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How Should Governments Create Liquidity?

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Abstract

Safe assets (liquidity) can be created by an economy's private banking system and also by its government. Our model shows that some banks create liquidity with low debt and efficient loan monitoring while other banks use high, tranched debt and inefficient loan monitoring. Government liquidity can also differ, either by the government directly issuing debt or by insuring bank deposits. Directly issued government debt allows for greater private liquidity, more efficient bank lending, and greater welfare for savers. Government insurance of bank deposits crowds out private liquidity but leads to greater bank lending and profits.

Keywords: Liquidity creation, Government debt, Deposit insurance

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1. Introduction

Risk-averse investors value safe, default-free assets for the certainty of their returns, but the easy-to-value quality of these assets also makes them liquid in transactions. The money-like nature of safe assets provides a liquidity premium that lowers investors' required return. Importantly, the quantity of an economy's safe assets or 'liquidity' is not exogenous. Safe assets can be created by private financial intermediaries (e.g., Gorton and Pennacchi (1990)) and also by a government (e.g., Krishnamurthy and Vissing-Jorgensen (2012)).

This paper studies the relationships between private liquidity created by a banking system and public liquidity created by a government. It models various ways that safe, liquid assets can be produced by banks and a government and shows how these different ways effect the financial system. In particular, the paper finds that the specific method chosen by a government to create liquidity will change the amount of private liquidity created by banks, the amount and efficiency of bank lending, and also the welfare of individuals in the economy.

Our model first shows that banks provide liquidity in different ways. Some banks will choose to create safe, liquid deposits by limiting their leverage and efficiently monitoring their assets (loans) to preserve asset recovery values in bad states of the world. Other banks will choose to create safe deposits by issuing risky junior debt to increase the assets that back liquid senior deposits. With this more levered senior-junior debt structure, bank equityholders have less 'skin in the game' and fail to monitor assets efficiently.

We also model the different methods that a government creates safe assets. One is by directly issuing its own debt, such as Treasury securities, to the public. These securities may be held directly by individuals or held by a 'narrow bank,' such as a Treasury-only money market fund, to back individuals' safe deposit accounts. A second indirect way is for the government to insure private debt, with the premier example being government insurance of bank deposits. For either method, the government's supply of safe assets is limited by its capacity to raise future taxes that cover its liabilities.

Our results show that a government's choice of direct liquidity versus indirect liquidity has major economic consequences. Directly-issued government debt allows for greater private liquidity, more efficient bank lending, and greater welfare for the economy's savers. This direct public liquidity has minimal effects on the private banking system but provides savers more safe assets which raise their welfare as long as the safe asset liquidity premium exceeds any direct costs of taxation needed to finance the government's debt.

In contrast, indirect government liquidity in the form of deposit insurance crowds out private liquidity because insured deposits displace many safe bank deposits that would have been privately created in the absence of insurance. Relative to direct liquidity, the smaller quantity of safe assets reduces saver welfare. A counter effect is that insured deposits' greater liquidity premium reduces banks' cost of funding, thereby raising their profits and expanding lending. However, average lending efficiency is worse when deposit insurance coverage is sufficiently generous.

Our paper contributes to a literature on the private and public provision of safe assets.[3] Prior research, including Gorton and Pennacchi (1990) and Dang et al. (2017), notes that safe assets are especially valuable for making transactions due to their information-insensitivity. Safe assets' 'money-like' liquidity premium is empirically documented by several studies including Krishnamurthy and Vissing-Jorgensen (2012), Sunderam (2015), Nagel (2016), and Perignon et al. (2017).

Research shows that safe assets can be created privately by levered financial intermediaries that invest in risky assets and issue limited amounts of safe debt. Examples include deposit-issuing banks (e.g., Diamond (2019) and Ahnert and Perotti (2018)) and special purpose vehicles that issue senior and junior tranched securities (e.g., DeMarzo and Duffie (1999) and DeMarzo (2005)). Related to this research, we find that banks with relatively low costs of monitoring loans choose to create safe deposits using low leverage that incentivizes efficient monitoring. Other banks with relatively high monitoring costs create safe senior deposits using high leverage that includes risky junior debt. This finding contrasts with DeAngelo and Stulz (2015) who argue that high leverage is optimal for banks that create liquidity. Our point is that in some cases low leverage is best to create liquidity, and while in other cases high leverage is used, not all of this high leverage is liquid.

Most research that analyzes the co-existence of private and public liquidity concentrates on issues of financial stability. Holmström and Tirole (1998) study an economy where firms

[3] See Gorton (2017) for an in-depth review of this literature.

experience uncertain needs for future financing and show that a government with taxing power can improve welfare by issuing state contingent bonds that help meet these needs. Similarly, Bolton et al. (2009) examine ways that a government can improve on investment efficiency by intervening to support trade in different maturity investment projects. More closely related to our model is Stein (2012) whereby banks raise funds from savers who especially value safe assets. A bank can lower its cost of funding by issuing safe short-term deposits but the consequence is potential asset firesales needed to repay these deposits. Government intervention in the form of central bank reserve requirements can limit short-term deposits and mitigate the negative externality of firesales.

Our model also assumes that banks have an incentive to issue safe deposits in order to reduce their cost of funding, but our analysis differs. First, our banks are special not only by creating safe liquid deposits but also, like Diamond (1984), by monitoring to improve loan returns. These two functions interact to determine how much liquidity and loans that banks supply. Second, we study the economic effects of the two major ways that governments supply liquidity: direct issuance of debt and deposit insurance. The former is the focus of most prior work, but the effects of deposit insurance on liquidity has received little attention.[4] We focus on financial system architecture by examining how a government's choice of liquidity affects private liquidity, bank lending and lending efficiency, and economic welfare.

The next section introduces our basic model and considers a fully-private banking system that serves as a benchmark for studying different choices of public liquidity creation. Section 3 considers a banking system where the government directly issues debt while Section 4 examines a banking system with indirect government liquidity via deposit insurance. Section 5 compares the economic consequences of the polar cases of a government only directly issuing debt versus only insuring deposits, while Section 6 considers a more realistic hybrid environment where a government does both types of liquidity creation simultaneously. Section 7 briefly discusses the robustness of our model, and Section 8 concludes.

[4] Ahnert and Perotti (2018) is one of the few papers that examine how government liquidity creation via directly issued debt or deposit insurance affects the provision of private liquidity. However, their model differs because, in equilibrium, both private and public liquidity are perfect substitutes, whereas they differ in our model. Their model focuses on deriving the equilibrium return on safe assets.

2. Liquidity in a Fully-Private Banking System

Prior to examining how various forms of government liquidity creation affect the financial system, it is important to understand how fully-private intermediaries create liquidity. Therefore, this section analyzes a private banking system with no government intervention.

2.1. Basic Model Assumptions

Consider a single-period economy with agents that are located across a continuum of separate local markets and who obtain utility from end-of-period consumption. These agents receive initial endowments that can be invested to produce the end-of-period consumption good. There are two investment technologies whose returns are subject to only aggregate (macroeconomic) risk.[5] Investment returns are determined by the realization of one of three end-of-period states. A 'good' state occurs with probability p_g, a 'bad' state occurs with probability p_b, and a 'catastrophe' state occurs with probability $p_c = 1 - p_g - p_b$.

One investment technology is a non-intermediated risky investment that is available to all agents and is in perfectly elastic supply. A unit investment returns $R_r/p_g > 0$ only in the good state and 0 in the bad and catastrophe states, implying that this technology's expected return is R_r. The other superior investment technology can be accessed only through lending intermediaries called 'banks.' One type of agent, a 'banker,' is capable of owning and managing a bank. The other type of agent, a 'saver,' has initial endowment to invest and especially values safe assets due to their money-like 'liquidity' services.

Each local market has a single risk-neutral banker who receives an initial endowment of k that can be invested in the bank. The bank can raise additional funds from the savers in its local market in the form of standard, non-state-contingent debt contracts.[6] Bank debt, which we refer to as 'deposits,' can differ by seniority, allowing banks to issue both senior and junior (subordinated) deposits. Each market has a continuum of 'small' savers whose

[5]We focus on macroeconomic risk because idiosyncratic risks might be diversified away through pooling as in Diamond (1984).

[6]Later, footnote 11 discusses savers investing in bank equity. In richer models where savers cannot verify the return on bank assets, debt may be preferred to equity (Townsend (1979)). Also, the restriction that banks issue debt only to local savers may be justified by information asymmetries across markets since we will assume savers know their local bank's leverage and monitoring cost, information that may be unknown to non-local agents and deter inter-market debt. Appendix C.4 considers inter-market debt.

total initial endowment equals 1. Savers also receive end-of-period wage income of ω that cannot be pledged or traded. Let $\gamma \leq 1$ denote the total amount of deposits issued by a local market's bank. Thus, a bank's beginning-of-period assets equal $(\gamma + k) \leq (1 + k)$.[7]

Banks are special due to their superior lending technology that funds identical projects in perfectly elastic supply. In the good state, each loan's end-of-period return per unit lent equals its promised return of $R_l > R_r/p_g$. In the bad state, loans default but have a strictly positive recovery value. In the catastrophe state, loans default with zero recovery value.

The banker is able to improve each loan's recovery value in the bad state by exerting costly, beginning-of-period effort to monitor the borrower.[8] Importantly, this effort, denoted by e, is not directly observable by the public nor is it contractible or verifiable by a court. Let $e \in \{0, 1\}$ be the banker's choice of monitoring effort. If $e = 1$, the bad state recovery value is d_1; otherwise, the bad state recovery value is d_0, where $0 < d_0 < d_1 < 1$.[9]

Monitoring effort diminishes a banker's utility at a fixed marginal cost. To generate an elastic supply of effort, liquidity, and lending, the cost of monitoring is assumed to differ across banks. Let banker i's cost of monitoring effort per unit loan be $c_i \in [\underline{c}, \bar{c}]$ where $f(c)$ is the continuous density of banks at cost level c in this interval. Assume that $\bar{c} \leq p_b [d_1 - d_0]$ so that even the highest cost bank would benefit from monitoring if it were contractible.

Savers derive utility from their expected end-of-period consumption but also obtain utility from holding 'money-like' safe assets or liquidity. This assumption is akin to the Sidrauski (1967) 'money-in-the-utility function,' and we follow Stein (2012) and Krishnamurthy and Vissing-Jorgensen (2012) who generalize this specification to safe assets. It is a reduced-form way of modeling safe asset liquidity services based on a richer model such as Gorton and Pennacchi (1990): safe assets' information-insensitivity makes them attractive transactions medium because trading losses to better-informed agents are avoided. Specifically, we assume

[7]As will become clear, due to the bank's superior investment technology, the banker has the incentive to invest the entire endowment k as bank equity.

[8]Rather than 'monitoring,' banker effort could be considered 'credit screening' that finds loan applicants whose projects have higher recovery value.

[9]Alternatively, the binary effort choice could be two strictly positive values where the lesser is a base level of verifiable and contractible effort. This would better-justify our assumption that $R_l > R_r/p_g$ and $d_0 > 0$. Also, Appendix C.1 allows effort to be a continuous choice. These alternative specifications for effort produce nearly identical results.

the representative saver's utility is

$$U = E\left[C\right] + \lambda_q m_q + \lambda_f m_f, \tag{1}$$

where $E[C]$ is the saver's expected end-of-period consumption, m_q is the saver's initial holdings of 'quasi-safe' assets, and m_f is the saver's initial holdings of 'fully-safe' assets. The constants λ_q and λ_f represent the utility bonuses or 'liquidity premia' from holding quasi-safe and fully-safe assets, respectively, where $0 < \lambda_q < \lambda_f$.

Quasi-safe assets are defined as paying their promised return in the good and bad states, but not the catastrophe state, making their probability of not defaulting $\wp \equiv p_g + p_b$. Let R_q be these assets' expected return, so if they have zero recovery value in the catastrophe state then their promised return is $R_q/\wp$. Examples include money market instruments such as A1/P1-rated commercial paper and wholesale, uninsured bank certificates of deposit.[10] In contrast, fully-safe assets pay their promised return, denoted as R_f, in all three states. While a fully-private banking system cannot produce fully-safe assets, we later consider how a government can do so because of its special power to tax non-pledgeable wage income. Examples of fully-safe assets include Treasury securities and government-insured deposits.

Since each local market has a single banker but a continuum of competitive local savers, all surplus from issuing deposits accrues to the banker in the form of bank profits. Savers' access to the risky technology, which has an expected return of R_r, determines their reservation utility. Consequently, the utility function (1) implies that a saver is indifferent between holding risky, quasi-safe, and fully-safe assets when $R_r = R_q + \lambda_q = R_f + \lambda_f$, so that $R_r > R_q > R_f$. This implication is consistent with empirical findings that liquidity premia lower required returns on quasi-safe private debt (Sunderam (2015), Perignon et al. (2017)) and fully-safe public debt (Krishnamurthy and Vissing-Jorgensen (2012), Nagel (2016)).

2.2. A Bank's Capital Structure Decision

A bank has an incentive to issue safe deposits because their liquidity premium lowers savers' required return and the bank's cost of funding. Since loans return zero in the catastrophe

[10] These assets might be considered a 'near-money' or 'shadow money' (Moreira and Savov (2017)).

state, a private bank can, at best, issue quasi-safe deposits that reduces its funding cost by λ_q. There are two potential ways to maximize quasi-safe deposits. One is to improve the recovery value of loans in the bad state by monitoring. But for depositors to believe that monitoring will occur, the bank must have an incentive to exert unobserved monitoring effort by restricting its leverage such that it receives the marginal benefit from its costly effort.

The second way that a bank can increase its quasi-safe deposits is by 'tranching' its debt by issuing both senior deposits and junior (subordinated) deposits. Designed appropriately, senior deposits can be made quasi-safe due to the additional assets funded by junior deposits. To see this, let R_s be the promised return on senior deposits and let the amount of these deposits, γ^s, be such that the bank has sufficient loan recovery value in the bad default state to pay them in full. If the amount of junior deposits is γ^j, then for a given bad state recovery value, d_e, where $e \in \{0, 1\}$, the amount of quasi-safe senior deposits satisfies:

$$(\gamma^s + \gamma^j + k)d_e \geq \gamma^s R_s = \gamma^s R_q/\wp, \tag{2}$$

where the equality in condition (2) follows because the required promised return on quasi-safe deposits is $R_q/\wp$. Equivalently, this condition holds when senior deposits are below a critical value, $\bar{\gamma}^s$, which is increasing in effort, e, and other forms of bank funding, $\gamma^j + k$:

$$\gamma^s \leq \bar{\gamma}^s \equiv \frac{(\gamma^j + k)d_e}{R_q/\wp - d_e}. \tag{3}$$

Due to their superior lending technology, bankers will always choose to invest their entire endowment, k, as their bank's equity capital. However, bankers' profit-maximizing choices of leverage and effort may result in savers' junior deposits being either quasi-safe or default-risky. We next consider the possible equilibrium behavior of bankers and savers.

2.3. Equilibrium

An *equilibrium* is defined as follows. First, a bank(er) announces that it will issue γ^s in senior deposits and γ^j in junior deposits where $\gamma \equiv \gamma^s + \gamma^j \leq 1$, so that its total assets equal $\gamma^s + \gamma^j + k$. Second, the promised returns on these senior and junior deposits, R_s and R_j, respectively, are set. Third, the bank chooses its unobserved effort level, e. An equilibrium are values of γ^s, γ^j, and e that maximize the bank's profits and promised deposit returns R_s and R_j that satisfy senior and junior depositors' participation constraints given the bank's choices of γ^s, γ^j, and e.

To solve for possible equilibria, note that since bank i has monitoring cost c_i, its profit maximization problem can be written as:

$$\max_{\gamma^j,\gamma^s,e} \quad p_g\left[(\gamma+k)R_l - \gamma^s R_s - \gamma^j R_j\right] + p_b \max\left[(\gamma+k)d_e - \gamma^s R_s - \gamma^j R_j, 0\right] - c_i e(\gamma+k), \tag{4}$$

subject to the following three constraints. First, its total deposits cannot exceed 1:

$$\gamma^s + \gamma^j \leq 1. \tag{5}$$

Second, condition (2) is satisfied so that senior deposits are quasi-safe: $R_s = R_q/\wp$. Third, junior depositors' participation constraint is satisfied:

$$R_j \geq \begin{cases} \frac{R_r - \frac{p_b}{\gamma^j}\left[(\gamma^s+\gamma^j+k)d_{e*} - \gamma^s R_q/\wp\right]}{p_g} & \text{if } (\gamma^s+\gamma^j+k)d_{e^*} - \gamma^s R_q/\wp < \gamma^j R_q/\wp, \\ R_q/\wp & \text{otherwise.} \end{cases} \tag{6}$$

Note that the expected profits given in (4) reflect the possibility of default in the bad state but the certainty of default in the catastrophe state due to loans' zero recovery value. Also, the junior depositors' participation constraint (6) reflects either default in the bad state (the first line on the right-hand side) or no default in the bad state (the second line on the right-hand side). In the former case, junior depositors' required expected return is R_r, but in the latter case it is R_q since junior deposits are quasi-safe.

2.4. Deposits and Profits if a Bank Monitors

To solve this problem, first consider a bank's deposit choice and expected profits if it chooses to monitor its loans; that is, $e = 1$. Given condition (2), a necessary condition for a bank to choose costly monitoring is that bank equity receives a positive return in the bad state:

$$(\gamma^s + \gamma^j + k)d_1 - \gamma^s R_q/\wp - \gamma^j R_j|_{d_{e^*}=d_1} > 0. \tag{7}$$

If this condition holds, junior deposits would be quasi-safe and no different from senior deposits. Consequently, a bank that monitors does not benefit from issuing more than one class of deposits, so with no loss of generality we can set $\gamma^j = 0$ and $\gamma^s = \gamma$.

However, a sufficient condition for bank i to choose monitoring requires that the present value of its equity's bad-state return in (7), $p_b[(\gamma + k)d_1 - \gamma R_q/\wp]$, exceed its cost of monitoring, $c_i(\gamma + k)$. Equivalently, this sufficient condition requires that total deposits, γ, not exceed

$$\gamma_1(c_i) \equiv k \frac{p_b d_1 - c_i}{p_b R_q/\wp - (p_b d_1 - c_i)}. \tag{8}$$

Moreover, since quasi-safe deposits are the low-cost source of funding, a profit-maximizing bank that monitors would choose this maximum deposit level, resulting in profits of

$$\pi_1(c_i) = (\gamma_1(c_i) + k)\,[p_g R_l + p_b d_1 - c_i] - \gamma_1(c_i) R_q. \tag{9}$$

Note that since $\gamma_1(c_i)$ is a decreasing function of c_i, so is $\pi_1(c_i)$.

2.5. Deposits and Profits if a Bank Does Not Monitor

If inequality (7) does not hold, a bank lacks the incentive to monitor, implying that junior deposits are default-risky and require an expected return of R_r. Since senior deposits are quasi-safe and require an expected return of $R_q < R_r$, the bank has the incentive to issue the maximum level of quasi-safe senior deposits, equal to $\gamma^s = \bar{\gamma}^s|_{d_{e^*}=d_0} \equiv \bar{\gamma}^s_0$. An implication is that junior deposits are paid 0 in the bad state and their promised return is R_r/p_g.[11] Denoting the no-monitoring bank's expected profits as π_0, we have

$$\pi_0 = p_g\left[(\gamma^j + \bar{\gamma}^s_0 + k)R_l - \bar{\gamma}^s_0 R_q/\wp - \gamma^j R_r/p_g\right]. \tag{10}$$

Given that the promised payment on the loan exceeds the promised payments on deposits, equation (10) is strictly increasing in γ^j, implying that the maximum is at the corner solution

[11] The fact that in equilibrium junior deposits receive nothing in the bad state makes their payoff similar that of the banker's inside equity, k. In this sense, junior deposits might be considered similar to outside equity. However, the effort incentive of the banker depends his/her inside equity, so issuing more junior deposits is not equivalent to the banker increasing inside equity.

$\gamma^j = 1 - \bar{\gamma}_0^s$.[12] Thus, this no-monitoring effort bank chooses maximum total leverage, $\gamma = \gamma^j + \gamma^s = 1$, where quasi-safe senior deposits are maximized at

$$\gamma_0^s = \frac{(1 - \bar{\gamma}_0^s + k)d_0}{R_q/\wp - d_0} = \frac{(1+k)d_0}{R_q/\wp}. \tag{11}$$

Therefore, this no-monitoring effort bank's maximum expected profits equals

$$\pi_0 = (1+k)[p_g R_l + p_b d_0] - (1 - \gamma_0^s)R_r - \gamma_0^s R_q. \tag{12}$$

2.6. Cost Threshold for Monitoring

Note that equation (9) indicates that π_1 is declining in c_i while equation (12) indicates that π_0 is independent of a bank's monitoring cost. Assuming that

$$\pi_1(\bar{c}) < \pi_0 < \pi_1(\underline{c}), \tag{13}$$

then there exists a unique threshold value c^* such that $\pi_0 = \pi_1(c^*)$, given by

$$c^* = p_b \left[d_1 - \frac{\pi_0/k - p_g R_l}{\pi_0/k - p_g R_q/\wp} R_q/\wp \right]. \tag{14}$$

The next proposition summarizes these results on equilibrium in a fully-private banking system.

Proposition 1. *If bank i's cost of monitoring is $c_i < c^*$, it issues only quasi-safe senior deposits equal to $\gamma_1(c_i)$, monitors its loans, and has expected profits equal to π_1 in equation* (9)*. Instead, if its cost is $c_i > c^*$, it issues quasi-safe senior deposits of γ_0^s in equation* (11)*, issues default-risky junior deposits of $1 - \gamma_0^s$ with promised payment R_r/p_g, does not monitor its loans, and has expected profits equal to π_0 given in equation* (12)*.*

Thus, while all banks lower their funding costs by creating quasi-safe deposits, they do so in very different ways. Banks with low monitoring costs choose low leverage and efficient

[12] Specifically, $\partial\pi_0/\partial\gamma^j$ is positive when the bank's interest rate margin $[R_l - R_r/p_g]\left(\gamma^j + k\right) + [R_l - R_q/\wp]\,\bar{\gamma}_0^s > 0$, which we assume holds.

monitoring while banks with high costs choose maximum leverage, do not monitor, and tranche their deposits. Obviously the low-cost banks earn higher profits due to the value they create by monitoring. But high-cost banks create quasi-safe assets via a type of financial engineering that has grown rapidly in recent decades, namely, securitization. Securitization vehicles hold loans as assets and issue various tranches of senior, subordinated, and equity securities. They embody our model's highly-levered private bank that fails to monitor efficiently. Indeed, a large body of research, including Keys et al. (2010) and Purnanandam (2011), finds a lack of efficient credit screening/monitoring and greater loan losses when loans are held by securitization vehicles.

Proposition 1 also addresses the question of whether banks will optimally choose high leverage if the deposits that they issue are liquid. DeAngelo and Stulz (2015) argue that banks will be highly levered, but our answer to this question is more nuanced. For deposits to be liquid, they must be safe. Some (low-cost) banks will optimally create safe deposits with low leverage and efficient monitoring that improves their loan returns. For other (high-cost) banks, high leverage is optimal. But in this case only part of their leverage (senior deposits) is safe and liquid while the other part of leverage (junior deposits) is risky and illiquid.[13]

We close this section by computing the aggregate utility of the banking system, which will be a welfare benchmark for comparing banking systems with government-provided liquidity.

2.7. Utility of Savers and Bankers

A saver's expected end-of-period consumption equals wage income, ω, plus investment returns. Investments include quasi-safe deposits, default-risky deposits, and, in markets where $\gamma < 1$, direct investments in the risky technology. The expected return on quasi-safe deposits is R_q while the expected return on default-risky deposits and the risky technology is R_r. However, due to the utility bonus from quasi-safe assets of $\lambda_q \equiv R_r - R_q$, the expected utility for all investments is R_r. Hence, each saver's expected utility for all local markets is

$$U = \omega + R_r, \tag{15}$$

[13]Berger and Bouwman (2009) empirically measure the relationship between bank liquidity creation and leverage. Consistent with our model, they find a mixed relationship that tends to be positive for small banks but negative for large banks.

which reflects our assumption that the continuum of consumers act competitively and all surplus is captured by each market's monopoly banker. In particular, the average expected utility of these risk-neutral bankers, U_b, equals average bank profits:

$$U_b = \int_{\underline{c}}^{c^*} \pi_1(c_i) f(c_i) dc_i + \pi_0 \int_{c^*}^{\bar{c}} f(c_i) dc_i. \tag{16}$$

Equations (15) and (16) are the benchmarks for welfare in a fully-private banking system.

3. Direct Government Liquidity

A government differs from private creditors due to its taxing authority, which is a channel for potentially improving welfare. This section considers how a government can create liquidity by directly issuing debt backed by future tax revenue.

3.1. Direct Government Liquidity Assumptions

The government is assumed to have the power to tax up to a proportion $\bar{t} < 1$ of each saver's end-of-period non-pledgeable wage, ω, but taxing is costly in that savers incur direct costs of paying taxes that diminish their utility by a proportion η of the amount collected.

Now suppose that at the beginning of the period the government issues Treasury securities. Since end-of-period tax revenue is available in all states, limited amounts of these securities can be fully safe so that savers require a return of R_f per unit investment.[14] Treasury securities could be sold directly to savers or to 'narrow banks' that use them to back liquid deposit-like accounts held by savers. Such narrow banks could operate exactly as do today's 'Treasury-only' money market mutual funds. Alternatively, they could operate as the proposed narrow banks that would own government debt and issue interest-paying central bank digital currency (CBDC) deposits.[15]

The government is assumed to sell Treasury securities uniformly across the local markets.

[14] Our model assumes a homogeneous class of government debt while, in reality, government debt varies in maturity. Longer-maturity government debt may be subject to short-run interest rate risk. Infante (2020) analyzes how repurchase agreements backed by long-term Treasuries can substitute for short-term Treasuries, such as Treasury bills, to meet the demand for liquid, money-like assets.

[15] Bank for International Settlements (2018), Norges Bank (2018), and Brunnermeier and Niepelt (2019).

The maximum amount sold per market, γ^d, is limited by the government's tax revenue:

$$\gamma^d = \frac{\bar{t}\omega}{R_f}, \tag{17}$$

where $\bar{t}\omega < R_f$ is assumed, so that $\gamma^d < 1$. For example, if each market has a narrow bank, γ^d is the maximum fully-safe deposits issued per narrow bank to savers.

Since each market continues to have a banker with a superior lending technology, 'broad' banks that make loans continue to operate similar to the private banks of our model of Section 2. Importantly, the savings available to these broad banks depends on how the government uses its revenue from selling Treasury securities. It is assumed that the government instantly rebates its revenue from Treasury sales, γ^d, back to savers as a lump sum at the beginning of the period. Such a debt-financed rebate does not change the savings available to each broad bank, which remains at 1.[16] It only increases savers' holdings of liquid public debt.

3.2. Equilibrium and Utility with Direct Liquidity

Since the government's proceeds from Treasury sales are instantly rebated to savers as a lump-sum transfer, the constraint on deposits raised by broad banks remains at $\gamma \leq 1$. Therefore, *the behavior of broad banks is exactly the same as banks in the fully-private system analyzed in Section 2*, resulting in bank profits under direct liquidity $U_b^{DL} = U_b$.

Relative to the fully-private system, savers now possess additional fully-safe (narrow bank) deposits that raise utility by $\gamma^d R_r$. However, they also incur end-of-period tax costs of $(1+\eta)\gamma^d R_f$ in all states. Consequently, savers' utility under direct liquidity equals

$$U^{DL} = U + \gamma^d R_r - (1+\eta)\gamma^d R_f = U + \gamma^d \left[\lambda_f - \eta R_f\right]. \tag{18}$$

The following proposition summarizes this section's results.

[16] This would be comparable to a debt-financed tax cut or credit. Alternative uses of Treasury proceeds are that the government invests them in the risky investment technology (Appendix C.2) or offers to deposit them in broad banks (Appendix C.3). We focus on a debt-financed rebate because it leaves all investment decisions to private agents and isolates the pure effects of the government's direct provision of liquidity. However, the two alternatives have many qualitatively similar implications to the case studied in this section.

Proposition 2. *A system where the government directly issues debt leads to: 1) broad bank behavior that is identical to that of a fully-private system; 2) total utility that exceeds that of a fully-private system if* $\lambda_f > \eta R_f$.

Thus, our main finding is that direct issuance of public debt can have no impact on the operations of a fully-private banking system but increases welfare if the debt's fully-safe liquidity premium exceeds the direct costs of taxes needed to finance that debt.

4. Indirect Government Liquidity

As an alternative to directly issuing public debt, this section considers indirect public liquidity creation via government deposit insurance.

4.1. Deposit Insurance Assumptions

Consider a government that offers fairly-priced deposit insurance backed by its end-of-period revenue from taxing savers' wage income.[17] To make deposits fully safe, the government must limit insurance such that it has sufficient tax capacity to cover losses in the worst-case catastrophe state when bank assets are worthless. Specifically, assume insurance is limited to small 'retail' deposits, equal to a proportion γ^r of total savings in each banking market.

The government assesses a fair premium payable by each bank at the end of the period, equal to ϕ per promised payment on insured deposits.[18] Thus, if a bank issues the maximum amount of insured deposits, its promised payment to insured depositors and the deposit insurer is $\gamma^r R_f(1+\phi)$, where ϕ varies based on each bank's default risk.[19] However, a bank might issue less than γ^r of insured deposits, and its behavior will qualitatively differ depending on whether its monitoring cost, c_i, is low, moderate, or high. Let us first take the deposit insurance limit of γ^r as given and analyze each type of bank's profit-maximizing choice of insured deposits. Then by aggregating over all banks' insured deposits, one can determine the maximum level of γ^r that is supported by the government's taxing power.

[17]Because our intent is to study the novel effects of government liquidity via deposit insurance, we ignore the well-known distortions due to insurance typically being subsidized in practice. See Pennacchi (2010).

[18]This promised payment makes ϕ analogous to a credit spread on uninsured debt. The government makes a lump sum payment to savers in states where aggregate premiums exceed aggregate insurance losses.

[19]As in practice, the insurer is assumed to have the same seniority (bankruptcy claimant status) as senior uninsured depositors and receives the proportion $\gamma^r/(\gamma^r+\gamma^s)$ of any asset recovery value.

4.2. Deposits and Profits if a Bank Monitors

As in a fully-private system, a deposit-insured bank with a small cost of monitoring may choose to restrict its total leverage in order to have the incentive to monitor. Banks whose restricted leverage exceeds the maximum of insured deposits, γ^r, are designated as 'low-cost' banks and denoted with the subscript L. When charged a fair insurance premium, these banks choose to issue the maximum γ^r of insured deposits having funding cost R_f with the remaining $\gamma - \gamma^r$ of quasi-safe, uninsured deposits having funding cost of R_q. Relative to a fully-private system, the lower-cost insured deposits raise the maximum leverage that preserves the bank's incentive to monitor. Appendix A.1 shows that low-cost bank i's fair insurance premium equals $\phi_1 = p_c/(1-p_c)$, and it chooses total deposits equal to

$$\gamma_{1,L}^{DI}(c_i) = \gamma_1(c_i) + \gamma^r \left(R_q - R_f\right) \frac{p_b/\wp}{p_b R_q/\wp - [p_b d_1 - c_i]} > \gamma_1(c_i). \tag{19}$$

This low-cost bank's expected profits are

$$\pi_{1,L}^{DI}(c_i) = (\gamma_{1,L}^{DI} + k)[p_g R_l + p_b d_1 - c_i] - \gamma_{1,L}^{DI} R_q + \gamma^r(\lambda_f - \lambda_q) > \pi_1(c_i), \tag{20}$$

which exceed its expected profits in the absence of deposit insurance. Profits are higher because insured deposits' funding cost is lower due to their higher fully-safe liquidity premium.

Other banks with somewhat greater monitoring costs need to further restrict their leverage to $\gamma \leq \gamma^r$ in order to have an incentive to monitor. This type of deposit-insured bank is referred to as 'moderate-cost' and denoted with subscript M. With fairly-priced insurance premium ϕ_1, these banks have an incentive to issue only insured deposits due to their least funding cost of R_f. Similar to low-cost banks, moderate-cost banks' maximum leverage that preserves their incentive to monitor is higher compared to that for the case of no deposit insurance. Appendix A.2 shows that this maximum leverage for moderate-cost bank i equals

$$\gamma_{1,M}^{DI}(c_i) = k \frac{p_b d_1 - c_i}{p_b R_f/\wp - (p_b d_1 - c_i)} > \gamma_1(c_i), \tag{21}$$

which takes the same form as γ_1 in equation (8) except that the smaller value R_f replaces

R_q in the denominator. Given this higher leverage, profits for these moderate-cost banks are

$$\pi_{1,M}^{DI}(c_i) = (\gamma_{1,M}^{DI} + k)[p_g R_l + p_b d_1 - c_i] - \gamma_{1,M}^{DI} R_f > \pi_1(c_i), \tag{22}$$

which is, of course, greater than profits in the fully-private, no-insurance case.

4.3. Deposits and Profits if a Bank Does Not Monitor

Recall that in the absence of deposit insurance, banks with relatively high monitoring costs choose not to monitor ($e = 0$), use maximum leverage ($\gamma = 1$), and tranche their deposits such that the promised payment on senior deposits equals the bank's asset return in the bad state (γ_0^s given by equation (11)). Let us refer to such banks as 'high-cost' banks and consider their behavior when offered deposit insurance.

For simplicity and realism, assume that γ^r is such that $\gamma^r R_f \geq \gamma_0^s R_q/\wp = (1+k)d_0$ so that the promised payment on maximum insured deposits exceeds the bank's bad state asset return when it chooses maximum leverage and no monitoring.[20] Consequently, a bank that issues maximum insured deposits has no incentive to issue senior deposits. Hence, the main effect of fairly-priced deposit insurance is that high-cost banks choose to replace γ_0^s of quasi-safe senior deposits having funding of R_q with γ^r of insured deposits having the lower funding cost of R_f. Maximum leverage continues to be profitable, so that $1-\gamma^r$ of uninsured deposits replace $1-\gamma_0^s$ of junior deposits, both having a funding cost of R_r.

Based on the above logic, Appendix A.3 shows when charged the fair insurance premium of $\phi_0 = [(1-p_g)R_f - p_b(1+k)d_0]/(p_g R_f)$, high-cost banks have expected profits of

$$\pi_0^{DI} = \pi_0 + \gamma^r \lambda_f - \gamma_0^s \lambda_q > \pi_0, \tag{23}$$

which exceed profits under a fully-private system due to the relatively lower funding cost of fully-safe insured deposits.

[20] The opposite case of more restricted deposit insurance coverage is considered in Section 6.

4.4. The Maximum Level of Deposit Insurance

Note that only moderate-cost banks issue deposits below γ^r, and their proportion of all banks is determined by two monitoring cost thresholds. One threshold, denoted c^*_{DI}, is where the profits of moderate-cost and high-cost banks are equal, $\pi^{DI}_{1,M}(c^*_{DI}) = \pi^{DI}_0(\gamma^r)$, which implies:

$$c^*_{DI}(\gamma^r) = p_b \left[d_1 - \frac{\pi^{DI}_0(\gamma^r)/k - p_g R_l}{\pi^{DI}_0(\gamma^r)/k - p_g R_f/\wp} R_f/\wp \right]. \tag{24}$$

The other threshold determines the boundary between low- and moderate-cost banks, equal to the monitoring cost c^m that satisfies $\gamma^{DI}_{1,M}(c^m) = \gamma^r$.

Given these proportions of different types of banks as a function of γ^r, and noting that all banks' assets equal zero in the catastrophe state, the government's maximum end-of-period insurance liability $L(\gamma^r)$ equals the the total of insured deposits:

$$L(\gamma^r) = \underbrace{\int_{\underline{c}}^{c^m} \gamma^r R_f \cdot f(c_i) dc_i + \int_{c^m}^{c^*_{DI}} \gamma^{DI}_{1,M}(c_i) R_f \cdot f(c_i) dc_i}_{\text{Liability for monitoring banks, } L_1(\gamma^r)} + \underbrace{\int_{c^*_{DI}}^{\bar{c}} \gamma^r R_f \cdot f(c_i) dc_i}_{\text{Liability for no-monitoring banks, } L_0(\gamma^r)}. \tag{25}$$

For insured deposits to be fully safe, $L(\gamma^r)$ cannot exceed the government's tax capacity:

$$L(\gamma^r) = \bar{t}\omega. \tag{26}$$

Equating the right-hand sides of equations (25) and (26) and using equation (24) determines the equilibrium values of c^*_{DI} and γ^r. See Appendix A.4 for computing the solution.

4.5. Cost Threshold for Monitoring

Recall that for a fully-private system, c^* given in equation (14) is the monitoring cost such that $\pi_1(c^*) = \pi_0$. Now consider the level of deposit insurance, γ^r, that would make the cost threshold for monitoring under deposit insurance, c^*_{DI}, the same as c^*. For $c^*_{DI} = c^*$, it would need to be that the increase in profits under deposit insurance relative to the fully-private system is the same whether a bank with cost c^* chooses to monitor or not monitor.

Now note from equation (23) that the increase in profit under deposit insurance, relative to a fully-private system, for a bank that does not monitor equals:

$$\pi_0^{DI} - \pi_0 = \gamma^r \lambda_f - \gamma_0^s \lambda_q, \tag{27}$$

which is increasing in γ^r and independent of c_i. Then consider the relative increase in profit for a bank with $c_i = c^*$ that does monitor. Since under deposit insurance a bank that is indifferent between monitoring or not is a moderate-cost bank, the increase in profit for this bank under deposit insurance relative to a fully-private system is

$$\pi_{1,M}^{DI}(c^*) - \pi_1(c^*) = \left\{\gamma_{1,M}^{DI}(c^*) - \gamma_1(c^*)\right\}[p_g R_l + p_b d_1 - c^* - R_f] + \gamma_1(c^*)(R_q - R_f). \tag{28}$$

Since equation (21) shows that $\gamma_{1,M}^{DI}(c^*)$ is independent of γ^r, so is equation (28). Thus, the γ^r that equates $\left(\pi_0^{DI} - \pi_0\right)$ in equation (27) to $\left(\pi_{1,M}^{DI}(c^*) - \pi_1(c^*)\right)$ in equation (28) equals

$$\gamma^{r*} = \frac{\left(\pi_{1,M}^{DI}(c^*) - \pi_1(c^*)\right) + \gamma_0^s \lambda_q}{\lambda_f}. \tag{29}$$

Therefore, γ^{r*} is the deposit insurance limit such that $c_{DI}^* = c^*$. An implication is that for deposit insurance limits exceeding γ^{r*}, the bank with monitoring cost c^* strictly prefers to not monitor when offered deposit insurance. Consequently, under deposit insurance the monitoring cost threshold must be such that $c_{DI}^* < c^*$ when $\gamma^r > \gamma^{r*}$.

4.6. Utility under Deposit Insurance

As defined in equation (25), let $L_1(\gamma^r)$ and $L_0(\gamma^r)$ be the insurer's catastrophe state liabilities for banks that monitor and banks that do not, respectively. Also define the insurer's net liability in the bad state as $L_b \equiv L_0(\gamma^r) - \gamma^r(1+k)d_0 \int_{c_{DI}^*}^{\bar{c}} f(c_i)dc_i - \phi_1 L_1(\gamma^r)$, where the first two terms reflect the insurer's losses net of recovery value for the high-cost banks that fail and the last term reflects the insurance premium received from banks that monitor and do not fail. Then savers' utility under deposit insurance can be computed as

$$\begin{aligned} U^{DI} &= U + p_g\left[\phi_1 L_1(\gamma^r) + \phi_0 L_0(\gamma^r)\right] - p_b\left[L_b + \eta L_b^+\right] - p_c(1+\eta)\bar{t}\omega, \\ &= U - \eta(p_b L_b^+ + p_c \bar{t}\omega), \end{aligned} \tag{30}$$

where $L_b^+ \equiv \max[L_b, 0]$ indicates that savers bear direct costs of taxation in the bad state only when the government insurer has a net positive cost.

Note that the first line of equation (30) equals savers' private system utility plus the expected values of the insurer's good-state premium revenue and net insurance and taxation costs in the bad and catastrophe states. Since insurance is fairly priced, the second line shows that utility relative to the private system is reduced by only the direct costs of taxes.

Bankers' utility equals the weighted average of low-, moderate- and high-cost bank profits:

$$U_b^{DI} = \int_{\underline{c}}^{c^m} \pi_{1,L}^{DI}(c_i)f(c_i)dc_i + \int_{c^m}^{c^*_{DI}} \pi_{1,M}^{DI}(c_i)f(c_i)dc_i + \int_{c^*_{DI}}^{\bar{c}} \pi_0^{DI} f(c_i)dc_i > U_b. \tag{31}$$

Recall that equations (20), (22), and (23) show that banks of each type have higher profits under deposit insurance relative to a fully-private system. Therefore, deposit insurance raises bankers' utilities at the expense of direct costs of taxes borne by savers.

This section's results are summarized in the next proposition.

Proposition 3. *Relative to a fully-private system, a system where the government provides fairly-priced deposit insurance leads to: 1) greater profits and lending for all banks; 2) a smaller proportion of banks that efficiently monitor when the deposit insurance limit exceeds* γ^{r*} *given by equation (29); 3) lower utility for savers due to direct costs of taxation.*

Banks profit and lend more due to the lower funding cost provided by insured deposits' fully-safe liquidity premium. However, the downside is that sufficiently generous deposit insurance leads to less efficient monitoring and increases savers' direct costs of paying taxes needed to back the insurance. It is also interesting to note that, though deposit insurance is fairly priced, riskier high-cost banks all choose maximum deposit insurance coverage while safer moderate-cost banks do not, consistent with adverse selection in insurance.

5. Comparing Methods of Government Liquidity Provision

Sections 3 and 4 analyzed banking systems with government liquidity using a fully-private system as the benchmark. We now re-assess these results to draw conclusions on the relative merits of government direct liquidity versus deposit insurance based on their performance in terms of total bank lending, monitoring efficiency, total liquidity provision, and welfare.[21]

5.1. Lending and Monitoring

In our model there is a tradeoff between the aggregate quantity of loans and the average efficiency that loans are monitored. To incentivize efficient monitoring, a bank with limited insider equity creates sufficient 'skin-in-the-game' by restricting leverage and, in turn, total lending.[22] In contrast, a bank that forgoes monitoring can maximize its leverage and lending. Importantly, the profitability of efficient lending versus greater total lending varies across systems that differ by their government's method of liquidity creation.

Proposition 2 showed that when a government provides direct liquidity, broad banks monitor and lend the same as in a fully-private banking system. Combing this result with Proposition 3 allows us to conclude that deposit-insured banks will monitor the least, and lend the most, if insurance coverage is sufficiently generous. Deposit insurance, even when fairly-priced, lowers banks' cost of funding by the fully-safe liquidity premium and induces more (inefficient) lending compared to uninsured banks.

5.2. Liquidity Creation

Governments providing direct or indirect liquidity face the same constraint that future revenue securing fully-safe deposits cannot exceed tax capacity. Thus, the quantity of fully-safe deposits under the two regimes is the same, equal to an average of $\bar{t}\omega/R_f$ per local market.

Differences emerge between the two regimes with regard to quasi-safe deposits. Under direct liquidity, all broad banks issue quasi-safe deposits. In contrast, Section 3 showed that under sufficiently generous deposit insurance, only low-cost insured banks issue quasi-safe deposits in excess of insured deposits. For all bank types, insured deposits crowd out quasi-safe deposits, with full crowding out for moderate- and high-cost banks.

Why does a system of direct government liquidity produce the same quantity of fully-safe deposits as under a system of indirect deposit insurance but far more quasi-safe deposits? The

[21]See Appendix B for numerical comparative statics of aggregate performance for these two systems.

[22]This qualitative result would hold in more general models where expanding inside equity is increasingly costly due to agency costs or a tax disadvantage.

intuition is as follows. Note that a government's power to tax allows it to create assets that are default-free in all future states, even the catastrophe state. An uninsured bank, on the other hand, creates quasi-safe assets that are default-free in all states except the catastrophe state. By insuring this bank's deposits, a government starts with a financial structure that produces quasi-safe assets and adds safety in only one additional (catastrophe) state, which is a small amount of safety at the margin. In this sense, government deposit insurance is inefficient relative to direct government liquidity that is produced from scratch outside of the broad banking system and does not replace quasi-safe deposits.

5.3. Welfare

Equation (18) shows that savers' utility under direct liquidity, U^{DL}, exceeds that of a fully-private system when $\eta < \frac{\lambda_f}{R_f}$. Savers benefit by owning fully-safe deposits in narrow banks, in addition to quasi-safe deposits in broad banks as in a fully-private system. These extra fully-safe deposits raise their utility as long as the fully-safe liquidity premium covers the direct costs of taxes needed to finance the government's debt. Krishnamurthy and Vissing-Jorgensen (2012) estimate the convenience yield on Treasury bills to be $\lambda_f = 0.73\%$ while the OECD (2019) estimates the direct cost of tax collection for the U.S. to be $\eta = 0.4\%$.[23] While this figure omits distortive costs of taxation, it does suggest a potential for improving the welfare of savers from direct liquidity issuance.

By contrast, equation (30) shows that saver utility under indirect government liquidity, U^{DI}, is always less than that under a fully-private banking system by the direct cost of taxes needed to finance deposit insurance, $\eta(p_b L_b^+ + p_c \bar{t}\omega)$. Similar to Holmström and Tirole (1998) these direct costs of taxes are state contingent and hence less than those under direct liquidity which requires that taxes finance debt in all states. However, unlike direct liquidity, under deposit insurance savers do not benefit from a fully-safe liquidity premium to offset these tax costs. The intuition for the difference relates to our finding that less total liquidity is produced under deposit insurance: savers hold deposits only in insured banks. Although these deposits are fully-safe, the benefits of the fully-safe liquidity premium accrue to the banks in the form of a lower cost of funding. Savers are left with only the direct costs of

[23] Equals the tax administration's operating cost per revenue collected (OECD (2019) Annex A Table D3).

taxes financing the deposit insurance.

Because the benefits of the fully-safe liquidity premium accrue to deposit-insured banks, equation (31) shows that bankers' utility under indirect liquidity is strictly higher than bankers' utility in a fully-private system, which Proposition 2 shows equals banker utility under direct liquidity. Hence, $U_b^{DI} > U_b = U_b^{DL}$.

Consequently banks are better off, but savers are likely to be worse off, under indirect liquidity relative to direct liquidity. Which regime is optimal depends on how banker and saver utility is weighted in overall social welfare. A social planner may prefer an interior solution that blends both direct and indirect liquidity, the topic of the next section.

6. Analysis of a Hybrid System

In most economies, governments directly issue debt and also insure bank deposits, perhaps because some insurance is necessary to avoid bank runs. Moreover, some governments, such as the U.S., insure the debt of government-sponsored enterprises (GSEs) that make loans and issue liquid debt.[24] Hence, this section analyzes a more realistic 'Hybrid' model with both direct- and indirect-liquidity. The tilde notation indicates variables for this hybrid system.

The government is assumed to provide direct liquidity by selling Treasury securities of amount $\tilde{\gamma}^d < \gamma^d$ to each market's narrow bank and also offer limited deposit insurance coverage, $\tilde{\gamma}^r$, to each market's loan-making 'broad' bank. Equating the government's maximum liability to tax capacity, the maximum level of deposit insurance, $\tilde{\gamma}^r$, must satisfy

$$L(\tilde{\gamma}^r) + \tilde{\gamma}^d R_f = \bar{t}\omega, \tag{32}$$

where $L(\cdot)$ is the total liability of the insurer in the catastrophe state given by equation (25) but where the integration limits reference the hybrid case and will be discussed below.

6.1. Insured Bank Behavior and Profits

Let us consider the change in insured bank behavior as a government starts from the system of only deposit-insured banks analyzed in Section 4 and gradually increases direct liquidity.

[24]These GSEs might be considered to be 'shadow banks' and include mortgage lenders Fannie Mae and Freddie Mac, as well as the Federal Home Loan Banks which lend to banks.

Equation (32) indicates that an increase in $\tilde{\gamma}^d$ above zero must lead to a decline in deposit insurance coverage relative to the system with only deposit-insured banks; that is, $\tilde{\gamma}^r < \gamma^r$. Recall that deposit-insured banks can be classified by their cost of monitoring as high-, moderate-, and low-cost. Let us discuss the reaction of each of these three types of bank.

Starting from the system of generous deposit insurance coverage analyzed in Section 4, high-cost banks which do not monitor initially respond to a decline in $\tilde{\gamma}^r$ by issuing more uninsured deposits at the higher funding cost of R_r, which leads to a reduction in their profits, $\tilde{\pi}_0^{DI} < \pi_0^{DI}$. With a further rise (*fall*) in direct liquidity (*insurance coverage*), eventually the bank's promised payment on insured deposits plus its fair insurance premium falls below the bad state recovery value: $\tilde{\gamma}^r R_f(1+\phi) < (1+k)d_0$. Appendix A.5 shows that the bank reacts to minimize its loss of profits by issuing some quasi-safe senior deposits along with risky junior deposits and pays a fair insurance premium of $\phi_1 = p_c/(1-p_c)$.

The effect of greater direct liquidity on low-cost banks which limit leverage and monitor is that they also issue fewer insured deposits and more quasi-safe deposits. Since the cost of quasi-safe deposits, R_q, exceeds that of fully-safe insured deposits, R_f, these banks have declines in profits and in the maximum leverage that preserves monitoring $\tilde{\gamma}_{1,L}^{DI} < \gamma_{1,L}^{DI}$.

Moderate-cost banks, defined as restricting their insured deposits to below the insurance limit, are not affected at the margin as direct liquidity increases and $\tilde{\gamma}^r$ declines. Since a reduction in $\tilde{\gamma}^r$ leaves the profits of moderate-cost banks unchanged but reduces the profits of high-cost banks, it follows that the cost threshold determining whether banks choose to monitor must initially rise relative to the system with only deposit-insured banks: $\tilde{c}_{DI}^* > c_{DI}^*$.

However, reduced insurance coverage causes some moderate-cost banks to switch to low-cost banks and issue both insured and quasi-safe deposits, implying that the cost threshold separating these banks increases with greater direct liquidity: $\tilde{c}^m > c^m$. Eventually, further declines in coverage imply that no moderate-cost banks exist. Once this happens, the bank that is just indifferent as to whether it should monitor will choose between being a low-cost or high-cost bank, both of which are experiencing profit declines with less insurance coverage.

Consistent with Proposition 3, once insurance coverage is insufficiently generous, a further decline in coverage can cause low-cost bank profits to fall more than high-cost bank profits, leading low-cost banks to switch to high-cost banks; that is, $\tilde{c}_{DI}^*$ declines and fewer banks monitor. Hence, declines in insurance coverage can lead to a non-monotonic relationship in the proportion of banks that monitor.

6.2. Lending and Liquidity Creation

As was just discussed, initial declines in insurance coverage lead to fewer high-cost banks which do not monitor. But once deposit insurance is insufficiently generous and no moderate-cost banks exist, further declines can increase the proportion of high-cost banks. Since these banks choose maximum leverage, the total volume of lending initially declines but later rises. Hence, the non-monotonic relationship between insurance coverage and monitoring leads to an inverse non-monotonic relationship between insurance coverage and total lending.

The quantity of fully-safe deposits under a hybrid system, equal to sum of narrow bank deposits plus deposits covered by government insurance, is the same as that under systems of pure deposit insurance or pure direct liquidity since each system's fully-safe assets are limited by the same government tax capacity, $\bar{t}\omega$. However, the quantity of quasi-safe deposits rises under a hybrid system as direct liquidity increases. The reason is due to the increase in quasi-safe deposits issued by high-cost and low-cost banks, and fewer moderate-cost banks that do not issue quasi-safe deposits.

6.3. Utility

As discussed in Section 6.1, bank profits for all types of banks decline in a hybrid system relative to those under a system with only deposit insurance and no direct liquidity. Banker utility, $\tilde{U}_b$, aggregates these profits and takes the form of equation (31) except that variables and integration limits now refer to the hybrid case. Utility is intermediate between the fully-private case and the pure deposit insurance case and declines as banks lose insured deposits as their lowest cost source of funding.

Saver utility under the hybrid system equals that of a fully-private system, U, plus the following three components. First, based on the analysis of Section 3.2, utility rises from savers' additional holdings of fully-safe direct liquidity (narrow bank deposits) but declines by the amount of taxes needed to finance this liquidity, resulting in a net utility gain equal to the fully-safe direct liquidity premium, $\tilde{\gamma}^d\lambda_f$. Second, the analysis of Section 4.6 shows that savers' holdings of insured deposits represents a zero net utility gain because their fully-safe liquidity premium raises bankers' profits and the fair premiums and taxes needed to insure these deposits have a net zero value. Third, savers' utility is reduced by the direct costs of taxes whenever net taxes are positive in each of the three states. Net taxes in the good, bad, and catastrophe states can be written as $[\tilde{\gamma}^d R_f + L_g]$, $[\tilde{\gamma}^d R_f + L_b]$, and $\bar{t}\omega$, respectively, where L_g and L_b represent the government's net deposit insurance liability in the good and bad states, respectively.[25] Combining these three components, the utility of savers equals

$$\tilde{U} = U + \tilde{\gamma}^d \lambda_f - \eta \left(p_g[\tilde{\gamma}^d R_f + L_g]^+ + p_b[\tilde{\gamma}^d R_f + L_b]^+ + p_c \bar{t}\omega \right). \tag{33}$$

In summary, a hybrid system generalizes the extremes of pure direct liquidity and pure deposit insurance systems. Not surprisingly, the implications of this more realistic system regarding total liquidity, lending, lending efficiency, and utility are intermediate between the two polar systems.

6.4. Hybrid Illustrations

This section illustrates the hybrid regime using parameter values reported in Table 1. The fully-safe return is 1.01, the expected quasi-safe return is 1.02, and the expected risky return is 1.03, which implies a liquidity premium of 100 basis points for each increase in safety. The promised loan return is assumed to be 1.15, and the probabilities of the good, bad, and catastrophe states are 90%, 9%, and 1%, respectively. Banker capital per unit of market savings, k, is set at 10%. For banks that monitor, the return in the default state, d_1, is set at $0.8 \times R_l = 0.92$, while the no monitoring effort bank default-state return, d_0, is $0.4 \times R_l = 0.46$. The maximum tax rate $\bar{t}$ equals 40% of end-of-period endowment of $\omega = 2$.[26] Finally, the direct cost of tax collection, η, is set at 0.4% based on OECD (2019). We assume that the density of bank monitoring costs is distributed uniform throughout, $f(c_i) = \frac{1}{\bar{c} - \underline{c}}$.

Figure 1 illustrates a series of hybrid systems where the proportion of fully-safe assets

[25] $L_g = -\phi_1 L_1(\tilde{\gamma}^r) - \phi_{01} L_0(\tilde{\gamma}^r)$ equals minus the insurance premiums collected in the good state where L_1 and L_0 are defined in equation (25) but with variables and integration limits referencing the hybrid case. $\phi_{01} = \phi_0$ if, as discussed in Section 6.1, high-cost banks default on insured deposits in the bad state. Otherwise, $\phi_{01} = \phi_1$. If high-cost banks default on insured deposits in the bad state, then L_b is the same as that given in Section 4.6 but with variables and integration limits referencing the hybrid case. Otherwise, $L_b = L_g$.

[26] The assumed endowment leads to a reasonable level of maximum insured deposits, γ^r.

in the form of direct liquidity ranges along the horizontal axis from 0 to 100 percent, or equivalently, from a system of 100 percent deposit insurance to a system of 100 percent direct liquidity. The first panel shows that while a pure deposit insurance system has the lowest proportion of monitored loans, the relationship is non-monotonic as it first rises and then falls with increases in direct liquidity. In turn, total lending is highest with 100 percent deposit insurance, but there is a range where total lending rises as direct liquidity increases.

The second panel of Figure 1 shows how greater direct liquidity reduces the effect that deposit insurance has in crowding out private liquidity (quasi-safe assets). However, more direct liquidity increases the direct costs of tax collection needed to finance the government's directly-issued debt. The third panel demonstrates that greater direct liquidity raises saver utility but lowers banker utility (bank profits). As discussed earlier, the benefits of the fully-safe liquidity premium accrue to savers under direct liquidity but to banks under deposit insurance.

7. Model Robustness

This section discusses the robustness of our model's results to some reasonable changes in assumptions. The model's assumption that bank loans are worthless in the catastrophe state is stark. If, instead, loans have a positive minimum recovery value, a government's deposit insurance losses would be lower and, for a given tax capacity, a government could create more fully-safe deposits under deposit insurance. However, a positive recovery value in the catastrophe state would allow uninsured broad banks to issue fully-safe deposits using a senior-junior deposit tranching structure. As a result, when the maximum fully-safe deposits of narrow banks and broad banks are combined, there would continue to be no difference in the total supply of fully-safe deposits under direct liquidity versus deposit insurance.

The model assumes savers gain utility from holding safe assets, which is a reduced form way of capturing safe assets' money-like transactions benefits. Liquidity premia for fully-safe and quasi-safe deposits are fixed in our model, but one might expect that they decline with the economy's supply of safe deposits. Since we show that the amount of fully-safe deposits is independent of how the government supplies liquidity, the direct effects of fully-safe deposit supply on liquidity premia should not differ across direct liquidity or deposit insurance regimes. Yet because the quantity of quasi-safe deposits are greater under direct liquidity, their liquidity premium would be lower under that regime. Moreover, if quasi-safe and fully-safe deposits are substitute transactions vehicles, the equilibrium fully-safe liquidity premium might also be smaller under direct liquidity.

The greater quantity of quasi-safe assets under direct liquidity raises saver utility in our model. But richer models that incorporate additional frictions can lead to a banking system that over-issues quasi-safe deposits (Gersbach (1998), Hart and Zingales (2011)), creating negative externalities such as fire-sale costs when a crisis occurs (Stein (2012)). When deposits are not fully safe, coordination failures can lead to inefficient bank run equilibria as in Diamond and Dybvig (1983) and Goldstein and Pauzner (2005).

While our model neglects these adverse consequences of quasi-safe deposits, it also does not account for potential costs of government liquidity. It was assumed that a government always respects its limit on tax capacity so that its debt and bank deposit guarantees are fully-safe. But as Reinhart and Rogoff (2009) document, history provides numerous examples of sovereign government defaults. Even without default, government liquidity in the form of deposit insurance may create inefficiencies due to bank risk-shifting.[27] Mitigating this moral hazard may require costly bank regulation. So while we acknowledge that our model misses potential costs of private liquidity, it also neglects other costs of government liquidity. A more complete modeling of these costs is needed to provide a definitive answer to the question of how governments should create liquidity.

8. Conclusions

A financial system's quantity of safe assets (liquidity) is not exogenous, but is still subject to constraints. The amount of liquid liabilities that can be created by private, uninsured banks is limited by their assets' recovery values in bad states of nature. Recovery values can be enhanced if a bank limits its leverage, thereby instilling incentives for it to efficiently monitor borrowers. Alternatively, a private bank can maximize its leverage and not monitor borrowers but create liquid senior deposits using the extra collateral funded by junior debt.

[27] Our model assumes deposit insurance is risk-sensitive and fairly priced. In practice, deposit insurance tends to be risk-insensitive and under-priced, which can worsen risk-shifting incentives.

This alternative production of liquidity has become increasingly popular with the growth of securitization vehicles that issue senior and junior tranched securities backed by loans. Collateralized loan obligations (CLOs) are just one recent example.

The amount of liquidity provided by a government is limited by its future taxing capacity, since ultimately taxes must fund its liabilities. Importantly, the method that a government uses to create its liquid assets has consequences for private liquidity creation. Government liquidity created via bank deposit insurance crowds out private liquidity but maximizes bank lending due to insured deposits' liquidity premium that reduces banks' cost of funding. However, sufficiently generous deposit insurance can dull loan monitoring incentives.

In contrast, a system where a government creates liquidity by directly issuing its debt avoids crowding out private liquidity and maintains banks' better incentives to monitor loans. Yet since loan-making banks' cost of funding is higher, they do not match the quantity of lending made by government-insured banks. Hence, banker utility is lower under direct government liquidity but savers' utility is likely to be higher because they benefit from the greater liquidity premium of directly held debt.

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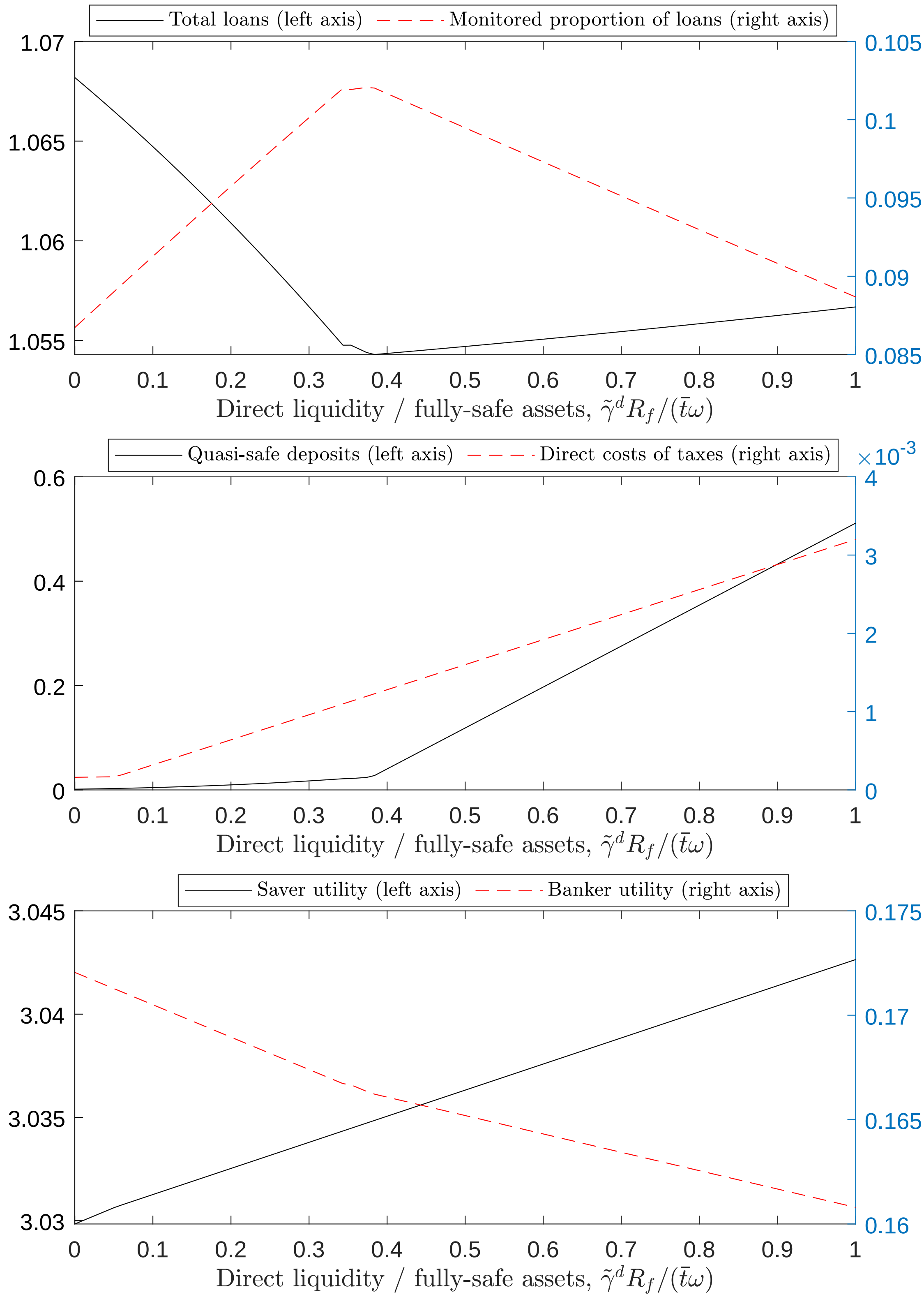
Table 1: Parameter values used for numerical illustrations

Parameter		Value	Parameter		Value
Risk-free return	R_f	1.01	Bank capital per savings	k	0.1
Safe liquidity premium	λ_f	0.02	No-effort recovery rate	d_0	0.46
Quasi-safe liquidity premium	λ_q	0.01	High-effort recovery rate	d_1	0.92
Promised loan return	R_l	1.15	Tax limit	$\bar{t}$	0.4
Probability of good state	p_g	0.9	Endowment	ω	2
Probability of bad state	p_b	0.09	Cost of tax collection	η	0.004

Figure 1: **Effects of varying the proportion of direct liquidity to total government liquidity**
This figure varies the ratio $\tilde{\gamma}^d R_f/(\bar{t}\omega)$ in a hybrid system with both direct government debt issuance and government deposit insurance. Parameter values are given in Table 1.



Appendix A. Detailed Derivations and Proofs

This appendix provides derivations and proofs of results in the main text.

Appendix A.1. Low-Cost Bank Behavior

Low-cost banks exert effort, $e = 1$, and do not default in the bad state, so that insurance covers only the catastrophe state. These banks' fair insurance premium, ϕ_1, satisfies:

$$\wp\phi_1\gamma^r R_f = (1-\wp)\gamma^r R_f, \tag{A.1}$$

or

$$\phi_1 = \frac{1-\wp}{\wp} = \frac{p_c}{1-p_c}. \tag{A.2}$$

Low-cost banks pay $R_q/\wp$ on their $\gamma - \gamma^r$ of quasi-safe uninsured deposits and, including their insurance premium, $(1+\phi_1)R_f = R_f/\wp$ on their γ^r of insured deposits. Bank i will monitor when the value of monitoring exceeds the monitoring cost:

$$p_b\left[(\gamma+k)d_1 - (\gamma-\gamma^r)R_q/\wp - \gamma^r R_f/\wp\right] - (\gamma+k)c_i > 0. \tag{A.3}$$

Solving for γ where this condition binds leads to equation (19).

Appendix A.2. Moderate-Cost Bank Behavior

As with low-cost banks, moderate-cost banks do not default in the bad state and pay the same insurance premium of ϕ_1 given in (A.2), so that their promised payment to insured depositors and the deposit insurer equals $(1+\phi_1)R_f = R_f/\wp$. Therefore, the condition that preserves their incentive to monitor is

$$p_b\left[(\gamma+k)d_1 - \gamma R_f/\wp\right] - (\gamma+k)c_i > 0. \tag{A.4}$$

Solving for the level of γ for which this inequality binds leads to equation (21).

Appendix A.3. High-Cost Bank Behavior

Note that under the assumption that $\gamma^r R_f \geq (1+k)d_0$, high-cost banks that do not monitor always default in the bad state and no uninsured deposits can be made quasi-safe. Therefore, there is no distinction between uninsured senior deposits or junior deposits. Without loss of generality, we assume all uninsured deposits have the same seniority as insured deposits, and thus the fair deposit insurance premium for high-cost banks satisfies:

$$p_g \phi_0 \gamma^r R_f = p_b[\gamma^r R_f - \gamma^r (1+k) d_0] + p_c \gamma^r R_f, \tag{A.5}$$

or

$$\phi_0 = \frac{(1-p_g)R_f - p_b(1+k)d_0}{p_g R_f}, \tag{A.6}$$

which is independent of the proportion of insured deposits. The promised payment on uninsured deposits that satisfies savers' participation constraint is then

$$R_u = \frac{R_r - p_b(1+k)d_0}{p_g}. \tag{A.7}$$

Calculating expected bank profits for this insurance premium and promised payment on insured deposits, where profits are non-zero only in the good state, results in equation (23).

Appendix A.4. Maximum Level of Deposit Insurance

To solve equations (24) and (26) simultaneously for c^*_{DI} and γ^r, one needs to account for the proportions and behaviors of low-, moderate- and high-cost banks. The following discussion outlines various possibilities that can obtain for different parameter values.

If deposit insurance is sufficiently generous such that the least-cost bank would not choose leverage above the insurance limit, $\gamma^{DI}_{1,M}(\underline{c}) < \gamma^r$, then low-cost insured banks do not exist and $c^m = \underline{c}$. Also as stated in the text, a high deposit insurance limit whereby $\gamma^s_0 < \gamma^r$ implies that insured high-cost banks cannot issue any uninsured, quasi-safe deposits so that all of their uninsured deposits are risky.

Alternatively, if the tax base is limited such that all banks that monitor choose leverage above the insurance limit, $\gamma^{DI}_{1,L}(c^*_{DI}) > \gamma^r$, then moderate-cost banks do not exist and $c^m = c^*_{DI}$. Since only moderate-cost banks would not fully insure, equilibrium insurance coverage is $\gamma^r = \bar{t}\omega/R_f$ in this case. Moreover, the cost threshold c^*_{DI} that equates the profits of low-cost banks and high-cost banks, $\pi^{DI}_{1,L}(c^*_{DI}) = \pi^{DI}_0$ replaces that value given in equation (24). Both low- and moderate-cost banks exist only if the tax base is such that the insurance limit is between these extremes, $\gamma^r \in \left(\gamma^{DI}_{1,M}(c^*_{DI}), \gamma^{DI}_{1,L}(\underline{c})\right)$. Our calibration that assumes a tax base large enough to support the levels of γ^r seen for U.S. banks corresponds to this case.

Similarly, a low deposit insurance limit such that $\gamma^r < \gamma^s_0$ implies that high-cost banks will issue quasi-safe uninsured senior deposits in addition to insured deposits and risky uninsured deposits. This case is discussed under the Hybrid Model, where the amount of these quasi-safe senior deposits equals $\tilde{\gamma}^s_0 \equiv \gamma^s_0 - \tilde{\gamma}^r \frac{R_f}{R_q}$. High-cost bank profits then equal $\tilde{\pi}^{DI}_{0,T} = \pi^{DI}_0(\tilde{\gamma}^r) + \tilde{\gamma}^s_0 \lambda_q$, which replaces π^{DI}_0 in the right-hand-side of equation (24).

Another possibility is that $\pi^{DI}_{1,L}(\underline{c}) < \pi^{DI}_0$ and $\pi^{DI}_{1,M}(\underline{c}) < \pi^0_{DI}$, in which case no banks choose to monitor and there are only high-cost banks. Here, $c^*_{DI} = \underline{c}$ and $\gamma^r = \bar{t}\omega/R_f$. Conversely, if $\pi^{DI}_{1,L}(\bar{c}) > \pi^{DI}_0$, then there are no high-cost banks, in which case $c^*_{DI} = \underline{c}$ and γ^r solves equation (26).

One modification to the above solution technique occurs under the Hybrid Model with Government Investment assumption set out in Appendix C.2. In this setting, banks face a leverage limit of $1 - \tilde{\gamma}^d$ instead of 1, which will reduces high-cost bank profits and also low-cost bank profits when $\gamma^{DI}_{1,L}(c_i) > 1 - \tilde{\gamma}^d$. In both cases, these banks lever up to the limit of $1 - \tilde{\gamma}^d$.

Thus, when simultaneously solving equations (24) and (26) for $\{\gamma^r, c^*_{DI}\}$, all of the relevant possibilities discussed above are considered, which place different restrictions on low-, moderate-, and high-cost banks.

Appendix A.5. High-Cost Bank Behavior in the Hybrid Model

When deposit insurance coverage is sufficiently restricted such that $\tilde{\gamma}^r R_f(1+\phi) < (1+k)d_0$, it becomes possible that a high-cost bank that does not monitor could fully pay its insured depositors and fair insurance premium in the bad state. The fair premium would be $\phi_1 = p_c/(1-p_c)$ since insurance is needed only in the catastrophe state. Moreover, given this situation the bank could lower its funding cost, and maximize its profits, by tranching its uninsured deposits and issuing quasi-safe senior deposits, $\tilde{\gamma}^s_0$, that satisfies

$$\tilde{\gamma}^s_0 = \max\left[0, \frac{(1+k)d_0 - \tilde{\gamma}^r R_f(1+\phi_1)}{R_q/\wp}\right], \tag{A.8}$$

along with risky junior deposits of $1 - \tilde{\gamma}^r - \tilde{\gamma}_0^s$. The bank's expected profits in this case are

$$\tilde{\pi}_{0,T}^{DI} = \pi_0^{DI}(\tilde{\gamma}^r) + \lambda_q \tilde{\gamma}_0^s, \tag{A.9}$$

where $\pi_0^{DI}(\tilde{\gamma}^r)$ denotes the profits of the bank if it does not tranche, given by equation (23).

Appendix B. Numerical Illustrations

This appendix provides numerical comparative statics of aggregate performance for the two main systems of direct liquidity with Treasury proceeds rebated to savers and indirect liquidity via deposit insurance. We consider how average loan monitoring efficiency, the aggregate amounts of loans and quasi-safe deposits, and aggregate bank profits are affected by variation in key parameters. Illustrations of saver utility and expected taxation are omitted as they are unaffected by the comparative statics presented here. Unless specified otherwise, the baseline model parameter values are those given in Section 6.4.

First consider variation in the liquidity premium on quasi-safe deposits which allows banks to fund loans at less than the expected return R_r. In Figure B.2 the premium on quasi-safe deposits, λ_q, and hence the quasi-safe return, R_q, varies by plus or minus 100 basis points while holding constant the risky return, $R_r = 1.03$, and the fully-safe liquidity premium, $\lambda_f = 0.02$. Under a system of direct liquidity, increasing the quasi-safe liquidity premium leads more broad banks to choose to monitor as, at the margin, the increased profits from monitoring exceed those from not monitoring. Since monitoring banks restrict leverage, total loans fall while total quasi-safe deposits rise. Profits of all banks rise as λ_q increases, as shown by the rising aggregate bank profits. Note that under the generous deposit insurance system assumed here, there are no low-cost or high-cost banks that issue quasi-safe deposits above the insured deposit limit. Hence, no quasi-safe deposits are issued, and the measures of aggregate performance are unaffected by the change in λ_q.

Figure B.2: Variation in the quasi-safe liquidity premium, λ_q

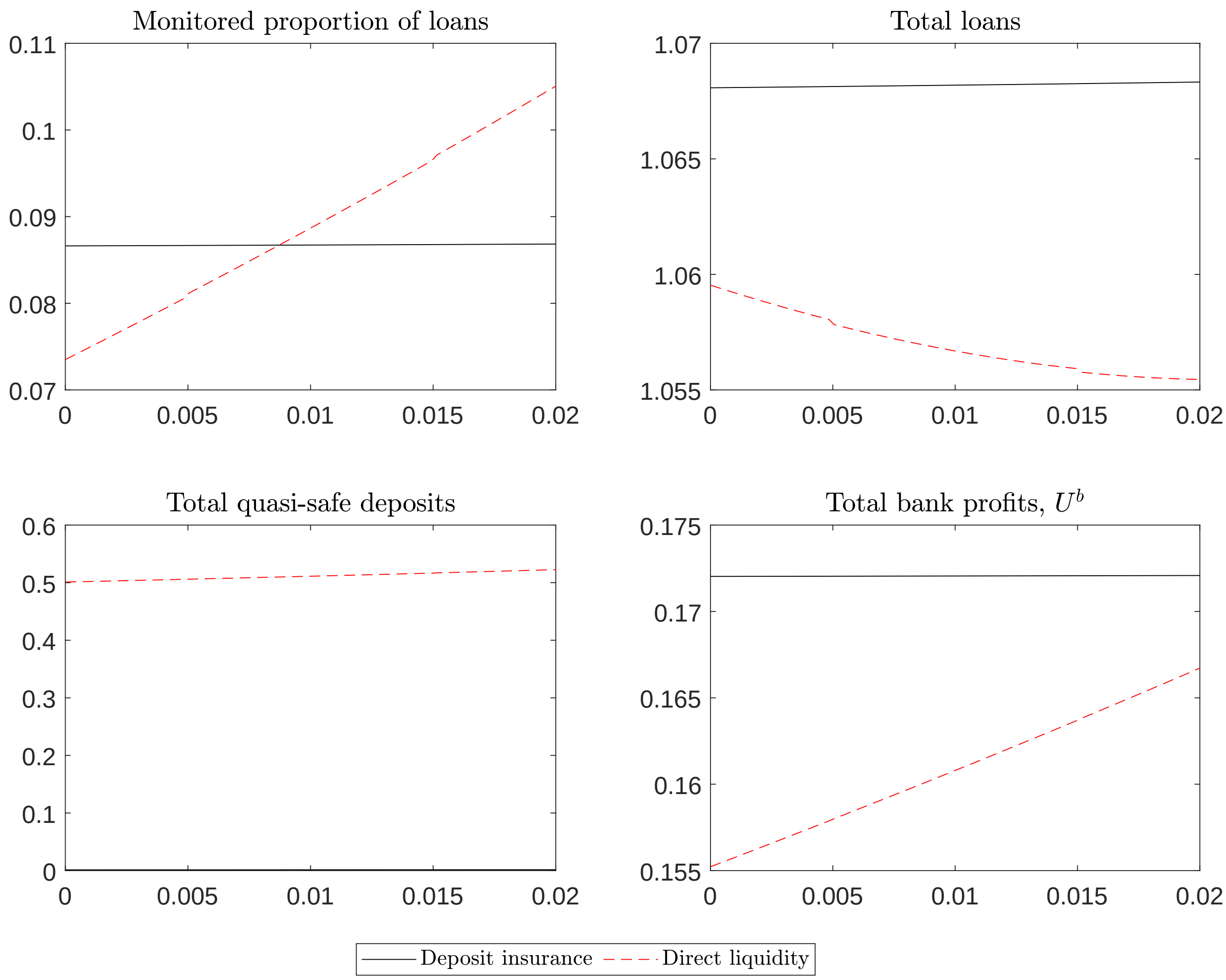


Figure B.3 considers variation in banker capital, k, and shows that higher capital creates a greater incentive to monitor under both direct liquidity and deposit insurance. Accordingly, quasi-safe deposits, which are concentrated at banks that monitor, rise under both systems. Ceteris paribus, higher capital allows for greater lending, but the aforementioned incentive for more banks to monitor implies that total loans may decrease initially as more banks restrict leverage. Hence there are regions over which total loans can decline. However, greater capital raises all banks' profits.

Figure B.3: Variation in bank capital, k

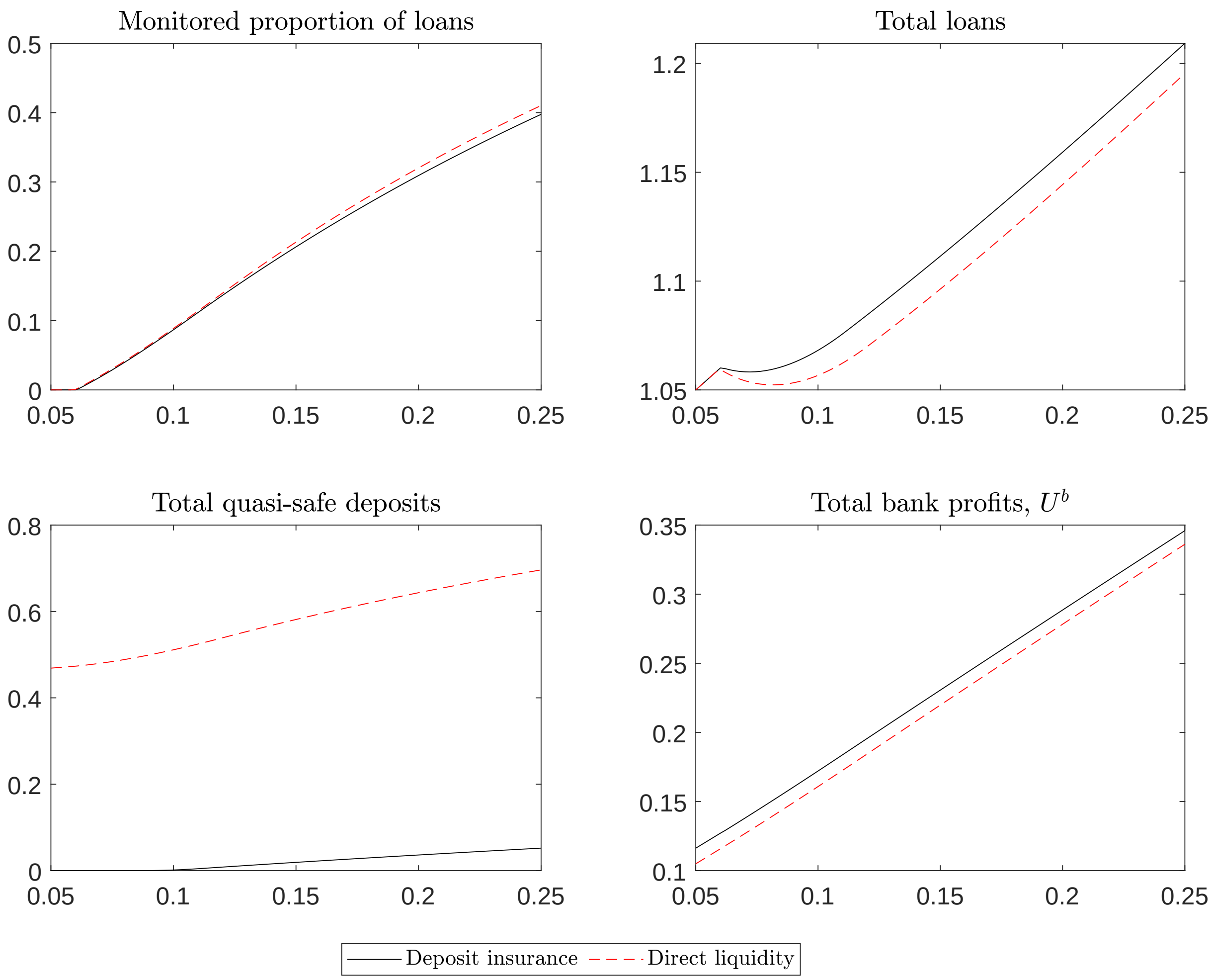


Figure B.4 illustrates variation in the bad state recovery rate of banks that do not monitor, d_0. Since higher values only benefit no-monitoring banks, it is not surprising that a rising d_0 leads to fewer monitored loans. Accordingly, since fewer banks restrict leverage to monitor, total loans rise. Also, since under a system of direct liquidity no-monitoring banks issue quasi-safe deposits equal to the bad state recovery value, an increase in this recovery value raises quasi-safe deposits. Moreover, since higher d_0 raises the profits of banks that do not monitor, aggregate bank profits rise.

Figure B.4: Variation in the recovery rate of banks that do not monitor, d_0

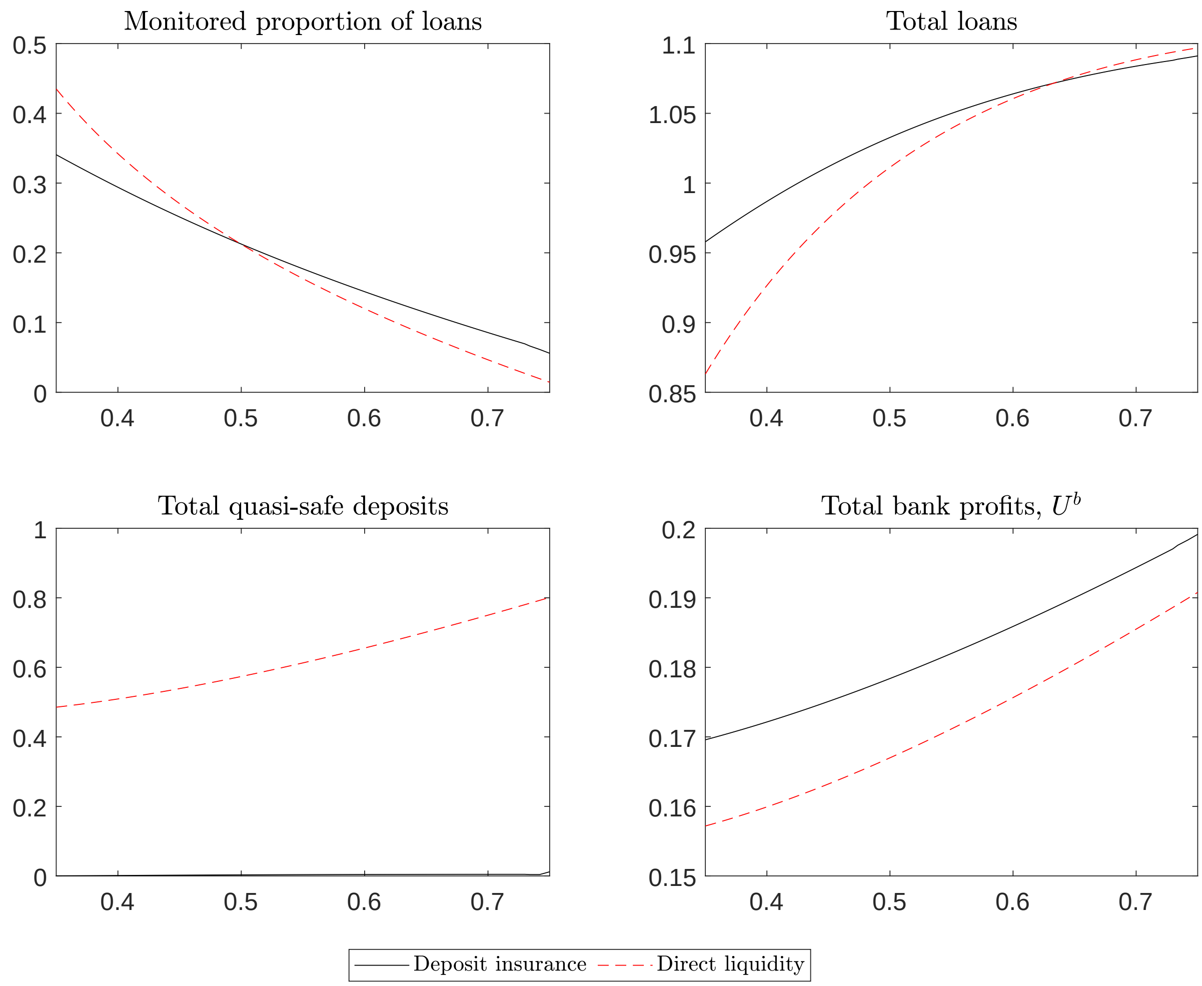
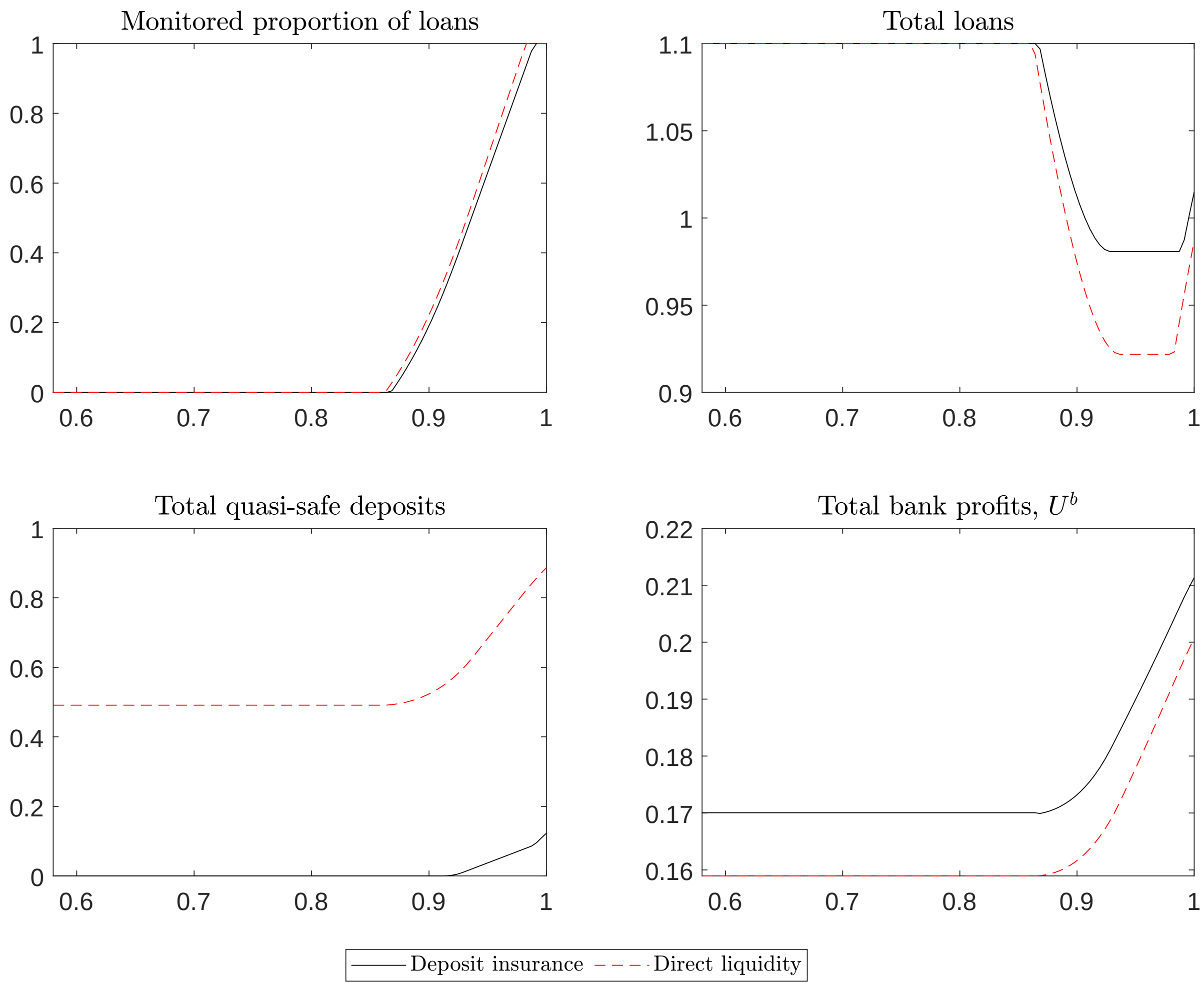


Figure B.5 complements the previous figure by examining variation in the recovery rate of banks that monitor, d_1. Since only monitoring banks benefit from higher d_1, the proportion of loans that are monitored increases once this rate is sufficiently high to induce any monitoring. In turn, since monitoring banks restrict leverage, more monitoring banks initially reduces total lending until this reduction is offset by the effect that higher d_1 has in raising these monitoring banks' maximum leverage ratios. Also, as would be expected, higher values of d_1 raise the quasi-safe deposits and profits of an increasingly large share of banks that monitor. Even under a deposit insurance system, sufficiently high d_1 allows low-cost banks to issue quasi-safe deposits above the insurance limit.

Figure B.5: Variation in the recovery rate of banks that monitor, d_1



Appendix C. Extensions

The relative simplicity of our model lends itself to extensions. In this appendix, we first generalize the binary effort decision to a continuum. Second, we assume a government provides direct liquidity by issuing Treasury securities and invests the proceeds in the risky investment technology. Third, we consider another case where the government provides direct liquidity by issuing Treasury securities and offers to make deposits (lend) to broad banks. Fourth, we allow savers to make deposits in banks outside of their local market; that is, an intermarket deposit facility.

Appendix C.1. Continuous effort

In this extension, we relax the assumption that bank effort is binary such that banks can choose any non-negative effort, $e > 0$. Recovery value per unit of loan is assumed to be the following increasing and concave function of banker effort:

$$d(e) = R_l \left(1 - \alpha \cdot exp(-\beta e)\right), \tag{C.1}$$

where $0 < \alpha < 1$ defines the no-effort loss-rate and $\beta > 0$.

To ensure that each bank's first-best effort is positive but still results in loans having a positive loss given default, we restrict monitoring costs to be in the range

$$c_i \in [p_b \beta (R_l - 1), p_b \alpha \beta R_l] \equiv [\underline{c}, \bar{c}]. \tag{C.2}$$

Optimal high effort, $e^*(c_i)$, is implied by the first-order condition equating the marginal benefit from effort to its unit cost:

$$p_b \frac{\partial d(e)}{\partial e} = c_i. \tag{C.3}$$

By substituting in the functional form for $d(e)$ from equation (C.1), the effort satisfying this first order condition is $e^* = e^h(c_i)$ where

$$e^h(c_i) \equiv \frac{1}{\beta} \ln \left(\frac{\beta \alpha p_b R_l}{c_i} \right). \tag{C.4}$$

High-effort, $e = e^h(c_i)$, results in the loan's bad state recovery value equaling

$$d(e^h) = R_l - \frac{c_i}{\beta p_b}. \tag{C.5}$$

Whenever inequality (7) holds so that the banker obtains a return in the default state, then the choice of effort is either the same corner solution of zero-effort or this effort level $e^h(c_i) > 0$. Thus, 0 or e^h are the only choices of effort that could possibly be profit-maximizing for the bank.

The threshold cost which separates no- and high-effort banks satisfies the implicit equation:

$$c^* = \frac{\pi_0 p_b (R_l - R_q/\wp)}{\left(\frac{1}{\beta} + e^h\right)(\pi_0 - p_g k R_q/\wp)}, \tag{C.6}$$

where $e^h(c^*) = \frac{1}{\beta}\ln\left(\frac{\beta\alpha p_b R_l}{c^*}\right)$.

Appendix C.2. Equilibrium and Utility under Direct Liquidity with Government Investment

When a government issues Treasury securities to narrow banks and invests the proceeds in the risky technology, the maximum deposits available to a broad bank is $\gamma^{GI} \equiv 1 - \gamma^d < 1$, which constrains its leverage, affects its profits, and changes its monitoring incentives. If a bank chooses to monitor, it limits leverage to the same level $\gamma_1(c_i) = k\frac{p_b d_1 - c_i}{p_b R_q/\wp - (p_b d_1 - c_i)}$ as in Section 2.4 unless $\gamma_1(c_i) > \gamma^{GI}$, in which case it chooses γ^{GI}. Hence, its profits are

$$\pi_1^{GI} = (\min[\gamma_1(c_i), \gamma^{GI}] + k)\,[p_g R_l + p_b d_1 - c_i] - \min[\gamma_1(c_i), \gamma^{GI}] R_q. \tag{C.7}$$

If a bank chooses not to monitor, similar to Section 2.5 it issues 'quasi-safe' deposits at rate $R_q/\wp$ up to the reduced limit $\gamma^s_{GI} = \frac{(\gamma^{GI}+k)d_0}{R_q/\wp}$. Its profits are

$$\pi_0^{GI} = (\gamma^{GI} + k)\,[p_g R_l + p_b d_0] - (\gamma^{GI} - \gamma^s_{GI})R_r - \gamma^s_{GI} R_q < \pi_0. \tag{C.8}$$

For parameters permitting an interior solution such that $\pi_1^{GI}(\bar{c}) < \pi_0^{GI}$, define c^*_{GI} as the critical value of c such that a bank's profits are equal when it monitors versus when it does not. Its profits satisfy $\pi_1^{GI}(c_{GI}^*) = \pi_0^{GI}$, which implies

$$c_{GI}^* = p_b \left[d_1 - \frac{\pi_0^{GI}/k - p_g R_l}{\pi_0^{GI}/k - p_g R_q/\wp} R_q/\wp \right]. \tag{C.9}$$

Consider the case where model parameters are such that $\gamma_1(c_{GI}^*) \leq \gamma^{GI}$ so that banks that monitor restrict leverage below their market's available deposits. Then relative to a fully-private system, profits of monitoring banks are unchanged while, since $\pi_0^{GI} < \pi_0$, profits of banks that do not monitor are less. This logic implies $c_{GI}^* > c^*$. That is, more broad banks choose to monitor when deposits are limited to $\gamma \leq \gamma^{GI}$ compared to $\gamma \leq 1$.

Savers' utility is not directly affected by holding fully-safe assets since their lower return of R_f is offset by the higher liquidity premium λ_f. However, savers receive a lump sum government rebate of $\gamma^d(R_r/p_g - R_f)$ in the good state while in the bad and catastrophe states their utility declines due to taxes by $(1+\eta)\bar{t}\omega = (1+\eta)\gamma^d R_f$. Thus, savers' utility is

$$U^{GI} = U + p_g \gamma^d \left(R_r/p_g - R_f\right) - \left(1 - p_g\right)\left(1+\eta\right)\gamma^d R_f = U + \gamma^d \left[\lambda_f - \left(1 - p_g\right)\eta R_f\right]. \tag{C.10}$$

Therefore, relative to the fully-private regime, direct liquidity with government investment raises savers' utility by the liquidity premium of fully-safe deposits less the expected direct costs of taxation. However, because of the crowding out effects of government investment, broad bankers' profits are lower:

$$U_b^{GI} = \int_{\underline{c}}^{c_{GI}^*} \pi_1^{GI}(c_i) f(c_i) dc_i + \pi_0^{GI} \int_{c_{GI}^*}^{\bar{c}} f(c_i) dc_i < U_b. \tag{C.11}$$

Appendix C.3. Equilibrium and Utility under Direct Liquidity with Government Deposits

Rather than rebate the revenue from Treasury sales to savers or invest it only in the risky investment technology, the government could offer to deposit its revenue in banks that wish to increase their leverage. We refer to this as the 'Government Deposits' assumption. The government is assumed to offer to make deposits at (lend to) banks at competitive market rates as long as a bank's total leverage satisfies $\gamma \leq 1$.[28] Any unused revenue is invested by the government in the risky investment technology. Under this assumption, the equilibrium behavior of banks is the same as under the fully-private system or the system of direct liquidity with a government rebate. In particular, the cost threshold for monitoring is c^* given by equation (14) and the utility of bankers, equal to their expected profits, is $U_b^{GD} = U_b$.

Now consider the utility of savers. If $\gamma^d \leq \gamma^j = 1 - \bar{\gamma}^s$, then banks that do not monitor will issue to the government only junior deposits of γ^d having the promised return of R_r/p_g. Instead, if $\gamma^d > \gamma^j$, these banks issue to the government all of their junior debt and $\gamma^d - \gamma^j$ of their quasi-safe senior deposits at promised return of $R_q/\wp$. For banks that limit leverage and monitor, they issue to the government quasi-safe deposits of $\gamma_1(c_i) - \gamma^d$ whenever this quantity is positive.

Thus, the government's total quantity of quasi-safe deposits, denoted γ^q, equals:

$$\gamma^q \equiv \int_{\underline{c}}^{c^*} \max(\gamma_1(c_i) - \gamma^d, 0) f(c_i) dc_i + \max(\gamma^d - \gamma^j, 0) \int_{c^*}^{\bar{c}} f(c_i) dc_i. \tag{C.12}$$

Recall that under the system of direct liquidity with Government Investment, the government's investment in the risky investment technology pays $\gamma^d R_r/p_g$ in the good state and nothing in the bad and catastrophe states. Relative to this system, under Government Deposits savers receive an end-of-period lump sum payment in the good state that is less by $\gamma^q(R_r/p_g - R_q/\wp)$ due to the lower promised return on the government's quasi-safe deposits. However, these savers' taxes plus direct costs of taxation are less by $\gamma^q(1+\eta)R_q/\wp$ in the bad state due to the positive return on the government's quasi-safe deposits. Therefore, savers' utility under Government Deposits equals

$$U^{GD} = U^{GI} - p_g \gamma^q (R_r/p_g - R_q/\wp) + p_b \gamma^q (1+\eta) R_q/\wp = U^{GI} - \gamma^q \left[\lambda_q - p_b \eta R_q/\wp\right], \tag{C.13}$$

where U^{GI} is the saver utility under Government Investment. Thus, saver utility under Government Deposits is lower compared to that under Government Investment if the quasi-

[28] If this limit or 'capital requirement' is not imposed, the results are similar to those of intermarket deposits with direct liquidity and a government rebate discussed in Appendix C.4.

safe liquidity premium is sufficiently high or tax-collection costs are sufficiently low such $\lambda_q > p_b \eta R_q/\wp$.

Appendix C.4. Intermarket Deposits

Recall that in the fully-private banking model that if bank i chooses to limit its deposits to $\gamma_1(c_i) < 1$ in order to have an incentive to monitor, savers in this bank's local market can only invest their residual savings of $1-\gamma_1(c_i)$ in the risky investment technology. This section considers an alternative assumption whereby the $1-\gamma_1(c_i)$ of savings may be deposited in a non-local market at a bank that chooses maximum leverage and does not monitor. Similar notation but with a prime $'$ is used to denote this regime.

Note that the deposit choice of banks that monitor are unaffected so that intermarket deposits serve only to increase the leverage of banks that do not monitor. Since these banks have identical incentives, assume that intermarket deposits are uniformly allocated across these no-monitoring banks so that they equal on a per-bank basis

$$\gamma' = 1 + \frac{\int_{\underline{c}}^{c^{*'}} [1-\gamma_1(c_i)] f(c_i) dc_i}{\int_{c^{*'}}^{\bar{c}} f(c_i) dc_i} > 1 \tag{C.14}$$

where $c^{*'}$ denotes the cost threshold at which a bank is indifferent to monitoring, which will be determined below. Assuming that banks make a take-it-or-leave-it offer to savers so that deposits are priced to reflect savers' reservation return on the risky technology, then banks that do not monitor issue quasi-safe senior deposits equal to:[29]

$$\gamma_0^{s'} = \frac{(\gamma'+k)d_0}{R_q/\wp} > \gamma_0^s, \tag{C.15}$$

and have profits equal to

$$\pi_0' = (\gamma'+k)\left[p_g R_l + p_b d_0\right] - (\gamma' - \gamma_0^{s'})R_r - \gamma_0^{s'} R_q > \pi_0. \tag{C.16}$$

[29]The assumption that the return on deposits reflects savers' reservation return only affects how total surplus is split between savers and bankers and does not affect total lending.

This profit level implies that the cost threshold for monitoring now equals

$$c^{*'} = p_b \left[d_1 - \frac{\pi_0'/k - p_g R_l}{\pi_0'/k - p_g R_q/\wp} R_q/\wp \right] < c^*. \tag{C.17}$$

The above analysis describes bank behavior in a fully-private system and also broad bank behavior in a system of narrow banks with a government rebate or with government deposits.

In a system of narrow banks with the government investing its Treasury proceeds of γ^d in the risky technology, $\gamma^{GI} \equiv 1 - \gamma^d < 1$ are the total deposits available to broad banks per market. Relative to the previous systems, intermarket deposits are lower. Indeed, there are no residual savings in markets of low-cost banks that monitor such that $\gamma_1(c_i) \geq \gamma^{GI}$. Only when leverage of banks that monitor are such that $\gamma^{GI} - \gamma_1(c_i) > 0$ are there residual savings that flow to broad banks that do not monitor. Therefore, defining $\gamma^{GI'}$ as the total of local and intermarket deposits available to no-monitoring banks, it equals

$$\gamma^{GI'} = \gamma^{GI} + \frac{\int_{\underline{c}}^{c_{GI}^{*'}} \max[\gamma^{GI} - \gamma_1(c_i), 0] f(c_i) dc_i}{\int_{c_{GI}^{*'}}^{\bar{c}} f(c_i) dc_i} > \gamma^{GI}. \tag{C.18}$$

Therefor, no-monitoring banks issue senior deposits of $\gamma_{GI}^{s'} = \frac{(\gamma^{GI'} + k) d_0}{R_q/\wp}$ and have profits equal to

$$\pi_0^{GI'} = (\gamma^{GI'} + k) \left[p_g R_l + p_b d_0 \right] - (\gamma^{GI'} - \gamma_{GI}^{s'}) R_r - \gamma_{GI}^{s'} R_q > \pi_0^{GI}. \tag{C.19}$$

This profit level implies a cost-threshold for monitoring of

$$c_{GI}^{*'} = p_b \left[d_1 - \frac{\pi_0^{GI'}/k - p_g R_l}{\pi_0^{GI'}/k - p_g R_q/\wp} R_q/\wp \right] < c_{GI}^*. \tag{C.20}$$

Thus, the general effects of intermarket deposits are to raise the profits of broad banks that do not monitor and thereby decrease banks' cost threshold for choosing whether to monitor. Total lending increases but with less monitoring efficiency.

Next, consider a system of deposit insurance with intermarket deposits. Note that in the absence of intermarket deposits, insured banks that do not monitor issue the maximum amount of insured deposits, γ^r. Consequently, intermarket deposits that flow to these banks will only increase their uninsured deposits, except for the indirect effect that intermarket deposits have on the equilibrium deposit insurance limit, $\gamma^{r'}$. Now residual savings from markets where low- and moderate-cost banks monitor imply that total local and intermarket deposits of banks that do not monitor equal

$$\gamma^{DI'} = 1 + \frac{\int_{\underline{c}}^{c^m} [1 - \gamma_{1,L}^{DI}(c_i)] f(c_i) dc_i + \int_{c^m}^{c_{DI}^{*'}} [1 - \gamma_{1,M}^{DI}(c_i)] f(c_i) dc_i}{\int_{c_{DI}^{*'}}^{\bar{c}} f(c_i) dc_i} > 1, \tag{C.21}$$

and these no-monitoring banks' profits equal

$$\pi_0^{DI'} = (\gamma^{DI'} + k)[p_g R_l + p_b d_0] - \gamma^{DI'} R_r + \gamma^{r'} \lambda_f. \tag{C.22}$$

Accordingly, the cost-threshold for monitoring, $c_{DI}^{*'}$, and the extent of insurance coverage, $\gamma^{r'}$, are the joint solutions to

$$\pi_{1,M}^{DI}(c_{DI}^{*'}) = \pi_0^{DI'}(\gamma^{r'}), \tag{C.23}$$

and

$$L'(\gamma^{r'}) = \bar{t}\omega, \tag{C.24}$$

where the deposit insurers' maximum liability is:

$$L'(\gamma^{r'}) = \underbrace{\int_{\underline{c}}^{c^{m'}} \gamma^{r'} R_f \cdot f(c_i) dc_i + \int_{c^{m'}}^{c_{DI}^{*'}} \gamma_{1,M}^{DI}(c_i) R_f \cdot f(c_i) dc_i}_{\text{Liability for monitoring banks, } L_1'(\gamma^{r'})} + \underbrace{\int_{c_{DI}^{*'}}^{\bar{c}} \gamma^{r'} R_f \cdot f(c_i) dc_i}_{\text{Liability for no-monitoring banks, } L_0'(\gamma^{r'})}, \tag{C.25}$$

and $c^{m'}$ defines the cost-threshold between least- and moderate- cost banks, the former are able to issue deposits above the insurance limit.

Since $\gamma_{DI}' > 1$ from condition (C.21), insured banks that do not monitor have higher leverage compared to the case of insured banks that do not monitor when there are no intermarket deposits. Therefore, if $\gamma^{r'}$ were equal to γ^r, profits of no-monitoring banks would be higher relative to profits of no-monitoring banks without intermarket deposits. Hence, it must be the case that the cost threshold for monitoring with intermarket deposits must be lower than that without intermarket deposits, $c^{*'}_{DI} < c^*_{DI}$.

Consequently, with intermarket deposits the proportion of moderate-cost banks that monitor declines while the proportion of high-cost banks that do not monitor rises. Since the former banks issue insured deposits at less than $\gamma^{r'}$ while the latter banks issue insured deposits equal to $\gamma^{r'}$, the deposit insurance limit with intermarket deposits that satisfies equation (C.23) must be lower than that without intermarket deposits: $\gamma^{r'} < \gamma^r$. Moreover, the smaller proportion of banks that monitor implies that monitoring efficiency declines.

Thus for all regimes, including fully-private and direct and indirect government liquidity creation, the introduction of intermarket deposits raises the profits of banks that do not monitor, thereby lowering the cost threshold for monitoring and the efficiency of bank lending but raising aggregate bank profits and banker welfare. Total lending is equal to the maximum of $1+k$ per market in all systems except direct liquidity with government investment. Thus the benefit of deposit insurance in increased lending and leverage relative to other regimes is overturned by the introduction of intermarket deposits.

Relative to a system without intermarket deposits, we see that banker profits (utility) are raised in each regime, proportional to the quantity of intermarket deposits each regime supports. This is greatest under the fully-private and direct liquidity with rebate regimes where the quantity of unused deposits is greatest, and least under deposit insurance where increased bank profits allow high-effort banks to lever more and direct liquidity with investment where the government makes use of unused funds.

Saver utility under the fully-private and direct liquidity regimes are unaffected by the introduction of intermarket deposits since each saver continues to receive his reserve utility, R_r per deposit and taxation is unchanged. Under fair deposit insurance, saver utility is reduced by tax-collection costs which may increase due to the reduction in bank monitoring. Defining $L^{'+}_b \equiv \max[L'_b, 0] \geq L^+_b$, savers' utility under deposit insurance with intermarket deposits is

$$U'_{DI} = U - \eta(p_b L^{'+}_b + p_c \bar{t}\omega) \leq U, \tag{C.26}$$

so that the change in savers' utility under deposit insurance due to the introduction of intermarket deposits is proportional to the change in the insurer's bad-state liability L_b', provided this is positive. It is defined as

$$L_b' \equiv L_0'(\gamma^{r'}) - \gamma^{r'} \frac{\gamma_{DI}' + k}{\gamma_{DI}'} d_0 \int_{c_{DI}^{*'}}^{\bar{c}} f(c_i) dc_i - \phi_1 L_1'(\gamma^{r'}), \tag{C.27}$$

where $L_1'(\gamma^{r'})$ and $L_0'(\gamma^{r'})$ are the insurer's liability for banks that monitor and do not monitor, respectively, defined in equation (C.25). Using equation (C.24), to substitute out $L_1'(\gamma^{r'})$ and the expression in the text for L_b, the difference in bad-state insurance liability under deposit insurance due to the introduction of intermarket deposits is:

$$L_b' - L_b \equiv \left[R_f/\wp - \frac{\gamma_{DI}' + k}{\gamma_{DI}'} d_0 \right] \gamma^{r'} \int_{c_{DI}^{*'}}^{\bar{c}} f(c_i) dc_i - \left[R_f/\wp - (1+k) d_0 \right] \gamma^{r} \int_{c_{DI}^{*}}^{\bar{c}} f(c_i) dc_i, \tag{C.28}$$

where intermarket deposits increase the mass of no-monitoring banks as $c_{DI}^{*'} < c_{DI}^{*}$ but reduce equilibrium insurance coverage, $\gamma^{r'} < \gamma^{r}$, by creating more moderate-cost banks which do not fully insure. Moreover, increased no-monitoring bank leverage, $\gamma_{DI}' > 1$, reduces the insurer's liability by greater loan recovery values that flow to the insurer. The conflicting effects suggest that difference in expected taxes may be small. The change in saver welfare will be smaller due to the relatively small costs of direct tax collection, η.

Table C.2 reports the percentage change in the economy's characteristics relative to the equivalent regime without intermarket deposits. Lending increases significantly under the assumption of government investment, with more modest increases under the rebate, government deposits, and deposit insurance regimes. Increased leverage allows banks to tranche and produce more quasi-safe deposits for all regimes, including under deposit insurance, though the level of liquidity production under deposit insurance remains marginal relative to the other regimes. Increased profits for banks that do not monitor naturally reduces average monitoring efficiency for all regimes, but most significantly for those with direct liquidity provision. Expected taxation increases under deposit insurance due to the increase in banks that do not monitor, but this has no discernible effect on saver welfare. Increased leverage increases bank profits which drive small increases in total utility.

Table C.2: Effect of introducing intermarket deposits on welfare measures under three forms of government liquidity provision.

Percent change in social welfare, relative to equivalent regime without intermarket deposits		Deposit insurance	Direct liquidity, investment	Direct liquidity, rebate	Direct liquidity, deposits
Total lending		3.3	8.2	4.6	4.6
Total quasi-safe deposits		3.1	9	3.6	3.6
Monitored loan proportion		−8.1	−7.2	−13	−13
Expected taxation	$E[\tau]$	0.72	0	0	1.5
Saver welfare	U	0	0	0	0.0063
Banker welfare	U^b	0.86	1.2	1.3	1.3
Total welfare	$U + U^b$	0.046	0.049	0.067	0.073

Figures are shown in percentage change relative to the equivalent regime without intermarket deposits, except for quasi-safe asset production under deposit insurance which is shown in levels, indicated by the symbol †. All figures are displayed to two significant figures.