. However, the shadow banking sector is only subject to the costly state verification and delegated monitoring as in Townsend (1979), Williamson (1987), and Gale and Hellwig (1985). In particular, this model builds on Williamson (2012) and adds one important feature: while all credit is given by traditional banks in Williamson (2012), this paper suggests that traditional and shadow banks compete to give funds. Therefore, there is a trade-off between traditional and shadow banks. On one hand, traditional banks are better equipped for collecting private information. That is, when shadow banks lend to entrepreneurs, they lose a fraction of the returns, yet the traditional banks do not. On the other hand, capital requirements associated with regular bank loans are stricter than those associated with loans to shadow banks. Thus, up to some limit, traditional banks can take advantage of lending to shadow banks—a simple version of off-balance sheet financing.

Traditional banks provide liquidity transformation. As in Diamond and Dybvig (1983), these banks offer deposit contracts to mitigate the risks arising from the needs of different liquid assets. Traditional (or Diamond-Dybvig) banks, which has access to the set of assets supplied by the government, are within the oversight of regulations. In contrast, shadow banks circumvent these regulations and have no access to the central bank's deposit facility. Moreover, the shadow banking structure of this paper is on the same line with Shin (2009), Acharya et al. (2013), and Acharya and Richardson (2009) in which regulated banks provide guarantees to those shadow banks, and when they are in trouble, part of those assets ends up in the balance sheets of the commercial banks. The structure of shadow banks in this paper involves a simplification in which the liabilities of shadow banks account for the assets of the traditional banks. In fact, traditional and shadow banks are intertwined to the extent that the liquidity creation (disruption) in the shadow banking sector can alleviate (exacerbate) the financial frictions in the traditional banking system. This simplification aims to capture these guarantees and all the regulatory arbitrage that ultimately bring the ABCPs back to the balance sheets of traditional banks. For example, when the ABCPs market broke down in August 2007, several large banks, including HSBC and Citigroup, were forced to transfer large amounts of these assets into their balance sheets.

In this model, financial frictions such as the lack of record-keeping and the limited commitment as in Kiyotaki and Moore (2012) and Gertler and Kiyotaki (2010) entail the use of collateral. These frictions reduce the liquidity creation and hence undermine real economic activity by tightening the collateral constraints. Shadow banks also incur additional monitoring and transaction costs. These costs induce the shadow funded credit to be information-sensitive and hence this generates incentive problems in the shadow banking sector. I associate these problems with the bank-centered nature of the recent crisis. In fact, these costs do not only cut back on new shadow loans, but also limit the expected payoffs of creditworthy borrowers.

First, I explore the effects of credit risk in the form of two experiments: (i) the probability mass of verification costs of entrepreneurs shifts from left to right tail and (ii) the probability mass of project returns of entrepreneurs shifts from right to left tail. When the monitoring cost of shadow banks is sufficiently small, both experiments lead to decreases in the size of funded projects, respectively. Since the receivables of these projects are posted as collateral, the ABSs outstanding diminishes. In turn, collateral constraints of traditional banks tighten up and the quantity of intermediated claims decreases. Thus, the spread between the ABSs and the government bonds soars. However, only credit risk cannot drive the safe borrowers out of the shadow banking system. On the other hand, sufficiently large increase in monitoring cost of shadow banks has similar results, except that safe entrepreneurs switch borrowing from shadow to traditional banks. It turns out that the loss of shadow funded credit outpaces the provision of traditional loans, as long as the initial monitoring cost is small. Thus, traditional loans are useful for the recovery, but only to a certain extent. The results are consistent with the evidence—the growth of banks' business loan outstanding increased while the liquidity-exposed banks decreased the sum of loan origination and commitments from June 2007 to September 2008. As documented by Cornett et al. (2011), the sharp increase in commercial and industrial loan outstanding and the steep decline in commercial paper outstanding occurred simultaneously in September 2008, inducing the commercial banks to take off-balance-sheet commitments on their balance sheets.

Second, I analyze the effects of Fed's intervention in the form of the Term Auction Facility (TAF) in 2007 and the ABCP Money Market Mutual Fund Liquidity Facility in 2010. When the monitoring cost of shadow banks is moderate in the low interest rate environment, the central bank's purchases of private assets will help transfer the liquidity from traditional to shadow banks. Moreover, the loan creation capacity of shadow bank with these purchases exceeds that of traditional banks without the purchases. Therefore, these purchases increase the size of funded projects, increase the quantity of intermediated claims and hence reduce the spread between private assets and government bonds. However, these purchases are ineffective as the shadow funded credit is strongly information-sensitive.

Lastly, a decrease in the interest rate on reserves involves an important policy implication to fix the liquidity shortages: this policy entails a stronger improvement in the lending capacity of shadow banks than that of traditional banks when the frictions are amplified in the shadow banking sector. However, this conventional policy cannot restore the off-balance sheet financing when the shadow funded credit is extremely information-sensitive. I show that (i) sufficiently plentiful public liquidity encourages traditional loans for any feasible monetary policy, yet an accommodative monetary policy results in a larger increase in the lending capacity of shadow banks; (ii) the moderate level of public liquidity, in the case of substantial easing of monetary policy, induces credit to move from traditional to shadow loans, and (iii) in the environment of low interest rates, the scarcity of public liquidity induces the safest entrepreneurs to prefer shadow loans even though lowering the interest rates results in a stronger increase in the loan creation capacity of traditional banks.

2. Related Literature

The shadow banking literature has been growing. Duca (2016) empirically analyzes how the long-term effects of regulatory capital and financial innovation, and short-run effects of financial market shocks alter the relative use of shadow funded credit. According to Adrian and Shin (2009a), Adrian and Shin (2009b), Adrian and Shin (2010) and Gorton and Metrick (2012), the shadow funded credit is pro-cyclical. While Acharya et al. (2013) focus on the effects of conduit exposure and credit guarantees on the price and issuance of ABCP, I analyze the impact of counterparty credit risk in the form of changes in the distributions of project returns and bankruptcy costs of borrowers. Gorton and Souleles (2005) predict that securitization increases with the bankruptcy costs of commercial banks. However, the bankruptcy costs in their setting should not be confused with verification costs of entrepreneurs who are, in this model, willing to borrow to finance their projects. In contrast to their approach, this paper suggests that skirting stringent capital requirements for on-balance-sheet loans is the product of the shadow banking activity. This view is supported by the evidences that the likelihood of forming a conduit increases with the economic capital ratio of a sponsoring bank and the liquidity-guaranteed ABCP outstanding sharply increased in September 2004 when the capital charges for ABCPs were relaxed by the regulators, as documented by Acharya et al. (2013) and Acharya et al. (2011). Although shadow banks typically provide some form of liquidity transformation as discussed in Gorton and Souleles (2005), Pozsar et al. (2010), Brunnermeier (2009), and Kacperczyk and Schnabl (2010), only traditional banks, in this paper, conduct the liquidity transformation based on risk sharing framework of Diamond and Dybvig (1983). In fact, shadow banks in this model issue ABSs to finance the entrepreneurs' projects—like commercial papers—and they post the pool of receivables as collateral.

This paper supports the quantitative studies of Cornett et al. (2011), Mora (2010), and Ivashina and Scharfstein (2010) who provide respective evidences that traditional banks cannot fully fill the vacuum left by shadow banks in a bank-centered crisis. In contrast to their analyses, (i) this model uniquely provides a qualitative study about the trade-offs between traditional and shadow banks as liquidity providers in the ABCP market, (ii) explicitly identifies the set of conditions—in the form of the severity of incentive problems in the shadow banking sector, the capital requirement wedge between ABCPs and regular loans, and the scarcity of public liquidity—in which the central bank's purchases of ABCPs are useful, and (iii) investigates the impact of the conventional monetary policy on the relative change in the loan creation capacity of shadow banks. In fact, the key contribution of this paper is to fill the gap in the New Monetarism literature by supporting the argument that traditional banks cannot fulfill the role of credit provision in the case of a collapse in the ABCPs market.

The entrepreneurs who are would-be borrowers are different ex ante with respect to their verification costs. The debt contracts are the results of a solution to bilateral contracting problem as in Gale and Hellwig (1985). The monitoring decisions are made, ex post, in the case of default as in Townsend (1979). It turns out that an intermediary rejects to offer debt contract to riskier entrepreneurs. Therefore, the model exhibits an endogenous *credit rationing* where among loan applicants who appear to have different verification costs some of these receive a loan and others do not and rejected applicants would not receive a loan even if they offered to pay a higher interest rate. In contrast, the credit rationing in Stiglitz and Weiss (1981), Keeton (1979) and Williamson (1986) entail identical borrowers ex ante. In this model, an entrepreneur and a financial intermediary are asymmetrically informed, ex post, regarding the project return of the entrepreneur as in Williamson (1987). In contrast, Stiglitz and Weiss (1981) and Keeton (1979) show that equilibrium rationing arises by the moral hazard and adverse selection in credit markets. The credit rationing uniquely differs with respect to the type of banking sectors since each sector has different market interest rate. A shadow bank potentially has an advantage over a traditional bank on reaching more projects since the first enjoys larger leverages due to lack of regulation. I use some ideas in *New Monetarist Economics* as discussed in Williamson and Wright (2010a), Williamson and Wright (2010b) and Sanches and Williamson (2010). The model also entails unconventional purchases of private assets as discussed in Fawley and Neely (2013), Gertler and Karadi (2013) and Williamson (2014).

3. Environment

I use the idea of combining decentralized trade with a periodic access to centralized market as in Lagos and Wright (2005). More precisely, time is discrete and indexed by $t = 0, 1, 2, \ldots$, and each period is divided into two subperiods, namely the centralized market (CM) and the decentralized market (DM). There are continuum of buyers and a continuum of sellers, each with unit mass. Trade is difficult because buyers can consume (produce) and sellers can produce (consume) only at the DM (CM). Each buyer has preferences given by

$$E_0 \sum_{t=0}^{\infty} \beta^t [-H_t + u(x_t)], \tag{1}$$

where H_t is the labor supply in the CM, x_t is the consumption at the DM, and $\beta \in (0, 1)$ is the discount factor. Suppose that $u(.)$ is strictly concave, strictly increasing, and twice continuously differentiable with $u'(0) = \infty$, $u'(\infty) = 0$ and $\frac{-xu''(x)}{u'(x)} = \alpha < 1$ and define x^* by $u'(x^*) = 1$.

Each seller has preferences given by

$$E_0 \sum_{t=0}^{\infty} \beta^t [X_t - h_t], \tag{2}$$

where X_t is the consumption in the CM, and h_t is the labor supply at the DM. One unit of labor supply either at the DM or in the CM produces one unit of perishable consumption good.

Basic environment is also related to Rocheteau and Wright (2005) in terms of types of agent and the matching technology. At the DM, each buyer will be randomly matched with a seller. As well, there exists no recordkeeping and the limited commitment friction implies that no one can be forced to work to repay debt. There also exists a continuum of entrepreneurs with mass $\sigma < 1$. Each is born in CM, lives for only one period, and then dies in the next period of CM. This process occurs in every period. Thus, an entrepreneur who is born in the CM of period t consumes only in the CM of period $t+1$. Assume also that the entrepreneurs are risk neutral and they have no endowments. Each entrepreneur has an access to his own investment project. Each project is indivisible, requires one unit of the consumption good in the CM of period t, and yields a random return of ω in the CM of period $t+1$, where ω is drawn from the distribution function $F(\omega)$. The associated density function is given by $f(\omega)$, where $f : [0, \overline{\omega}] \rightarrow \mathbb{R}$ is strictly positive and continuously differentiable. Project returns are independent across entrepreneurs. ω is private information, but it is subject to the costly state verification, i.e., any lender can bear a fixed cost and observe ω ex post. The verification cost κ is drawn from the distribution function $G(\kappa)$, where κ is independent of ω. If an entrepreneur's project is funded, then the lender will, in case of default, incur the cost κ, learn ω and seize it. The default implies no consumption for the entrepreneur.

The setup for the DM directly follows from Williamson (2012) and Williamson (2014). On one hand, a buyer participates the *currency transactions* DM with probability ρ. That is, she is matched with a seller who only accepts currency as a means of payment. On the other hand, a buyer participates the *non-currency transaction* DM with probability $1-\rho$. In the latter, each seller can verify the entire asset portfolio. In fact, a buyer transfers the ownership of the claim of entire portfolio through a financial intermediary to the seller. Currency and other assets can be verifiable in these meetings. In the currency meetings, a seller acquires cash on the spot while, in the non-currency meetings, she redeems the claims that are backed by asset portfolios in the next CM. Each buyer learns whether he will be in the currency or non-currency meetings after the consumption and production decisions take place in the CM.

A government bond sells for z_t^b units of money in terms of CM good of period t, and pays off one unit of money in terms of CM good of period $t+1$. One unit of reserve can be acquired for z_t^m units of money in terms of CM good of period t, and pays off one unit of money in terms of CM good of period $t+1$. One unit of ABS sells at the price q_t in terms of CM good of period t and is a promise to pay one unit of consumption good in the CM of period $t+1$. As well, each entrepreneur is in need of one unit of consumption good to operate his or her project. The repayment is endogenous and it depends on $F(\omega)$, $G(\kappa)$ and the expected rate of return of the lender. As well, a shadow bank (traditional bank), which is perfectly diversified, gains a fixed one-period return r_t^s (r_t) per unit lent to the entrepreneur. The total loan origination L_t^s (L_t) and the rate of return r_t^s (r_t) for each loan originated in the shadow banking sector (traditional banking sector) are endogenously determined.

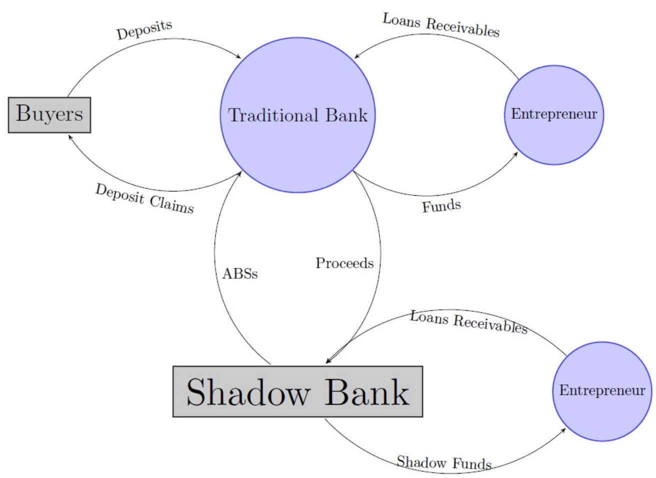
The consolidated government issues currency, reserves, and nominal bonds, denoted by, respectively, C_t, M_t, and B_t in nominal terms in period t. The government makes transactions only in the CM, including the lump-sum transfer τ_t to each buyer in the period t. Thus, the consolidated government budget constraints are given by

$$\psi_0(C_0 + z_0^m M_0 + z_0^b B_0) - \tau_0 = 0, \tag{3}$$

$$\psi_t(C_t - C_{t-1} + z_t^m M_t - M_{t-1} + z_t^b B_t - B_{t-1}) - \tau_t = 0, \quad \forall t = 1, 2, 3... \tag{4}$$

where ψ_t is the price of money in terms of CM good of period t.

Figure 1: The Transactions in the Centralized Market



All financial arrangements in the CM are displayed in Figure 1. The following is the timing of the CM. First, all private debts are repaid and taxes are paid. A funded entrepreneur processes his own project, consumes the return, and then dies out. Second, new entrepreneurs are born. Each receives a draw of verification cost from G while shadow and traditional banks are formed. Third, a traditional bank acquires deposits from the buyers, the government pays off bonds and reserves, and it issues new government debt, reserves, and currency. The traditional bank purchases currency, reserves, government debt, and ABS by using its deposits. As well, a shadow bank issues ABSs and lend to fund the entrepreneurs' projects by using the proceedings of the ABSs. Finally, given the market interest rates offered by shadow banks and traditional banks, each entrepreneur can offer a debt contract to both shadow and traditional banks. When both intermediaries are willing to fund the project, the relevant contract is the one with smallest repayment schedule. When only one intermediary is willing to fund, the offer associated with the other intermediary is redundant. Lastly, the entrepreneur cannot operate his project if no lender wants to fund it.

Traditional banks are subject to the regulations. Therefore, each bank must hold the fractions $\underline{\delta}_1 \in [0,1]$ and $\underline{\delta}_2 \in [0,1]$ of the ABS and receivables of entrepreneurs' loans, respectively, as *regulatory* capital. I assume that $\underline{\delta}_1 < \underline{\delta}_2$.

This assumption is consistent with the differential in minimum capital requirements between on- and off-balance sheet financing of traditional banks. In fact, the U.S. commercial banks are not required to consolidate the ABCPs onto their balance sheets and hence capital requirements for ABCPs are more relaxed than those for commercial industrial loans as discussed in Gilliam (2005). This assumption justifies the competitive advantage of shadow banks over traditional banks on diversification and pooling of debt contracts associated with the entrepreneurial activity.[2]

3.1. The Shadow Bank's Problem

Each shadow bank is risk-neutral and a perfectly competitive profit maximizer. The problem of each shadow bank is given by

$$\max_{l_t^s, L_t^s} \left\{ q_t l_t^s - L_t^s - \beta l_t^s + \beta r_t^s L_t^s \right\} \tag{5}$$

subject to

$$-l_t^s + r_t^s L_t^s \geq 0. \tag{6}$$

The collateral constraint of the shadow bank is given by (6). Let L_t^s and l_t^s denote the total loan supply for entrepreneurs' projects and the quantity of ABSs issued by the shadow bank, respectively. Also, let r_t^s denote the fixed rate of return from each loan contract offered by the intermediary. This rate is endogenously determined. The objective function (5) captures the expected payoff $q_t l_t^s - L_t^s$ in the CM of period t. This payoff comes from issuing l_t^s units of security and supplying L_t^s units of funds for the entrepreneurial activity. As well, the quantity $-\beta l_t^s + \beta r_t^s L_t^s$ is the discounted payoff in the CM of period $t+1$ from discharging the obligations of ABSs and collecting the project returns. Lastly, the shadow bank diversifies the loan contracts, pools the repayments from each contract in the next CM and finally posts pool of repayments as collateral to back the ABSs.

Limited commitment implies that traditional banks, in the case of default, seize all the pool of loan receivables. Since no capital requirements are enforced, the shadow bank activates the borrowing up to full value of collateral. On one hand, the shortages of safe assets imply that (6) binds. Therefore, I am interested in equilibrium such that the collateral is not plentiful enough to render the incentive constraint slack. On the other hand, the central bank's reserves outstanding is sufficiently large to the extent that a traditional bank provides a better insurance for the buyers against the need for different liquid assets than a shadow bank does. Given that the shadow bank has no access to the public backstops, if a buyer had deposited to the shadow bank, then he would have been worse off.

[2]According to Gorton and Metrick (2010), innovations and regulatory changes reduce the competitiveness of the traditional banks on the supply side. On the demand side, demand for collateral also justifies how the shadow banking sector has grown rapidly. Our assumption of differing capital requirements supports these two forces.

In reality, the sponsored conduits sell ABCPs to the outside investors and money market mutual funds. However, U.S. commercial banks provide guarantees to their conduits and hence the balance sheets of these sponsors implicitly (explicitly in the case of default) capture the ABCPs issued by these conduits. In this model, the traditional banks are the buyers of the ABSs issued by the shadow banks to capture these guarantees in a tractable way. Therefore, a simple version of off-balance sheet is included such that shadow banks can be interpreted as the conduits of commercial banks.

3.2. The Traditional Bank's Problem

Traditional banks are Bertrand competitors offering deposit contracts to the buyers in order to maximize their expected utility. In equilibrium, each buyer deposits k_t units of money balance in terms of CM good of period t. Second, traditional banks offer c_t units of cash in terms of CM goods of period t and a deposit claim worth of d_t units of consumption goods in the CM of period $t+1$ in the currency and non-currency DM meetings, respectively. Although the currency can be used in non-currency meetings, it is optimal to hold currency just enough to exhaust all at the currency DM meetings as discussed in Williamson (2012) and Williamson (2014). Note that the currency DM meetings are subject to full commitment. There exists a strong commitment device in these meetings, like ATM.

The problem of each traditional bank is given by

$$\max_{k_t,c_t,d_t,m_t,b_t,l_t,L_t} -k_t + \rho u\left(\frac{\beta\psi_{t+1}}{\psi_t}c_t\right) + (1-\rho)u(\beta d_t) \tag{7}$$

subject to

$$k_t - z_t^m m_t - z_t^b b_t - q_t l_t - L_t - \rho c_t - (1-\rho)\beta d_t + \frac{\beta\psi_{t+1}}{\psi_t}(m_t+b_t) + \beta l_t + \beta r_t L_t \geq 0, \tag{8}$$

$$-(1-\rho)d_t + \frac{\psi_{t+1}}{\psi_t}(m_t+b_t) + l_t(1-\underline{\delta}_1) + r_t L_t(1-\underline{\delta}_2) \geq 0, \tag{9}$$

where (7), (8) and (9) denote the buyer's expected payoff, non-negative expected payoff of the bank, and the bank's collateral constraint, respectively. Let $\underline{\delta}_1$ and $\underline{\delta}_2$ denote the fraction of ABS and the fraction of receivables of debt contracts held by the regulatory institutions, respectively. The deposit liabilities are backed by the government debt, reserves, and liquid private assets. It turns out that $l_t\underline{\delta}_1 + r_t L_t \underline{\delta}_2$ accounts for the total value of bank capital, which cannot be posted as collateral. Traditional banks must hold *regulatory capital* that involves minimum requirement for the private assets. Otherwise, banks cannot operate in the traditional banking sector. Since $\underline{\delta}_1 < \underline{\delta}_2$, the ABSs activate more liquidity than the regular loans.

Traditional banks perform a useful role since they efficiently allocate the liquid assets to appropriate types of engagements. Once they are formed, they acquire deposits from the buyers and then purchase government debt, reserves, cash and ABSs. Similar to shadow banks, they can fund the entrepreneurs' projects. Further, any buyer can run a traditional bank[3].

Buyers make take-it-or-leave-it offers at the DM. Each buyer who deposits k_t units of consumption good in the CM of period t will exchange currency worth of $\frac{\psi_{t+1}}{\psi_t}c_t$ units of consumption goods in the CM of period $t+1$ in the currency DM meeting. The buyer will exchange deposit liabilities worth of d_t units of good in the CM of period $t+1$ in the non-currency meeting. Collateral constraint (9) binds in equilibrium. I am interested in equilibrium in which the collateral is too scarce to render the incentive constraint slack. Therefore, the quantity of exchange at the DM is inefficient, i.e., $\beta d_t < x^*$.

3.3. The Entrepreneurs' Problem

I permit the private production of liquidity by a way of costly-state-verification and delegated monitoring financial intermediation in the spirit of Williamson (1987) and Williamson (2012). The entrepreneurs are subject to the full commitment and there exists no stochastic verification. As in Williamson (1986), I obtain that the optimal loan contract under incentive compatibility condition is a non-contingent debt. The non-contingent debt is associated with a specific loan contract in which an entrepreneur with verification cost κ sells for one unit of consumption good in the CM and promises to pay off R_t (R_t^θ) units of consumption goods in the next CM to traditional (shadow) banks. If an intermediary is willing to accept the contract, then the entrepreneur will invest on her project and then acquire ω in the next CM. If it turns out that the non-contingent repayment exceeds the project return, then the lender will incur κ, receive the information regarding ω and then seize it in the subsequent CM. Thus, monitoring decisions are taken ex-post.

The individual contract $R_t^\theta(\kappa)$ in the shadow banking sector associated with an entrepreneur whose verification cost is κ satisfies

$$(1-\theta)\left[R_t^\theta(\kappa) - \kappa F\big(R_t^\theta(\kappa)\big) - \int_0^{R_t^\theta(\kappa)} F(\omega)d\omega\right] \geq r_t^s, \tag{10}$$

where (10) implies that the effective expected payoff must be at least as large as the market expected return r_t^s, which is treated as fixed by both entrepreneurs and the shadow bank. A fraction $\theta \in (0,1)$ of shadow bank's expected return from each contract is deemed to be useless due to the additional monitoring costs. I specifically use *iceberg transportation cost* for the tractability of the model. As θ increases, each contract becomes increasingly information-sensitive. This not only limits the loan creation capacity of the shadow bank, but also increases the repayment of each shadow funded entrepreneur. While the capital

[3]If an entrepreneur had operated a traditional bank, he would have vanished too soon in the forthcoming period without collecting the payoffs from the reserves. If a seller had operated a traditional bank, the deposit contract would have implied inefficient allocation of resources. Remember that a seller does not verify non-currency assets with probability ρ.

arbitrage supports shadow loans, the monitoring cost of shadow banks restricts its ability to reach longer arm on financing the entrepreneurial activity.

Traditional banks have better technology in evaluating the loan applications. Thus, the debt contracts are information-insensitive in the sense that they only incur the verification cost of the associated entrepreneur in case of a default. The equilibrium debt contract $R_t(\kappa)$ originated in the traditional banking sector associated with an entrepreneur with verification cost κ solves

$$R_t(\kappa) - \kappa F\big(R_t(\kappa)\big) - \int_0^{R_t(\kappa)} F(\omega)d\omega \geq r_t. \tag{11}$$

The Diamond-Dybvig bank diversifies the debt contracts where r_t denotes the market rate of return for traditional banks. In (11), the expected payoff of a loan application must be at least as large as r_t. In equilibrium, both (10) and (11) bind.

Assumption 1. *$\kappa f'(R) + f(R) > 0$ for all $R \in [0, \overline{\omega}]$ and for all $0 \leq \kappa$.*

Each intermediary diversifies the loan contracts in equilibrium. Next characterizes the optimal debt contracts for both traditional and shadow banks.

$$0 = 1 - \kappa f(\tilde{R}_t(\kappa)) - F(\tilde{R}_t(\kappa)). \tag{12}$$

Using the Assumption 1, the right hand side of (12) strictly decreases with $\tilde{R}_t(\kappa)$ and thus there exists a unique debt contract that maximizes the expected payoff of each intermediary. Second, the optimal debt contracts are independent of θ. Thus, monitoring costs of shadow banks do not alter the optimal contracts of both intermediaries.

Let $(R^*_\theta, \kappa^*_\theta)$ characterize the marginal contract in the shadow banking sector that solves binding (10) and (12), where R^*_θ shows the gross rate of return associated with the marginal entrepreneur with verification cost κ^*_θ. Thus, shadow banks are willing to finance no loan application of an entrepreneur whose verification cost is larger than κ^*_θ. Similarly, (R^*, κ^*) characterizes the marginal contract in the traditional banking sector that solves binding (11) and (12), where R^* shows the marginal gross rate of return associated with the marginal entrepreneur and κ^* is the loan creation capacity of traditional banks.

Traditional and shadow banks are willing to fund safe entrepreneurs with verification cost κ, i.e., $\kappa \leq \min(\kappa^*_\theta, \kappa^*)$. Moreover, the traditional bank funds if $R_t(\kappa) \leq R^\theta_t(\kappa)$. Otherwise, the loan is originated by a shadow bank. For the entrepreneurs with moderate verification costs $\kappa \in (\min(\kappa^*, \kappa^*_\theta), \max(\kappa^*, \kappa^*_\theta)]$, the intermediary with larger loan creation capacity accepts the entrepreneur's offer. Lastly, for risky entrepreneurs with verification cost $\kappa > \max(\kappa^*_\theta, \kappa^*)$, no intermediaries fund projects. Thus, the total demand of entrepreneurial credit originated by shadow and traditional banks, respectively, can be expressed by

$$L^s(r^s_t) = \sigma I(\kappa^* < \kappa^*_\theta)[G(\kappa^*_\theta) - G(\kappa^*)] + \sigma \int_0^{\min(\kappa^*, \kappa^*_\theta)} I\big(R^\theta_t(\kappa) < R_t(\kappa)\big) dG(\kappa), \tag{13}$$

$$L(r_t) = \sigma I(\kappa_\theta^* \le \kappa^*)[G(\kappa^*) - G(\kappa_\theta^*)] + \sigma \int_0^{\min(\kappa^*,\kappa_\theta^*)} I\big(R_t(\kappa) < R_t^\theta(\kappa)\big) dG(\kappa), \tag{14}$$

with I satisfying $I(a_1 \le a_2) = 1$ if $a_1 \le a_2$; otherwise, $I(a_1 \le a_2) = 0$.

4. Equilibrium

In equilibrium, asset markets must clear.

$$\rho c_t = \psi_t C_t, \;\; \text{[market in currency clears]} \tag{15}$$

$$m_t = \psi_t M_t, \;\; \text{[market in reserves clears]} \tag{16}$$

$$b_t = \psi_t B_t, \;\; \text{[bond market clears]} \tag{17}$$

$$l_t^s = l_t, \;\; \text{[market in ABSs clears]} \tag{18}$$

$$L_t^s = L^s(r_t^s), \;\; \text{[traditional loans market clears]} \tag{19}$$

$$L_t = L(r_t). \;\; \text{[shadow loans market clears]} \tag{20}$$

I confine my attention to the stationary equilibrium in which all nominal quantities grow at the constant rate μ. Thus, the gross rate of return on money is given by

$$\frac{\psi_{t+1}}{\psi_t} = \frac{1}{\mu} \quad \forall\, t. \tag{21}$$

The market clearing conditions imply $\beta \le \mu$. Using the budget constraints (3) and (4) and the market clearing conditions (15), (16) and (17), I obtain

$$\rho c + z^m m + z^b b - q l^g - \tau_0 = 0, \tag{22}$$

$$V\left(1 - \frac{1}{\mu}\right) + \frac{m}{\mu}(z^m - 1) + \frac{b}{\mu}(z^b - 1) - l^g\left[q\left(\frac{1}{\mu} - 1\right) - 1\right] = \tau. \tag{23}$$

The fiscal authority fixes the real value of tax in period 0. More specifically, $\tau_0 = V$ where V is exogenous. The real value of tax τ on each buyer in each period $t = 1, 2, 3, ...$ is determined by (23) where τ is endogenous. The equilibrium satisfies

$$\rho c + z^m m + z^b b = V. \tag{24}$$

Let x_1 and x_2 denote the consumptions at the DM of currency and non-currency trades, respectively. The first order conditions imply

$$q = \beta[\underline{\delta}_1 + (1 - \underline{\delta}_1) u'(x_2)] = \frac{1}{r^s}, \tag{25}$$

$$z^m = z^b = \frac{u'(x_2)}{u'(x_1)}, \tag{26}$$

$$r = \frac{1}{\beta[\underline{\delta}_2 + (1-\underline{\delta}_2)u'(x_2)]}, \tag{27}$$

$$\lambda^s = \lambda(1-\underline{\delta}_1) = \beta(1-\underline{\delta}_1)[u'(x_2)-1] > 0, \tag{28}$$

$$l = \frac{1}{\beta[\underline{\delta}_1 + (1-\underline{\delta}_1)u'(x_2)]} L^s\left(\frac{1}{\beta[\underline{\delta}_1 + (1-\underline{\delta}_1)u'(x_2)]}\right). \tag{29}$$

The gross nominal interest rate spread between ABSs and government debts is given by

$$s(x_2) \equiv \frac{\underline{\delta}_1[u'(x_2)-1]}{z^b[\underline{\delta}_1 + (1-\underline{\delta}_1)u'(x_2)]}. \tag{30}$$

Using (30), the inefficient DM exchange, that is $x_2 < x^*$, leads to a positive ABSs spread. The ABSs outstanding is given by

$$ql \equiv L^s\left(\frac{1}{\beta[\underline{\delta}_1 + (1-\underline{\delta}_1)u'(x_2)]}\right). \tag{31}$$

Assumption 2. $\overline{\omega} - \int_0^{\overline{\omega}} F(\omega)d\omega > \beta^{-1}$.

Lemma 1. *Suppose that the assumptions 1 and 2 hold. Given a real number x_2 with satisfying $x_2 \in (0, x^*)$, the loan origination capacity of traditional banks is always positive, i.e., $\kappa^* > 0$.*

Proof. The gross rate of return on the marginal contract in the traditional banking sector satisfies

$$T(R^*) = \frac{1}{\beta[\underline{\delta}_2 + (1-\underline{\delta}_2)u'(x_2)]}, \tag{32}$$

where the function $T : [0, \overline{\omega}] \to \mathbb{R}$ is given by

$$T(x) \equiv x - \frac{[1-F(x)]F(x)}{f(x)} - \int_0^x F(\omega)d\omega. \tag{33}$$

Using Assumption 1, $T'(x) = \frac{F(x)[f(x)+\kappa f'(x)]}{f(x)} > 0$. Assumption 2 implies

$$T(\overline{\omega}) = \overline{\omega} - \int_0^{\overline{\omega}} F(\omega)d\omega > \beta^{-1} > r = \frac{1}{\beta[\underline{\delta}_2 + (1-\underline{\delta}_2)u'(x_2)]},$$

with $T(0) = 0$. By the intermediate value theorem (IVT), there exists a unique $R^* \in (0, \overline{\omega})$ such that (32) holds. Using (12), it requires $0 < \kappa^*$. ■

Lemma 2. *Suppose that the assumptions 1 and 2 hold. Given a real number x_2 with satisfying $x_2 \in (0, x^*)$, there exists a unique threshold $\overline{\theta} \in (0, 1)$ such that $\theta < \overline{\theta}$ if and only if $0 < \kappa^*_\theta$.*

Proof. Given Assumption 1, there exists a unique marginal contract $(R_\theta^*, \kappa_\theta^*)$ in the shadow banking sector. If $\kappa_\theta^* = 0$, then the IVT will imply $T(\overline{\omega}) \leq T(R_\theta^*) = \frac{r^s}{1-\theta}$. Given $x_2 \in (0, x^*)$, there exists a unique $\overline{\theta} \in \mathbb{R}$ such that $\overline{\theta} \leq \theta$, where

$$\overline{\theta} = 1 - \frac{1}{\beta[\overline{\omega} - \int_0^{\overline{\omega}} F(\omega)d\omega][\underline{\delta}_1 + (1 - \underline{\delta}_1)u'(x_2)]}. \tag{34}$$

Since Assumption 2 holds, $\overline{\theta} \in (0, 1)$. When $\kappa_\theta^* > 0$, it requires that $R_\theta^* \in (0, \overline{\omega})$, that is, $\theta < \overline{\theta}$. ■

In Lemma 1, since traditional banks are better equipped in collecting private information, there are always some safe entrepreneurs for these banks to fund. However, Lemma 2 states that when the monitoring cost of shadow banks is sufficiently large, shadow banks reject lending to even the safest entrepreneurs. As θ is sufficiently large, it creates incentive problems in shadow banking sector to the extent that it is not optimal for shadow banks to accept any loan applications. As the collateral constraint of traditional banks binds less severely (or x_2 increases), $\overline{\theta}$ decreases. That is, even a lower monitoring cost might not be sufficient to activate shadow loans.

Figure 2: Trade-offs Between Traditional and Shadow Banks

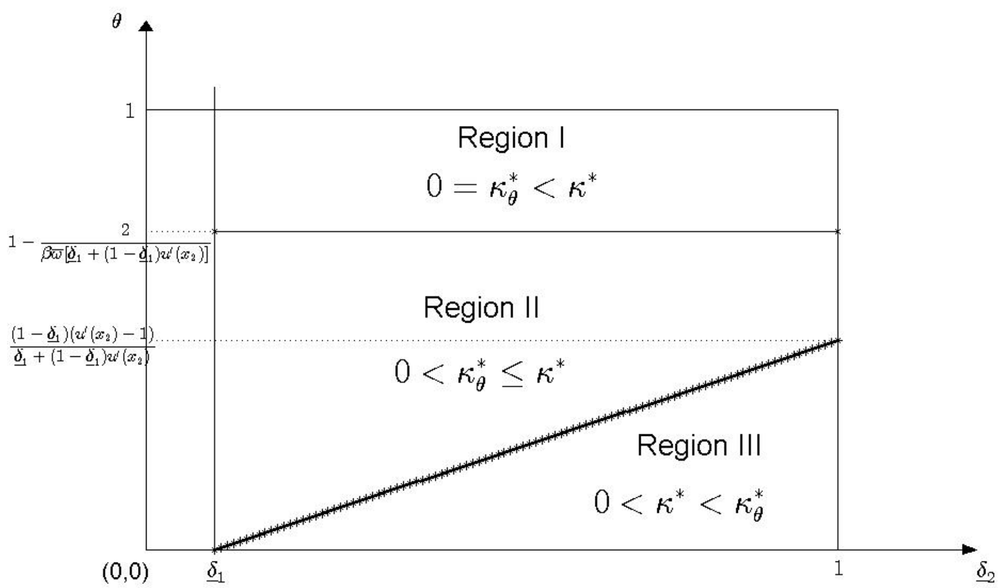


Figure 2 is a numerical exercise—F and G follow uniform and triangular distributions, respectively, on the support $[0, \overline{\omega}]$—that displays the equilibrium conditions for the competition between traditional and shadow banks in a $(\theta, \underline{\delta}_2)$ space. The vertical and horizontal axes represent the additional monitoring cost of shadow banks and the capital requirements for the receivables of the debt contracts originated in the regulated banking sector, respectively. When θ is sufficiently large, as depicted by Region I, shadow banking activity becomes highly information-sensitive to the extent that shadow banks are willing to finance no loans. Moreover, $\underline{\delta}_2$ has no impact on shadow banks' willingness to fund since $\underline{\delta}_1$ (not $\underline{\delta}_2$) shows the corresponding capital requirements for ABSs issued by shadow banks.

Proposition 1. *Suppose that the assumptions 1 and 2 hold. Given a real number x_2 with satisfying $x_2 \in (0, x^*)$, the following statements are equivalent:*

I. *The loan creation capacity of shadow banks is larger than that of traditional banks, i.e., $\kappa_\theta^* \leq \kappa^*$.*
II. *There exists a unique threshold $\tilde{\theta} \in \left(0, \frac{\underline{\delta}_2 - \underline{\delta}_1}{1-\underline{\delta}_1}\right)$ such that $\tilde{\theta} \leq \theta$.*
III. *Each project—if funded—is originated by the traditional banks.*

Proof. The proof is constructed as follows: (I) $\implies$ (II) $\implies$ (III) $\implies$ (I). Since $\kappa_\theta^* \leq \kappa^*$, (12) implies $R^* \leq R_\theta^*$ and hence $r = T(R^*) \leq T(R_\theta^*) = \frac{r^s}{1-\theta}$. That is, there exists a unique threshold $\tilde{\theta}$ such that $\tilde{\theta} \leq \theta$, where

$$\tilde{\theta} = \frac{(\underline{\delta}_2 - \underline{\delta}_1)[u'(x_2) - 1]}{\underline{\delta}_1 + (1 - \underline{\delta}_1)u'(x_2)}. \tag{35}$$

Since $x_2 \in (0, x^*)$, I obtain $\left(0, \frac{\underline{\delta}_2 - \underline{\delta}_1}{1-\underline{\delta}_1}\right)$. Thus, (I) implies (II). Consider the safe entrepreneurs with verification costs $\kappa \in [0, \kappa_\theta^*]$ where both banks are willing to fund entrepreneurs' projects. Using (10), (11), and (12), $\max[R_\theta(\kappa), R(\kappa)] \leq \tilde{R}(\kappa)$. The left hand sides of (10) and (11) increase with $R_\theta(\kappa)$ and $R(\kappa)$, respectively. Thus, $r(1-\theta) \leq r^s$ implies $R(\kappa) \leq R_\theta(\kappa)$. That is, an entrepreneur with a verification cost $\kappa \in [0, \kappa_\theta^*]$ prefers traditional funds as these funds are cheaper than shadow funds. For entrepreneurs with moderate verifications costs $\kappa \in (\kappa_\theta^*, \kappa^*]$, only traditional banks fund their projects. Thus, (II) implies (III). If all funds are created by traditional banks, then $R(\kappa) \leq R_\theta(\kappa)$ for all $\kappa \in [0, \min(\kappa_\theta^*, \kappa^*)]$. Using (10) and (11), $r(1-\theta) \leq r^s$. Thus, $T(R^*) \leq T(R_\theta^*)$ implies $R^* \leq R_\theta^*$ and in turn $\kappa_\theta^* \leq \kappa^*$. Therefore, (III) implies (I). ■

When traditional banks have longer reach on the entrepreneurs' projects than shadow banks, by using (13) and (14), the total demand of loans in shadow and traditional banking sectors can be expressed by

$$L^s(r^s) = 0 < L(r) = \sigma G(\kappa^*). \tag{36}$$

The condition in the second statement of Proposition 1 can be illustrated by the region I and the region II, as depicted in Figure 2. It turns out that shadow banks are vanished from the entrepreneurial credit market for very large θ as illustrated in the region I. If θ is moderate, then shadow banks will be interested in funding safe borrowers with low verification costs. However, shadow funded credit is still information-sensitive to the extent that entrepreneurs avoid shadow loans. When $\underline{\delta}_2$ is sufficiently small, an entrepreneur's offer to traditional bank might be relevant since the rate of return from each debt contract associated with the traditional banking sector is sufficiently small. Region II displays this case in which $0 < \kappa_\theta^* \leq \kappa^*$. When the loan creation capacities are equal, $\theta = \tilde{\theta}$, or $x_2 = \tilde{x}_\theta$, where $\tilde{x}_\theta$ satisfies

$$u'(\tilde{x}_\theta) = \frac{\underline{\delta}_2 - \underline{\delta}_1(1-\theta)}{\underline{\delta}_2 - \underline{\delta}_1 - \theta(1-\underline{\delta}_1)}. \tag{37}$$

If θ is sufficiently small, then financial frictions in the unregulated banking sector will induce shadow banks to accept individual debt contracts. Similarly, when $\underline{\delta}_2$ is sufficiently large, the safest entrepreneurs are worse off by choosing traditional banks as depicted in Region III. As the regulatory institution holds heavy capital requirements on the receivables of debt contracts, the expected return of traditional banks on each contract becomes large enough to cause the liquidity creation move from traditional to shadow banking sectors. In fact, as $\underline{\delta}_2$ increases, an entrepreneur knows that he needs to repay more and receives less payoff, as long as he offers to traditional banks. This is consistent with the empirical findings. For example, Basel I increased the capital requirements on commercial and industrial loans held in portfolio from 5.5% to 8% in 1990. In turn, the relative use of short-term shadow funded credit versus traditional banking lending significantly increased. Therefore, if the central bank increases $\underline{\delta}_2$, then the reallocation will result in the substitution of the shadow funded credit for traditional banking lending.

When traditional banks have longer reach on the entrepreneurs' projects than shadow banks, by using (13) and (14), I obtain

$$L(r) = 0 < L^s(r^s) = \sigma G(\kappa_\theta^*). \tag{38}$$

By using (6), (9), (13), (14), (24)-(29), (36), (38), and Proposition 1, the incentive constraint is given by

$$\begin{aligned} 0 =& V - \rho x_1 u'(x_1) - (1-\rho)x_2 u'(x_2) + \frac{(1-\underline{\delta}_1)u'(x_2)\sigma G(\kappa_\theta^*)I(\kappa^* < \kappa_\theta^*)}{\underline{\delta}_1 + (1-\underline{\delta}_1)u'(x_2)} \\ &+ \frac{(1-\underline{\delta}_2)u'(x_2)\sigma G(\kappa^*)I(\kappa_\theta^* \leq \kappa^*)}{\underline{\delta}_2 + (1-\underline{\delta}_2)u'(x_2)}. \end{aligned} \tag{39}$$

By using (26), the monetary policy tool z^b is given by

$$z^b = \frac{u'(x_2)}{u'(x_1)}. \tag{40}$$

The zero lower bound (ZLB) must satisfy in equilibrium, so

$$z^b \leq 1. \tag{41}$$

Given the fiscal policy V, the monetary authority chooses z^b, and traditional banks, shadow banks and entrepreneurs determine the allocation of the entrepreneurial credit between the two sectors. The equilibrium allocation (x_1, x_2) satisfies (39), (40) and (41) for given monetary policy z^b and the consolidated government debt V.

4.1. Optimal Monetary Policy

I analyze the optimal monetary policy and how the equilibrium behaves at the optimum. The central bank determines z^b that yields the largest the welfare among feasible equilibrium allocations. Let me define the welfare measure by

$$W = \sigma \int_0^{\max(\kappa^*, \kappa_\theta^*)} \left[\int_{\min(R_\theta(\kappa), R(\kappa))}^{\overline{\omega}} [\omega - \min(R_\theta(\kappa), R(\kappa))] dF(\omega) \right] dG(\kappa) + \\ + \rho[u(x_1) - x_1] + (1-\rho)[u(x_2) - x_2]. \tag{42}$$

Let $\rho[u(x_1) - x_1]$ and $(1-\rho)[u(x_2) - x_2]$ denote the total surplus in both currency and non-currency DM meetings. The first expression in (42) characterizes the total expected payoff of the entrepreneurs. I am interested in equilibrium in which σ is sufficiently small to the extent that the total expected payoff of entrepreneurs is negligible against the total surplus of the households (buyers and sellers). Therefore, the optimal monetary policy solves

$$\max_{x_1, x_2, z^b} \rho[u(x_1) - x_1] + (1-\rho)[u(x_2) - x_2] \tag{43}$$

subject to (39), (40), and (41).

For realistic monetary policy analyses, I assume that the sum of public and private liquidities is not large enough to render the efficient DM trade, or

$$\underbrace{V}_{\text{public liquidity}} + \underbrace{\sigma G\left(\frac{1 - F(T^{-1}(\beta^{-1}))}{f(T^{-1}(\beta^{-1}))} \right)}_{\text{private liquidity}} < (1-\rho)x^*. \tag{44}$$

Using (35), $\tilde{\theta} = 0$ at $x_2 = x^*$. Thus, Proposition 1 implies that the safe entrepreneurs choose traditional funded credit near the Friedman Rule. In turn, (44) guarantees that the Friedman Rule is not feasible in equilibrium.

Proposition 2. *If the assumptions 1 and 2, and* (44) *hold and* V *satisfies*

$$\frac{\tilde{x}_\theta[\underline{\delta}_2 - \underline{\delta}_1(1-\theta)]}{\underline{\delta}_2 - \underline{\delta}_1 - \theta(1-\underline{\delta}_1)} \leq V + \frac{(1-\underline{\delta}_2)[\underline{\delta}_2 - \underline{\delta}_1(1-\theta)]\sigma}{(1-\theta)(\underline{\delta}_2 - \underline{\delta}_1)} G\left(\frac{1 - F\left(T^{-1}\left(\frac{\underline{\delta}_2 - \underline{\delta}_1 - \theta(1-\underline{\delta}_1)}{\beta(1-\theta)(\underline{\delta}_2 - \underline{\delta}_1)}\right)\right)}{f\left(T^{-1}\left(\frac{\underline{\delta}_2 - \underline{\delta}_1 - \theta(1-\underline{\delta}_1)}{\beta(1-\theta)(\underline{\delta}_2 - \underline{\delta}_1)}\right)\right)} \right), \tag{45}$$

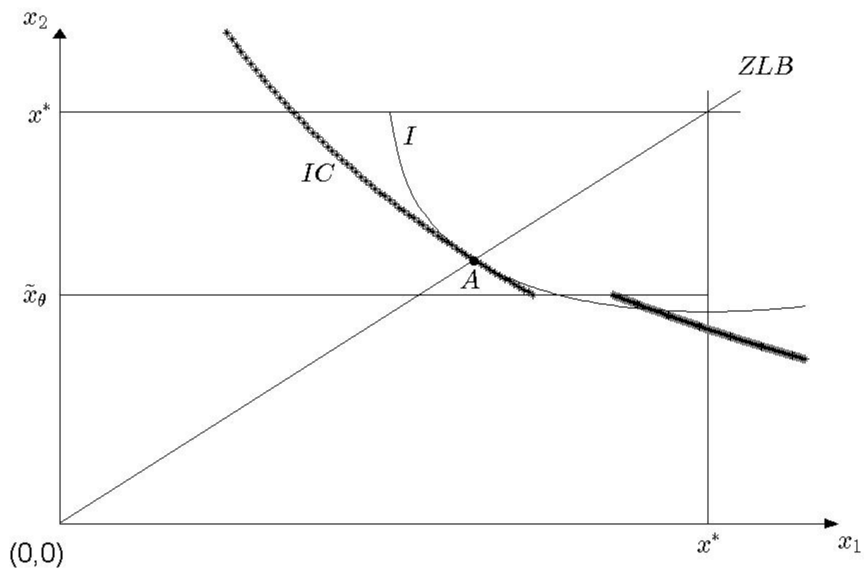
then ZLB exists in equilibrium. Moreover, $z^b = 1$ *is optimal and each funded entrepreneur is financed by only traditional banks at* $z^b = 1$.

Proof. Using (39), when $\kappa_\theta^* \leq \kappa^*$, the derivative of the incentive constraint is negative, or

$$\frac{dx_2}{dx_1} = \frac{-\rho(1-\alpha)u'(x_1)}{(1-\rho)(1-\alpha)u'(x_2) - \beta^2(1-\underline{\delta}_2)u''(x_2)\sigma r^2 \left[\underline{\delta}_2 G\left(\frac{1-F(T^{-1}(r))}{f(T^{-1}(r))}\right) + \frac{(1-\underline{\delta}_2)u'(x_2)r}{F(T^{-1}(r))} g\left(\frac{1-F(T^{-1}(r))}{f(T^{-1}(r))}\right) \right]}, \tag{46}$$

where r satisfies (27). Using the assumptions 1 and 2, (44), (45) and (46), there exists a unique allocation $x_1 = x_2 = x^t$ for $z^b = 1$. Moreover, $x^t \in [\tilde{x}_\theta, x^*)$. Using Proposition (1), each funded entrepreneur is financed by only traditional banks. Lastly, the derivative (46) of the incentive constraint at $z^b = 1$ is smaller than $\frac{-\rho}{1-\rho}$, which is the derivative of the indifference curve associated with the welfare measure (42) evaluated at ZLB. Thus, $z^b = 1$ must be optimal. ∎

Figure 3: Funded Projects are Financed by Only Traditional Banks at the ZLB



Proposition 2 states that when the consolidated government debt is sufficiently large, the zero nominal interest rate policy is feasible and the entrepreneurs are better off by traditional banking funds at the ZLB. Moreover, it is optimal for the central bank to choose nominal interest rate to be zero. By using (39) and Proposition 1, the derivative of the incentive constraint is always negative and hence there exists a unique equilibrium allocation for any feasible z^b with satisfying (41). Constant relative risk aversion with $\alpha < 1$ is crucial for the existence and the uniqueness. For sufficiently large θ, financial frictions in the shadow banking sector are amplified, leading to larger repayments for entrepreneurs. Hence, this induces entrepreneurs to flee from this sector in equilibrium. Traditional loans, at the expense of minimum capital requirements, improve the expected payoffs of the funded entrepreneurs. Although the consolidated government debt is not sufficient to support the efficient DM trade, public liquidity is plentiful enough to support traditional banks against shadow banks as each entrepreneur strives for resources to operate his individual project.

Figure 3 is a numerical exercise for Proposition 2 in which the economy reaches the largest welfare at the zero nominal interest rate. The incentive constraint (39) describes a convex locus in (x_1, x_2) space, as depicted by the curve IC. The ZLB represents $z^b = 1$ line. Thus, there exists no feasible allocation in the lower triangle below the ZLB. By using (44), (45), and (46), $x_2 = x^t \in [\tilde{x}_\theta, x^*)$ at the ZLB. Then by using the proposition 1, all funded loans are originated in the traditional banking sector in equilibrium. The point A, as depicted in Figure 3, shows the intersection of the ZLB and the IC. An increase in z^b is associated with a decrease in interest rate on reserves. This decrease results in a change in the equilibrium along the IC curve towards A. The rate of return on government debt decreases as total currency outstanding increases. The funded entrepreneurs enjoy lower repayments and hence they reach larger expected payoffs. The welfare measure (43) at the ZLB describes a convex indifference curve I passing through A. The slope of the IC is flatter than the slope of the indifference curve I at the point A. Thus, Proposition 2 shows that the point A represents the optimal equilibrium allocation. Therefore, there exists no monetary policy away from the ZLB that accomplishes larger welfare.

Proposition 3. *If the assumptions 1 and 2 hold and V satisfies*

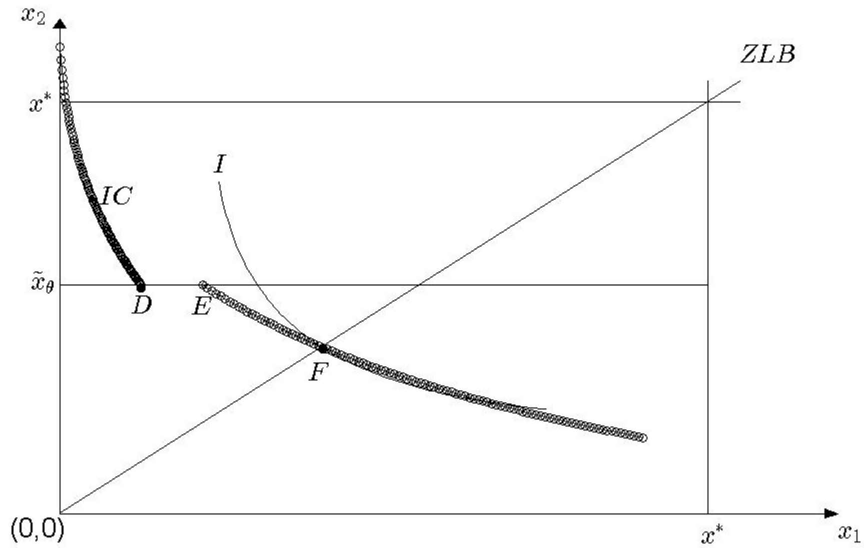
$$V + \frac{(1-\underline{\delta}_1)[\underline{\delta}_2 - \underline{\delta}_1(1-\theta)]\sigma}{\underline{\delta}_2 - \underline{\delta}_1} G\left(\frac{1 - F\left(T^{-1}\left(\frac{\underline{\delta}_2 - \underline{\delta}_1 - \theta(1-\underline{\delta}_1)}{\beta(1-\theta)(\underline{\delta}_2 - \underline{\delta}_1)}\right)\right)}{f\left(T^{-1}\left(\frac{\underline{\delta}_2 - \underline{\delta}_1 - \theta(1-\underline{\delta}_1)}{\beta(1-\theta)(\underline{\delta}_2 - \underline{\delta}_1)}\right)\right)}\right) < \frac{\tilde{x}_\theta[\underline{\delta}_2 - \underline{\delta}_1(1-\theta)]}{\underline{\delta}_2 - \underline{\delta}_1 - \theta(1-\underline{\delta}_1)} \tag{47}$$

then ZLB exists in equilibrium. Moreover, $z^b = 1$ is optimal and each funded entrepreneur is financed by only shadow banks at $z^b = 1$.

Proposition 3 states that if θ is sufficiently low and V is sufficiently small, then zero nominal interest rate policy will exist in equilibrium and all loans will be created in the shadow banking sector at the ZLB. The scarcity of public liquidity improves the availability of the shadow banking activity when the monitoring cost of shadow banks is moderate. By Proposition 1, each funded entrepreneur prefers shadow funded credit due to the cheaper contracts when the central bank maintains a low interest rate. It turns out that the derivative of the incentive constraint is always negative and hence there exists a unique equilibrium allocation for any feasible z^b. For sufficiently small θ, funded entrepreneurs enjoy higher expected payoffs since the effective market interest rate is sufficiently small. However, the capital requirements are too restrictive for traditional banks to offer cheaper contracts to the entrepreneurs. Thus, shadow banks have stronger pull on financing the entrepreneurial activity. However, an increase in θ offsets the comparative advantage of the shadow banks on lack of regulation.

Figure 5 is a numerical exercise for Proposition 3. The incentive constraint (39) describes disconnected convex loci in (x_1, x_2) space, as depicted by the curve IC. The point D, as depicted in Figure 3, shows the intersection of

Figure 4: Funded Projects are Financed by Only Shadow Banks at the ZLB



$x_2 = \tilde{x}_\theta$ line and IC. As the loan origination switches from one sector to the other, IC jumps from D to E. The welfare measure (43) at the ZLB describes a convex indifference curve I passing through F, as depicted in the same figure. Notice that the slope of IC is flatter than the slope of the indifference curve I. Since no allocation is feasible in the lower triangle below the ZLB, F implies the optimal equilibrium allocation. Therefore, there exists no monetary policy away from the ZLB that reaches a superior allocation. It turns out that the function (39) associated with the incentive constraint exhibits a discontinuity at the quantity of DM exchange in which $\kappa_\theta^* = \kappa^*$ holds. This discontinuity arises due to differential in the value of collateral with respect to the banking sector.

4.2. Counterparty Credit Risk Overview

In this subsection, I am interested in the credit risk associated with the entrepreneurs at the ZLB. In fact, the next proposition entails the effects of a change in the distribution of verification costs on the quantity of intermediated claims, the loan creation capacity, the ABSs outstanding, and the nominal interest rate spread between the ABSs and the government debts.

Proposition 4. *Suppose that* (47) *and the assumptions 1 and 2 hold. If the distribution of verification costs shifts from* $G : \mathbb{R}_+ \to [0, 1]$ *to* $G^* : \mathbb{R}_+ \to [0, 1]$

with satisfying $G^*(\kappa) \equiv G(\kappa - \varepsilon)$ for sufficiently small $\varepsilon > 0$, then the ZLB exists in equilibrium. Further, at the ZLB, it satisfies

$$\left.\frac{d\kappa_\theta^*}{d\varepsilon}\right|_{\varepsilon=0} > 0, \quad \left.\frac{dx_2}{d\varepsilon}\right|_{\varepsilon=0} < 0, \quad \left.\frac{d(ql)}{d\varepsilon}\right|_{\varepsilon=0} < 0, \quad \text{and} \quad \left.\frac{ds(x_2)}{d\varepsilon}\right|_{\varepsilon=0} > 0. \tag{48}$$

Proposition 4 states that if the probability mass (of bankruptcy costs) moves from left tail to right tail, then, at the ZLB, (i) the verification cost κ_θ^* of marginal entrepreneur will increase, (ii) the total mass $\sigma G^*(\kappa_\theta^*)$ of funded projects will decrease and hence this will disrupt the quantity of intermediated claims at the DM, (iii) the ABSs outstanding will diminish, and (iv) the nominal interest rate spread between the ABSs and the government debts will increase. In fact, the credit disruption increases the cost of collateral and hence this magnifies financial frictions in the traditional banking sector. In turn, the DM consumption diminishes and hence the welfare declines. Further, the currency-to-consumption ratio increases and thus inflation rises.

The derivative of a debt contract $R^\theta(\kappa)$ for all $\kappa \leq \kappa_\theta^*$ with respect to ε at $\varepsilon = 0$ is negative, or

$$\left.\frac{dR^\theta(\kappa)}{d\varepsilon}\right|_{\varepsilon=0} = \frac{-(1-\underline{\delta}_1)u''(x^s)}{\beta(1-\theta)[\underline{\delta}_1 + (1-\underline{\delta}_1)u'(x^s)]^2[1-\kappa f(R_\theta(\kappa)) - F(R_\theta(\kappa))]} \left.\frac{dx_2}{d\varepsilon}\right|_{\varepsilon=0} < 0.$$

This result is interesting in the sense that this financial crisis shock increases an individual payoff for the safe borrower, yet the total mass of safe borrowers declines.

Proposition 5. *Suppose that* (47) *and the assumptions 1 and 2 hold. If the distribution of project returns shifts from $F : [0, \overline{\omega}] \to [0,1]$ to $F^* : [-\varepsilon, \overline{\omega} - \varepsilon] \to [0,1]$ with satisfying $F^*(\omega) \equiv F(\omega + \varepsilon)$ for sufficiently small $\varepsilon > 0$, then the ZLB exists in equilibrium. Further, at the ZLB, it satisfies*

$$\left.\frac{d\kappa_\theta^*}{d\varepsilon}\right|_{\varepsilon=0} < 0, \quad \left.\frac{dx_2}{d\varepsilon}\right|_{\varepsilon=0} < 0, \quad \left.\frac{d(ql)}{d\varepsilon}\right|_{\varepsilon=0} < 0, \quad \text{and} \quad \left.\frac{ds(x_2)}{d\varepsilon}\right|_{\varepsilon=0} > 0. \tag{49}$$

Proposition 5 states that when the probability mass of project returns moves from right tail to left tail, (i) the loan creation capacity of shadow banks decreases, (ii) the collateral constraint of traditional banks binds more severely, (iii) the ABSs outstanding diminishes, and (iv) the nominal interest rate gap between ABSs and government debts increases. The risk associated with the project returns erodes the loan creation capacity of shadow banks since the moderate entrepreneurs whose verification costs close to κ_θ^* are now too risky to fund for shadow banks. Similar to Proposition 4, the credit disruption in shadow banking sector limits the ABSs outstanding and hence this results in a decrease in the quantity of DM exchange. Further, the yield spread for the ABSs increases. Even though there are credit disruptions in the shadow banking sector in the propositions 4 and 5, respectively, the credit does not depart from shadow to traditional banks.

4.3. Information-sensitivity of Shadow Funded Credit

In this subsection, I am interested in the monitoring cost of shadow banks in the low interest rate environment. The next proposition entails the impact of information-sensitivity of shadow funded credit on the real economic activity and the allocation of credit between traditional and shadow banks.

Proposition 6. *Suppose that* (47)*, and the assumptions 1 and 2 hold. If the monitoring cost of shadow banks increases from* θ *to* $\theta+\varepsilon$ *for sufficiently small* $\varepsilon > 0$*, then the ZLB exists in equilibrium and it satisfies* (49) *at the ZLB.*

As in Proposition 5, Proposition 6 states that when the monitoring cost of shadow banks increases, (i) some entrepreneurs' projects, which are formerly safe, are now too risky for shadow banks to finance, (ii) the total mass of funded projects diminishes, the collateral constraint of traditional banks binds more severely, and hence the quantity of DM exchange decreases, (iii) the ABSs outstanding declines, and (iv) the interest rate wedge between the ABSs and the government debts increases. When the shadow funded credit becomes more information-sensitive, not only the aggregate mass of safe borrowers declines, but also the expected payoff of a safe borrower diminishes. In fact, the derivative of a debt contract $R^{\theta}(\kappa)$ for all $\kappa \leq \kappa_{\theta}^{*}$ with respect to ε at $\varepsilon = 0$ is positive, or

$$\left.\frac{dR^{\theta}(\kappa)}{d\varepsilon}\right|_{\varepsilon=0} = \frac{-F(R_{\theta}^{*})}{[1-\kappa f(R_{\theta}(\kappa)) - F(R_{\theta}(\kappa))]} \left.\frac{d\kappa_{\theta}^{*}}{d\varepsilon}\right|_{\varepsilon=0} > 0.$$

In contrast to the effects of credit risk arising from the shift in G, the safe borrowers are worse off as the monitoring cost of shadow banks rises. As well, using (8), (9), and (39), the aggregate amount of deposits at the ZLB is given by

$$k = x_2 u'(x_2). \tag{50}$$

In the case of zero interest rate policy, (50) implies that an increase in θ reduces the total amount of deposits while traditional banks swap ABSs for reserves (or government bonds) in the asset side of their balance sheets.

Combining (37), (39), (40) and $z^b = 1$, define a function $\phi : [0,1] \to \mathbb{R}$ by

$$\phi(\theta) = \frac{\tilde{x}_{\theta}[\underline{\delta}_2 - \underline{\delta}_1(1-\theta)]}{\underline{\delta}_2 - \underline{\delta}_1 - \theta(1-\underline{\delta}_1)} - \frac{(1-\underline{\delta}_1)[\underline{\delta}_2 - (1-\theta)\underline{\delta}_1]\sigma}{(\underline{\delta}_2 - \underline{\delta}_1)} G\left(\frac{1 - F\left(T^{-1}\left(\frac{\underline{\delta}_2 - \underline{\delta}_1 - \theta(1-\underline{\delta}_1)}{\beta(1-\theta)(\underline{\delta}_2 - \underline{\delta}_1)}\right)\right)}{f\left(T^{-1}\left(\frac{\underline{\delta}_2 - \underline{\delta}_1 - \theta(1-\underline{\delta}_1)}{\beta(1-\theta)(\underline{\delta}_2 - \underline{\delta}_1)}\right)\right)}\right). \tag{51}$$

Lemma 3. *Suppose that* (44)*, the assumptions 1 and 2 hold. Then there exists a unique* $\breve{\theta} \in \left(0, \frac{\underline{\delta}_2 - \underline{\delta}_1}{1-\underline{\delta}_1}\right)$ *such that* $\phi(\breve{\theta}) = V$*. Further, if* $\theta < \breve{\theta}$*, then the ZLB exists and the funded entrepreneurs choose shadow funded credit at the ZLB.*

Lemma 3 states that when the monitoring cost of shadow banks are sufficiently small, there exists a unique equilibrium allocation at the ZLB and shadow banks propose cheaper loans for the entrepreneurs' projects than traditional banks.

Lemma 4. *Suppose that* (44)*, the assumptions 1 and 2 hold. Then there exists a unique* $\theta^t \in (\breve{\theta}, 1)$ *such that* $\theta^t = (\underline{\delta}_2 - \underline{\delta}_1)[u'(x^t) - 1][\underline{\delta}_1 + (1 - \underline{\delta}_1)u'(x^t)]^{-1}$*, where* $x^t \in (0, x^*)$ *satisfies*

$$V = x^t u'(x^t) - \frac{(1-\underline{\delta}_2)u'(x^t)\sigma}{\underline{\delta}_2 + (1-\underline{\delta}_2)u'(x^t)} G\left(\frac{1 - F\big(T^{-1}(\beta^{-1}[\underline{\delta}_2 + (1-\underline{\delta}_2)u'(x^t)]^{-1})\big)}{f\big(T^{-1}(\beta^{-1}[\underline{\delta}_2 + (1-\underline{\delta}_2)u'(x^t)]^{-1})\big)}\right). \tag{52}$$

Further, if $\theta \in [\breve{\theta}, \theta^t)$*, then the ZLB does not exist. If* $\theta^t \leq \theta$*, then the ZLB exists and the funded entrepreneurs choose traditional funded credit at the ZLB.*

Lemma 4 implies that when the shadow funded credit is sufficiently information-sensitive, there exists a unique equilibrium allocation at the ZLB in which the funded entrepreneurs are better off by traditional loans. Since there exists a discontinuity in the incentive constraint due to the regulatory arbitrage, the equilibrium allocation does not exist for some moderate values of the monitoring cost of the shadow banks.

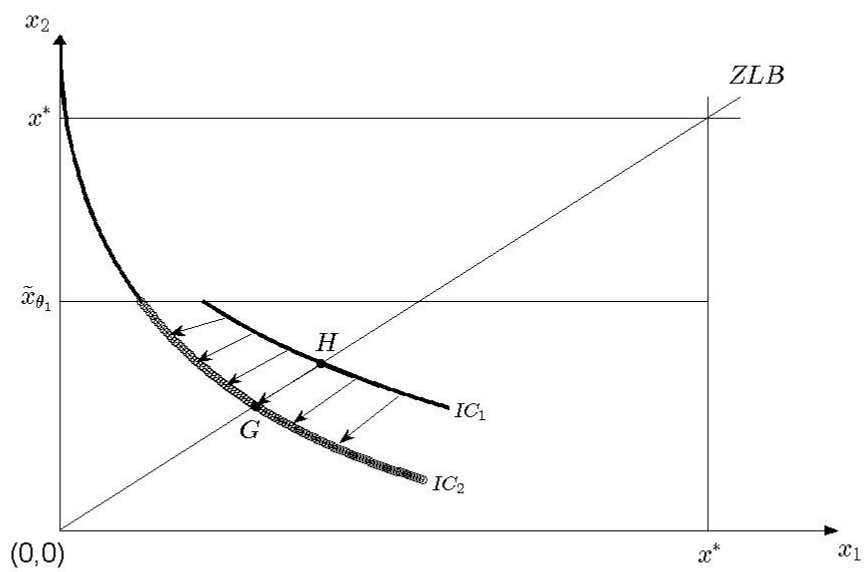
Proposition 7. *Suppose that* (44)*, the assumptions 1 and 2 hold. If* θ *increases from* $\theta = \theta_1 \in [0, \breve{\theta})$ *to* $\theta = \theta_2 \in [\theta^t, 1]$*, then the entrepreneurial credit will depart from shadow to traditional banks at the ZLB. Moreover, when* α *is sufficiently small, there exists a unique* $\theta^* \in (0, \breve{\theta})$ *such that if* $\theta_1 < \theta^*$*, then the previous loan creation capacity (of shadow banks) for* $\theta = \theta_1$ *will exceed the new loan creation capacity (of traditional banks) for* $\theta = \theta_2$*.*

Proposition 7 has two results. When the increase in monitoring cost of shadow banks is sufficiently large, (i) the shadow funded credit vanishes and (ii) traditional banks can partially fill the void in the credit market by funding the entrepreneurs' projects, as long as θ is initially sufficiently low. In other words, traditional banks can be useful to replace the credit loss in the shadow banking sector; however, the credit provision by traditional banks is overwhelmed by the loss in the shadow banking sector.

Figure 5 is a numerical exercise for the first part of Proposition 7. The incentive constraint (39) describes discontinuous two convex loci in (x_1, x_2) space, as depicted by the curve IC_1 with bold line. The point H shows the intersection of ZLB and IC_1. As the regime switches from $\theta = \theta_1$ to $\theta = \theta_2$, the incentive constraint shifts to the curve IC_2 for $x_2 < \tilde{x}_{\theta_1}$. The shift in monitoring cost of shadow banks implies that the equilibrium jumps from H to G at the ZLB. Therefore, the quantity of each DM trade diminishes. Moreover, θ_2 is large to the extent that all funded entrepreneurs choose traditional banks over shadow banks at $z^b = 1$.

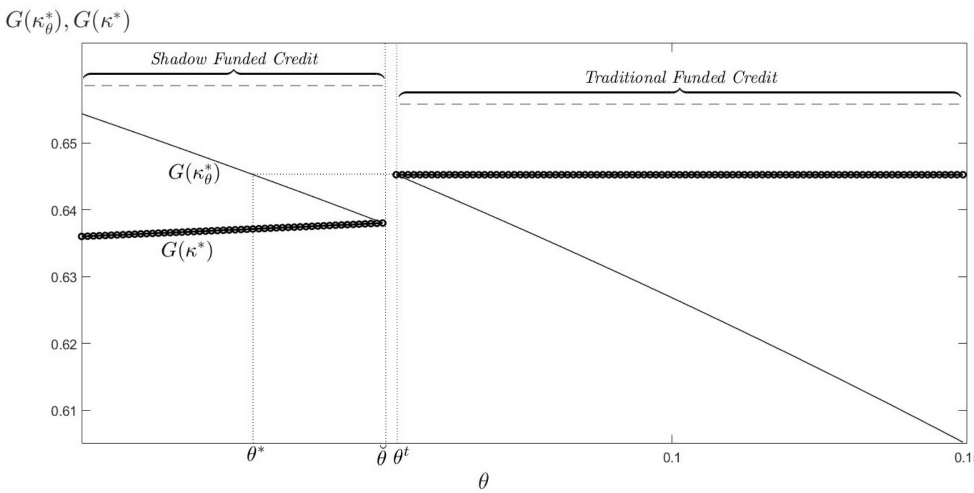
In Figure 6, the horizontal and vertical axes are represented by the fraction of the shadow banks' losses due to the monitoring costs and the loan creation capacities of both sectors, respectively, in equilibrium at the ZLB. The solid and circled lines show the loan creation capacities of shadow and traditional banks, respectively, at the ZLB as a function of monitoring cost of shadow banks. When this cost is sufficiently small, the safest projects are funded by

Figure 5: Increase in Monitoring Cost of Shadow Banks



shadow banks at the ZLB since shadow banks are willing to fund more projects than traditional banks. In contrast, the loan creation capacity of traditional banks overwhelms that of shadow banks when the shadow funded credit becomes highly information-sensitive. Further, when the initial monitoring cost of shadow banks is sufficiently low, the large increase in monitoring cost does not only result in the reallocation of credit from shadow to traditional banks, but also the latter cannot fund all the projects that are initially financed by the first. That is, credit shifts from risky to safer borrowers with the emergence of traditional loans. As well, the expected payoffs of safe (funded) entrepreneurs decrease. Even though traditional loans generate larger welfare than shadow loans after the increase in θ, traditional banks are not willing to fund some projects that are previously funded by shadow banks before the increase. That is, traditional banks have limitations on fulfilling the role of credit provision that shadow banks have previously played. Since credit leaves shadow banking sector, the ABSs outstanding diminishes while the increase in the traditional loans outstanding cannot offset the loss of shadow funded credit. Thus, the collateral constraint of traditional banks binds more severely and hence the quantity of DM exchange diminishes. Finally, this results in the increase in the nominal interest rate gap between the ABSs and government debts.

Figure 6: Loan Creation Capacities of Both Sectors at the ZLB



5. Monetary Policy

5.1. Unconventional Monetary Policy

The central bank's unconventional monetary policy captures the purchases of ABSs issued by shadow banks. In this section, I concentrate on the effects of this program on the relative use of the shadow banking activity and the real economic activity. It is important to note that the central bank sets a monetary policy tool $\tilde{q}$ that characterizes how much the central bank will pay for a unit of an ABS. The first type of intervention involves that the central bank purchases at the market price q. Second, the central bank accounts for all the asset-backed security, i.e., $q < \tilde{q}$. Hence, depositors and traditional banks are phased out. Now I reorganize the consolidated government budget constraint as follows

$$\rho c + z^m m + z^b b - \tilde{q} l^g - V = 0. \tag{53}$$

To eliminate the existence problem, assume that the rate of return on the ABS cannot be smaller than the rate of return on safe government debts, or

$$\frac{1}{\beta u'(x_2)} \leq \frac{1}{\tilde{q}}, \tag{54}$$

where $\beta^{-1} u'(x_2)^{-1}$ and $\tilde{q}^{-1}$ denote the rate of return of government debts and the ABSs, respectively. In this case, the central bank sets $\tilde{q} = q$, where the market price q is given by (25). Let l and l^g denote the quantities of ABSs demanded by traditional banks and the central bank, respectively. The relevant market clearing condition is given by

$$l^s = l + l^g, \tag{55}$$

where l^s is the quantity of ABSs issued by shadow banks. By using (6), (9), (13), (14), (25)-(29), (36), (38), (53), and Proposition 2, the incentive constraint is given by

$$\begin{aligned}0 =& V - \rho x_1 u'(x_1) - (1-\rho)x_2 u'(x_2) + \left(\beta\underline{\delta}_1 l^g + \frac{(1-\underline{\delta}_1)u'(x_2)}{\underline{\delta}_1 + (1-\underline{\delta}_1)u'(x_2)}\sigma G(\kappa_\theta^*)\right) I(\kappa^* < \kappa_\theta^*) \\ &+ \frac{(1-\underline{\delta}_2)u'(x_2)}{\underline{\delta}_2 + (1-\underline{\delta}_2)u'(x_2)}\sigma G(\kappa^*) I(\kappa_\theta^* \leq \kappa^*), \end{aligned} \tag{56}$$

If funded projects are financed by shadow banks, then the central bank's purchases of ABSs will increase both currency outstanding and the non-currency DM consumption for the same interest rate policy. Thus, both real rates of return on government debt and entrepreneurial credit increase. In turn, the loan creation capacity of each sector decreases and funded entrepreneurs make larger repayments. Thus, this intervention transfers the welfare from entrepreneurs to households (buyers and sellers). As l^g increases, the welfare (43) increases. That is, $l^s = l^g$ is optimal. Therefore, the incentive constraint can be rewritten by

$$0 = V - \rho x_1 u'(x_1) - (1-\rho)x_2 u'(x_2) + \sigma G(\kappa_\theta^*) I(\kappa^* < \kappa_\theta^*) + \frac{(1-\underline{\delta}_2)u'(x_2)}{\underline{\delta}_2 + (1-\underline{\delta}_2)u'(x_2)}\sigma G(\kappa^*) I(\kappa_\theta^* \leq \kappa^*).$$

The central bank's purchases at $\tilde{q} = q$ increase welfare when loans are originated by shadow banks, shifting the IC curve towards a superior equilibrium allocation. As well, the IC exhibits a larger jump at $x_2 = \tilde{x}_\theta$ where the production capacity of traditional banks equals to that of shadow banks.

When the central bank purchases ABSs at a higher price than the market price, the market clearing condition implies $l^s = l^g$ and $l = 0$. The incentive constraint can be written by

$$0 = V - \rho x_1 u'(x_1) - (1-\rho)x_2 u'(x_2) + \sigma G(\kappa_{\theta,\tilde{q}}^*) I(\kappa^* < \kappa_{\theta,\tilde{q}}^*) + \frac{(1-\underline{\delta}_2)u'(x_2)\sigma G(\kappa^*) I(\kappa_{\theta,\tilde{q}}^* \leq \kappa^*)}{\underline{\delta}_2 + (1-\underline{\delta}_2)u'(x_2)}, \tag{57}$$

where $\kappa_{\theta,\tilde{q}}^*$ can be expressed by

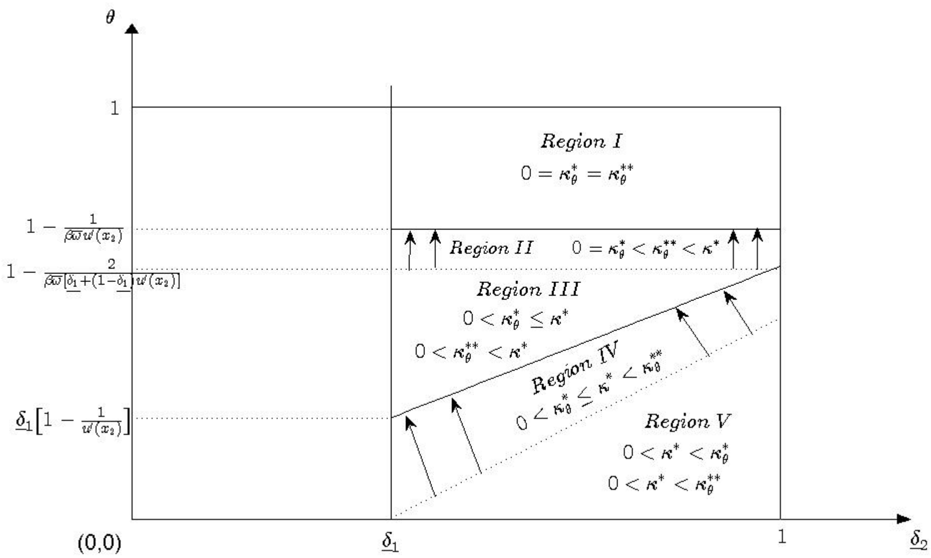
$$\kappa_{\theta,\tilde{q}}^* = \frac{1 - F(T^{-1}(\tilde{q}^{-1}(1-\theta)^{-1}))}{f(T^{-1}(\tilde{q}^{-1}(1-\theta)^{-1}))}. \tag{58}$$

As $\tilde{q}$ increases, so does $\kappa_{\theta,\tilde{q}}^*$. Therefore, it is optimal for the central bank to choose $\tilde{q} = \beta u'(x_2)$. Using (58), the arm length of shadow banks is given by

$$\kappa_\theta^{**} = \frac{1 - F(T^{-1}([\beta(1-\theta)u'(x_2)]^{-1}))}{f(T^{-1}([\beta(1-\theta)u'(x_2)]^{-1}))}. \tag{59}$$

Corollary 1. *Suppose that the central bank conducts the optimal purchases of ABSs and the assumptions 1 and 2 hold. Given a real number x_2 with satisfying $x_2 \in (0, x^*)$, there exists a unique threshold $\theta' \in (0,1)$ such that $\theta < \theta'$ if and only if $0 < \kappa_\theta^{**}$.*

Figure 7: Unconventional Monetary Policy: Trade-offs Between Traditional and Shadow Banks



Using (34) and (78), $\overline{\theta} < \theta'$ for any $x_2 \in (0, x^*)$. That is, when the central bank conducts optimal purchases, the monitoring cost of shadow banks should be larger to induce the shadow banking sector to avoid funding entrepreneurs. Moreover, using Proposition 1, the loan creation capacity of traditional banks exceeds that of shadow banks with the central bank's intervention if and only if $\overline{x}_\theta \leq x_2$, where $\overline{x}_\theta$ satisfies

$$u'(\overline{x}_\theta) = \frac{\underline{\delta}_2}{\underline{\delta}_2 - \theta}. \tag{60}$$

Figure 7 is a numerical exercise—F and G follow uniform and triangular distributions, respectively, on the support $[0, \overline{\omega}]$—that displays the equilibrium conditions for the competition between traditional and shadow banks in $(\theta, \underline{\delta}_2)$ space with and without the central bank's ABSs purchases. When the monitoring cost of shadow banks is sufficiently large or $\theta' \leq \theta$, as depicted by Region I, shadow banks have no loan origination capacity and hence this program is irrelevant. In Region II and Region III, this program can increase the loan creation capacity of shadow banks, but the entrepreneurs choose traditional banks over shadow banks since θ is sufficiently large. Region IV captures the pair $(\theta, \underline{\delta}_2)$ in which the central bank's intervention is relevant. Initially, all loans are originated by traditional banks; however, loans are, with the optimal purchases, created in the shadow banking sector. In other words, credit moves from traditional to shadow banks by the central bank's intervention. In the region V, loans are already originated in the shadow banking sector and it gives an extra liquidity by decreasing the rate of return on the debt contract associated with shadow banks.

Proposition 8. *Suppose that* (44) *and* (45) *hold and the assumptions 1 and 2 satisfy. If V satisfies*

$$V < \frac{\overline{x}_\theta(\underline{\delta}_2 - \theta)}{\underline{\delta}_2 - \theta} - \sigma G\left(\frac{1 - F(T^{-1}(\frac{\delta_2-\theta}{\beta\underline{\delta}_2(1-\theta)}))}{f(T^{-1}(\frac{\delta_2-\theta}{\beta\underline{\delta}_2(1-\theta)}))}\right), \tag{61}$$

then the ZLB exists in equilibrium and the entrepreneurial credit moves from traditional banks to shadow banks at the ZLB with the optimal purchases of ABSs. Further, $z^b = 1$ is optimal.

Proposition 8 states that the central bank's unconventional intervention induces the entrepreneurs to switch borrowing from traditional to shadow banks for moderate values of public liquidity at the ZLB. The intervention reinforces the shadow banking sector relative to the traditional banking sector in the sense that the loan creation capacity of shadow banks increases. When the central bank faces the zero lower bound problem, this intervention improves the liquidity conditions of households as the collateral constraint binds less severely. In turn, by using (43), the new allocation reaches the superior allocation.

Figure 8: Unconventional Monetary Policy

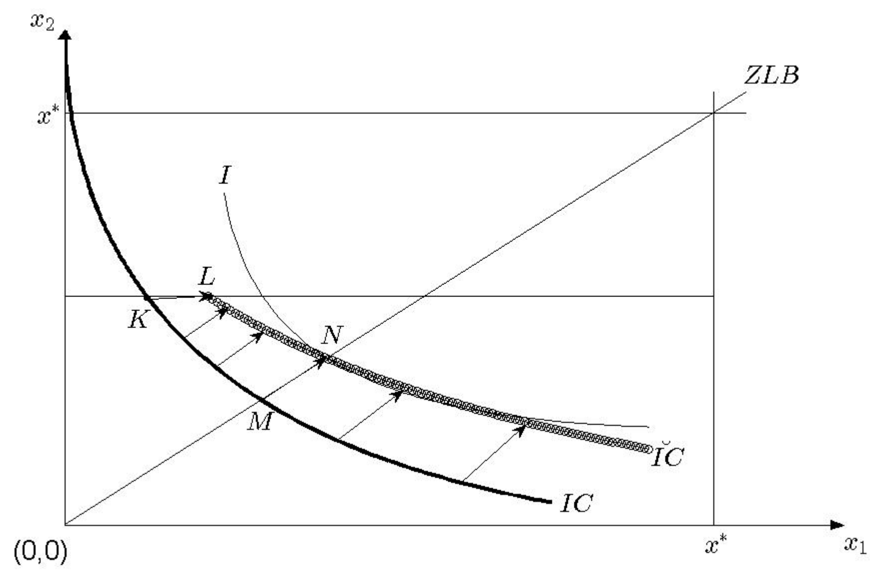


Figure 8 is a numerical exercise for Proposition 8. The incentive constraint (39) describes the convex locus in (x_1, x_2) space, as depicted by the curve IC

with the bold line. The point M is the intersection of the ZLB and IC. All loans are initially originated in the traditional banking sector. As the central bank conducts the purchases of ABSs, the incentive constraint shifts from IC to $\breve{IC}$ and all funded projects are originated by shadow banks at around the ZLB. Thus, all funded projects that are initially originated by traditional banks are now created by shadow banks in a welfare increasing fashion. Finally, the point N, as depicted in the same figure, is the intersection of ZLB and $\breve{IC}$. The allocation, represented by N, exists and it is unique. The welfare measure (43) describes a convex indifference curve passing through N, as depicted by I. Notice that the slope of the IC is flatter than the slope of the indifference curve I at the ZLB. Therefore, N characterizes the optimal equilibrium allocation.

Combining (40), (57), (60), $\tilde{q} = \beta u'(x_2)$ and $z^b = 1$, define a function $\pi : [0, 1] \to \mathbb{R}$ by

$$\pi(\theta) = \frac{\overline{x}_\theta \underline{\delta}_2}{\underline{\delta}_2 - \theta} - \sigma G\left(\frac{1 - F\left(T^{-1}\left(\frac{\underline{\delta}_2 - \theta}{\beta(1-\theta)(\underline{\delta}_2 - \underline{\delta}_1)}\right)\right)}{f\left(T^{-1}\left(\frac{\underline{\delta}_2 - \theta}{\beta(1-\theta)(\underline{\delta}_2 - \underline{\delta}_1)}\right)\right)}\right). \tag{62}$$

Corollary 2. *Suppose that the central bank conducts the optimal purchases of ABSs and* (44)*, the assumptions 1 and 2 hold. Then there exists a unique* $\hat{\theta} \in (0, \underline{\delta}_2)$ *such that* $\pi(\hat{\theta}) = V$*. Further, if* $\theta < \hat{\theta}$*, then the ZLB exists and funded entrepreneurs choose shadow funded credit at the ZLB.*

Corollary 2 states that if financial frictions in the shadow banking sector are sufficiently relaxed with the central bank's optimal purchases of ABSs, then funded entrepreneurs will receive cheaper loans in the shadow banking sector for low interest rates, as in the same line with the results of Lemma 3.

Corollary 3. *Suppose that the central bank conducts the optimal purchases of ABSs and* (44)*, the assumptions 1 and 2 hold. Then there exists a unique* $\theta^{tt} \in (\hat{\theta}, 1)$ *such that* $\theta^{tt} = \underline{\delta}_2[1 - u'(x^t)^{-1}]$*, where* x^t *satisfies* (52)*. Further, if* $\theta \in [\hat{\theta}, \theta^{tt})$*, then the ZLB does not exist. If* $\theta^{tt} \leq \theta$*, then the ZLB exists and funded entrepreneurs choose traditional funded credit at the ZLB.*

Corollary 3 implies that when the monitoring cost of shadow banks is sufficiently large in spite of the central bank's purchases of ABSs, funded entrepreneurs are better off by traditional loans as the central bank faces the ZLB problem.

Proposition 9. *Suppose that the central bank conducts the optimal purchases of the ABSs and* (44)*, the assumptions 1 and 2 hold. If* $\theta \in [\theta^t, \hat{\theta})$*, then credit will move from traditional to shadow banks at the ZLB with these purchases. Moreover, when* α *is sufficiently small, there exists a unique* $\theta^{**} \in \left(0, \hat{\theta}\right)$ *such that if* $\theta \in [\theta^t, \theta^{**})$*, then the previous loan creation capacity (of traditional banks) without the optimal purchases will be smaller than the new loan creation capacity (of shadow banks) with the optimal purchases.*

Proposition 9 states that when the monitoring cost of shadow banks is moderate, credit shifts from traditional to shadow banks at the ZLB as the central bank conducts the purchases of ABSs. Moreover, if the shadow funded credit is not very information-sensitive, then the central bank's unconventional monetary policy will also improve the lending capacity of the private markets, i.e., the aggregate mass of funded projects increases. That is, this program reinforces the shadow banking sector to the extent that some projects that are too risky for traditional banks to finance in the case of no intervention are now financed by shadow banks. Therefore, this intervention diminishes the market interest rate in the shadow banking sector and hence this leads to an increase in the risk appetite of the shadow banks on the entrepreneurs' projects. In turn, every funded entrepreneur enjoys larger expected payoff since each contracts becomes cheaper. This program renders the collateral constraint of traditional banks relaxed and hence results in an increase in the quantity of DM exchange. Thus, the interest rate spread between the ABSs and the government bonds diminishes.

Proposition 9 implicitly implies that if $\theta \in (\theta^{**}, \hat{\theta})$, then loans will move from traditional to shadow banks; however, this program will not be sufficient to increase the aggregate mass of funded projects for the policy of zero interest rate. As well, if the monitoring cost of shadow banks is very large to the extent that $\theta^{tt} \leq \theta$, then the central bank's purchase of ABSs cannot even activate the shadow banking sector. In this case, neither lowering the rates nor the unconventional monetary policy alleviates the financial frictions in the loan markets. Therefore, the central bank's intervention has limitations on the recovery of the funded projects.

5.2. Conventional Monetary Policy

In this subsection, I focus on the central bank's conventional monetary policy. This environment implies an interpretation of monetary policies relevant to the "floor" operating system with excess reserves. Thus, government debt and reserves are equal investments for traditional banks, i.e., central bank conducts the monetary policy by altering the interest rate on reserves. I assume, for the tractability, that the project returns are drawn from the uniform distribution. When the central bank decreases the interest rate on reserves, the collateral constraint of traditional banks gets tighter and hence the real rate of return on an entrepreneurial credit decreases. In turn, if the funded entrepreneurs choose shadow banks over traditional banks, then the ABSs outstanding will increase. Otherwise, the traditional loans outstanding increases. However, the effect of lowering interest rates on the ABSs spread is ambiguous. Lastly, the currency outstanding rises.

Lemma 5. *Suppose that* (44) *holds, the assumptions 1 and 2 satisfy, and the project returns are drawn from the uniform distribution on the support* $[0, \overline{\omega}]$*, i.e.,* $\omega \sim U(0, \overline{\omega})$*. For any feasible monetary policy* $z^b = z \in [0, 1]$*, there exists* *a unique* $\theta^z \in \mathbb{R}$ *such that if* $\theta^z < \theta$, *then it will satisfy*

$$0 < \left.\frac{d\kappa^*}{dz^b}\right|_{z^b=z} < \left.\frac{d\kappa^*_\theta}{dz^b}\right|_{z^b=z}. \tag{63}$$

Lemma 5 states that when $\omega \sim U(0, \overline{\omega})$ and the shadow funded credit is sufficiently information-sensitive, the decrease in the interest rate on reserves improves the loan creation capacity of each sector. Moreover, the increase in the loan creation capacity of shadow banks outweighs the increase in that of traditional banks. That is, the central bank's open market operation entails a better cushion against the liquidity constraint of shadow banks than that of traditional banks when the monitoring cost of shadow banks is sufficiently large. This result is intuitive in the sense that the Fed's low interest rate policy helps the shadow banking sector recover from the financial crisis when the incentive problems arise in this sector. Using (81), $\theta^z < \tilde{\theta}$ for any $x_2 \in (0, x^*)$. Moreover, (i) when θ is sufficiently large in the sense that $\tilde{\theta} \leq \theta$, the funded entrepreneurs choose traditional loans, yet the increase in the loan creation capacity of shadow banks is larger than that of traditional banks as the central bank increases z. (ii) When the monitoring cost of shadow banks is moderate, or $\theta^z < \theta < \tilde{\theta}$, shadow loans are cheaper than traditional loans while lower nominal interest rate on reserves implies a larger increase in the loan creation capacity of shadow banks than that of traditional banks. Note that $\theta^z < \theta$ is equivalent to $\hat{x}_\theta < x_2$, where $\hat{x}_\theta \in (0, \tilde{x}_\theta)$ satisfies

$$u'(\hat{x}_\theta) = \frac{\underline{\delta}_2 - \underline{\delta}_1(1-\theta)^{\frac{1}{3}}\left(\frac{1-\underline{\delta}_2}{1-\underline{\delta}_1}\right)^{\frac{2}{3}}}{(1-\underline{\delta}_1)(1-\theta)^{\frac{1}{3}}\left(\frac{1-\underline{\delta}_2}{1-\underline{\delta}_1}\right)^{\frac{2}{3}} - (1-\underline{\delta}_2)}. \tag{64}$$

Proposition 10. *Suppose that* (44), (45), *and the assumptions 1 and 2 hold, and* $\omega \sim U(0, \overline{\omega})$. *The set of feasible monetary policy is given by* $Z_1 \equiv [0, 1]$. *Further, for any* $z^b = z \in Z_1$, (63) *holds and funded entrepreneurs are financed by only traditional banks.*

Proposition 10 implies that when the public liquidity is sufficiently plentiful or the monitoring cost of shadow banks is sufficiently small, the effect of plentiful public liquidity dominates that of the capital requirements, hence favoring traditional funded credit. On one hand, traditional banks propose cheaper credit than shadow banks for any feasible monetary policy. On the other hand, the decrease in interest rate on reserves, at any $z \in Z_1$, improves the lending capacity of shadow banks more than that of traditional banks. In the case of large V, an accommodative monetary policy yields a stronger reinforcement to the shadow banking sector, yet this is not large enough to induce entrepreneurs to swap traditional loans for shadow loans.

For the following proposition, define $\underline{x}_1 \in (0, x^*)$ and $\overline{x}_1 \in (0, x^*)$ by

$$V = \rho\underline{x}_1 u'(\underline{x}_1) + (1-\rho)\tilde{x}_\theta u'(\tilde{x}_\theta) - \frac{(1-\underline{\delta}_2)[\underline{\delta}_2 - \underline{\delta}_1(1-\theta)]\sigma}{(1-\theta)(\underline{\delta}_2 - \underline{\delta}_1)} G\left(\frac{1 - F\left(T^{-1}\left(\frac{\underline{\delta}_2 - \underline{\delta}_1 - \theta(1-\underline{\delta}_1)}{\beta(1-\theta)(\underline{\delta}_2 - \underline{\delta}_1)}\right)\right)}{f\left(T^{-1}\left(\frac{\underline{\delta}_2 - \underline{\delta}_1 - \theta(1-\underline{\delta}_1)}{\beta(1-\theta)(\underline{\delta}_2 - \underline{\delta}_1)}\right)\right)}\right), \tag{65}$$

$$V = \rho \overline{x}_1 u'(\overline{x}_1) + (1-\rho)\tilde{x}_\theta u'(\tilde{x}_\theta) - \frac{(1-\underline{\delta}_1)[\underline{\delta}_2 - \underline{\delta}_1(1-\theta)]\sigma}{\underline{\delta}_2 - \underline{\delta}_1} G\left(\frac{1 - F\left(T^{-1}\left(\frac{\underline{\delta}_2 - \underline{\delta}_1 - \theta(1-\underline{\delta}_1)}{\beta(1-\theta)(\underline{\delta}_2 - \underline{\delta}_1)}\right)\right)}{f\left(T^{-1}\left(\frac{\underline{\delta}_2 - \underline{\delta}_1 - \theta(1-\underline{\delta}_1)}{\beta(1-\theta)(\underline{\delta}_2 - \underline{\delta}_1)}\right)\right)} \right). \tag{66}$$

Proposition 11. *Suppose that* (47)*, the assumptions 1 and 2 hold,* $\omega \sim U(0, \overline{\omega})$*, and* V *satisfies*

$$\hat{x}_\theta u'(\hat{x}_\theta) < V + \frac{(1-\underline{\delta}_1)u'(\hat{x}_\theta)\sigma}{\underline{\delta}_1 + (1-\underline{\delta}_1)u'(\hat{x}_\theta)} G\left(\frac{1 - F\left(T^{-1}([\beta(1-\theta)(\underline{\delta}_1 + (1-\underline{\delta}_1)u'(\hat{x}_\theta))]^{-1})\right)}{f\left(T^{-1}([\beta(1-\theta)(\underline{\delta}_1 + (1-\underline{\delta}_1)u'(\hat{x}_\theta))]^{-1})\right)} \right). \tag{67}$$

The set of feasible monetary policy is given by $Z_2 \equiv [0, \underline{z}] \cup (\overline{z}, 1]$*, where* $(\underline{z}, \overline{z}) \in (0,1)^2$ *satisfies*

$$\underline{z} = \frac{u'(\tilde{x}_\theta)}{u'(\underline{x}_1)} < \overline{z} = \frac{u'(\tilde{x}_\theta)}{u'(\overline{x}_1)}, \tag{68}$$

and $\underline{x}_1$ *and* $\overline{x}_1$ *satisfy* (65) *and* (66)*, respectively. Moreover,* (63) *holds for any* $z \in Z_2$ *and if* $z \in [0, \underline{z}]$*, then funded entrepreneurs are financed by only traditional banks while if* $z \in (\overline{z}, 1]$*, then funded entrepreneurs are financed by only shadow banks.*

Proposition 11 states that when the consolidated government debt persists at the moderate level, a large interest rate, that is $z^b = z \in [0, \underline{z}]$, induces entrepreneurs to choose traditional loans while a low interest rate, that is $z^b = z \in (\overline{z}, 1]$, supports shadow loans. In addition, (67) implies that financial frictions in the shadow banking sector are sufficiently strong to the extent that an accommodative monetary policy enhances the loan creation capacity of shadow banks at a higher rate than that of traditional banks. For example, as z^b increases from $z^b = z_1 \in [0, \underline{z}]$ to $z^b = z_2 \in (\overline{z}, 1]$, the safest projects, which are initially financed by traditional banks, are now funded by shadow banks. Had not shadow banks taken over funding creditworthy borrowers, the increase in aggregate mass of funded projects would have been smaller. In contrast to Proposition 10, the moderate level of public liquidity tips the scale in favor of shadow banks as the decrease in the interest rate on reserves is sufficiently large. Lastly, the capital requirement gap between ABSs and regular loans implies that there exists no equilibrium for $z \in Z_1 - Z_2 \equiv (\underline{z}, \overline{z}]$. However, no-equilibrium condition is not significant in this discussion as this gap is minimal in the case of scarce collateral.

Proposition 12. *Suppose that the assumptions 1 and 2 hold,* $\omega \sim U(0, \overline{\omega})$*, and* V *satisfies*

$$V + \frac{(1-\underline{\delta}_1)u'(\hat{x}_\theta)\sigma}{\underline{\delta}_1 + (1-\underline{\delta}_1)u'(\hat{x}_\theta)} G\left(\frac{1 - F\left(T^{-1}([\beta(1-\theta)(\underline{\delta}_1 + (1-\underline{\delta}_1)u'(\hat{x}_\theta))]^{-1})\right)}{f\left(T^{-1}([\beta(1-\theta)(\underline{\delta}_1 + (1-\underline{\delta}_1)u'(\hat{x}_\theta))]^{-1})\right)} \right) \leq \hat{x}_\theta u'(\hat{x}_\theta). \tag{69}$$

The set of feasible monetary policy is given by Z_2*. Moreover, there exists a unique threshold* $\hat{z} \in (\overline{z}, 1]$ *such that if* $z \in [0, \hat{z}) \cap Z_2$*, then it will satisfy* (63)*.*

However, if $z \in [\hat{z}, 1]$*, then it will satisfy*

$$0 < \left.\frac{d\kappa_\theta^*}{dz^b}\right|_{z^b=z} \leq \left.\frac{d\kappa^*}{dz^b}\right|_{z^b=z}. \tag{70}$$

In Proposition 12, when the central bank decreases the interest rate on reserves in the case of sufficiently scarce public liquidity, the loan creation capacity of shadow banks increases more than that of traditional banks for sufficiently large interest rates. Interestingly, when the interest rates are sufficiently low, lowering the rates results in a stronger reinforcement for traditional banks than shadow banks; however, the safest entrepreneurs prefer shadow loans at these rates. For example, as z^b increases from $z^b = z_1 \in (\overline{z}, \hat{z})$ to $z^b = z_2 \in [\hat{z}, 1]$, the increase in the loan creation capacity of traditional banks begins to dominate that of shadow banks, yet this push is not strong enough to encourage entrepreneurs borrowing from traditional banks.

6. Conclusion

This paper concentrates on the trade-offs between on-the-balance-sheet loans and off-the-balance-sheet financing via ABCPs. While traditional banks have a better technology in evaluating the loan applications, they face more stringent capital requirements for these regular loans. Thus, it might be optimal for traditional banks to lend to shadow banks, which can propose cheaper contracts by exploiting the regulatory arbitrage. In fact, traditional and shadow banks compete to give funds by offering different market interest rates.

I associate the changes in the distribution of entrepreneurs' verification costs or project returns with the credit risk. This risk leads to a decrease in the volume of funded projects, a decrease in ABSs outstanding, and an increase in ABSs spread while it does not induce safe entrepreneurs to entirely dismiss shadow loans. On the other hand, I associate the increase in monitoring cost of shadow banks with the bank-centered financial crisis in 2007. In fact, a large increase in monitoring cost exacerbates financial frictions in the shadow banking sector and in turn, traditional loans displace shadow loans. However, the loss of credit left by shadow banks dominates the provision of credit by traditional banks, as long as the initial monitoring cost is sufficiently small. Thus, one of the key results is that traditional banks cannot fulfill the role of credit provision that shadow banks played before the banking crisis. In reality, this vacuum seems to be responsible for the slow recovery of restoring credit to a level consistent with that of the pre-crisis era. Thus, the policy implication suggests that the central bank's intervention must focus specifically on reinforcing the shadow banking sector. My results indicate that an aggressive (conventional or unconventional) monetary easing helps recover shadow loans unless the shadow funded credit is extremely information-sensitive.

Another novelty of this paper is that it explicitly identifies to what extent a monetary policy is useful to mitigate a bank-centered crisis. On one hand, (i) when financial frictions in the shadow banking sector are moderate, the central bank's purchases of ABSs induce credit to flee from traditional to shadow banking sectors, increase the size of funded projects, and diminish the ABSs spread. (ii) As the monitoring cost of shadow banks is sufficiently large, these purchases tip the balance in favor of shadow banks even though the size of funded projects with these purchases falls short of that without purchases. (iii) When the shadow funded credit is extremely information-sensitive, the central bank's unconventional monetary policy cannot even trigger shadow loans. On the other hand, my results indicate that lowering interest rates on reserves increases the lending capacity of shadow banks more than that of traditional banks, yet this increase is not sufficient to activate shadow loans in an economy with sufficiently large consolidated government debt. When the public liquidity is moderate, an aggressive monetary easing induces entrepreneurs to switch borrowing from traditional to shadow banks and increases the loan creation capacity more than what could be achieved by only traditional banks. In an economy with very scarce public liquidity, an accommodative monetary policy implies a larger increase in the loan creation capacity of shadow banks than that of traditional banks if the interest rate on reserves is sufficiently large. For low interest rates, cutting the rate generates a large increase in the lending capacity of traditional banks than that of shadow banks; however, this policy cannot force entrepreneurs out of shadow loans.

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Appendix

Proof of Proposition 3

Proof. Using (39), when $\kappa^* < \kappa_\theta^*$, the derivative of the incentive constraint is negative, or

$$\frac{dx_2}{dx_1} = \frac{-\rho(1-\alpha)u'(x_1)}{(1-\rho)(1-\alpha)u'(x_2) - \beta^2(1-\underline{\delta}_1)u''(x_2)\sigma(r^s)^2\left[\underline{\delta}_1 G\left(\frac{1-F(R_\theta^*)}{f(R_\theta^*)}\right) + \frac{(1-\underline{\delta}_1)u'(x_2)r^s}{(1-\theta)F(R_\theta^*)} g\left(\frac{1-F(R_\theta^*)}{f(R_\theta^*)}\right)\right]}, \tag{71}$$

where $R_\theta^* = T^{-1}(\frac{r^s}{1-\theta})$ and r^s satisfies (25). Using (47), and (71), and the assumptions 1 and 2, there exists a unique allocation $x_1 = x_2 = x^s$ with $x^s < \tilde{x}_\theta$ for $z^b = 1$. Using Proposition 1, each funded entrepreneur is financed by only shadow banks. Lastly, following from the proof of Proposition 2, $z^b = 1$ is optimal. ■

Proof of Proposition 4

Proof. Using (47), the assumptions 1 and 2, and Proposition 3, there exists a unique allocation at the ZLB with $\kappa^* < \kappa_\theta^*$. Using (39), the derivative of x_2 with respect to ε at the ZLB evaluated at $\varepsilon = 0$ is negative, or

$$\left.\frac{dx_2}{d\varepsilon}\right|_{\varepsilon=0} = \frac{-\frac{(1-\underline{\delta}_1)u'(x^s)\sigma g(\kappa_\theta^*)}{\underline{\delta}_1+(1-\underline{\delta}_1)u'(x^s)}}{(1-\alpha)u'(x^s) - \frac{(1-\underline{\delta}_1)\underline{\delta}_1 u''(x^s)\sigma G(\kappa_\theta^*)}{[\underline{\delta}_1+(1-\underline{\delta}_1)u'(x^s)]^2} - \frac{(1-\underline{\delta}_1)^2 u'(x^s)u''(x^s)\sigma g(\kappa_\theta^*)}{\beta(1-\theta)F(R_\theta^*)[\underline{\delta}_1+(1-\underline{\delta}_1)u'(x^s)]^3}},$$

where $x_1 = x_2 = x^s$ for $z^b = 1$. Using (10) and (12), the derivative of κ_θ^* with respect to ε at the ZLB evaluated at $\varepsilon = 0$ is positive, or

$$\left.\frac{d\kappa_\theta^*}{d\varepsilon}\right|_{\varepsilon=0} = \frac{(1-\underline{\delta}_1)u''(x^s)}{\beta(1-\theta)F(R_\theta^*)[\underline{\delta}_1+(1-\underline{\delta}_1)u'(x^s)]^2}\left.\frac{dx_2}{d\varepsilon}\right|_{\varepsilon=0} > 0.$$

Using (30) and (31), the derivatives of the ABSs outstanding and the ABSs spread, respectively, with respect to ε at the ZLB evaluated at $\varepsilon = 0$ are given by

$$\left.\frac{d(ql)}{d\varepsilon}\right|_{\varepsilon=0} = \sigma g(\kappa_\theta^*)\left[\left.\frac{d\kappa_\theta^*}{d\varepsilon}\right|_{\varepsilon=0} - 1\right] < 0,$$

$$\left.\frac{ds(x_2)}{d\varepsilon}\right|_{\varepsilon=0} = \frac{\underline{\delta}_1 u''(x^s)}{[\underline{\delta}_1+(1-\underline{\delta}_1)u'(x^s)]^2}\left.\frac{dx_2}{d\varepsilon}\right|_{\varepsilon=0} > 0. \tag{72}$$

■

Proof of Proposition 5

Proof. Using (47), the assumptions 1 and 2, and Proposition 3, $x_1 = x_2 = x^s$ at the ZLB with $\kappa^* < \kappa_\theta^*$. Using (39), I obtain

$$\left.\frac{dx_2}{d\varepsilon}\right|_{\varepsilon=0} = \frac{-\frac{(1-\underline{\delta}_1)u'(x^s)\sigma g(\kappa_\theta^*)}{F(R_\theta^*)[\underline{\delta}_1+(1-\underline{\delta}_1)u'(x^s)]}}{(1-\alpha)u'(x^s) - \frac{(1-\underline{\delta}_1)\underline{\delta}_1 u''(x^s)\sigma G(\kappa_\theta^*)}{[\underline{\delta}_1+(1-\underline{\delta}_1)u'(x^s)]^2} - \frac{(1-\underline{\delta}_1)^2 u'(x^s)u''(x^s)\sigma g(\kappa_\theta^*)}{\beta(1-\theta)F(R_\theta^*)[\underline{\delta}_1+(1-\underline{\delta}_1)u'(x^s)]^3}},$$

Using (10) and (12), I get

$$\left.\frac{d\kappa_\theta^*}{d\varepsilon}\right|_{\varepsilon=0} = \frac{[\underline{\delta}_1+(1-\underline{\delta}_1)u'(x^s)]}{(1-\underline{\delta}_1)u'(x^s)\sigma g(\kappa_\theta^*)}\left[(1-\alpha)u'(x^s) - \frac{(1-\underline{\delta}_1)\underline{\delta}_1 u''(x^s)\sigma G(\kappa_\theta^*)}{[\underline{\delta}_1+(1-\underline{\delta}_1)u'(x^s)]^2}\right]\left.\frac{dx_2}{d\varepsilon}\right|_{\varepsilon=0} < 0. \tag{73}$$

Using (30) and (31), I obtain

$$\left.\frac{d(ql)}{d\varepsilon}\right|_{\varepsilon=0} = \sigma g(\kappa_\theta^*)\left.\frac{d\kappa_\theta^*}{d\varepsilon}\right|_{\varepsilon=0} < 0, \tag{74}$$

and the derivative of the ABSs spread with respect to ε at the ZLB evaluated at $\varepsilon = 0$ satisfies (72). ∎

Proof of Proposition 6

Proof. Using (47), the assumptions 1 and 2, and Proposition 3, $x_1 = x_2 = x^s$ at the ZLB with $\kappa^* < \kappa_\theta^*$. Using (39), I get

$$\left.\frac{dx_2}{d\varepsilon}\right|_{\varepsilon=0} = \frac{-\frac{(1-\underline{\delta}_1)u'(x^s)\sigma g(\kappa_\theta^*)}{\beta(1-\theta)^2 F(R_\theta^*)[\underline{\delta}_1+(1-\underline{\delta}_1)u'(x^s)]^2}}{(1-\alpha)u'(x^s) - \frac{(1-\underline{\delta}_1)\underline{\delta}_1 u''(x^s)\sigma G(\kappa_\theta^*)}{[\underline{\delta}_1+(1-\underline{\delta}_1)u'(x^s)]^2} - \frac{(1-\underline{\delta}_1)^2 u'(x^s)u''(x^s)\sigma g(\kappa_\theta^*)}{\beta(1-\theta)F(R_\theta^*)[\underline{\delta}_1+(1-\underline{\delta}_1)u'(x^s)]^3}}.$$

Using (10) and (12), the derivative of κ_θ^* with respect to ε at the ZLB evaluated at $\varepsilon = 0$ satisfies (73). Using (30) and (31), the derivatives of ABSs outstanding and ABSs spread with respect to ε at the ZLB evaluated at $\varepsilon = 0$ are given by (72) and (74), respectively. ∎

Proof of Lemma 3

Proof. Using (51), $\phi'(\theta) < 0$ for all $\theta \in \big[0, \frac{\delta_2-\underline{\delta}_1}{1-\underline{\delta}_1}\big)$. Since (44) holds, $\phi(0) = x^* - (1-\underline{\delta}_1)G\big(\frac{1-F(T^{-1}(\beta^{-1}))}{f(T^{-1}(\beta^{-1}))}\big) > V$. Further, $\lim_{\theta \to \frac{\delta_2-\underline{\delta}_1}{1-\underline{\delta}_1}} \phi(\theta) = -\sigma G\big(f(0)^{-1}\big) \leq 0$. By using the IVT, there exists a unique $\breve{\theta} \in (0, \frac{\delta_2-\underline{\delta}_1}{1-\underline{\delta}_1})$ such that $\phi(\breve{\theta}) = V$. As $\theta < \breve{\theta}$, $\phi(\breve{\theta}) = V < \phi(\theta)$, that is, (47) holds. Using (47) and the assumptions 1 and 2, Proposition 3 implies that the ZLB exists and each funded entrepreneur chooses shadow loans at the ZLB. ∎

Proof of Lemma 4

Proof. Using (44), and the assumptions 1 and 2, there exists a unique $x_1 = x_2 = x^t \in (0, x^*)$ such that (52) holds. Using (51) and Lemma 3, $\phi(\theta^t) < V = \phi(\breve{\theta})$. Since $\phi'(\theta) < 0$ for all $\theta \in \left[0, \frac{\underline{\delta}_2 - \underline{\delta}_1}{1-\underline{\delta}_1}\right)$, $\breve{\theta} < \theta^t$. If $\breve{\theta} \leq \theta < \theta^t$, then neither (45) nor (47) holds and thus there exists no equilibrium at the ZLB. As $\theta^t \leq \theta$ holds, (45) satisfies and hence Proposition 2 implies that the ZLB exists and funded entrepreneurs choose traditional loans at the ZLB. ■

Proof of Proposition 7

Proof. Using (44), and the assumptions 1 and 2, Lemma 3 and Lemma 4 imply that if θ increases from $\theta = \theta_1 < \breve{\theta}$ to $\theta = \theta_2 \geq \theta^t$, then funded entrepreneurs—initially financed by shadow banks—will choose traditional loans at the ZLB. When $\theta = 0$, there exists a unique equilibrium $x_1 = x_2 = x_0^s$ at the ZLB. Given the marginal contract (R_0^*, κ_0^*) for $\theta = 0$ and $z^b = 1$, I obtain $\frac{dx_2}{d\underline{\delta}_1} < 0$ and

$$\frac{d\kappa_0^*}{d\underline{\delta}_1} = -\frac{\frac{(1-\alpha)(u'(x_0^s)-1)u'(x_0^s)}{\beta F(R_0^*)[\underline{\delta}_1+(1-\underline{\delta}_1)u'(x_0^s)]^2} - \frac{\alpha(1-\underline{\delta}_1)^2 u'(x_0^s)u''(x_0^s)u''(x_0^s)\sigma G(\kappa_0^*)}{\beta F(R_0^*)x_0^s[\underline{\delta}_1+(1-\underline{\delta}_1)u'(x_0^s)]^4}}{(1-\alpha)u'(x_0^s) - \frac{(1-\underline{\delta}_1)\underline{\delta}_1 u''(x_0^s)\sigma G(\kappa_0^*)}{[\underline{\delta}_1+(1-\underline{\delta}_1)u'(x_0^s)]^2} - \frac{(1-\underline{\delta}_1)^2 u''(x_0^s)u'(x_0^s)\sigma g(\kappa_0^*)}{\beta F(R_0^*)[\underline{\delta}_1+(1-\underline{\delta}_1)u'(x_0^s)]^3}}. \quad (75)$$

Thus, $x^t < x_0^s$ holds where x^t satisfies (52). Using (75), if α is sufficiently small, then $\frac{d\kappa_0^*}{d\underline{\delta}_1} < 0$ and hence I get

$$T(R_0^*) = \frac{1}{\beta[\underline{\delta}_1 + (1-\underline{\delta}_1)u'(x_0^s)]} < T(R^*) = \frac{1}{\beta[\underline{\delta}_2 + (1-\underline{\delta}_2)u'(x^t)]}. \quad (76)$$

Using Lemma 3, $x^t < \lim_{\theta \to \breve{\theta}} \tilde{x}_\theta$ and hence I obtain

$$\frac{1}{\beta[\underline{\delta}_2 + (1-\underline{\delta}_2)u'(x^t)]} < \lim_{\theta \to \breve{\theta}} T(R_\theta^*) = \frac{1}{\beta(1-\theta)[\underline{\delta}_1 + (1-\underline{\delta}_1)u'(\tilde{x}_\theta)]} = \frac{1}{\beta[\underline{\delta}_2 + (1-\underline{\delta}_2)u'(\tilde{x}_\theta)]}. \quad (77)$$

Using (76) and (77), $\kappa_0^* < \kappa^* < \lim_{\theta \to \breve{\theta}} \kappa_\theta^*$, where (R^*, κ^*) is the marginal contract with $x_1 = x_2 = x^t$ if $\kappa_\theta^* \leq \kappa^*$. Using Proposition 6, $\frac{d\kappa_\theta^*}{d\theta} < 0$. Thus, the IVT implies that there exists a unique $\theta^* \in (0, \breve{\theta})$ such that $\kappa^* = \lim_{\theta \to \theta^*} \kappa_\theta^*$. Thus, when $\theta = \theta_1 < \theta^*$, the loan origination capacity decreases from $\kappa_{\theta_1}^*$ to κ^* as θ increases from $\theta = \theta_1$ to $\theta = \theta_2$. ■

Proof of Corollary 1

Proof. Using Assumption 1, there exists a unique marginal contract $(R_\theta^{**}, \kappa_\theta^{**})$ in the shadow banking sector. If $\kappa_\theta^{**} = 0$, then the IVT will imply $T(\overline{\omega}) \leq T(R_\theta^{**}) = [\beta(1-\theta)u'(x_2)]^{-1}$. Thus, there exists $\theta' \in \mathbb{R}_+$ such that $\theta' \leq \theta$, where

$$\theta' = 1 - \frac{1}{\beta[\overline{\omega} - \int_0^{\overline{\omega}} F(\omega)d\omega]u'(x_2)}. \quad (78)$$

The rest follows from the proof of Lemma 2. ■

Proof of Proposition 8

Proof. Using (44) and (45), and the assumptions 1 and 2, Proposition 2 implies that the ZLB exists and traditional loans are preferred at the ZLB. Similarly, using (61), and the assumptions 1 and 2, when the central bank makes the optimal purchases, Proposition 3 implies that the ZLB exists and funded entrepreneurs choose the shadow funded credit at the ZLB. ■

Proof of Corollary 2

Proof. By replacing the function ϕ in (51) by π in (62), the proof follows from the proof of Lemma 3. ■

Proof of Corollary 3

Proof. By replacing the function ϕ in (51) by π in (62), the proof follows from the proof of Lemma 4. ■

Proof of Proposition 9

Proof. By replacing the function ϕ in (51) by π in (62), the proof follows from the proof of Proposition 7. ■

Proof of Lemma 5

Proof. Using (44), the assumptions 1 and 2, and $\omega \sim U(0, \overline{\omega})$, there exists a unique allocation (x_1, x_2) for any feasible $z^b = z \in [0, 1]$ such that (39) and (40) satisfy. Then I obtain

$$\left.\frac{d\kappa^*}{dz^b}\right|_{z^b=z} = \frac{\overline{\omega}^{0.5}(1-\underline{\delta}_2)u''(x_2)}{(2\beta)^{0.5}[\underline{\delta}_2 + (1-\underline{\delta}_2)u'(x_2)]^{1.5}} \left.\frac{dx_2}{dz^b}\right|_{z^b=z}, \tag{79}$$

$$\left.\frac{d\kappa^*_\theta}{dz^b}\right|_{z^b=z} = \frac{\overline{\omega}^{0.5}(1-\underline{\delta}_1)u''(x_2)}{[2\beta(1-\theta)]^{0.5}[\underline{\delta}_1 + (1-\underline{\delta}_1)u'(x_2)]^{1.5}} \left.\frac{dx_2}{dz^b}\right|_{z^b=z}. \tag{80}$$

Using (79) and (80), $\left.\frac{d\kappa^*}{dz^b}\right|_{z^b=z} < \left.\frac{d\kappa^*_\theta}{dz^b}\right|_{z^b=z}$ requires that there exists a unique $\theta^z \in \mathbb{R}$ such that $\theta^z < \theta$, where θ^z satisfies

$$\theta^z = 1 - \left(\frac{1-\underline{\delta}_1}{1-\underline{\delta}_2}\right)^2 \left(\frac{\underline{\delta}_2 + (1-\underline{\delta}_2)u'(x_2)}{\underline{\delta}_1 + (1-\underline{\delta}_1)u'(x_2)}\right)^3. \tag{81}$$

■

Proof of Proposition 10

Proof. Following from Proposition 2, by using (44), (45), and the assumptions 1 and 2, there is a unique allocation $x_1 = x_2 = x^t \in [\tilde{x}_\theta, x^*)$ that satisfies (39), (40) and $z^b = 1$. Using (44), (45), and the assumptions 1 and 2, I obtain $x_1 = 0$ and $x_2 \in (x^t, x^*)$ that satisfies (39), (40) and $z^b = 0$. Therefore, the IVT implies that $\forall z^b = z \in [0, 1]$ $\exists$ a unique allocation (x_1, x_2) that satisfies (39) and (40). Using (37) and (64), I get $\hat{x}_\theta < \tilde{x}_\theta$ and thus Lemma 5 implies that (63) holds for all $z^b = z \in [0, 1]$. ■

Proof of Proposition 11

Proof. Following from Proposition 3, by using (47), and the assumptions 1 and 2, there is a unique allocation $x_1 = x_2 = x^s \in (0, \tilde{x}_\theta)$ that satisfies (39), (40) and $z^b = 1$. Using (66) and (68), there exists a unique $\overline{z} \in (0, 1)$ such that $\forall z \in (\overline{z}, 1]$ $\exists$ a unique allocation (x_1, x_2) with $x_2 \in (0, \tilde{x}_\theta)$ that satisfies (39) and (40). Thus, Proposition 1 implies that funded entrepreneurs choose shadow loans $\forall z \in (\overline{z}, 1]$. Similarly, using (65) and (68), there exists a unique $\underline{z} \in (0, \overline{z})$ such that $\forall z \in [0, \underline{z}]$ $\exists$ a unique allocation (x_1, x_2) with $x_2 \in [\tilde{x}_\theta, x^*)$ that satisfies (39) and (40). Therefore, Proposition 1 implies that funded entrepreneurs choose traditional loans $\forall z \in [0, \underline{z}]$. The set of feasible monetary policy satisfies $Z_2 \equiv [0, \underline{z}] \cup (\overline{z}, 1]$. Finally, (67) implies that $\hat{x} < x^s$ and hence this requires that (63) holds $\forall z^b = z \in Z_2$. ■

Proof of Proposition 12

Proof. Following from Proposition 11, by using (69), and the assumptions 1 and 2, the feasible monetary policy is given by Z_2, where $\forall z^b = z \in Z_2$ $\exists$ a unique equilibrium allocation (x_1, x_2) that satisfies (39) and (40). In fact, $z^b = 1$ requires $x_1 = x_2 = x^s$ in equilibrium. Since $\hat{x}_\theta < \tilde{x}_\theta$, there exists a unique $\hat{z} \in (\overline{z}, 1]$ that satisfies $\hat{z} = u'(\hat{x}_\theta)[u'(\hat{x}_1)]^{-1}$, where $\hat{x}_1 \in (\overline{x}_1, x^s]$ satisfies

$$V = \rho \hat{x}_1 u'(\hat{x}_1) + (1-\rho)\hat{x}_\theta u'(\hat{x}_\theta) - \frac{(1-\underline{\delta}_1)u'(\hat{x}_\theta)\sigma}{\underline{\delta}_1 + (1-\underline{\delta}_1)u'(\hat{x}_\theta)} G\left(\frac{1 - F\big(T^{-1}\big([\beta(1-\theta)(\underline{\delta}_1 + (1-\underline{\delta}_1)u'(\hat{x}_\theta))]^{-1}\big)\big)}{f\big(T^{-1}\big([\beta(1-\theta)(\underline{\delta}_1 + (1-\underline{\delta}_1)u'(\hat{x}_\theta))]^{-1}\big)\big)}\right). \tag{82}$$

Using (82), $\forall z^b = z \in Z_2 \cap [0, \hat{z})$, $\exists$ a unique equilibrium allocation (x_1, x_2) with satisfying $x_2 \in (\hat{x}_\theta, x^*)$. Thus, Lemma 5 requires that (63) holds $\forall z^b = z \in Z_2 \cap [0, \hat{z})$. On the other hand, $\forall z^b = z \in [\hat{z}, 1]$ $\exists$ a unique allocation (x_1, x_2) with $x_2 \leq \hat{x}_\theta$ and hence Lemma 5 implies that (70) holds. ■