Stablecoins, CBDC, and the Impact on Bank Lending

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Abstract

We study how improvements in stablecoin usability and the introduction of a central bank digital currency (CBDC) affect bank intermediation in a general-equilibrium model in which households derive liquidity services from deposits, public money, and stablecoins, and banks set deposit rates with market power while facing a profit-linked leverage constraint. We show that the effects of improvements in outside money are state-dependent and can be non-monotonic. When banks' leverage constraints are slack, higher non-pecuniary benefits or greater remuneration of outside money intensify deposit competition, compress deposit spreads, and expand deposits and bank lending. By contrast, when leverage constraints bind, deposit holdings decline, loan spreads increase, and intermediation contracts. Sufficiently large quality improvements can therefore generate non-monotonic effects—initially expanding and eventually contracting bank lending. We establish an equivalence between remuneration and non-pecuniary benefits and derive neutrality conditions under which improvements in outside money merely reshuffle portfolios. A calibration to U.S. data illustrates these results.

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1 Introduction

Stablecoins and central bank digital currencies (CBDCs) are at the center of current policy debates. In the United States, Congress has enacted the GENIUS Act, establishing a federal framework for regulating stablecoins, while the House of Representatives has passed legislation that would prohibit the issuance of a retail CBDC.[1] In Europe, work on a digital euro continues alongside the European Union's Markets in Crypto-Assets (MiCA) regulation, which provides a legal framework for privately issued stablecoins.[2]

Proponents of both initiatives emphasize their potential to modernize payment systems long reliant on commercial banks and cash. Critics, warn that these instruments could weaken bank intermediation and pose risks to financial stability.[3] In this paper, we study the macroeconomic effects of stablecoins and CBDCs, with a focus on whether they will disintermediate bank lending.

Both stablecoins and CBDCs are designed as electronic means of payment that serve as alternatives to bank deposits. If these instruments offer greater liquidity services, households may reallocate funds away from bank deposits. A key distinction, however, is that banks use deposits to fund loans to firms and households, whereas stablecoins and CBDCs are anchored in public money—directly in the case of a CBDC and indirectly in the case of fully backed stablecoins—and are therefore not associated with the creation of new private credit. This distinction underlies policymakers' concerns that substitution toward stablecoins or a CBDC could reduce bank intermediation.

This simple logic, however, relies on a delicate chain of assumptions. For stablecoins or a CBDC to reduce lending, three conditions must hold. First, deposits must play a special role in bank funding, i.e., banks cannot readily replace them with alternative sources at comparable cost. Second, bank credit must be essential for production, i.e., firms cannot easily substitute toward market-based finance. Third, banks must not respond by competing aggressively to retain deposits. If banks instead increase deposit rates to keep depositors, lending need not fall. In fact, by compressing spreads, increased competition from stablecoins or a CBDC may expand intermediation.

[1] U.S. Congress (2025*b*,*a*).
[2] European Central Bank (2025*b*); European Union (2023).
[3] Bailey (2025); Financial Stability Board (2023); Bank for International Settlements (2025).

In this paper, we formalize the above logic in a general-equilibrium model in which banks possess deposit-pricing power and face a leverage constraint linked to profits. Households have access to outside money—stablecoins and public money (cash or a newly introduced CBDC). Our central results are state dependence and non-monotonicity: the effect of improvements in outside money depends on banks' proximity to their leverage constraint, and the effect can reverse as that constraint tightens. Better outside-money alternatives intensify competition for deposits. When the constraint is slack, this competition compresses deposit markups, raises deposits, and expands lending. As markups fall, however, profits decline until the leverage constraint binds; beyond this point, further improvements in outside money reduce deposits and contract intermediation.

In the model, households derive liquidity services from three imperfectly substitutable forms of money: bank deposits, stablecoins and public money. Banks fund themselves exclusively with deposits, which they use to lend to small, bank-dependent firms in the non-corporate sector. Banks are subject to a profit-linked leverage constraint that may limit deposit issuance. Stablecoin providers issue liabilities that are fully backed by government bonds, while the government supplies public money. Aggregate output combines production by non-corporate firms and large corporate firms. Unlike small non-corporate firms, large corporate firms can finance investment through the bond market. Apart from these features, the environment corresponds to a standard detrended neoclassical growth model with capital as the sole input.

The first part of the paper analytically characterizes the effects of increasing the liquidity services of stablecoins and of public money through the introduction of a CBDC. We show that the impact on bank intermediation depends on which friction constrains deposit supply. When banks limit deposit issuance to sustain higher markups, stronger competition from outside money induces them to reduce spreads, expand deposits and increase lending, thereby improving intermediation. By contrast, when a leverage constraint restricts deposit issuance, improvements in outside money compress profits and tighten the constraint. Banks are then unable to lower deposit spreads sufficiently to retain deposits, leading to a decline in deposits and a contraction in lending, i.e., disintermediation.

We show three additional results. First, improvements in outside money can have non-monotonic effects: modest improvements expand lending, but beyond a threshold profits thin, the constraint tightens, and intermediation contracts. Second, outside money's remuneration and non-pecuniary benefits are substitutes: a policymaker can achieve equivalent intermediation outcomes by adjusting either margin. Debates over whether to remunerate CBDCs or stablecoins are therefore second-order from an intermediation perspective. Third, we show conditions for neutrality: if deposits are not special on the funding side or bank credit is not special on the production side, improvements in outside money leave lending and output unchanged, merely reshuffling household portfolios.

Finally, we calibrate the model to U.S. data moments and simulate improvements in the liquidity services of stablecoins, such as faster or more cost-efficient payments and new use cases enabled by issuance on distributed ledger technology (DLT). In the calibrated steady state, banks' market power—rather than the leverage constraint—is the marginal friction. The quantitative exercise shows that there is room to improve stablecoin convenience before disintermediation occurs. Modest improvements compress deposit spreads and expand lending, even as stablecoin holdings grow. Stablecoin holdings can nearly double before the leverage constraint binds and intermediation begins to contract. In this region, loan spreads fall, output rises, and bank profits decline as market power erodes.

Related Literature A growing literature studies the implications of introducing a central bank digital currency (CBDC) for bank intermediation and monetary policy. A first set of papers—such as Andolfatto (2021) and Chiu et al. (2023)—show that introducing a CBDC need not lead to disintermediation when banks possess market power: competition for deposits can reduce spreads and expand lending. By contrast, Keister and Sanches (2023) show that in a competitive banking sector with balance-sheet constraints, a CBDC can crowd out deposits and contract lending. Our model nests both mechanisms and shows how the interaction between market power and leverage constraints generates non-monotonic effects on intermediation.

Our framework shares similarities with Whited, Wu and Xiao (2023), but it differs in focus. Their analysis is primarily quantitative, estimating the effects of introducing a CBDC both in the aggregate and across heterogeneous banks. We complement their work by providing analytical results that highlight the mechanisms behind the positive or negative effects on intermediation, including the potential for non-monotonic responses.

Our neutrality result connects to the work of Brunnermeier and Niepelt (2019) and

Fernández-Villaverde et al. (2021), who show that a CBDC can be neutral if the central bank redistributes appropriately across sectors. More broadly, our framework relates to Kashyap, Rajan and Stein (2002) and subsequent work emphasizing the special role of deposits in the economy. We formalize this insight within a general-equilibrium setting and show that, absent such "specialness," changes in competition from stablecoins or a CBDC merely reshuffle portfolios without affecting real outcomes.

The emerging literature on stablecoins has focused primarily on their design and stability—examining, for instance, whether they resemble money-market funds (see Aramonte, Schrimpf and Shin, 2021; Gorton and Zhang, 2022; Ma, Zeng and Zhang, 2025) and how leverage and peg mechanisms shape risk. Liao (2022) analyzes the macro-financial implications of large-scale stablecoin adoption, showing that its effects on bank intermediation depend on whether reserves are held as deposits at the central bank or as bank liabilities. Our contribution is to analyze the introduction of stablecoins within a general-equilibrium framework, treating them as another form of outside money, and to derive the conditions under which they affect bank lending and output.

2 Model

The model integrates public and private money in a general-equilibrium framework without uncertainty. Households can save in public money, bank deposits, stablecoins, corporate bonds, and government bonds. Stablecoin providers supply liquidity to households, fully backing their liabilities one-for-one with government bonds. Commercial banks issue deposits and set deposit rates with market power, subject to a leverage constraint. Banks use deposits to extend credit to non-corporate firms, which must borrow to finance capital investment. Corporate firms differ in that they can bypass banks by accessing capital markets directly. Firms in both sectors produce intermediate goods that are combined to produce a final good used for consumption and investment.

In this setting, we analyze improvements in the liquidity services of stablecoins—understood as greater convenience and wider acceptance—as well as the introduction of a central bank digital currency (CBDC), modeled as an improvement in the liquidity services of public money that may or may not pay interest.

2.1 Households

There is a unit mass of identical, infinitely lived households. Each household derives utility from consumption and from the liquidity services provided by holdings of bank deposits, public money and stablecoins. In addition, households can save in risk-free bonds issued by corporate firms or the government, which provide no liquidity services. The household's problem in recursive form is

$$V(A) = \max_{\{C,D,S,M,B_H\}} \log \left(C + \nu^{\eta} \frac{L^{1-\eta}}{1-\eta} \right) + \beta\, V(A') \tag{1}$$

subject to,

$$C + D + S + M + B_H + T = \Pi + A \tag{2}$$

$$A' = D\,(1 + r_D) + S\,(1 + r_S) + M\,(1 + r_M) + B_H\,(1 + r) \tag{3}$$

where C denotes consumption and L is an aggregator of bank deposits, stablecoins and public money—defined in Equation (4)—that aggregates the liquidity services these assets provide to households. The household receives profits Π from financial intermediaries and firms. Each period, the household enters with savings A, consisting of the principal and interest from all fungible real assets: bank deposits D, stablecoins S, public money M, and risk-free bonds $B_H = B_{H,C} + B_{H,P}$, defined as the sum of government and corporate bonds.[4] The corresponding real interest rates are denoted as r_D, r_S, r_M, and r, respectively.[5]

We refer to the aggregator L as the *liquidity aggregator*[6] and to the level of L as liquidity holdings. Similar to Drechsler, Savov and Schnabl (2017), liquid assets L are modeled as an aggregator of deposits D, stablecoins S, and public money M, with these three assets treated as imperfect substitutes. In addition, consistent with Abadi, Brunnermeier and

[4]In equilibrium, both bonds pay the same interest rate by no arbitrage.

[5]As we solely focus on steady-state comparisons and neglect the analysis of transition periods, we represent all variables in real terms. Jumps in the price level during transitions will not impact our findings, while changes in inflation would be reflected through adjustments in real interest rates, affecting the demand for real balances.

[6]Strictly speaking, all assets are liquid in the sense that they can be converted into consumption without cost or delay. However, only public money, stablecoins and bank deposits provide direct liquidity services.

Koby (2023), we introduce a liquidity satiation point $L^\star$ that bounds the demand for liquidity services.[7] We assume that L follows a CES form defined by

$$L = \min\{L^\star, \left(\omega_M^\varepsilon \cdot M^{1-\varepsilon} + \omega_S^\varepsilon \cdot S^{1-\varepsilon} + D^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}\} \tag{4}$$

The functional forms assumed allow us to write households' optimal demands for liquidity, deposits, stablecoins and public money solely as a function of current spreads:

$$L = \min\{L^\star, \nu s_L^{-1/\eta}\}, \tag{5}$$

$$D = L\left(\frac{s_D}{s_L}\right)^{-1/\varepsilon}, \tag{6}$$

$$S = \omega_S L\left(\frac{s_S}{s_L}\right)^{-1/\varepsilon}, \tag{7}$$

$$M = \omega_M L\left(\frac{s_M}{s_L}\right)^{-1/\varepsilon}, \tag{8}$$

where spreads are defined as

$$s_D \equiv \frac{r - r_D}{1+r}, s_S \equiv \frac{r - r_S}{1+r}, s_M \equiv \frac{r - r_M}{1+r}, s_L \equiv \left[s_D^{\frac{\varepsilon-1}{\varepsilon}} + \omega_M s_M^{\frac{\varepsilon-1}{\varepsilon}} + \omega_S s_S^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}}.$$

Finally, the households' problem is completed by the Euler equation:

$$\left[C + \nu^\eta \frac{L^{(1-\eta)}}{1-\eta}\right]^{-1} = \beta(1+r)\left[C' + \nu^\eta \frac{L'^{(1-\eta)}}{1-\eta}\right]^{-1} \tag{9}$$

Details on the derivation are provided in Appendix A.1. For future reference, the household's intertemporal discount factor, denoted by Λ, is given by

$$\Lambda \equiv \beta \frac{\left[C' + \nu^\eta \frac{L'^{(1-\eta)}}{1-\eta}\right]^{-1}}{\left[C + \nu^\eta \frac{L^{(1-\eta)}}{1-\eta}\right]^{-1}} \tag{10}$$

[7] The satiation point is introduced solely for technical reasons, i.e., to rule out a corner solution in which households demand infinite deposits. As long as the satiation point does not bind, its level does not affect our results.

Below, we impose an elasticity ordering that guarantees a unique interior monopoly-pricing solution for banks:

Assumption 1 (Elasticity ordering)**.** *We assume $\varepsilon^{-1} > 1$ (deposits, stablecoins, and public money are imperfect substitutes as sources of liquidity) and $\eta^{-1} < 1$ (aggregate liquidity demand has elasticity below one).*

2.2 Firms

The economy produces a final good used for consumption and investment and intermediate goods used as inputs in final-good production. Intermediate goods are supplied by two sectors that differ in productivity and financing options. The large-firm corporate sector can issue bonds on financial markets, while the non-corporate small-firm sector relies exclusively on bank loans to fund its operations. Similar financing assumptions are made in Abadi, Brunnermeier and Koby (2023). Moreover, such arrangements can arise as an optimal choice by banks and firms and are consistent with the data (De Fiore and Uhlig, 2011).

Final-good producers operate in a competitive market, produce output Y and use imperfectly substitutable intermediate inputs from the corporate sector, y_C, and the non-corporate sector, y_N. In each period, they maximize

$$\max_{\{y_N, y_C\}} Y\left(y_N, y_C\right) - p_N y_N - p_C y_C, \tag{11}$$

where the final good is the numeraire and p_N and p_C are the relative prices of non-corporate and corporate output, respectively. The production function is

$$Y = \left[y_N^{\frac{\rho-1}{\rho}} + y_C^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}}, \tag{12}$$

where ρ is the elasticity of substitution between the intermediate goods. The solution to the problem is characterized by

$$y_C = Y\, p_C^{-\rho}, \tag{13}$$

$$y_N = Y\, p_N^{-\rho}. \tag{14}$$

Intermediate good producers use only capital to produce. Small firms in the non-corporate sector and large firms in the corporate sector produce outputs y_N and y_C, respectively, using a decreasing-returns-to-scale technology with constant productivities A_N and A_C. Capital depreciates over time at rate δ. Firms distribute all profits to households every period. To invest in new capital, firms must borrow the full amount of their investment. Corporate firms issue risk-free bonds B_C at rate r that can be held by both households and banks. The problem of the corporate firm in sequential form is:

$$\max_{\{K_{C,t+1},I_{C,t}\}} \sum_{t=0}^{\infty} \Lambda^t \left[p_{C,t} A_C K_{C,t}^{\alpha} - I_{C,t-1}\left(1 + r_{t-1}\right)\right] \tag{15}$$

subject to:

$$K_{C,t+1} = (1-\delta)\, K_{C,t} + I_{C,t} \tag{16}$$

where $\Lambda^t \equiv \prod_{h=0}^{t} \Lambda_h$ and Λ_t is the household's intertemporal discount factor defined in (10). The corporate firm sells its output $y_C = A_C K_C^{\alpha}$ to final goods producers at price p_C. Equation (16) depicts a standard flow equation for capital without adjustment costs. The solution to the corporate firm's problem is characterized by:

$$\alpha p_C' A_C {K_C'}^{\alpha-1} = r + \delta \tag{17}$$

where primed variables denote next-period values. This condition incorporates the equilibrium discount factor from the household's problem.

Non-corporate firms cannot issue bonds directly to households and must borrow from banks at rate r_ℓ. Their problem is:

$$\max_{\{K_{N,t+1},\, I_{N,t}\}} \sum_{t=0}^{\infty} \Lambda^t \left[p_{N,t} A_N K_{N,t}^{\alpha} - I_{N,t-1}\left(1 + r_{\ell,t-1}\right)\right]$$

subject to:

$$K_{N,t+1} = (1-\delta) K_{N,t} + I_{N,t}.$$

The non-corporate firm sells its output $y_N = A_N K_N^{\alpha}$ to final goods producers at price

p_N. The solution to the non-corporate firm's optimization problem is:

$$\alpha p'_N A_N {K'_N}^{\alpha-1} = 1 + r_\ell - (1-\delta)\frac{1+r'_\ell}{1+r'} \tag{18}$$

A derivation of both the corporate and the non-corporate firms' optimization problems is available in Appendix A.2.

To highlight how interest rate wedges induced by bank intermediation distort the allocation, it is useful to express the preceding condition in steady state:

$$\alpha p_N A_N K_N^{\alpha-1} = (1+s_\ell)(r+\delta) \tag{19}$$

Combining this expression with the FOC of corporate firms (17) in steady state yields

$$\frac{\alpha p_N A_N K_N^{\alpha-1}}{\alpha p_C A_C K_C^{\alpha-1}} = (1+s_\ell) \tag{20}$$

The left-hand side represents the ratio of the marginal products of capital across the two sectors. The loan spread s_ℓ appears as a wedge that prevents the marginal products from being equal. Reducing this wedge would increase output and improve welfare.

2.3 Banks

There is a unit mass of homogeneous banks, owned by households, each bank operating on a separate island. An equal random sample of households resides on each island, and households cannot relocate across islands. Banks collect deposits, D, from households and extend loans, ℓ, to small firms. Loan supply is perfectly competitive on a common island where production and consumption take place. By contrast, deposits are raised locally: on each island, the resident bank is a monopolist in its deposit market. As a result, banks internalize the impact of their deposit pricing on local households' consumption and savings decisions, while remaining too small to influence other aggregate quantities and prices.

Banks can also hold risk-free bonds issued by corporate firms as well as public debt, $B_B = B_{B,C} + B_{B,P}$, in positive quantities. Each period, profits are distributed back to households.[8] Banks are subject to a leverage constraint that links profits, Π_B, to their debt level through an increasing function $\phi(\Pi_B)$. We assume that $\phi(\Pi_B)$ is weakly increasing $\phi'(\Pi_B) \geq 0$, satisfies $\phi(0) = 0$ and is weakly concave $\phi''(\Pi_B) \leq 0$.[9] Each period, a representative bank solves

$$\max_{\ell, B_B, r_D} \Lambda \cdot \Pi_B = \max_{\ell, B_B, r_D} \Lambda \cdot \left[\ell\left(1+r_\ell\right) + B_B\left(1+r_B\right) - D(r_D)\left(1+r_D\right)\right] \tag{21}$$

subject to

$$\ell + B_B = D(r_D),$$
$$D(r_D) \leq \phi\left(\Pi_B\right),$$
$$B_{B,C}, B_{B,P} \geq 0.$$

where Λ is the households' intertemporal discount factor. The first constraint represents the balance sheet identity: loans and bond holdings must be financed by deposits. The second constraint is the leverage constraint, which requires leverage not to exceed the function $\phi(\Pi_B)$. In addition, we assume that banks cannot borrow risk-free bonds.

The optimal deposit spread chosen by banks is derived in Appendix A.3 and characterized by

$$s_D = \varepsilon_D^{-1} + \kappa - s_\ell \tag{22}$$

where κ is zero if the leverage constraint is loose, i.e., $D(r_D) < \phi\left(\Pi_B\right)$, and positive otherwise. $\varepsilon_D(s_D)$ is the semi-elasticity of the demand for deposits with respect to the deposit spread which is characterized by[10]

$$\varepsilon_D(s_D) = \frac{\varepsilon^{-1}\left(1-\omega_D\right) + \eta^{-1}\omega_D}{s_D} \tag{23}$$

[8] We abstract from equity issuance and from financing loans through wholesale funding. These features could be incorporated by introducing an additional cost of raising external funding, as in Whited, Wu and Xiao (2023).

[9] In Appendix A.4 we discuss and motivate the shape of this constraint.

[10] A derivation of ε_D is available in Appendix A.5.

where

$$\omega_D \equiv \frac{s_D D}{s_D D + s_M M + s_S S} \tag{24}$$

Equation (22) shows that the optimal deposit spread in the banking sector, denoted as s_D, is influenced by three factors. The first one arises from market power in the deposit market, manifesting itself in the first term of Equation (22) as the inverse of the semi-elasticity of deposits, $\varepsilon_D(s_D)^{-1}$. Similar to a classical monopoly scenario, a higher demand elasticity implies a lower markup that the monopolist optimally charges its customers. Notably, this elasticity depends on the market share of deposits within overall liquidity, $\omega_D \in [0, 1]$. The larger the share of deposits, the closer it aligns with the elasticity of liquidity, η^{-1}. The smaller the share, the closer it is to the elasticity between deposits and public money, ε^{-1}. Changes in household preferences for public money will influence the market share of deposits, thereby affecting the optimal spread charged by banks.

The second factor shaping the spread is the potentially binding leverage constraint, which is captured by the second term in Equation (22): $\kappa \geq 0$. The term is only positive when the leverage constraint binds, i.e., when $D = \phi(\Pi_B)$. In a binding state, the bank would like to expand deposits to finance additional lending but is constrained by the leverage limit. As a result, it lowers the deposit rate (raising the deposit spread) relative to the unconstrained optimum in order to reduce deposit inflows and satisfy the constraint.

The last term in Equation (22), s_ℓ, corresponds to the spread on loans, acting as a counteracting force to the deposit spread: the higher the spread on loans, the lower the one on deposits. A higher spread on loans s_ℓ incentivizes banks to issue more deposits to fund them, leading to a lowering of the deposit spread s_D.

Lastly, Proposition 1 shows that banks do not hold bonds if loans pay a higher interest rate.

Proposition 1. *If the interest rate spread between loans and bonds is positive, i.e.* $r_\ell - r > 0$ *or* $s_\ell > 0$*, then banks do not hold bonds, i.e.,* $B_B = 0$

A proof is available in Appendix B.1. The intuition is straightforward: banks are purely return-maximizing investors and therefore allocate their portfolios entirely to the asset with the highest return.

2.4 Stablecoin Providers

Stablecoin providers collect funds from households and issue stablecoins. We focus on the type of stablecoin that is fully collateralized with government bonds.[11] Specifically, for each unit of stablecoins S demanded by households, providers hold an equal amount of bonds $B_{S,P}$, so that $S = B_{S,P}$. These providers may earn profits whenever the return on bonds exceeds the interest they promise on stablecoins:

$$\Pi_S = (1+r)B_{S,P} - (1+r_S)S, \quad \text{with } S = B_{S,P}. \tag{25}$$

These profits are rebated to households every period. We take stablecoin pricing as given and assume that stablecoins pay the same return as public money, $r_S = r_M$, consistent with the prevailing practice for custodial stablecoins that pay zero nominal return.[12] When analyzing changes in the return on public money, we keep the return on stablecoins as fixed at its steady-state level.

2.5 Government - Central Bank

The government determines the return on public money r_M and the aggregate level of government bonds B_P. Its budget constraint is

$$B_P(1+r) + M(1+r_M) = M' + B'_P + T \tag{26}$$

where public money M is determined by demand and taxes/transfers T balance the equation.

[11] Reserve composition differs across issuers. For example, Tether (USDT), the largest stablecoin, reports that the majority of its reserves are invested in short-term U.S. Treasury bills, with smaller shares in repos, cash, gold, Bitcoin, and secured loans (see BDO Italia S.p.A., 2025).

[12] This assumption is consistent with current regulatory practice in both the United States and the European Union, where stablecoin issuers are generally prohibited from paying interest to their customers.

2.6 Equilibrium

In each period the goods and the lending markets clear:

$$Y = C + I_C + I_N \tag{27}$$

$$I_C = B_{H,C} + B_{B,C} \tag{28}$$

$$I_N = \ell \tag{29}$$

$$B_P = B_{S,P} + B_{H,P} + B_{B,P} \tag{30}$$

Given market clearing, we can define an equilibrium.

Definition 1. *An equilibrium is an allocation* $\{C_t, L_t, M_t, D_t, S_t, B_{H,t}\}_{t=0}^{\infty}$ *for the representative household, an allocation for the final good producers* $\{y_{C,t}, y_{N,t}\}_{t=0}^{\infty}$*, an allocation for corporate firms* $\{K_{C,t+1}, I_{C,t}\}_{t=0}^{\infty}$*, an allocation for non-corporate firms* $\{K_{N,t+1}, I_{N,t}\}_{t=0}^{\infty}$*, an allocation for banks* $\{\ell_t, B_{B,t}, r_{D,t}\}_{t=0}^{\infty}$*, an allocation for stablecoin suppliers* $\{S_t, B_{S,t}, r_{S,t}\}_{t=0}^{\infty}$*, a set of prices* $\{p_{C,t}, p_{N,t}, r_t, r_{\ell,t}\}_{t=0}^{\infty}$*, government policy* $\{T_t, B_{P,t}, r_{M,t}\}_{t=0}^{\infty}$*, given initial states* $\{K_{C,0}, K_{N,0}, B_{P,0}\}$*, such that:*

1. *Given* $\{r_t, r_{D,t}, r_{S,t}, r_{M,t}, T_t, \Pi_t\}_{t=0}^{\infty}$*—where* Π_t *denotes aggregate profits rebated to households—the household allocation* $\{C_t, L_t, M_t, D_t, S_t, B_{H,t}\}_{t=0}^{\infty}$ *solves the household's problem.*

2. *Given* $\{p_{C,t}, p_{N,t}\}_{t=0}^{\infty}$*, the allocation for the final good producers* $\{y_{C,t}, y_{N,t}\}_{t=0}^{\infty}$ *solves their problem.*

3. *Given* $\{p_{C,t}, r_t\}_{t=0}^{\infty}$ *and* $K_{C,0}$*, the allocation for corporate firms* $\{K_{C,t+1}, I_{C,t}\}_{t=0}^{\infty}$ *solves their problem.*

4. *Given* $\{p_{N,t}, r_{\ell,t}\}_{t=0}^{\infty}$ *and* $K_{N,0}$*, the allocation for non-corporate firms* $\{K_{N,t+1}, I_{N,t}\}_{t=0}^{\infty}$ *solves their problem.*

5. *Given* $\{r_{\ell,t}, r_t\}_{t=0}^{\infty}$*, the allocation for banks* $\{\ell_t, B_{B,t}, r_{D,t}\}_{t=0}^{\infty}$ *solves their problem.*

6. *Stablecoin providers are passive entities. For each* t*, they satisfy the balance-sheet identity* $S_t = B_{S,P,t}$ *and the pricing convention that* $r_{S,t}$ *is exogenous with* $r_S = r_M$ *in steady state.*

7. *Market for goods and lending clear.*

8. *The government budget constraint is satisfied.*

In Appendix C we describe the equilibrium equations and show how we solve the model.

We focus exclusively on steady-state equilibria. An equilibrium is defined as a steady-state if relative prices and real quantities are constant. We restrict attention to equilibria with positive and finite quantities and prices and for liquidity impose the condition $L < L^\star$. We choose $L^\star$ sufficiently large such that this condition is satisfied. Positive prices are also imposed on spreads, i.e., $s_D, s_\ell > 0$. Finally, we assume $r > -1$ and $r_D > -1$, which rules out negative gross returns: neither bonds nor banks can require repayments that exceed the principal in the following period.

3 Stablecoins, CBDC, and Bank Intermediation

In this section we study how improvements in stablecoins and the introduction of a central bank digital currency (CBDC) affect bank intermediation and aggregate output. We model stablecoin improvements in reduced form as an increase in households' preference for holding liquidity in the form of stablecoins, captured by a rise in ω_S. Such improvements reflect ongoing efforts to enhance their safety, usability, regulation[13], wider acceptance as well as their integration into payment systems. By contrast, the introduction of a CBDC is modeled as an increase in households' preference for public money, ω_M, and/or as an increase in its pecuniary return, represented by a lower spread s_M. Throughout, we focus on steady-state comparisons.

Our first result is that both stablecoin improvements and the introduction of a CBDC unambiguously lower the deposit spread s_D—the implicit price households pay for holding deposits. The effect on bank lending, however, depends on whether the leverage constraint binds. When the constraint is binding ($\kappa > 0$), stronger competition from alternative liquid instruments tightens banks' profit-based constraint and reduces intermediation. By contrast, when it does not bind ($\kappa = 0$), greater household demand for stablecoins or public money reduces banks' market power in deposit markets and lending expands. Our findings also imply that the common policy debate on whether a CBDC

[13] Such as recent U.S. legislation, including the GENIUS Act, which establishes a regulatory framework for stablecoin issuance.

should pay interest is of second-order importance: what matters is that households value both the non-pecuniary attributes (ω_S or ω_M) and the pecuniary return (s_M or s_S) of alternative liquid instruments. From a policy perspective, ω_M and s_M act as substitutes, and raising either dimension can trigger disintermediation.

We also show that improvements in stablecoins or the introduction of a CBDC may have non-monotonic effects. Increases in ω_S or ω_M may initially expand intermediation by compressing deposit and loan spreads, but if they rise too much, this effect can reverse once the leverage constraint becomes binding. Finally, we show that these innovations affect aggregate output only if deposits and banks play a "special" role in the economy: deposits must be imperfect substitutes for banks' wholesale funding and bank loans must be an imperfect substitute for firms' bond financing.

3.1 Analytical Results

We begin by showing that the effects of improvements in outside-money quality on bank lending and output depend on which friction binds in the banking system. First, we define the two possible regions in which the equilibrium of this economy can lie.

Definition 2. *For a given ω_S, ω_M and r_M, the equilibrium steady-state prices and quantities belong to the constrained region if the bank's borrowing constraint is binding—that is, if $\kappa > 0$ and $D = \phi(\Pi_B)$. Alternatively, if the borrowing constraint does not bind ($\kappa = 0$), the equilibrium belongs to the unconstrained region.*

The key takeaway is that the marginal source of deposits spreads differs across regions. In the unconstrained region, spreads are driven by banks' market power over depositors: banks optimally set deposit rates below lending rates ($r_D < r_\ell$), and marginal changes in the borrowing constraint have no effect, as it is not binding. In the constrained region, by contrast, the borrowing constraint binds and spreads are determined at the margin by the tightness of this constraint.

Improvements in the quality of stablecoins or the introduction of a CBDC increase competition for deposits from outside money. The effect of this additional competition depends on which friction is relevant in the banking sector. The following proposition formalizes this idea.

Proposition 2. *An improvement in stablecoins—modeled as a marginal increase in households' valuation of their non-pecuniary benefits (ω_S)—or the introduction of a CBDC—modeled as a marginal increase in households' valuation of central bank money (ω_M) and/or its return (r_M)—has the following steady-state effects:*

1. *The deposit spread s_D decreases.*
2. *Unconstrained region ($\kappa = 0$):*
   - (a) *The loan spread s_ℓ decreases.*
   - (b) *Deposits D and bank lending ℓ increase.*
   - (c) *Aggregate output Y increases.*
3. *Constrained region ($\kappa > 0$):*
   - (a) *The loan spread s_ℓ increases.*
   - (b) *Deposits D and bank lending ℓ decrease.*
   - (c) *Aggregate output Y falls.*

Proofs are presented in Appendices B.2 and B.3.

Proposition 2 implies that when the bank's leverage constraint does not bind, a marginal increase in the quality of stablecoins (ω_S), in public money (ω_M), and/or in its return (r_M) reduces the household cost of holding deposits s_D without causing disintermediation. In fact, it leads to an expansion of bank lending.

The intuition is that improvements in the non-pecuniary benefits of outside money relative to bank deposits increase the attractiveness of outside money and reduce the market share of deposits. A smaller market share implies a higher demand elasticity, since elasticity varies inversely with market share as illustrated in Equation (23).[14] A higher demand elasticity intensifies competition in the deposit market by making the deposit demand curve faced by banks more elastic at given prices. Banks then optimally respond to this increased competition by lowering deposit spreads, thereby raising deposit remuneration.

[14] This relationship requires that the elasticity of substitution between deposits, stablecoins, and public money exceed that between liquidity and consumption—formally, $\varepsilon^{-1} > \eta^{-1}$, as assumed in Assumption 1.

The lower relative price of deposits outweighs the initial preference shift. Deposits increase and this expansion passes through to loan pricing: the loan spread s_ℓ falls, which stimulates borrowing by small non-corporate firms. As a result, both deposits and bank lending rise. The fall in spreads reduces the wedge in marginal products between sectors in Equation (20), thereby raising aggregate output.

The effect of stablecoins and CBDC depends crucially on whether market power, rather than the leverage constraint, is the marginal source of deposit spreads. Point (3) of Proposition 2 states that if the leverage constraint binds, an increase in ω_S, ω_M and/or r_M leads to bank disintermediation. The reason is that the banking sector cannot absorb additional deposits without violating the leverage constraint ($D \leq \phi(\Pi_B)$).

In this case, when ω_S, ω_M, or r_M rises, a bank with market power would, absent the constraint, lower the deposit spread to attract more deposits and maximize profits. However, the leverage constraint prevents this adjustment. As a result, improvements in stablecoins or the introduction of a CBDC intensify competition, reduce bank profits, and tighten the constraint, ultimately displacing deposits. This outflow contracts loan supply, raises the equilibrium lending rate and reduces aggregate output.

In summary, Proposition 2 shows that the effects of stablecoin improvements or a CBDC on intermediation depend on the binding friction: lending expands when market power is the marginal source of deposit spreads, but contracts when the leverage constraint binds.

An important implication of Proposition 2 is the possibility of non-monotonic effects: as the attractiveness of stablecoins or public money increases, the economy can transition from the unconstrained to the constrained region. The next proposition formalizes this "region-switching".

Proposition 3 (Non-monotonic effects). *If the initial equilibrium lies in the* uncon-strained *region ($\kappa = 0$) and the elasticity of output with respect to capital is sufficiently low (i.e., α is low), then:*

1. *For small increases in either ω_S, ω_M or r_M, the loan spread s_ℓ decreases and bank lending ℓ increases, as established in Proposition 2.*

2. *There exists a threshold for each variable $\{\bar{\omega}_S, \bar{\omega}_M, \bar{r}_M\}$ such that for increases*

beyond this point the equilibrium is pushed into the constrained *region ($\kappa > 0$) and the effects reverse: s_ℓ increases and ℓ decreases.*

The proof is presented in Appendix B.2.1.

Proposition 3 follows because more useful stablecoins or a CBDC increase competition in the market for liquid funds. Banks would like to respond by cutting the deposit spread s_D, which attracts deposits and expands intermediation. This adjustment is feasible only in the *unconstrained* region. Narrower spreads, however, compress banks profits Π_B. With more deposits, D, and lower profits, Π_B, the leverage condition $D \leq \phi(\Pi_B)$, tightens, moving the bank closer to the constraint. A low output elasticity of capital (small α) ensures that the additional loans issued do not raise profits sufficiently to offset this tightening.

Once ω_S, ω_M or r_M are sufficiently large, the leverage constraint binds. At that point, the bank cannot reduce the deposits spread s_D further without violating the constraint. The market share of deposits falls, deposits fall, loan supply contracts, and the loan spread s_ℓ rises—i.e., disintermediation sets in.

It is worth noting that Propositions 2 and 3 establish that increasing the quality of stablecoins (ω_S), the quality of public money (ω_M), or the return on public money (r_M) has the same qualitative effect on equilibrium interest rates, bank lending, and output. The next corollary formalizes this equivalence and provides a quantitative mapping from changes in the return on public money r_M, or equivalently its price s_M, to changes in the quality of public money and stablecoins ω_M and ω_S.

Corollary 1. *Qualitative and quantitative equivalence of quality and remuneration changes*

i) A 1 percent increase in the quality of public money ω_M has the same effect on steady-state equilibrium variables as a $\frac{1}{\varepsilon^{-1}-1}$ percent reduction in the spread on public money s_M. Formally, for any variable of interest x (such as equilibrium loans ℓ or aggregate output Y),

$$\frac{\partial \log x}{\partial \log \omega_M} = -\frac{1}{\varepsilon^{-1} - 1} \frac{\partial \log x}{\partial \log s_M}.$$

ii) A 1 percent increase in the quality of stablecoins ω_S has the same effect on steady-state equilibrium variables as a $\frac{\omega_S}{\omega_M}$ percent increase in the quality of public money ω_M.

Formally, for any variable of interest x,

$$\frac{\partial \log x}{\partial \log \omega_S} = \frac{\omega_S}{\omega_M} \frac{\partial \log x}{\partial \log \omega_M}.$$

A proof is available in Appendix B.4.

Policymakers have generally opposed paying interest on retail CBDC.[15] Corollary 1 implies that, if disintermediation is the relevant concern, remuneration of CBDC is not the only relevant margin. Design features that enhance the non-pecuniary value of a CBDC—such as convenience, acceptance, interoperability, or privacy (captured by ω_M)—can be just as powerful as interest-bearing features in shifting household portfolios and affecting intermediation.

Corollary 1 also provides a quantitative mapping between equilibrium responses to changes in the public-money spread s_M and to changes in money quality. In elasticity terms, it shows how the sensitivity of equilibrium variables to s_M translates into their sensitivity to ω_M and ω_S. This allows to map comparative statics with respect to the relatively opaque preference parameter ω_M into observable changes in the spread on public money s_M. For example, suppose we have an estimate of the elasticity of loans with respect to the public-money spread, $\hat{\beta}_{s_M} \equiv \frac{\partial \ln \ell}{\partial \ln s_M}$, and a reasonable value for the liquidity-substitution elasticity ε^{-1}. Then the corresponding elasticity with respect to ω_M is $\frac{\partial \ln \ell}{\partial \ln \omega_M} = -\frac{1}{\varepsilon^{-1}-1} \hat{\beta}_{s_M}$.[16]

The final point in this section clarifies the conditions under which stablecoins or a CBDC affect bank intermediation: deposits must be "special" on both sides of the bank balance sheet. On the liability side, deposits must constitute a special source of funding for banks. This condition holds in our model because deposits are banks' only funding source; there is no access to wholesale funding or bond issuance. On the asset side, bank credit must be special for aggregate production. This condition is also satisfied, as non-corporate firms are bank-dependent and the final-good technology requires their input due to imperfect substitutability between non-corporate and corporate goods. If either

[15] See, for example, the ECB's public materials on the digital euro and the Bank of England/HM Treasury response to the digital pound consultation, which state that holdings would *not* be remunerated; e.g., European Central Bank (2025*a*); HM Treasury and Bank of England (2024).

[16] Since public money has traditionally not paid interest, estimating the elasticity with respect to s_M is equivalent to estimating the elasticity with respect to short-term interest rates r. This can be done empirically by using an exogenous instrument for r; see, for example, Nakamura and Steinsson (2018).

form of "specialness" is absent, increased competition for liquid balances affects only the composition of household portfolios and leaves equilibrium intermediation unchanged.

If either banks can borrow on wholesale markets or non-corporate firms can bypass banks and borrow like corporates, improving stablecoin quality or introducing a CBDC is neutral for intermediation. The next proposition formalizes this neutrality result.

Proposition 4 (Neutrality without deposit or bank-credit "specialness")**.** *Suppose one of the following holds:*

1. Deposits not special: *Banks can replace deposits with wholesale funding supplied by households at a given constant rate and wholesale funding does not enter the borrowing constraint; or*

2. Bank credit not special: *Small firms can borrow directly from households at a given constant rate.*

Then improvements in stablecoins (modeled as an increase in ω_S) or the introduction of a CBDC (modeled as an increase in ω_M) have no effect on bank intermediation: equilibrium bank lending ℓ, the loan spread s_ℓ and aggregate output Y are unchanged. The only impact is on the composition of household balance sheets, as households reshuffle between deposits, public money, and stablecoins.

A proof is available in Appendix B.5.

Proposition 4 formalizes that changes in banking competition affect real outcomes only when the instruments on both sides of banks' balance sheets are special—deposits as a special source of funding and loans as a special production input. Absent either feature, a stablecoin or CBDC induced increase in competition for liquid funds is neutral for intermediation and output.

Without both forms of specialness, competition from stablecoins or CBDC merely reshuffles household portfolios without affecting real activity. Quantitatively, the magnitude of these effects depends on two key elasticities: (i) banks' liability-side substitution between deposits and wholesale funding, and (ii) firms' substitution between bank loans and market (bond) borrowing.[17]

[17] Estimating these elasticities is beyond the scope of this paper. For a related quantitative assessment, see Whited, Wu and Xiao (2023).

The next section presents a quantitative exercise that illustrates our results.

3.2 Numerical Illustration

In this section, we simulate improvements in outside money and examine how frictions in the financial sector determine their impact on bank lending. We calibrate the parameters of the model to match key moments in the U.S. economy and simulate an increase in the households' preference for outside money—either through increasing stablecoins' non-pecuniary benefits (ω_S) or an introduction of a CBDC (ω_M).

3.2.1 Calibration

The model is calibrated to match key moments of the U.S. economy over the period 1987–2007.[18] Each each period in the model corresponds to one year. A subset of parameters is taken directly from the existing literature, while the remaining ones are chosen to match moments in the data. Table 1 summarizes the parameters calibrated externally.

Table 1: Externally calibrated parameters

Parameter	Description	Value	Source
ρ	Elasticity between intermediate goods	3.9	Abadi, Brunnermeier and Koby (2023)
δ	Depreciation rate	0.1	Abadi, Brunnermeier and Koby (2023)
ε	Elasticity between M, D, and S	0.5	see text
ϕ	Leverage constraint ($D \leq \phi\,\Pi_B$)	22	see text

We follow Abadi, Brunnermeier and Koby (2023) in setting the elasticity of substitution between intermediate goods to $\rho = 3.9$ and the depreciation rate to $\delta = 0.1$. The elasticity of substitution between liquidity sources, denoted by ε^{-1}, governs the sensitivity of flows from private money to alternative forms of money in response to changes in outside money. However, the literature does not provide a consensus estimate for this parameter. We therefore set $\varepsilon = 0.5$, which we view as a reasonable midpoint within

[18] The sample begins in 1987 due to FDIC data availability and ends in 2007 to exclude the zero lower bound (ZLB) period, during which the model is indeterminate. Our results are robust to extending the sample through 2025 while excluding years when the federal funds rate was at the ZLB.

the range of values used in prior studies.[19]

For our calibration, we assume a linear borrowing constraint of the form $\phi(\Pi_B) = \phi \cdot \Pi_B$ and set $\phi = 22$. As shown in Appendix A.4, a linear borrowing constraint expressed in terms of profits ($D \leq \phi \Pi_B$) can be mapped into the more common formulation in the literature that links balance-sheet size to equity e, namely $\ell + B \leq \varphi \cdot e$. This mapping requires an estimate of the ratio of bank profits, Π_B, to equity, as well as a choice of the leverage parameter φ. We estimate profits using net interest margins and measure equity using FDIC data. Our choice of $\phi = 22$ is derived from targeting $\varphi = 10$, corresponding to a midpoint within the range of values used in the literature.[20] See Appendix A.4 and E for a more detailed discussion.

The remaining parameters are chosen to match moments observed in US data, presented in Table 2. We target the time-series average of the deposit spread s_D, the spread on cash s_M, the loan rate spread s_ℓ, the deposit-to-GDP ratio D/Y, the share of money holdings over deposit holdings M/D, and the real rate r.

Furthermore, we define a target ratio of stablecoins to GDP, S/Y. Although stablecoins were not present during our sample period, we calibrate an initial supply that reflects their current scale. In our model, stablecoins are fully backed by U.S. Treasury securities. Accordingly, we base the calibration on estimates of stablecoin issuers' direct holdings of U.S. Treasuries. Using the estimate reported by Jacewitz (2025) of approximately \$125 billion[21], and relating this to current U.S. GDP of about \$30 trillion, we obtain a target ratio S/Y of roughly 0.4 percent. We set the stablecoin interest rate spread equal to that on cash, reflecting the fact that stablecoins generally do not pay interest.

Lastly, following Abadi, Brunnermeier and Koby (2023), we interpret the bank-dependent non-corporate sector as small and medium-sized enterprises (SMEs) and use estimates from Kobe and Schwinn (2018), who report the share of SMEs in U.S. GDP over time.

[19] For example, Wang (2020) uses $\varepsilon \approx 0.125$, Abad, Nuño and Thomas (2023) $\varepsilon \approx 0.15$, Burlon, Muñoz and Smets (2023) $\varepsilon \approx 0.3$, George, Xie and Alba (2022) $\varepsilon \approx 0.4$, and Perazzi and Bacchetta (2022) $\varepsilon \approx 0.7$.

[20] Values of φ in the literature vary with the interpretation of the borrowing constraint. For example, Gertler and Kiyotaki (2015) use $\varphi = 8$, while Whited, Wu and Xiao (2023) adopt $\varphi = 0.06^{-1} \approx 16.66$. In Appendix A.4.1 we briefly discuss how papers in the literature interpret the constraint differently.

[21] This estimate excludes Treasury-collateralized repurchase agreements and therefore represents a conservative lower bound. Public and audited reserve disclosures by Circle and Tether report direct U.S. Treasury holdings that are broadly consistent with this estimate, with total backing rising further once Treasury-collateralized instruments are included.

In the calibrated equilibrium, SMEs account for roughly 48 percent of U.S. output. Further details on the data are provided in Appendix D. We choose parameters assuming that the leverage constraint is slack in steady state and confirm afterward that this is indeed the case, implying that in our calibration the marginal friction arises from banks' market power in deposits.

Table 2: Targeted Moments

Moment	**Description**	**Value**	**Source**
r	Real rate on bonds	1.8%	FRED
s_D	Deposit spread	2.6%	FDIC
s_M	Cash spread	4.7%	FRED
s_S	Stablecoin spread	4.7%	s_M
s_ℓ	Loan spread	3.4%	FDIC
D/Y	Deposits over GDP	0.23	FRED
M/D	Cash over deposit holdings	0.09	FRED
S/Y	Stablecoins over GDP	0.004	Jacewitz (2025)
$p_N y_N/Y$	Share of non corporate production	0.48	Kobe and Schwinn (2018)

Note: The table presents the targeted moments used to derive the parameters shown in Table 3. Data values represent the time series average of the US economy from 1987 to 2007. Cash holdings are adjusted for currency holdings abroad, following Judson (2017). For additional information on the data, refer to Appendix D.

The calibrated parameters are presented in Table 3. The procedure to pin down parameter values is described in Appendix E. The discount factor β matches the real rate r, $\beta = (1+r)^{-1}$. The preference parameters for public money and stablecoins are chosen to match the respective shares of money and stablecoins relative to deposits. The liquidity elasticity (η) and preference (ν) parameters are chosen to match money demand and the deposit rate spread. The parameters governing the firm problem (α, A_S, A_C) are chosen to target the corporate vs. non-corporate production shares and the loan spread. Lastly, we set the liquidity satiation point L^* large enough that it never binds, ensuring an interior solution to the bank's problem.

3.2.2 Numerical Exercise

Our main quantitative exercise simulates improvements in the non-pecuniary benefits of stablecoins, which corresponds to a higher value of the parameter ω_S. Intuitively, this

Table 3: Calibrated Parameters

Par.	**Description**	**Value**
β	Discount factor	0.98
ω_M	Preference for M	0.31
ω_S	Preference for S	0.06
η^{-1}	Liquidity elasticity	0.11
ν	Liquidity Preference	0.52
α	Output elasticity of capital	0.59
A_N	Productivity non-corporate firm	0.33
A_C	Productivity corporate firm	0.34
ϕ	Leverage ratio	22.3

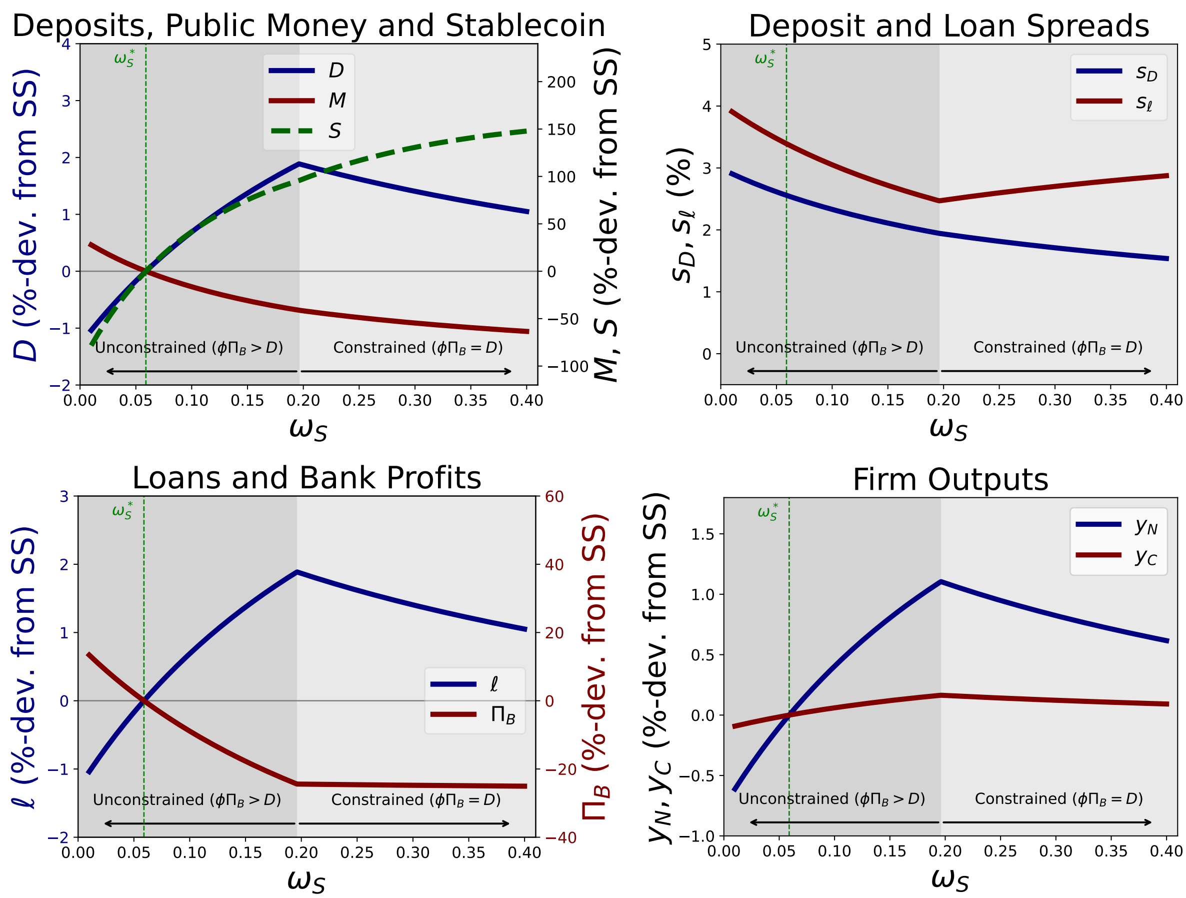
Note: The table shows the calibrated parameters to match the moments in Table 2.

reflects stablecoins becoming safer, more widely accepted, or otherwise more useful as a means of payment. We trace how such improvements affect the equilibrium steady state.

Figure 1 illustrates the effect of increasing the quality of stablecoins, ω_S, from its baseline steady-state value to higher levels. The upper-left panel shows the response of deposits, public money, and stablecoins as percentage deviations from the calibrated steady state. The figure illustrates point (b) of Proposition 2: in the unconstrained region, improvements in stablecoin quality increase not only stablecoin holdings but also bank deposits. This outcome arises because banks respond to stronger competition from higher-quality outside money by optimally reducing deposit spreads. As a result, improvements in stablecoins do not crowd out bank deposits when banks are unconstrained. Higher deposits, in turn, expand intermediation: loan spreads decline, lending increases, and output rises in both the corporate and non-corporate sectors. At the same time, bank profits fall as increased competition erodes market power.

Yet, as shown in Proposition 3, this effect eventually reverses. When the improvement in ω_S is large enough, the leverage constraint binds. Beyond this threshold, banks can no longer expand their balance sheets to absorb additional deposits and intermediation begins to contract. Loan spreads rise, lending falls and output in both sectors declines. Because intermediate goods are imperfect substitutes in final-good production, the reduction in credit provision also negatively affects the sector that is not dependent on

Figure 1: Effects of improving stablecoins (ω_S).



Note: The figure shows the steady-state equilibrium outcomes for different values of the quality of stablecoins (ω_S) in our calibrated economy. The unconstrained region refers to steady states such that $D < \phi \cdot \Pi_B$; the constrained regions to those with $D = \phi \cdot \Pi_B$.

bank lending.

Our illustrative calibration shows that there is room to enhance the liquidity services of stablecoins before any crowding out of deposits from the banking sector occurs. Importantly, improvements in stablecoins may not translate into large observed inflows toward these instruments: even though the stock of stablecoins almost doubles before the leverage constraint binds, their absolute level remains below 1% of GDP at that point. What matters is that, even when small, stablecoins operate as a latent competitive force on banks' market power, increasing intermediation without disrupting bank lending.[22]

[22] A very similar argument is made in Lagos and Zhang (2022) regarding cash as a latent disciplinary force on banks' market power.

Finally, in Appendix F we conduct an analogous exercise for the introduction of a CBDC by increasing the quality of public money (ω_M). As established in Corollary 1, the qualitative results are similar to those shown for stablecoins: improvements in public money quality expand intermediation in the unconstrained region but crowd out lending once the leverage constraint binds.

4 Conclusion

We develop a general-equilibrium framework to study how improvements in stablecoin usability and the introduction of a CBDC affect bank intermediation when banks possess deposit market power and face a profit-linked leverage constraint. The central insight is state dependence. When banks can expand their balance sheets, making outside money more attractive through either higher pecuniary or non-pecuniary benefits intensifies deposit competition, compresses deposit markups, and expands deposits and lending. Once profits thin and the constraint binds, however, the same improvements reduce deposit market shares, raise loan spreads, and shrink intermediation, yielding non-monotonic effects. We further show an equivalence between remuneration and non-pecuniary benefits and provide neutrality conditions under which outside money improvements merely reshuffle portfolios without affecting lending or output.

Our quantitative illustration, calibrated to U.S. moments, suggests there is scope to raise the quality of stablecoins without triggering deposit flight: modest improvements reduce deposit markups and expand lending.

References

Abad, Jorge, Galo Nuño, and Carlos Thomas. 2023. "CBDC and the operational framework of monetary policy." BIS Working Papers No 1126.

Abadi, Joseph, Markus Brunnermeier, and Yann Koby. 2023. "The Reversal Interest Rate." *American Economic Review*, 113: 2084–2120.

Adrian, Tobias, and Nina Boyarchenko. 2012. "Intermediary leverage cycles and financial stability." *Becker Friedman Institute for Research in Economics Working Paper*, , (2012-010).

Andolfatto, David. 2021. "Assessing the Impact of Central Bank Digital Currency on Private Banks." *The Economic Journal*, 131: 525–540.

Aramonte, Sirio, Andreas Schrimpf, and Hyun Song Shin. 2021. "Non-bank Financial Intermediaries and Financial Stability." Bank for International Settlements BIS Working Paper 972. Revised January 2022.

Bailey, Andrew. 2025. "The new stablecoin regime." *Financial Times*. Op-ed; Accessed Oct. 3, 2025.

Bank for International Settlements. 2025. "Annual Economic Report 2025, Chapter III: The next-generation monetary and financial system." Accessed Oct. 3, 2025.

BDO Italia S.p.A. 2025. "Independent Auditor's Report on the Financial Figures and Reserves Report of Tether International, S.A. de C.V." BDO Italia S.p.A. Attestation Report. As of March 31, 2025.

Brunnermeier, Markus K., and Dirk Niepelt. 2019. "On the equivalence of private and public money." *Journal of Monetary Economics*, 106: 27–41.

Burlon, Lorenzo, Manuel A Muñoz, and Frank Smets. 2023. "The optimal quantity of CBDC in a bank-based economy." *American Economic Journal: Macroeconomics*, (forthcoming).

Chiu, Jonathan, Mohammad Davoodalhosseini, Janet Jiang, and Yu Zhu. 2023. "Bank Market Power and Central Bank Digital Currency: Theory and Quantitative Assessment." *Journal of Political Economy*, 131: 1213–1248.

De Fiore, Fiorella, and Harald Uhlig. 2011. "Bank finance versus bond finance." *Journal of Money, Credit and Banking*, 43(7): 1399–1421.

Drechsler, Itamar, Alexi Savov, and Philipp Schnabl. 2017. "The Deposit Channel of Monetary Policy." *Quarterly Journal of Economics*, 132: 1819–1976.

European Central Bank. 2025*a*. "FAQs on a digital euro."

European Central Bank. 2025*b*. "Timeline and progress on a digital euro." Accessed Oct. 3, 2025.

European Union. 2023. "Regulation (EU) 2023/1114 on Markets in Crypto-Assets (MiCA)." Official Journal of the European Union; Accessed Oct. 3, 2025.

Fernández-Villaverde, Jesús, Daniel Sanches, Linda Schilling, and Harald Uhlig. 2021. "Central bank digital currency: Central banking for all?" *Review of Economic Dynamics*, 41: 225–242.

Financial Stability Board. 2023. "High-level Recommendations for the Regulation, Supervision and Oversight of Global Stablecoin Arrangements: Final Report." Accessed Oct. 3, 2025.

George, Ammu, Taojun Xie, and Joseph D Alba. 2022. "Central Bank Digital Currency with Adjustable Interest Rate in Small Open Economies." Available at SSRN: `https://ssrn.com/abstract=3605918`.

Gertler, Mark, and Nobuhiro Kiyotaki. 2015. "Banking, Liquidity, and Bank Runs in an Infinite Horizon Economy." *American Economic Review*, 105(7): 2011–43.

Gorton, Gary, and Jeffery Zhang. 2022. "Taming Wildcat Stablecoins." *University of Chicago Law Review*, 89(1): 113–182.

HM Treasury, and Bank of England. 2024. "Bank of England and HM Treasury respond to digital pound consultation."

Jacewitz, Stefan. 2025. "Stablecoins Could Increase Treasury Demand, but Only by Reducing Demand for Other Assets." Federal Reserve Bank of Kansas City Economic Bulletin.

Judson, Ruth. 2017. "The Death of Cash? Not So Fast: Demand for U.S. Currency at Home and Abroad, 1990-2016." International Cash Conference 2017 - War on Cash: Is there a Future for Cash? 25 - 27 April 2017, Island of Mainau, Germany, Deutsche Bundesbank, Frankfurt a. M.

Kashyap, Anil K, Raghuram Rajan, and Jeremy C Stein. 2002. "Banks as liquidity providers: An explanation for the coexistence of lending and deposit-taking." *The Journal of finance*, 57(1): 33–73.

Keister, Todd, and Daniel Sanches. 2023. "Should Central Banks Issue Digital Currency?" *The Review of Economic Studies*, 90: 404–431.

Kobe, Kathryn, and Richard Schwinn. 2018. "Small Business GDP 1998–2014." U.S. Small Business Administration.

Lagos, Ricardo, and Shengxing Zhang. 2022. "The limits of ONETARY economics: On money as a constraint on market power." *Econometrica*, 90(3): 1177–1204.

Liao, Gordon Y. 2022. "Stablecoins: Growth Potential and Impact on Banking." Federal Reserve Board International Finance Discussion Paper 1334.

Ma, Yiming, Yao Zeng, and Anthony Lee Zhang. 2025. "Stablecoin runs and the centralization of arbitrage." National Bureau of Economic Research.

Nakamura, Emi, and Jón Steinsson. 2018. "High-Frequency Identification of Monetary Non-Neutrality: The Information Effect." *Quarterly Journal of Economics*, 133(3): 1283–1330.

Perazzi, Elena, and Philippe Bacchetta. 2022. "CBDC as Imperfect Substitute for Bank Deposits: A Macroeconomic Perspective." Swiss Finance Institute Research Paper No. 21-81.

U.S. Congress. 2025*a*. "H.R. 1919 (119th Congress): Anti-CBDC Surveillance State Act." *U.S. Congress*, Accessed Oct. 3, 2025.

U.S. Congress. 2025*b*. "Text – S.1582 (119th Congress): Guiding and Establishing National Innovation for U.S. Stablecoins (GENIUS) Act." *U.S. Congress*, Public Law 119-27; Accessed Oct. 3, 2025.

Wang, Olivier. 2020. "Banks, low interest rates, and monetary policy transmission." ECB Working Paper Series No 2492.

Whited, Toni M, Yufeng Wu, and Kairong Xiao. 2023. "Will Central Bank Digital Currency Disintermediate Banks?" IHS Working Paper Series 47. Institute for Advanced Studies.

Appendix

for Online Publication

Appendix A Derivations

A.1 Derivation of the household equations

We solve the household's optimization problem defined in Equation (1) using the constraints in Equations (2) and (3), and the liquidity aggregator in Equation (4) assuming the solution is internal $L < L^\star$. The first order conditions, where the superscript $'$ defines the subsequent period, are:

$$[C]: \quad \lambda \; = \; \left[C + \nu^\eta \frac{L^{1-\eta}}{1-\eta}\right]^{-1}$$

$$[B]: \quad \lambda \; = \; \beta(1+r)\,\lambda'$$

$$[M]: \quad \lambda \; = \; \beta(1+r_M)\,\lambda' + \left[C + \nu^\eta \frac{L^{1-\eta}}{1-\eta}\right]^{-1} \nu^\eta L^{-\eta}\left(\omega_M^\varepsilon M^{1-\varepsilon} + \omega_S^\varepsilon S^{1-\varepsilon} + D^{1-\varepsilon}\right)^{\frac{\varepsilon}{1-\varepsilon}} \omega_M^\varepsilon M^{-\varepsilon}$$

$$[D]: \quad \lambda \; = \; \beta(1+r_D)\,\lambda' + \left[C + \nu^\eta \frac{L^{1-\eta}}{1-\eta}\right]^{-1} \nu^\eta L^{-\eta}\left(\omega_M^\varepsilon M^{1-\varepsilon} + \omega_S^\varepsilon S^{1-\varepsilon} + D^{1-\varepsilon}\right)^{\frac{\varepsilon}{1-\varepsilon}} D^{-\varepsilon}$$

$$[S]: \quad \lambda \; = \; \beta(1+r_S)\,\lambda' + \left[C + \nu^\eta \frac{L^{1-\eta}}{1-\eta}\right]^{-1} \nu^\eta L^{-\eta}\left(\omega_M^\varepsilon M^{1-\varepsilon} + \omega_S^\varepsilon S^{1-\varepsilon} + D^{1-\varepsilon}\right)^{\frac{\varepsilon}{1-\varepsilon}} \omega_S^\varepsilon S^{-\varepsilon}.$$

Define,

$$\chi \; \equiv \; \left[C + \nu^\eta \frac{L^{1-\eta}}{1-\eta}\right]^{-1} \nu^\eta L^{-\eta}\left(\omega_M^\varepsilon M^{1-\varepsilon} + \omega_S^\varepsilon S^{1-\varepsilon} + D^{1-\varepsilon}\right)^{\frac{\varepsilon}{1-\varepsilon}}$$

In $[M]$, $[S]$, and $[D]$, replace λ as defined in $[B]$ and divide by $\beta\lambda'$ to get

$$r - r_M = \frac{\mathcal{X}\,\omega_M^{\varepsilon} M^{-\varepsilon}}{\beta\lambda'},$$
$$r - r_S = \frac{\mathcal{X}\,\omega_S^{\varepsilon} S^{-\varepsilon}}{\beta\lambda'},$$
$$r - r_D = \frac{\mathcal{X}\,D^{-\varepsilon}}{\beta\lambda'}.$$

Next, divide the equations pairwise to obtain relative spreads,

$$\frac{r - r_M}{r - r_D} = \frac{\omega_M^{\varepsilon} M^{-\varepsilon}}{D^{-\varepsilon}},$$
$$\frac{r - r_S}{r - r_D} = \frac{\omega_S^{\varepsilon} S^{-\varepsilon}}{D^{-\varepsilon}},$$

Express relative to public money

$$\frac{r - r_M}{r - r_D} = \frac{\omega_M^{\varepsilon} M^{-\varepsilon}}{D^{-\varepsilon}} \quad \Rightarrow \quad \frac{D}{M} = \frac{1}{\omega_M}\left(\frac{r - r_D}{r - r_M}\right)^{-1/\varepsilon},$$
$$\frac{r - r_M}{r - r_S} = \frac{\omega_M^{\varepsilon} M^{-\varepsilon}}{\omega_S^{\varepsilon} S^{-\varepsilon}} \quad \Rightarrow \quad \frac{S}{M} = \frac{\omega_S}{\omega_M}\left(\frac{r - r_M}{r - r_S}\right)^{1/\varepsilon}.$$

Replace in the liquidity aggregator

$$\begin{aligned} L &= \left(\omega_M^{\varepsilon} M^{1-\varepsilon} + \omega_S^{\varepsilon} S^{1-\varepsilon} + D^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}} \\ &= M\left[\omega_M^{\varepsilon} + \omega_S^{\varepsilon}\left(\frac{S}{M}\right)^{1-\varepsilon} + \left(\frac{D}{M}\right)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} \\ &= M\left[\omega_M^{\varepsilon} + \omega_S^{\varepsilon}\left(\frac{\omega_S}{\omega_M}\right)^{1-\varepsilon}\left(\frac{r - r_M}{r - r_S}\right)^{\frac{1-\varepsilon}{\varepsilon}} + \left(\frac{1}{\omega_M}\right)^{1-\varepsilon}\left(\frac{r - r_D}{r - r_M}\right)^{\frac{1-\varepsilon}{\varepsilon}}\right]^{\frac{1}{1-\varepsilon}}. \end{aligned}$$

Define spreads as

$$s_D \equiv \frac{r - r_D}{1+r}, \qquad s_M \equiv \frac{r - r_M}{1+r}, \qquad s_S \equiv \frac{r - r_S}{1+r},$$
$$s_L \equiv \left[s_D^{\frac{\varepsilon-1}{\varepsilon}} + \omega_M \, s_M^{\frac{\varepsilon-1}{\varepsilon}} + \omega_S \, s_S^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}}.$$

therefore we have

$$M = \omega_M \, L \left(\frac{s_M}{s_L} \right)^{-1/\varepsilon},$$
$$S = \omega_S \, L \left(\frac{s_S}{s_L} \right)^{-1/\varepsilon},$$
$$D = L \left(\frac{s_D}{s_L} \right)^{-1/\varepsilon}.$$

Next, we want to find an expression for L. To do so we first rearrange $[M]$. By using Equation (4) for the liquidity aggregator with M, S, D, we can rewrite the last part in $[M]$, i.e.,

$$\begin{aligned} \left[\omega_M^{\varepsilon} M^{1-\varepsilon} + \omega_S^{\varepsilon} S^{1-\varepsilon} + D^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}-1} \omega_M^{\varepsilon} M^{-\varepsilon} &= L^{\varepsilon} \, \omega_M^{\varepsilon} M^{-\varepsilon} \\ &= L^{\varepsilon} \, \omega_M^{\varepsilon} \, (\omega_M L)^{-\varepsilon} \left(\frac{s_M}{s_L} \right) \\ &= \left(\frac{s_M}{s_L} \right). \end{aligned}$$

which then yields

$$\lambda = (1 + r_M) \, \beta \lambda' + \left[C + \nu^{\eta} \frac{L^{1-\eta}}{1-\eta} \right]^{-1} \nu^{\eta} L^{-\eta} \left(\frac{s_M}{s_L} \right),$$
$$\frac{\lambda}{\beta \lambda'} - (1 + r_M) = \frac{\left[C + \nu^{\eta} \frac{L^{1-\eta}}{1-\eta} \right]^{-1} \nu^{\eta} L^{-\eta} \left(\frac{s_M}{s_L} \right)}{\beta \lambda'}.$$

Use $[B]$ to replace $\beta\lambda'$:

$$
\begin{aligned}
(r - r_M) &= \frac{\left[C + \nu^\eta \frac{L^{1-\eta}}{1-\eta}\right]^{-1} \nu^\eta L^{-\eta} \left(\frac{s_M}{s_L}\right)}{\lambda/(1+r)}, \\
\lambda\, s_L &= \left[C + \nu^\eta \frac{L^{1-\eta}}{1-\eta}\right]^{-1} \nu^\eta L^{-\eta}.
\end{aligned}
$$

Take $[C]$, i.e.,

$$
\lambda = \left[C + \nu^\eta \frac{L^{1-\eta}}{1-\eta}\right]^{-1},
$$

and insert:

$$
s_L \left[C + \nu^\eta \frac{L^{1-\eta}}{1-\eta}\right]^{-1} = \left[C + \nu^\eta \frac{L^{1-\eta}}{1-\eta}\right]^{-1} \nu^\eta L^{-\eta}.
$$

It follows

$$
\begin{aligned}
s_L &= \nu^\eta L^{-\eta}, \quad \text{or} \\
L &= \nu\, s_L^{-1/\eta}.
\end{aligned}
$$

A.2 Derivation of the intermediate goods producers equations

The problem of the corporate firms in sequential form cum-dividend is to solve the following problem:

$$
\max_{\{K_{C,t+1}, I_{C,t}\}} \sum_{t=0}^{\infty} \beta^t \lambda_t \left[p_{C,t} A_C \left(K_{C,t}\right)^\alpha - I_{C,t-1}\left(1 + r_{t-1}\right)\right]
$$

subject to:

$$
K_{C,t+1} = (1-\delta)\, K_{C,t} + I_{C,t}
$$

where $\lambda_t = \left[C_t + \nu^\eta \frac{L_t^{1-\eta}}{1-\eta}\right]^{-1}$ is the Lagrange multiplier for the household's problem. The problem can be formulated in a Lagrangean:

$$\begin{aligned}\mathcal{L}(K_{C,t+1}, I_C) = &\sum_{t=0}^{\infty} \beta^t \lambda_t \left[p_{C,t} A_C \left(K_{C,t}\right)^{\alpha} - I_{C,t-1}\left(1 + r_{t-1}\right)\right] \\ &+ \sum_{t=0}^{\infty} \beta^t \lambda_t \mu_t \left[\left(1-\delta\right) K_{C,t} + I_{C,t} - K_{C,t+1}\right]\end{aligned}$$

The first order conditions are:

$$\begin{aligned}\left[K_{C,t+1}\right] &: \beta^{t+1} \lambda_{t+1} \left[p_{C,t+1} A_C \alpha K_{C,t+1}^{\alpha-1} + \mu_{t+1}\left(1-\delta\right)\right] - \beta^t \lambda_t \mu_t = 0 \\ \left[I_{C,t}\right] &: -\beta^{t+1} \lambda_{t+1} \left(1 + r_t\right) + \beta^t \lambda_t \mu_t = 0\end{aligned}$$

Combining both yields:

$$\begin{aligned}\mu_t = \beta \frac{\lambda_{t+1}}{\lambda_t}\left(1 + r_t\right) = 1 \\ p_{C,t+1} A_C \alpha K_{C,t+1}^{\alpha-1} + \mu_{t+1}\left(1-\delta\right) = 1 + r_t\end{aligned}$$

The first equality follows from the households optimization for bonds B. It follows:

$$p_{C,t+1} A_C \alpha K_{C,t+1}^{\alpha-1} = r_t + \delta$$

Non-corporate small firms solve:

$$\max_{\{K_{N,t+1}, I_{N,t}\}} \sum_{t=0}^{\infty} \beta^t \lambda_t \left[p_{N,t} A_N \left(K_{N,t}\right)^{\alpha} - I_{N,t-1}\left(1 + r_{\ell,t-1}\right)\right]$$

subject to:

$$K_{N,t+1} = (1-\delta) K_{N,t} + I_{N,t}.$$

Rearranged as a Lagrangian:

$$\begin{aligned}\mathcal{L}(K_{N,t+1}, I_{N,t}) = &\sum_{t=0}^{\infty} \beta^t \lambda_t \left[p_{N,t} A_N \left(K_{N,t}\right)^{\alpha} - I_{N,t-1}\left(1 + r_{\ell,t-1}\right)\right] \\ &+ \sum_{t=0}^{\infty} \beta^t \lambda_t \mu_t \left[(1-\delta) K_{N,t} + I_{N,t} - K_{N,t+1}\right].\end{aligned}$$

The first-order conditions are:

$$\begin{aligned}[K_{N,t+1}]: &\quad \beta^{t+1}\lambda_{t+1}\left[p_{N,t+1}\alpha A_N K_{N,t+1}^{\alpha-1} + \mu_{t+1}(1-\delta)\right] - \beta^t \lambda_t \mu_t = 0, \\ [I_{N,t}]: &\quad -\beta^{t+1}\lambda_{t+1}(1 + r_{\ell,t}) + \beta^t \lambda_t \mu_t = 0.\end{aligned}$$

Combining both yields:

$$\begin{aligned}\mu_t = \beta \frac{\lambda_{t+1}}{\lambda_t}(1 + r_{\ell,t}) = \frac{1 + r_{\ell,t}}{1 + r_t}, \\ \alpha p_{N,t+1} A_N K_{N,t+1}^{\alpha-1} = (1 + r_{\ell,t}) - (1-\delta)\frac{1 + r_{\ell,t+1}}{1 + r_{t+1}}.\end{aligned}$$

The first equality again uses the household's first-order condition for bonds B.

A.3 Derivation of the bank equations

Banks are small and homogeneous. Each bank monopolizes a random local market of households, over which it enjoys market power in deposit taking. Banks use the collected deposits to extend loans to small firms and, if profitable, to invest in corporate bonds. Because all dividends are fully rebated to households each period, the bank's problem is static and can be written as:

$$\max_{\ell, B, r_D} \Pi_B = \max_{\ell, B, r_D} \ell\left(1 + r_\ell\right) + B_B\left(1 + r_B\right) - D(r_D)\left(1 + r_D\right)$$

subject to

$$(\lambda) : \ell + B_B = D(r_D),$$
$$(\mu) : D(r_D) \leq \phi\left(\Pi_B\right),$$
$$(\zeta) : 0 \leq B_B.$$

The Lagrangian for this problem is:

$$\mathcal{L} = \left[\ell\left(1+r_\ell\right) + B_B\left(1+r_B\right) - D\left(1+r_D\right)\right] - \lambda\left[\ell + B_B - D(r_D)\right] + \mu\left[\phi\left(\Pi_B\right) - D(r_D)\right] + \zeta B_B$$

The first order conditions are:

$$[\ell] : \left[1+\mu\phi'\left(\Pi_B\right)\right]\left(1+r_\ell\right) - \lambda = 0$$
$$[r_D] : -\left[D'\left(1+r_D\right) + D\right]\left(1+\mu\phi'\left(\Pi_B\right)\right) - \mu D' + \lambda D' = 0$$
$$[B_B] : \left(1+r_B\right)\left[1+\mu\phi'\left(\Pi_B\right)\right] - \lambda + \zeta = 0$$

plus a complementary slackness condition on deposits,

$$\mu \cdot [\phi(\Pi_B) - D(r_D)] = 0 \text{ with } \mu \geq 0$$

and bonds,

$$\zeta \cdot B_B = 0 \text{ with } \zeta \geq 0$$

First, we show that the bank will never hold safe bonds if the spread between loans and bonds is positive. Combine the FOC of bonds $[B_B]$ and loans $[\ell]$ to get,

$$\frac{\zeta}{1+\mu\phi'\left(\Pi_B\right)} = r_\ell - r$$

which means that if $r_\ell - r > 0 \rightarrow \zeta > 0$ as $\mu \geq 0$ and $\phi' > 0$ which implies that if $r_\ell - r > 0$ then $B = 0$.

Next combine the FOC of loans $[\ell]$ and deposits $[r_D]$ to get,

$$s_\ell + s_D = \varepsilon_D^{-1} + \frac{\mu}{1+\mu\phi'\left(\Pi_B\right)}\frac{1}{1+r}$$

where $\varepsilon_D = -\dfrac{1}{D}\dfrac{\partial D}{\partial s_D}$ is the semi-elasticity of deposit demand with respect to the spread. In the main text we define $\kappa \equiv \frac{\mu}{1+\mu\phi'(\Pi_B)}\frac{1}{1+r}$.

A.4 Bank's Leverage Constraint

We assume a bank's admissible deposits satisfy $D \leq \phi(\Pi_B)$, where ϕ is weakly increasing, weakly concave, and $\phi(0) = 0$. These monotonicity and zero restrictions imply that more profitable banks can raise more funding, while a bank that generates no profits cannot expand its balance sheet through this channel—features consistent with a leverage-type cap. Weak concavity means that each additional dollar of profit relaxes the constraint by an equal or smaller amount, so that funding capacity increases at a diminishing rate with profits.

Our constraint $D \leq \phi(\Pi_B)$ nests the equity constraints typically used in macro-finance intermediation (e.g., Gertler and Kiyotaki 2015; Abadi, Brunnermeier and Koby 2023) for steady-state analysis as a particular case. In these papers, financial intermediaries are subject to a constraint of the form,

$$D \;\leq\; \psi\, e$$

and it is assumed that a fraction $\gamma \in (0,1)$ of equity is paid out at the end of each period. With this, equity evolves as

$$e_{t+1} \;=\; (1-\gamma)\, e_t \;+\; \Pi_{B,t}, \qquad \Pi_{B,t} \;=\; (1+r_t^{\ell})\, \ell_t \;-\; (1+r_t^{D})\, D_t, \qquad \ell_t \;=\; e_t + D_t,$$

In a steady state:

$$e \;=\; (1-\gamma)e + \Pi_B \quad \Rightarrow \quad e \;=\; \frac{\Pi_B}{\gamma}.$$

Hence, the equity cap becomes

$$D \;\leq\; \psi\, e \;=\; \frac{\psi}{\gamma}\, \Pi_B,$$

which is exactly our profit-based constraint with a linear mapping $\phi(\Pi) = \big(\psi/\gamma\big)\Pi_B$. This mapping requires setting $\phi = \varphi/\gamma$, where φ denotes the maximum leverage ratio and γ is the ratio of profits to equity, $\gamma = \Pi_B/e$. Equity-type constraints are therefore a special (linear) case of our formulation; allowing $\phi(\cdot)$ to be concave provides additional flexibility. Further details regarding mapping to the data are provided in Appendix E.

A.4.1 Mapping to the Data

Crucial for our conclusions is how we interpret—and thus calibrate—the borrowing constraint faced by banks. The literature offers several interpretations and microfoundations. In the macro-finance tradition, the constraint is typically microfounded as an agency or moral-hazard limit on leverage (e.g., Gertler and Kiyotaki (2015)) and is generally the sole source of banking spreads. In the banking and corporate-finance literature, constraints reflect regulatory capital requirements or risk-based leverage rules (e.g., Whited, Wu and Xiao (2023), Adrian and Boyarchenko (2012)). This choice is crucial for our framework because, in our model, both the source of bank spreads—whether they arise from market power in deposit markets or from a binding leverage constraint—and the tightness of banks' constraint determine the effects of improving the quality of outside liquidity.

We adopt $\varphi = 10$, a midpoint between the macro-finance and banking literatures. As discussed in Section 3.2.1, under this calibration the leverage constraint is slack in steady state, implying that bank spreads arise from market power rather than binding leverage limits.

A.5 Derivation of deposit semi-elasticity

The semi-elasticity of deposit demand, ε_D, is defined as

$$\varepsilon_D \;=\; -\frac{\partial D/\partial s_D}{D} \;=\; -\frac{\partial \log D}{\partial s_D}.$$

Using the demand system $D = \nu\, s_L^{\frac{1}{\varepsilon}-\frac{1}{\eta}}\, s_D^{-1/\varepsilon}$, we have

$$D \;=\; \nu\, s_L^{\frac{1}{\varepsilon}-\frac{1}{\eta}}\, s_D^{-\frac{1}{\varepsilon}}.$$

Taking logs:

$$\log D \;=\; \log\nu \;+\; \left(\frac{1}{\varepsilon}-\frac{1}{\eta}\right)\log s_L \;-\; \frac{1}{\varepsilon}\log s_D.$$

With three liquid assets, the liquidity spread is

$$s_L \;=\; \left[\, s_D^{\frac{\varepsilon-1}{\varepsilon}} \;+\; \omega_M\, s_M^{\frac{\varepsilon-1}{\varepsilon}} \;+\; \omega_S\, s_S^{\frac{\varepsilon-1}{\varepsilon}} \,\right]^{\frac{\varepsilon}{\varepsilon-1}}.$$

Differentiate s_L w.r.t. s_D:

$$\frac{\partial s_L}{\partial s_D} = s_L^{\frac{1}{\varepsilon}}\, s_D^{-\frac{1}{\varepsilon}}.$$

Hence,

$$\begin{aligned}
\frac{\partial \log D}{\partial s_D}\, s_D &= \left(\frac{1}{\varepsilon}-\frac{1}{\eta}\right)\frac{s_L^{\frac{1}{\varepsilon}}\, s_D^{-\frac{1}{\varepsilon}}}{s_L}\, s_D \;-\; \frac{1}{\varepsilon} \\
&= \left(\frac{1}{\varepsilon}-\frac{1}{\eta}\right)\frac{s_D^{\frac{\varepsilon-1}{\varepsilon}}}{s_L^{\frac{\varepsilon-1}{\varepsilon}}} \;-\; \frac{1}{\varepsilon} \\
&= \left(\frac{1}{\varepsilon}-\frac{1}{\eta}\right)\frac{s_D^{\frac{\varepsilon-1}{\varepsilon}}}{s_D^{\frac{\varepsilon-1}{\varepsilon}} + \omega_M s_M^{\frac{\varepsilon-1}{\varepsilon}} + \omega_S s_S^{\frac{\varepsilon-1}{\varepsilon}}} \;-\; \frac{1}{\varepsilon}.
\end{aligned}$$

Using the demand ratios

$$\frac{M}{D} \;=\; \omega_M\left(\frac{s_M}{s_D}\right)^{-\frac{1}{\varepsilon}}, \qquad \frac{S}{D} \;=\; \omega_S\left(\frac{s_S}{s_D}\right)^{-\frac{1}{\varepsilon}},$$

we get

$$\omega_M\,\frac{s_M^{\frac{\varepsilon-1}{\varepsilon}}}{s_D^{\frac{\varepsilon-1}{\varepsilon}}} = \frac{s_M M}{s_D D}, \qquad \omega_S\,\frac{s_S^{\frac{\varepsilon-1}{\varepsilon}}}{s_D^{\frac{\varepsilon-1}{\varepsilon}}} = \frac{s_S S}{s_D D}.$$

Therefore,

$$\frac{\partial \log D}{\partial s_D} s_D = \left(\frac{1}{\varepsilon} - \frac{1}{\eta}\right) \frac{1}{1 + \frac{s_M M}{s_D D} + \frac{s_S S}{s_D D}} - \frac{1}{\varepsilon}$$
$$= \left(\frac{1}{\varepsilon} - \frac{1}{\eta}\right) \frac{s_D D}{s_D D + s_M M + s_S S} - \frac{1}{\varepsilon}.$$

Define the deposit share

$$\omega_D \equiv \frac{s_D D}{s_D D + s_M M + s_S S},$$

so that the semi-elasticity is

$$\varepsilon_D = -\frac{\partial \log D}{\partial s_D} = \frac{1}{s_D}\left[\frac{1}{\varepsilon}(1-\omega_D) + \frac{1}{\eta}\omega_D\right].$$

A.6 Bank Second Order Condition

For the problem to have an internal unique solution, as we assume, it is sufficient for the bank's second-order condition to be strictly negative.

Using the result that $s_\ell > 0$ implies that banks do not hold bonds, we impose the discount factor condition $\Lambda = (1+r)^{-1}$ and substitute the balance-sheet identity into the bank's objective. Under these assumptions, the bank's problem can be written solely in terms of the spread as:

$$\mathcal{L} = \max_{s_D} D(s_D)(s_D + s_\ell) + \mu[\phi(\Pi_B) - D(s_D)]$$

where the FOC, as before, is

$$[\text{FOC}] : D'(s_D + s_\ell) + D + \mu[\phi'(.)(D'(s_D + s_\ell) + D) - D'] = 0$$

and the SOC is

$$[\text{SOC}] : D''(s_D + s_\ell) + 2D' + \mu\left[\phi''(D'(s_D + s_\ell) + D)^2 + \phi'(D''(s_D + s_\ell) + 2D') - D''\right] < 0 \tag{A.1}$$

and so

$$\left[D''\left(s_D+s_\ell\right)+2D'\right]\left[1+\mu\phi'\right]+\mu\left[\phi''\left(D'\left(s_D+s_\ell\right)+D\right)^2-D''\right]<0 \tag{A.2}$$

$$\left[\frac{D''}{D'}\left(s_D+s_\ell\right)+2\right]\left[1+\mu\phi'\right]+\mu\left[\phi''\left(\left(s_D+s_\ell\right)+\frac{D}{D'}\right)^2 D'-\frac{D''}{D'}\right]>0 \tag{A.3}$$

$$\frac{D''}{D'}\left(s_D+s_\ell\right)+2>-\frac{\mu}{\left[1+\mu\phi'\right]}\left[\phi''\left(\left(s_D+s_\ell\right)+\frac{D}{D'}\right)^2 D'-\frac{D''}{D'}\right] \tag{A.4}$$

where the change of sign is due to $D'<0$. The right hand side is weakly positive as ϕ is weakly concave and D convex. It is equal to zero only if the constraint binds. Remember that the semi-elasticity of D with respect to s_D is

$$\varepsilon_D=-\frac{\partial D}{\partial s_D}=\frac{1}{s_D}\left[\varepsilon^{-1}+\left(\eta^{-1}-\varepsilon^{-1}\right)\omega_D\right] \tag{A.5}$$

take logs

$$\ln\varepsilon_D=-\ln D+\ln\left(-\frac{\partial D}{\partial s_D}\right)=-\ln\left(s_D\right)+\ln\left(\varepsilon^{-1}+\left(\eta^{-1}-\varepsilon^{-1}\right)\omega_D\right)$$

and differentiate it with respect to s_D

$$\underbrace{-\frac{1}{D}\frac{\partial D}{\partial s_D}}_{\varepsilon_D}+\frac{\frac{\partial^2 D}{\partial s_D^2}}{\frac{\partial D}{\partial s_D}}=-\frac{1}{s_D}+\frac{\left(\eta^{-1}-\varepsilon^{-1}\right)}{\varepsilon^{-1}+\left(\eta^{-1}-\varepsilon^{-1}\right)\omega_D}\frac{\partial\omega_D}{\partial s_D} \tag{A.6}$$

We will need $\frac{\partial\omega_D}{\partial s_D}$:

$$\frac{\partial\omega_D}{\partial s_D}=\left(1-\omega_D\right)\frac{\omega_D}{s_D}\left(1-\varepsilon^{-1}\right) \tag{A.7}$$

where the steps to this last equation are the same as to get (B.32). Now combine to get

$$\varepsilon_D+\frac{D''}{D'}=-\frac{1}{s_D}+\frac{\left(\eta^{-1}-\varepsilon^{-1}\right)}{\varepsilon^{-1}+\left(\eta^{-1}-\varepsilon^{-1}\right)\omega_D}\left[\left(1-\omega_D\right)\frac{\omega_D}{s_D}\left(1-\varepsilon^{-1}\right)\right] \tag{A.8}$$

Since in the unconstrained regime $\varepsilon_D^{-1}=s_\ell+s_D$ we have

$$\frac{D''}{D'}=-\frac{1}{s_\ell+s_D}-\frac{1}{s_D}+\frac{\left(\eta^{-1}-\varepsilon^{-1}\right)}{\varepsilon^{-1}+\left(\eta^{-1}-\varepsilon^{-1}\right)\omega_D}\left[\left(1-\omega_D\right)\frac{\omega_D}{s_D}\left(1-\varepsilon^{-1}\right)\right] \tag{A.9}$$

Use (A.9) in (A.4) in the unconstrained space ($\mu = 0$) to get the inequality of the SOC,

$$\left[-\frac{1}{s_\ell + s_D} - \frac{1}{s_D} + \frac{\left(\eta^{-1} - \varepsilon^{-1}\right)}{\varepsilon^{-1} + \left(\eta^{-1} - \varepsilon^{-1}\right)\omega_D}\left[\left(1 - \omega_D\right)\frac{\omega_D}{s_D}\left(1 - \varepsilon^{-1}\right)\right]\right]\left(s_D + s_\ell\right) + 2 > 0 \tag{A.10}$$

Re-arrange to get a useful condition for later

$$\frac{\left(\eta^{-1} - \varepsilon^{-1}\right)\left(1 - \omega_D\right)\left(1 - \varepsilon^{-1}\right)\omega_D}{\varepsilon^{-1} + \left(\eta^{-1} - \varepsilon^{-1}\right)\omega_D} - \frac{s_\ell}{s_\ell + s_D} > 0 \tag{A.11}$$

Use the definition in (B.33) of Γ to rewrite the equation as

$$\Gamma\left(1 - \varepsilon^{-1}\right) - \frac{s_\ell}{s_\ell + s_D} > 0 \tag{A.12}$$

a condition which will then be used.

Appendix B Proofs

B.1 Proof of Proposition 1

From Appendix A.3, combine the first order condition of the bank's problem for loans $[\ell]$ and bonds $[B_B]$:

$$\frac{\zeta}{\lambda} = r_\ell - r$$

Since $\zeta \geq 0$, a positive interest rate spread implies that ζ has to be positive, i.e. $r_\ell - r > 0 \implies \zeta > 0$. A positive ζ, by the complementary slackness condition, implies that the inequality constraint for bonds is binding, i.e. $B_B = 0$.

B.2 Proof of Proposition 2 & 3 - Unconstrained Scenario

In this section we show the effect on spreads and quantities of both improving the quality of stablecoins and introducing a CBDC. First, we begin by defining an aggregator between public money M and stablecoins S called public money P. The reason for the name is that, since every dollar in stablecoin is backed with public debt, then effectively stablecoins are a form of public money.

Definition of the public-money composite.

$$\omega_P \equiv \omega_M + \omega_S, \qquad s_P^{\frac{\varepsilon-1}{\varepsilon}} \equiv \frac{\omega_M\, s_M^{\frac{\varepsilon-1}{\varepsilon}} + \omega_S\, s_S^{\frac{\varepsilon-1}{\varepsilon}}}{\omega_P}$$

With this definition, the liquidity spread aggregator can be written as

$$s_L = \left[s_D^{\frac{\varepsilon-1}{\varepsilon}} + \omega_M s_M^{\frac{\varepsilon-1}{\varepsilon}} + \omega_S s_S^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}} = \left[s_D^{\frac{\varepsilon-1}{\varepsilon}} + \omega_P s_P^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}}.$$

Where the demand for the composite P is given by:

$$P \equiv \omega_P\, L \left(\frac{s_P}{s_L}\right)^{-\frac{1}{\varepsilon}}.$$

and we can write the demand for public money M and stablecoins S in terms of public money aggregator P and its spread:

$$\frac{M}{P} = \frac{\omega_M}{\omega_P}\left(\frac{s_M}{s_P}\right)^{-\frac{1}{\varepsilon}}, \qquad \frac{S}{P} = \frac{\omega_S}{\omega_P}\left(\frac{s_S}{s_P}\right)^{-\frac{1}{\varepsilon}}.$$

Since all our experiments will be changes in ω_M, s_M and/or ω_S then all our proofs will be studying changes in ω_P and s_P.

The relevant share is

$$\omega_D \equiv \frac{s_D D}{s_D D + s_M M + s_S S} = \frac{s_D D}{s_D D + s_P P}$$

Now differentiate the steady-state system to characterize deviations. We would like to map changes in $\omega_{S,M}$ and r_M to the new equilibrium. Variables with hat, i.e. $\widehat{x}$, represent log-changes, including for interest rates and spreads.

Household deviations Perturbation of households equations give:

$$\widehat{L} = -\frac{1}{\eta}\,\widehat{s}_L, \tag{B.1}$$

$$\widehat{D} = \widehat{L} - \frac{1}{\varepsilon}\big(\widehat{s}_D - \widehat{s}_L\big), \tag{B.2}$$

$$\widehat{P} = \widehat{\omega}_P + \widehat{L} - \frac{1}{\varepsilon}\big(\widehat{s}_P - \widehat{s}_L\big), \tag{B.3}$$

$$\widehat{r} = 0, \tag{B.4}$$

$$\widehat{s}_L = \omega_D\,\widehat{s}_D + (1-\omega_D)\,\widehat{s}_P - \frac{\varepsilon}{1-\varepsilon}\,(1-\omega_D)\,\widehat{\omega}_P, \tag{B.5}$$

$$C\cdot\widehat{C} = \Pi\cdot\widehat{\Pi} + D\cdot r_D\big(\widehat{D}+\widehat{r}_D\big) + P\cdot r_P\big(\widehat{P}+\widehat{r}_P\big) + B_H\cdot r\big(\widehat{B}_H+\widehat{r}\big). \tag{B.6}$$

Spread equations:

$$\widehat{s}_x = \frac{r\widehat{r} - r_x\widehat{r}_x}{r - r_x} - \frac{r\widehat{r}}{1+r} \quad \forall x \in \{D, P\} \tag{B.7}$$

Bank equations:

$$-\widehat{\varepsilon}_D = \widehat{s}_D - \frac{(\eta^{-1}-\varepsilon^{-1})\,\omega_D\widehat{\omega}_D}{\varepsilon^{-1}\,(1-\omega_D) + \eta^{-1}\omega_D} \tag{B.8}$$

$$\widehat{\omega}_D = (1-\omega_D)\Big[\,(\widehat{s}_D+\widehat{D}) - (\widehat{s}_P+\widehat{P})\,\Big] \tag{B.9}$$

$$\widehat{\ell} = \widehat{D} \tag{B.10}$$

In the unconstrained scenario ($\mu = 0$):

$$-\widehat{\varepsilon}_D = \frac{s_\ell\widehat{s}_\ell + s_D\widehat{s}_D}{s_\ell + s_D} \tag{B.11}$$

In the constrained scenario ($\mu > 0$):

$$\frac{s_\ell \widehat{s}_\ell + s_D \widehat{s}_D}{s_\ell + s_D} = \frac{-\widehat{\varepsilon}_D \varepsilon_D^{-1} + [1 + \mu\phi'(\Pi_B)] \left[-\mu^{-1}\widehat{\mu} + \phi''(\Pi_B)\Pi_B \widehat{\Pi}_B\right]}{\varepsilon_D^{-1} + \frac{\mu}{1+\mu\phi'(\Pi_B)}} \tag{B.12}$$

$$\widehat{D} = \frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)} \widehat{\Pi}_B \tag{B.13}$$

where bank profits evolve as,

$$\widehat{\Pi}_B = \frac{s_\ell \widehat{s}_\ell + s_D \widehat{s}_D}{s_\ell + s_D} + \frac{r_B \widehat{r}_B}{1 + r_B} + \widehat{D} \tag{B.14}$$

Final goods producer equations:

$$\widehat{y}_C = \widehat{Y} - \rho \cdot \widehat{p}_C \tag{B.15}$$

$$\widehat{y}_N = \widehat{Y} - \rho \cdot \widehat{p}_N \tag{B.16}$$

$$\widehat{Y} = \frac{p_N y_N}{Y} \widehat{y}_N + \frac{p_C y_C}{Y} \widehat{y}_C \tag{B.17}$$

Intermediate goods producer equations:

$$\widehat{p}_C + (\alpha - 1)\widehat{K}_C = \frac{r\widehat{r}}{r + \delta} \tag{B.18}$$

$$\widehat{p}_N + (\alpha - 1)\widehat{K}_N = \frac{s_\ell \widehat{s}_\ell}{1 + s_\ell} + \frac{r\widehat{r}}{r + \delta} \tag{B.19}$$

$$\widehat{y}_C = \alpha \widehat{K}_C \tag{B.20}$$

$$\widehat{y}_N = \alpha \widehat{K}_N \tag{B.21}$$

$$\widehat{K}_C = \widehat{I}_C \tag{B.22}$$

$$\widehat{K}_N = \widehat{I}_N \tag{B.23}$$

Market clearing equations:

$$\widehat{Y} = \frac{C}{Y}\widehat{C} + \frac{I_N}{Y}\widehat{I}_N + \frac{I_C}{Y}\widehat{I}_C \tag{B.24}$$

$$\widehat{I}_C = \widehat{B}_H \tag{B.25}$$

$$\widehat{I}_N = \widehat{\ell} \tag{B.26}$$

The first step is to write $\widehat{Y}$ in terms of $\widehat{s}_\ell$. Start by combining the final good producer and the corporate firm equations (B.15), (B.18) and (B.20).

$$\rho^{-1}\left[\widehat{Y} - \widehat{y}_C\right] + \alpha^{-1}(\alpha - 1)\,\widehat{y}_C = \frac{r\widehat{r}}{r+\delta}$$

Use Equation (B.4), i.e. $\widehat{r} = 0$.

$$\widehat{y}_C = \left[1 + \frac{\rho}{\alpha}(1-\alpha)\right]^{-1}\widehat{Y} \tag{B.27}$$

Combine the final good producers and non-corporate firm equations (B.16), (B.19) and (B.21).

$$\widehat{y}_N = \left[1 + \frac{\rho}{\alpha}(1-\alpha)\right]^{-1}\left[\widehat{Y} - \rho\frac{s_\ell \widehat{s}_\ell}{1+s_\ell}\right] \tag{B.28}$$

Replace the expressions for $\widehat{y}_C$ (B.27) and $\widehat{y}_N$ (B.28) in the final good producer equation (B.17).

$$\widehat{Y} = \frac{p_N y_N}{Y}\left[1 + \frac{\rho}{\alpha}(1-\alpha)\right]^{-1}\left[\widehat{Y} - \rho\frac{s_\ell \widehat{s}_\ell}{1+s_\ell}\right] + \frac{p_C y_C}{Y}\left[1 + \frac{\rho}{\alpha}(1-\alpha)\right]^{-1}\widehat{Y}$$

$$\widehat{Y} = -\frac{p_N y_N}{Y}\left[\frac{\rho}{\alpha}(1-\alpha)\right]^{-1}\rho\frac{s_\ell \widehat{s}_\ell}{1+s_\ell}$$

$$\widehat{Y} = -\frac{p_N y_N}{Y}\,\alpha(1-\alpha)^{-1}\,\frac{s_\ell}{1+s_\ell}\widehat{s}_\ell \tag{B.29}$$

Since we restrict our analysis to cases with a positive loan spread, i.e. $s_\ell > 0$, Equation (B.29) implies that an increase in the loan interest rate r_ℓ reduces final good output Y.

Now the objective is to write $\widehat{s}_\ell$ as a function of $\widehat{\omega}_P$, which determines the effect of a shift to public money on loan interest rates. But this will take several steps. Thus, we begin by writing $\widehat{D}$ as a function of $\widehat{\omega}_P$, $\widehat{s}_M$ and $\widehat{s}_D$. Take the household's deposit demand equation (B.2) and combine with (B.1) and (B.5).

$$
\begin{aligned}
\widehat{D} &= -\frac{1}{\eta}\,\widehat{s}_L \;-\; \frac{1}{\varepsilon}\,(\widehat{s}_D - \widehat{s}_L) \\
&= \left(\frac{1}{\varepsilon} - \frac{1}{\eta}\right)\widehat{s}_L \;-\; \frac{1}{\varepsilon}\widehat{s}_D \\
&= \left(\frac{1}{\varepsilon} - \frac{1}{\eta}\right)\Big[\omega_D\,\widehat{s}_D + (1-\omega_D)\,\widehat{s}_P - \tfrac{\varepsilon}{1-\varepsilon}(1-\omega_D)\,\widehat{\omega}_P\Big] - \frac{1}{\varepsilon}\widehat{s}_D \\
&= -\left(\tfrac{1}{\varepsilon} - \tfrac{1}{\eta}\right)\tfrac{\varepsilon}{1-\varepsilon}(1-\omega_D)\,\widehat{\omega}_P + \left(\tfrac{1}{\varepsilon} - \tfrac{1}{\eta}\right)(1-\omega_D)\,\widehat{s}_P - \Big[\tfrac{1}{\varepsilon}(1-\omega_D) + \tfrac{1}{\eta}\omega_D\Big]\widehat{s}_D. \quad \text{(B.30)}
\end{aligned}
$$

Next, we write $\widehat{P}$ as a function of $\widehat{\omega}_P$, $\widehat{s}_P$ and $\widehat{s}_D$. Take the household's money demand equation (B.3) and combine with (B.1) and (B.5).

$$
\begin{aligned}
\widehat{P} &= \widehat{\omega}_P - \frac{1}{\eta}\widehat{s}_L - \frac{1}{\varepsilon}\big(\widehat{s}_P - \widehat{s}_L\big) \\
&= \widehat{\omega}_P + \left(\frac{1}{\varepsilon} - \frac{1}{\eta}\right)\widehat{s}_L - \frac{1}{\varepsilon}\widehat{s}_P \\
&= \widehat{\omega}_P + \left(\frac{1}{\varepsilon} - \frac{1}{\eta}\right)\Big[\omega_D\widehat{s}_D + (1-\omega_D)\widehat{s}_P - \tfrac{\varepsilon}{1-\varepsilon}(1-\omega_D)\widehat{\omega}_P\Big] - \frac{1}{\varepsilon}\widehat{s}_P \\
&= \left[1 - \left(\frac{1}{\varepsilon} - \frac{1}{\eta}\right)\frac{\varepsilon}{1-\varepsilon}(1-\omega_D)\right]\widehat{\omega}_P \;+\; \left(\frac{1}{\varepsilon} - \frac{1}{\eta}\right)\omega_D\,\widehat{s}_D \;-\; \left[\frac{\omega_D}{\varepsilon} + \frac{1-\omega_D}{\eta}\right]\widehat{s}_P. \quad \text{(B.31)}
\end{aligned}
$$

Next we look at the banking equations. First, we write changes in the deposit share as a function of $\widehat{\omega}_P$, $\widehat{s}_P$ and $\widehat{s}_D$. Take Equation (B.9) and insert (B.30) and (B.31) in it:

$$
\begin{aligned}
\widehat{\omega}_D &= (1-\omega_D)\Big[(\widehat{s}_D + \widehat{D}) - (\widehat{s}_P + \widehat{P})\Big] \\
&= (1-\omega_D)\left[\left(1 - \frac{1}{\varepsilon}\right)\big(\widehat{s}_D - \widehat{s}_P\big) \;-\; \widehat{\omega}_P\right]. \quad \text{(B.32)}
\end{aligned}
$$

We now replace the expression for $\widehat{\omega}_D$ into the expression of the deposit elasticity in

Equation (B.8).

$$-\widehat{\varepsilon}_D = \widehat{s}_D - \frac{\left(\eta^{-1} - \varepsilon^{-1}\right) \omega_D}{\varepsilon^{-1}\left(1-\omega_D\right) + \eta^{-1}\omega_D} \widehat{\omega}_D$$
$$= \widehat{s}_D - \frac{\left(\eta^{-1} - \varepsilon^{-1}\right) \omega_D \left(1-\omega_D\right)}{\varepsilon^{-1}\left(1-\omega_D\right) + \eta^{-1}\omega_D} \left[\left(1 - \frac{1}{\varepsilon}\right)\left(\widehat{s}_D - \widehat{s}_P\right) - \widehat{\omega}_P\right].$$

Define

$$\Gamma \equiv \frac{\left(\eta^{-1} - \varepsilon^{-1}\right) \omega_D \left(1-\omega_D\right)}{\varepsilon^{-1}\left(1-\omega_D\right) + \eta^{-1}\omega_D} < 0 \tag{B.33}$$

since $\eta^{-1} < 1 < \varepsilon^{-1} \implies \Gamma < 0$. Rewrite previous equation:

$$-\widehat{\varepsilon}_D = \left[1 - \Gamma\left(1 - \frac{1}{\varepsilon}\right)\right]\widehat{s}_D + \Gamma\left(1 - \frac{1}{\varepsilon}\right)\widehat{s}_P + \Gamma\widehat{\omega}_P \tag{B.34}$$

Next, we write $\widehat{s}_\ell$ as a function of $\widehat{\omega}_P$, $\widehat{s}_P$ and $\widehat{s}_D$. Combine (B.11) with (B.34).

$$\frac{s_\ell}{s_\ell + s_D}\widehat{s}_\ell = \widehat{s}_D\left[1 - \Gamma\left(1 - \frac{1}{\varepsilon}\right) - \frac{s_D}{s_\ell + s_D}\right] + \Gamma\left(1 - \frac{1}{\varepsilon}\right)\widehat{s}_P + \Gamma\widehat{\omega}_P \tag{B.35}$$

Next we need to move to the supply side, or how $\widehat{s}_\ell$ relates to $\widehat{s}_D$ through the supply of loans. The demand for loans comes from non-corporate small firms. We know from the market clearing condition (B.26) and the non-corporate firm Equations (B.23) and (B.21) that

$$\widehat{y}_N/\alpha = \widehat{K}_N = \widehat{I}_N = \widehat{\ell}.$$

Combine Equations (B.28) and (B.29)

$$\widehat{y}_N = -\left[1 + \frac{\rho}{\alpha}\left(1-\alpha\right)\right]^{-1} \frac{s_\ell}{1+s_\ell}\left[\frac{p_N y_N}{Y}\alpha\left(1-\alpha\right)^{-1} + \rho\right]\widehat{s}_\ell \tag{B.36}$$

From Equation (B.36) we see that non-corporate firm output decreases if the loan interest rate increases. Now plug in Equation (B.36) into $\widehat{\ell} = \widehat{y}_N/\alpha$:

$$\widehat{\ell} = -\frac{1}{\alpha}\left[1 + \frac{\rho}{\alpha}\left(1-\alpha\right)\right]^{-1} \frac{s_\ell}{1+s_\ell}\left[\frac{p_N y_N}{Y}\alpha\left(1-\alpha\right)^{-1} + \rho\right]\widehat{s}_\ell \tag{B.37}$$

It is straightforward that outstanding loans decrease if the loan interest rate increases.

Next, use the resource constraint from the bank (B.10) to get,

$$\widehat{D} = -\frac{1}{\alpha}\left[1+\frac{\rho}{\alpha}(1-\alpha)\right]^{-1}\frac{s_\ell}{1+s_\ell}\left[\frac{p_N y_N}{Y}\alpha(1-\alpha)^{-1}+\rho\right]\widehat{s}_\ell \tag{B.38}$$

and use (B.30) in this last equation to get,

$$\begin{aligned}&-\left(\frac{1}{\varepsilon}-\frac{1}{\eta}\right)\frac{\varepsilon}{1-\varepsilon}(1-\omega_D)\widehat{\omega}_P+\left(\frac{1}{\varepsilon}-\frac{1}{\eta}\right)(1-\omega_D)\widehat{s}_P-\left[(1-\omega_D)\frac{1}{\varepsilon}+\omega_D\frac{1}{\eta}\right]\widehat{s}_D\\&\quad=-\frac{1}{\alpha}\left[1+\frac{\rho}{\alpha}(1-\alpha)\right]^{-1}\frac{s_\ell}{1+s_\ell}\left[\frac{p_N y_N}{Y}\alpha(1-\alpha)^{-1}+\rho\right]\widehat{s}_\ell.\end{aligned} \tag{B.39}$$

call,

$$\clubsuit \equiv -\frac{1}{\alpha}\left[1+\frac{\rho}{\alpha}(1-\alpha)\right]^{-1}\frac{s_\ell}{1+s_\ell}\left[\frac{p_N y_N}{Y}\alpha(1-\alpha)^{-1}+\rho\right] < 0 \tag{B.40}$$

and rearrange (B.39) to get,

$$\widehat{s}_\ell = \frac{-\left(\frac{1}{\varepsilon}-\frac{1}{\eta}\right)\frac{\varepsilon}{1-\varepsilon}(1-\omega_D)\widehat{\omega}_P+\left(\frac{1}{\varepsilon}-\frac{1}{\eta}\right)(1-\omega_D)\widehat{s}_P-\left[(1-\omega_D)\frac{1}{\varepsilon}+\omega_D\frac{1}{\eta}\right]\widehat{s}_D}{\clubsuit} \tag{B.41}$$

We end up with a 2 by 2 system on $\widehat{s}_\ell$ and $\widehat{s}_D$ given by (B.35) and (B.41) which we rewrite below

$$\frac{s_\ell}{s_\ell+s_D}\widehat{s}_\ell = \widehat{s}_D\left[1-\Gamma\left(1-\frac{1}{\varepsilon}\right)-\frac{s_D}{s_\ell+s_D}\right]+\Gamma\left(1-\frac{1}{\varepsilon}\right)\widehat{s}_P+\Gamma\widehat{\omega}_P$$

$$\widehat{s}_\ell = \frac{-\left(\frac{1}{\varepsilon}-\frac{1}{\eta}\right)\frac{\varepsilon}{1-\varepsilon}(1-\omega_D)\widehat{\omega}_P+\left(\frac{1}{\varepsilon}-\frac{1}{\eta}\right)(1-\omega_D)\widehat{s}_P-\left[(1-\omega_D)\frac{1}{\varepsilon}+\omega_D\frac{1}{\eta}\right]\widehat{s}_D}{\clubsuit}$$

Combine these two equations to get,

$$\widehat{s}_D = \frac{\left[\frac{1}{\clubsuit}\left(\frac{1}{\varepsilon}-\frac{1}{\eta}\right)(1-\omega_D)-\frac{s_\ell+s_D}{s_\ell}\Gamma\left(1-\frac{1}{\varepsilon}\right)\right]}{\left[\left(1-\Gamma\left(1-\frac{1}{\varepsilon}\right)-\frac{s_D}{s_\ell+s_D}\right)\frac{s_\ell+s_D}{s_\ell}+\frac{\left[(1-\omega_D)\frac{1}{\varepsilon}+\omega_D\frac{1}{\eta}\right]}{\clubsuit}\right]}\left[\widehat{s}_P-\frac{1}{\varepsilon^{-1}-1}\widehat{\omega}_P\right]. \tag{B.42}$$

To know the effect of $\widehat{s}_P$ or $\widehat{\omega}_P$ on $\widehat{s}_D$, label

$$\widehat{s}_D = \frac{\mathcal{B}}{\mathcal{A}}\left[\widehat{s}_P-\frac{1}{\varepsilon^{-1}-1}\widehat{\omega}_P\right], \tag{B.43}$$

with

$$\mathcal{A} \equiv \left[1 - \Gamma\left(1 - \frac{1}{\varepsilon}\right) - \frac{s_D}{s_\ell + s_D}\right] \frac{s_\ell + s_D}{s_\ell} + \frac{\left[(1-\omega_D)\,\frac{1}{\varepsilon} + \omega_D \frac{1}{\eta}\right]}{\clubsuit}, \tag{B.44}$$

$$\mathcal{B} \equiv \frac{1}{\clubsuit}\left(\frac{1}{\varepsilon} - \frac{1}{\eta}\right)(1-\omega_D) - \frac{s_\ell + s_D}{s_\ell}\Gamma\left(1 - \frac{1}{\varepsilon}\right), \tag{B.45}$$

where $\Gamma < 0$ is defined in (B.33) and $\clubsuit < 0$ in (B.40).

Fist we show that $\mathcal{A} < 0$. To see this note that $\clubsuit < 0$ and from bank's SOC (B.33) in the unconstrained regime we get that $\left[1 - \Gamma\left(1 - \frac{1}{\varepsilon}\right) - \frac{s_D}{s_\ell + s_D}\right] \frac{s_\ell + s_D}{s_\ell} = \left[\frac{s_\ell}{s_D + s_\ell} - \Gamma\left(1 - \frac{1}{\varepsilon}\right)\right] \frac{s_\ell + s_D}{s_\ell} < 0$ which together with $\omega_D \in [0, 1]$ proves it.

Lastly, the sign of $\mathcal{B}$ is more straightforward since $\eta^{-1} < 1 < \varepsilon^{-1}$, $\clubsuit < 0$ and $\Gamma < 0$ we have that $\mathcal{B} < 0$.

We are interested in the effect of ω_M, ω_S and s_M, so it remains to prove the effect of these variables in ω_P and s_P. Go back to our definition of them, which we rewrite below

$$\omega_P \equiv \omega_M + \omega_S, \qquad s_P^{\frac{\varepsilon-1}{\varepsilon}} \equiv \frac{\omega_M\, s_M^{\frac{\varepsilon-1}{\varepsilon}} + \omega_S\, s_S^{\frac{\varepsilon-1}{\varepsilon}}}{\omega_P}$$

Then we have that,

$$\widehat{\omega}_P = \widehat{\omega}_M \frac{\omega_M}{\omega_P} + \widehat{\omega}_S \frac{\omega_S}{\omega_P}$$

Now, using the previous expression for the evolution of ω_P, imposing the steady-state condition that the spreads on public money and stablecoins coincide $s_M = s_S$, and focusing on changes in s_M only, we get

$$\widehat{s}_P = \frac{\omega_M}{\omega_P}\,\widehat{s}_M \tag{B.46}$$

Next, go back to equation (B.43) and insert the previous results,

$$\widehat{s}_D = \frac{\mathcal{B}}{\mathcal{A}}\left[\frac{\omega_M}{\omega_P}\,\widehat{s}_M - \frac{1}{\varepsilon^{-1} - 1}\left(\widehat{\omega}_M \frac{\omega_M}{\omega_P} + \widehat{\omega}_S \frac{\omega_S}{\omega_P}\right)\right] \tag{B.47}$$

Then we have

$$\frac{\partial s_D}{\partial s_M} = \frac{\mathcal{B}}{\mathcal{A}}\frac{\omega_M}{\omega_P}\frac{s_D}{s_M} > 0 \tag{B.48}$$

$$\frac{\partial s_D}{\partial \omega_M} = \frac{\partial s_D}{\partial \omega_S} = -\frac{\mathcal{B}}{\mathcal{A}}\left(\varepsilon^{-1}-1\right)^{-1}\frac{s_D}{\omega_P} < 0 \tag{B.49}$$

which proves point (1) of Proposition 2 in the unconstrained region.

To pin down the effect on s_ℓ, which ultimately will give the effect on loans, deposits and aggregate output from equations (B.29), (B.37), (B.38) and (B.40), go back to Equation (B.35), i.e.:

$$\widehat{s}_\ell = \widehat{s}_D \underbrace{\left[1-\Gamma\left(1-\frac{1}{\varepsilon}\right)-\frac{s_D}{s_\ell+s_D}\right]\frac{s_\ell+s_D}{s_\ell}}_{\mathcal{C}<0} + \frac{s_\ell+s_D}{s_\ell}\Gamma\left(1-\frac{1}{\varepsilon}\right)\widehat{s}_P + \frac{s_\ell+s_D}{s_\ell}\Gamma\widehat{\omega_P}$$

Remember that we showed above using the SOC of the bank's problem that $\mathcal{C}$ is negative. Replace the expression for $\widehat{s}_D$ and collect terms:

$$\widehat{s}_\ell = \frac{\mathcal{BC}}{\mathcal{A}}\left[\widehat{s}_P - \frac{1}{\varepsilon^{-1}-1}\widehat{\omega}_P\right] + \frac{s_\ell+s_D}{s_\ell}\Gamma\left(1-\frac{1}{\varepsilon}\right)\widehat{s}_P + \frac{s_\ell+s_D}{s_\ell}\Gamma\widehat{\omega}_P \tag{B.50}$$

$$= \left[\frac{\mathcal{BC}}{\mathcal{A}} + \frac{s_\ell+s_D}{s_\ell}\Gamma\left(1-\frac{1}{\varepsilon}\right)\right]\widehat{s}_P + \left[\frac{s_\ell+s_D}{s_\ell}\Gamma - \frac{\mathcal{BC}}{\mathcal{A}(\varepsilon^{-1}-1)}\right]\widehat{\omega}_P \tag{B.51}$$

$$= \left[\frac{\mathcal{BC}}{\mathcal{A}} + \frac{s_\ell+s_D}{s_\ell}\Gamma\left(1-\varepsilon^{-1}\right)\right]\cdot\left[\widehat{s}_P - \frac{1}{\varepsilon^{-1}-1}\widehat{\omega}_P\right] \tag{B.52}$$

Remember that

$$\widehat{s}_P - \frac{1}{\varepsilon^{-1}-1}\widehat{\omega}_P = \frac{\omega_M}{\omega_P}\widehat{s}_M - \frac{1}{\varepsilon^{-1}-1}\left(\widehat{\omega}_M\frac{\omega_M}{\omega_P} + \widehat{\omega}_S\frac{\omega_S}{\omega_P}\right) \tag{B.53}$$

and hence the sign of the effect of changes in s_P is the same as in s_M and the same for ω_P and $\omega_{M,S}$. Therefore, we want to determine the sign of the first bracket term of equation (B.52). We will show that

$$\left[\frac{\mathcal{BC}}{\mathcal{A}} + \frac{s_\ell+s_D}{s_\ell}\Gamma\left(1-\varepsilon^{-1}\right)\right] > 0 \tag{B.54}$$

Let's begin by using the definition of $\mathcal{A}, \mathcal{B}, \mathcal{C}$ and Γ to simplify,

$$\mathcal{C} \equiv \left[1 - \Gamma\left(1 - \frac{1}{\varepsilon}\right) - \frac{s_D}{s_\ell + s_D}\right] \frac{s_\ell + s_D}{s_\ell} < 0 \text{ (due to bank SOC)} \tag{B.55}$$

$$\mathcal{A} \equiv \left[1 - \Gamma\left(1 - \frac{1}{\varepsilon}\right) - \frac{s_D}{s_\ell + s_D}\right] \frac{s_\ell + s_D}{s_\ell} + \frac{\left[(1-\omega_D)\frac{1}{\varepsilon} + \omega_D \frac{1}{\eta}\right]}{\clubsuit} = \mathcal{C} + \frac{\left[(1-\omega_D)\frac{1}{\varepsilon} + \omega_D \frac{1}{\eta}\right]}{\clubsuit} \tag{B.56}$$

$$\mathcal{B} \equiv \frac{1}{\clubsuit}\left(\frac{1}{\varepsilon} - \frac{1}{\eta}\right)(1-\omega_D) - \frac{s_\ell + s_D}{s_\ell}\Gamma\left(1 - \frac{1}{\varepsilon}\right) = \frac{1}{\clubsuit}\left(\frac{1}{\varepsilon} - \frac{1}{\eta}\right)(1-\omega_D) + (\mathcal{C} - 1) \tag{B.57}$$

$$\Gamma = \left[\frac{(\eta^{-1} - \varepsilon^{-1})\,\omega_D\,(1-\omega_D)}{\varepsilon^{-1}(1-\omega_D) + \eta^{-1}\omega_D}\right] < 0 \tag{B.58}$$

We want to establish the sign of

$$E \ \equiv \ \frac{\mathcal{B}\mathcal{C}}{\mathcal{A}} + \frac{s_\ell + s_D}{s_\ell}\,\Gamma\big(1 - \varepsilon^{-1}\big)\,. \tag{B.59}$$

From (B.55) we have

$$\mathcal{C} = \left[1 - \Gamma\big(1 - \varepsilon^{-1}\big) - \frac{s_D}{s_\ell + s_D}\right] \frac{s_\ell + s_D}{s_\ell} = 1 - \frac{s_\ell + s_D}{s_\ell}\Gamma\big(1 - \varepsilon^{-1}\big)\,,$$

so that

$$\frac{s_\ell + s_D}{s_\ell}\Gamma\big(1 - \varepsilon^{-1}\big) = 1 - \mathcal{C}.$$

Substituting into (B.59) yields

$$E \ = \ \frac{\mathcal{B}\mathcal{C}}{\mathcal{A}} + 1 - \mathcal{C}. \tag{B.60}$$

Using (B.56) and (B.57)

$$(\mathcal{A} - \mathcal{C}) - \big(\mathcal{B} - (\mathcal{C} - 1)\big) = \frac{\eta^{-1}}{\clubsuit},$$

hence

$$\mathcal{B} = \mathcal{A} - 1 - \frac{\eta^{-1}}{\clubsuit}. \tag{B.61}$$

Substituting (B.61) into (B.60) we obtain

$$E = \frac{\mathcal{C}}{\mathcal{A}}\Big(\mathcal{A} - 1 - \tfrac{\eta^{-1}}{\clubsuit}\Big) + 1 - \mathcal{C} = 1 - \frac{\mathcal{C}}{\mathcal{A}}\left(1 + \frac{\eta^{-1}}{\clubsuit}\right).$$

Thus,

$$E \;=\; 1 - \frac{\mathcal{C}}{\mathcal{A}}\Big(1 + \tfrac{\eta^{-1}}{\clubsuit}\Big). \tag{B.62}$$

Since $\mathcal{C} < 0$ (bank SOC, see (B.55)) and $\clubsuit < 0$. From (B.56), $\mathcal{A} = \mathcal{C} + \frac{(1-\omega_D)\varepsilon^{-1} + \omega_D \eta^{-1}}{\clubsuit}$, where the fraction is negative. Thus $\mathcal{A} < \mathcal{C} < 0$, implying

$$0 < \frac{\mathcal{C}}{\mathcal{A}} < 1.$$

Moreover, since $\eta^{-1} > 0$ and $\clubsuit < 0$, we have

$$1 + \frac{\eta^{-1}}{\clubsuit} < 1.$$

Therefore the product $\frac{\mathcal{C}}{\mathcal{A}}(1 + \eta^{-1}/\clubsuit)$ is strictly less than 1, and from (B.62) it follows that

$$E > 0.$$

Hence, we have shown that

$$\left[\frac{\mathcal{B}\mathcal{C}}{\mathcal{A}} + \frac{s_\ell + s_D}{s_\ell}\Gamma\left(1 - \varepsilon^{-1}\right)\right] > 0 \tag{B.63}$$

and it follows

$$\frac{\partial s_\ell}{\partial s_P} > 0 \quad \text{and} \quad \frac{\partial s_\ell}{\partial \omega_P} < 0 \tag{B.64}$$

Since signs are preserved:

$$\frac{\partial s_\ell}{\partial s_M} > 0 \quad \text{and} \quad \frac{\partial s_\ell}{\partial \omega_{M,S}} < 0$$

which proves point (2) and (3) of Proposition 2.

B.2.1 Dynamics of the Constraint in the Unconstrained Regime

We finish this section by studying movements in profits to determine whether the constraint is becoming tighter as stablecoins' quality is improved or CBDC introduced. Bank profits evolve as stated in Equation (B.14)—recall $\widehat{r}_B = 0$:

$$\widehat{\Pi}_B = \frac{s_\ell \widehat{s}_\ell + s_D \widehat{s}_D}{s_\ell + s_D} + \widehat{D}$$

We know that $\widehat{D} = \clubsuit \widehat{s}_\ell$. Note that the evolution of profits is not immediate as spreads might contract but quantities grow:

$$\begin{aligned} \widehat{\Pi}_B &= \frac{s_\ell \widehat{s}_\ell + s_D \widehat{s}_D}{s_\ell + s_D} + \widehat{D} \\ &= \frac{s_D \widehat{s}_D}{s_\ell + s_D} + \widehat{s}_\ell \left[\clubsuit + \frac{s_\ell}{s_\ell + s_D}\right] \end{aligned}$$

The sign of $\left[\clubsuit + \frac{s_\ell}{s_\ell + s_D}\right]$ is not straightforward since $\clubsuit$ determines the elasticity of bank loans with respect to their price. In case they are very elastic, quantities might respond strongly to the fall in loan prices such that bank profits will not fall.

A sufficient condition that guarantees falling profits after stablecoin quality is improved or CBDC introduced is to bound the elasticity of loans to prices in order to get $\left[\clubsuit + \frac{s_\ell}{s_\ell + s_D}\right] > 0$. Note that,

$$\begin{aligned} &\left[\clubsuit + \frac{s_\ell}{s_\ell + s_D}\right] \\ &\quad = -\frac{1}{\alpha}\left[1 + \frac{\rho}{\alpha}(1-\alpha)\right]^{-1} \frac{s_\ell}{1 + s_\ell}\left[\frac{p_N y_N}{Y}\alpha(1-\alpha)^{-1} + \rho\right] + \frac{s_\ell}{s_\ell + s_D} \\ &\quad = -\frac{s_\ell}{1 + s_\ell}\frac{1}{1-\alpha}\frac{\frac{p_N y_N}{Y}\alpha(1-\alpha)^{-1} + \rho}{\alpha(1-\alpha)^{-1} + \rho} + \frac{s_\ell}{s_\ell + s_D} \end{aligned}$$

A sufficient condition to guarantee that the term is positive is to have a sufficiently small elasticity of output with respect to capital, $\alpha \to 0$. To see this note that

$$\begin{aligned} \frac{s_\ell}{1 + s_\ell} &\in (0, 1) \\ \frac{\frac{p_N y_N}{Y}\alpha(1-\alpha)^{-1} + \rho}{\alpha(1-\alpha)^{-1} + \rho} &\in (0, 1) \end{aligned}$$

then in the limit, when $\alpha \to 0$, it follows that for the term to be negative we need,

$$\frac{s_\ell}{1+s_\ell} < \frac{s_\ell}{s_\ell + s_D} \tag{B.65}$$

which is satisfied as long as $0 < s_D < 1$ a condition we impose for the equilibrium prices. Note that $s_D > 1$ will imply that deposits return is less than the principal, that is, $r_D < -1$, which is economically irrelevant.

It follows that for a sufficiently low α, profits move like deposit and loan spreads, s_D and s_ℓ, which fall as a CBDC is introduced or stablecoin quality improved.

Next, we study the movements in $D - \phi(\Pi_B)$ in order to show that μ will eventually become greater than zero when s_M falls or $\omega_{S,M}$ increases enough.

Notice that in the unconstrained region we have $D - \phi(\Pi_B) < 0$. Therefore, the complementary slackness condition $\mu \cdot [D - \phi(\Pi_B)] = 0$ implies $\mu = 0$. Yet if, for example, $D - \phi(\Pi_B)$ increases with $\omega_{S,M}$ monotonically and we can show that there exists an $\omega_{S,M}$ such that it is positive, then given the continuity of the functions it follows that eventually $D - \phi(\Pi_B) > 0$ and we move to the constraint region if $\omega_{S,M}$ grows sufficiently.

The evolution of $D(r_D) - \phi(\Pi_B)$ is driven by

$$\left[D\,\widehat{D} - \phi'\left(\Pi_B\right)\Pi_B \widehat{\Pi}_B\right]$$

We know that $\widehat{D} = \clubsuit \widehat{s}_\ell$ and so D moves contrarily to s_ℓ as $\clubsuit < 0$. If again we impose that α is sufficiently low, then profits move like s_ℓ, which gives that

$$\frac{\partial\left[D(r_D) - \phi(\Pi_B)\right]}{\partial s_M} < 0 \text{ and } \frac{\partial\left[D(r_D) - \phi(\Pi_B)\right]}{\partial \omega_{S,M}} > 0$$

which makes the constraint "tighter" as stablecoin quality improve or CBDC is introduced.

What remains is to show that there exists a s_M or $\omega_{S,M}$ such that the constraint binds. But since $\phi(0) = 0$ and deposits are monotonically increasing in $\omega_{S,M}$ and decreasing in s_M (conditional on $L^\star$ being sufficiently high). Then the constraint will eventually bind.

B.3 Proof of Proposition 2 - Constrained Scenario

In this case, the bank deposit spread equation is driven by the constraint, whose evolution is driven by (B.13):

$$\widehat{D} = \frac{\phi'(\Pi_B)\,\Pi_B}{\phi(\Pi_B)}\widehat{\Pi}_B \tag{B.66}$$

where bank profits evolve as (B.14):

$$\widehat{\Pi}_B = \frac{s_\ell \widehat{s}_\ell + s_D \widehat{s}_D}{s_\ell + s_D} + \frac{r_B \widehat{r}_B}{1+r_B} + \widehat{D} \tag{B.67}$$

and the multiplier as (B.12)

$$\frac{s_\ell \widehat{s}_\ell + s_D \widehat{s}_D}{s_\ell + s_D} = \frac{-\widehat{\varepsilon}_D \varepsilon_D^{-1} + [1+\mu\phi'(\Pi_B)]\left[-\mu^{-1}\widehat{\mu} + \phi''(\Pi_B)\,\Pi_B \widehat{\Pi}_B\right]}{\varepsilon_D^{-1} + \frac{\mu}{1+\mu\phi'(\Pi_B)}}$$

Combine (B.13) and (B.14) with the fact that in steady state $\widehat{r}_B = 0$ and assume a strictly concave constraint[23] to get

$$\widehat{D} = \frac{\phi'(\Pi_B)\,\Pi_B}{\phi(\Pi_B) - \phi'(\Pi_B)\,\Pi_B}\left(\frac{s_\ell \widehat{s}_\ell + s_D \widehat{s}_D}{s_\ell + s_D}\right). \tag{B.68}$$

Then use (B.30) to get

$$\begin{aligned}\frac{\phi'(\Pi_B)\,\Pi_B}{\phi(\Pi_B) - \phi'(\Pi_B)\,\Pi_B}\left(\frac{s_\ell \widehat{s}_\ell + s_D \widehat{s}_D}{s_\ell + s_D}\right) &= -\left(\frac{1}{\varepsilon} - \frac{1}{\eta}\right)\frac{\varepsilon}{1-\varepsilon}(1-\omega_D)\,\widehat{\omega}_P \\ &+ \left(\frac{1}{\varepsilon} - \frac{1}{\eta}\right)(1-\omega_D)\,\widehat{s}_P - \left[(1-\omega_D)\frac{1}{\varepsilon} + \omega_D\frac{1}{\eta}\right]\widehat{s}_D.\end{aligned} \tag{B.69}$$

[23] The case of linear constraint is addressed below as a special case.

Collect the terms,

$$\left(\tfrac{1}{\varepsilon}-\tfrac{1}{\eta}\right)(1-\omega_D)\left[\widehat{s}_P-\tfrac{1}{\varepsilon^{-1}-1}\,\widehat{\omega}_P\right]-\Bigg[(1-\omega_D)\varepsilon^{-1}+\omega_D\eta^{-1}$$
$$+\ \frac{\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}{1-\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}\,\tfrac{s_D}{s_D+s_\ell}\Bigg]\widehat{s}_D$$
$$=\ \frac{\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}{1-\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}\,\tfrac{s_\ell}{s_\ell+s_D}\,\widehat{s}_\ell. \tag{B.70}$$

We also know from (B.41) that

$$\widehat{s}_\ell=\frac{-\left(\frac{1}{\varepsilon}-\frac{1}{\eta}\right)\frac{\varepsilon}{1-\varepsilon}\,(1-\omega_D)\,\widehat{\omega}_P+\left(\frac{1}{\varepsilon}-\frac{1}{\eta}\right)(1-\omega_D)\,\widehat{s}_P-\left[(1-\omega_D)\,\frac{1}{\varepsilon}+\omega_D\frac{1}{\eta}\right]\widehat{s}_D}{\clubsuit}$$

Now combine the previous equation (B.41) with (B.70) to get

$$\left(\tfrac{1}{\varepsilon}-\tfrac{1}{\eta}\right)(1-\omega_D)\left[\widehat{s}_P-\tfrac{1}{\varepsilon^{-1}-1}\,\widehat{\omega}_P\right]-\Bigg[(1-\omega_D)\varepsilon^{-1}+\omega_D\eta^{-1}$$
$$+\ \frac{\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}{1-\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}\,\tfrac{s_D}{s_D+s_\ell}\Bigg]\widehat{s}_D$$
$$=\ \frac{\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}{1-\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}\,\tfrac{s_\ell}{s_\ell+s_D}\,\tfrac{1}{\clubsuit}\Bigg[\left(\varepsilon^{-1}-\eta^{-1}\right)(1-\omega_D)\left(\widehat{s}_P-\tfrac{1}{\varepsilon^{-1}-1}\,\widehat{\omega}_P\right)$$
$$-\left((1-\omega_D)\varepsilon^{-1}+\omega_D\eta^{-1}\right)\widehat{s}_D\Bigg]. \tag{B.71}$$

Collect terms,

$$\left[\widehat{s}_P - \tfrac{1}{\varepsilon^{-1}-1}\,\widehat{\omega}_P\right]\left(\tfrac{1}{\varepsilon}-\tfrac{1}{\eta}\right)(1-\omega_D)\left[1-\frac{\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}{1-\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}\,\tfrac{s_\ell}{s_\ell+s_D}\,\tfrac{1}{\clubsuit}\right]$$

$$= \left[\left((1-\omega_D)\varepsilon^{-1}+\omega_D\eta^{-1}\right)\left(1-\frac{\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}{1-\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}\,\tfrac{s_\ell}{s_\ell+s_D}\,\tfrac{1}{\clubsuit}\right) + \frac{\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}{1-\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}\,\tfrac{s_D}{s_D+s_\ell}\right]\widehat{s}_D. \tag{B.72}$$

Now we proceed with determining the sign. The term on the left hand side is,

$$\mathcal{F} \equiv \left(\tfrac{1}{\varepsilon}-\tfrac{1}{\eta}\right)(1-\omega_D)\left[1-\frac{\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}{1-\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}\,\tfrac{s_\ell}{s_\ell+s_D}\,\tfrac{1}{\clubsuit}\right]$$

where we know that $\left(\tfrac{1}{\varepsilon}-\tfrac{1}{\eta}\right) > 0$ and $(1-\omega_D) > 0$. For the last term note that since $\phi(\Pi_B)$ is strictly concave, then

$$\phi'(\Pi_B) < \frac{\phi(\Pi_B)}{\Pi_B} \rightarrow 1-\tfrac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)} > 0$$

Since $\clubsuit < 0$, it follows that

$$\mathcal{F} > 0 \tag{B.73}$$

Similarly, the right hand side is

$$\mathcal{G} \equiv \left[\left((1-\omega_D)\varepsilon^{-1}+\omega_D\eta^{-1}\right)\left(1-\frac{\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}{1-\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}\,\tfrac{s_\ell}{s_\ell+s_D}\,\tfrac{1}{\clubsuit}\right) + \frac{\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}{1-\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}\,\tfrac{s_D}{s_D+s_\ell}\right]$$

Using the concavity of $\phi(\Pi_B)$ together with $\clubsuit < 0$, it follows that

$$\mathcal{G} > 0 \tag{B.74}$$

Therefore, the effect of s_M and ω_M on s_D is given by

$$\widehat{s}_D = \frac{\mathcal{F}}{\mathcal{G}}\left[\widehat{s}_P - \tfrac{1}{\varepsilon^{-1}-1}\,\widehat{\omega}_P\right] \tag{B.75}$$

and it follows

$$\frac{\partial s_D}{\partial s_P} > 0 \text{ and } \frac{\partial s_D}{\partial \omega_P} < 0 \tag{B.76}$$

Furthermore, by the same argument as we used to derive Equation (B.53), we know

$$\frac{\partial s_D}{\partial s_M} > 0 \text{ and } \frac{\partial s_D}{\partial \omega_{S,M}} < 0 \tag{B.77}$$

This proves point (1) of Proposition 2 for the constrain region with a strictly concave constraint function.

If we assume a linear constraint, instead of Equation (B.68) we have

$$0 = \frac{s_\ell}{s_\ell + s_D}\widehat{s}_\ell + \frac{s_D}{s_\ell + s_D}\widehat{s}_D \tag{B.78}$$

or

$$\widehat{s}_\ell = -\frac{s_D}{s_\ell}\widehat{s}_D$$

Combine again with (B.41) to get,

$$-\frac{s_D}{s_\ell}\widehat{s}_D = \frac{-\left(\frac{1}{\varepsilon} - \frac{1}{\eta}\right)\frac{\varepsilon}{1-\varepsilon}\left(1-\omega_D\right)\widehat{\omega}_P + \left(\frac{1}{\varepsilon} - \frac{1}{\eta}\right)\left(1-\omega_D\right)\widehat{s}_P - \left[\left(1-\omega_D\right)\frac{1}{\varepsilon} + \omega_D\frac{1}{\eta}\right]\widehat{s}_D}{\clubsuit}$$

Collect the terms

$$\widehat{s}_D = \frac{\left(\frac{1}{\varepsilon} - \frac{1}{\eta}\right)\left(1-\omega_D\right)}{\left(1-\omega_D\right)\frac{1}{\varepsilon} + \omega_D\frac{1}{\eta} - \frac{s_D}{s_\ell}\clubsuit}\left[\widehat{s}_P - \frac{1}{\varepsilon^{-1}-1}\widehat{\omega}_P\right].$$

Since $\clubsuit < 0$, the term multiplying the bracket is positive. Therefore, the sign results in (B.77) carry through.

Back to the strictly concave constraint. Replace (B.75) in (B.41) to get the effect on s_ℓ

$$\widehat{s}_\ell = \frac{-\left(\frac{1}{\varepsilon} - \frac{1}{\eta}\right)\frac{\varepsilon}{1-\varepsilon}\left(1-\omega_D\right)\widehat{\omega}_P + \left(\frac{1}{\varepsilon} - \frac{1}{\eta}\right)\left(1-\omega_D\right)\widehat{s}_P - \left[\left(1-\omega_D\right)\frac{1}{\varepsilon} + \omega_D\frac{1}{\eta}\right]\widehat{s}_D}{\clubsuit}$$

replace the solution for $\widehat{s}_D$, collect terms and simplify

$$\widehat{s}_\ell = \frac{1}{\clubsuit}\left\{\left(\tfrac{1}{\varepsilon}-\tfrac{1}{\eta}\right)(1-\omega_D)\left[\widehat{s}_P - \tfrac{1}{\varepsilon^{-1}-1}\,\widehat{\omega}_P\right] - \left[(1-\omega_D)\varepsilon^{-1}+\omega_D\eta^{-1}\right]\frac{\mathcal{F}}{\mathcal{G}}\left[\widehat{s}_P - \tfrac{1}{\varepsilon^{-1}-1}\,\widehat{\omega}_P\right]\right\} \tag{B.79}$$

$$= \frac{1}{\clubsuit}\left[\left(\tfrac{1}{\varepsilon}-\tfrac{1}{\eta}\right)(1-\omega_D) - \left((1-\omega_D)\varepsilon^{-1}+\omega_D\eta^{-1}\right)\frac{\mathcal{F}}{\mathcal{G}}\right]\left[\widehat{s}_P - \tfrac{1}{\varepsilon^{-1}-1}\,\widehat{\omega}_P\right]. \tag{B.80}$$

We want to sign the first term, so let's begin with the bracket and show it is positive

$$\left[\left(\tfrac{1}{\varepsilon}-\tfrac{1}{\eta}\right)(1-\omega_D) - \left((1-\omega_D)\varepsilon^{-1}+\omega_D\eta^{-1}\right)\frac{\mathcal{F}}{\mathcal{G}}\right] > 0$$

Next, we work on the bracket and use the definitions of $\mathcal{F}$ and $\mathcal{G}$

$$\left[\left(\tfrac{1}{\varepsilon}-\tfrac{1}{\eta}\right)(1-\omega_D) - \left((1-\omega_D)\varepsilon^{-1}+\omega_D\eta^{-1}\right)\frac{\mathcal{F}}{\mathcal{G}}\right]$$

$$= \frac{\left(\tfrac{1}{\varepsilon}-\tfrac{1}{\eta}\right)(1-\omega_D)\,\mathcal{G} - \left((1-\omega_D)\varepsilon^{-1}+\omega_D\eta^{-1}\right)\mathcal{F}}{\mathcal{G}}$$

$$= \frac{\left(\tfrac{1}{\varepsilon}-\tfrac{1}{\eta}\right)(1-\omega_D)\left\{\left((1-\omega_D)\varepsilon^{-1}+\omega_D\eta^{-1}\right)\left[1 - \frac{\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}{1-\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}\,\frac{s_\ell}{s_\ell+s_D}\,\frac{1}{\clubsuit}\right] + \frac{\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}{1-\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}\,\frac{s_D}{s_D+s_\ell}\right\}}{\mathcal{G}}$$

$$- \frac{\left((1-\omega_D)\varepsilon^{-1}+\omega_D\eta^{-1}\right)\left(\tfrac{1}{\varepsilon}-\tfrac{1}{\eta}\right)(1-\omega_D)\left[1 - \frac{\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}{1-\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}\,\frac{s_\ell}{s_\ell+s_D}\,\frac{1}{\clubsuit}\right]}{\mathcal{G}}$$

$$= \frac{\left(\tfrac{1}{\varepsilon}-\tfrac{1}{\eta}\right)(1-\omega_D)\,\frac{\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}{1-\frac{\phi'(\Pi_B)\Pi_B}{\phi(\Pi_B)}}\,\frac{s_D}{s_D+s_\ell}}{\mathcal{G}} > 0$$

where the sign is positive because $\mathcal{G} > 0$, $\phi(\Pi_B)$ is increasing and concave and $\varepsilon^{-1} > \eta^{-1}$.

Coming back to Equation (B.80), we know that

$$\widehat{s}_\ell = \frac{1}{\clubsuit}\left[\left(\tfrac{1}{\varepsilon}-\tfrac{1}{\eta}\right)(1-\omega_D) - \left((1-\omega_D)\varepsilon^{-1}+\omega_D\eta^{-1}\right)\frac{\mathcal{F}}{\mathcal{G}}\right]\left[\widehat{s}_P - \tfrac{1}{\varepsilon^{-1}-1}\,\widehat{\omega}_P\right]$$

Since we showed that the term in brackets is positive and $\clubsuit < 0$, it follows that

$$\frac{\partial s_\ell}{\partial s_M} < 0 \quad \text{and} \quad \frac{\partial s_\ell}{\partial \omega_{S,M}} > 0 \tag{B.81}$$

This proves point (2) and (3) of Proposition 2 for a strictly concave constraint. The effect on quantities come from (B.29), (B.37), (B.38) and (B.40) which are valid under both scenarios as they come from the production side.

The linear constraint equation (B.80) now becomes

$$\widehat{s}_\ell = -\frac{s_D}{s_\ell}\,\frac{\left(\frac{1}{\varepsilon}-\frac{1}{\eta}\right)(1-\omega_D)}{(1-\omega_D)\,\frac{1}{\varepsilon}+\omega_D\frac{1}{\eta}-\frac{s_D}{s_\ell}\clubsuit}\left[\widehat{s}_P - \frac{1}{\varepsilon^{-1}-1}\,\widehat{\omega}_P\right].$$

Again since $\clubsuit < 0$, the term multiplying the bracket, i.e.,

$$-\frac{s_D}{s_\ell}\,\frac{\left(\frac{1}{\varepsilon}-\frac{1}{\eta}\right)(1-\omega_D)}{(1-\omega_D)\,\frac{1}{\varepsilon}+\omega_D\frac{1}{\eta}-\frac{s_D}{s_\ell}\clubsuit} < 0$$

and the results in (B.81) carry through for the linear case as well.

For deposits quantities, take (B.80), (B.38) and (B.41) to get

$$\widehat{D} = \left[\left(\tfrac{1}{\varepsilon}-\tfrac{1}{\eta}\right)(1-\omega_D) - \left((1-\omega_D)\varepsilon^{-1}+\omega_D\eta^{-1}\right)\frac{\mathcal{F}}{\mathcal{G}}\right]\left[\widehat{s}_P - \tfrac{1}{\varepsilon^{-1}-1}\,\widehat{\omega}_P\right] \tag{B.82}$$

We already proved that the term in brackets is positive. Therefore, $\frac{\partial D}{\partial s_M} > 0$ and $\frac{\partial D}{\partial \omega} < 0$. The same is true for loans.

B.4 Proof of Corollary 1

The proof of Corollary 1 comes naturally from previous proofs. Note that all our results, for example Equations (B.75), (B.43) or (B.52), depend on the effect of movements in $\left[\widehat{s}_P - \frac{1}{\varepsilon^{-1}-1}\widehat{\omega}_P\right]$. Therefore, changes in $\omega_{S,M}$ or s_M that make the term move by the same magnitude will have the same effect on equilibrium variables.

First, we decompose the term using the definitions of s_P and ω_P. Call the term $\widehat{\varphi}$:

$$\widehat{\varphi} = \widehat{s}_P - \tfrac{1}{\varepsilon^{-1}-1}\widehat{\omega}_P = \frac{\omega_M}{\omega_P}\widehat{s}_M - \frac{1}{\varepsilon^{-1}-1}\left(\widehat{\omega}_M\frac{\omega_M}{\omega_P} + \widehat{\omega}_S\frac{\omega_S}{\omega_P}\right)$$

If we only care about the partial effect of perturbing one variable at a time we get,

$$\frac{\widehat{\varphi}}{\widehat{s}_M} = \frac{\partial \log \varphi}{\partial \log s_M} = \frac{\omega_M}{\omega_P}$$
$$\frac{\widehat{\varphi}}{\widehat{\omega}_M} = \frac{\partial \log \varphi}{\partial \log \omega_M} = -\frac{1}{\varepsilon^{-1}-1}\frac{\omega_M}{\omega_P}$$
$$\frac{\widehat{\varphi}}{\widehat{\omega}_S} = \frac{\partial \log \varphi}{\partial \log \omega_S} = -\frac{1}{\varepsilon^{-1}-1}\frac{\omega_S}{\omega_P}$$

Corollary 1 follows from previous equations by replacing φ for any variable of interest.

B.5 Proof of Proposition 4

Case (i): Deposits not special. Remove banks constraint on wholesale funding, i.e., now $B \lesseqgtr 0$. Also assume that wholesale liabilities do not enter the borrowing constraint. Then the bank's problem is

$$\max_{\ell, r_D, B} \; (1+r_\ell)\,\ell + (1+r)\,B - (1+r_D)\,D, \quad \text{s.t. } \ell + B = D, \;\; D \leq \phi(\Pi_B).$$

The FOC that characterize the solution are,

$$[\ell] : (1+r_\ell)\,[1+\mu\phi'] = \lambda$$
$$[B] : (1+r)\,[1+\mu\phi'] = \lambda$$
$$[r_D] : [(1+r_D) + D/D']\,[1+\mu\phi'] = -\lambda + \mu$$

Combine [ℓ], [B] to get,

$$r = r_\ell \rightarrow r_\ell = \frac{1}{\beta} - 1$$

where the last equation comes from the household's Euler equation at the steady state.

Case (ii): Bank credit not special. If non-corporate firms can borrow directly from households at an exogenous rate, then by a non-arbitrage condition of households' portfolio, it follows that the borrowing rate should equal the bond interest rate. Since also small firms can now arbitrage between bank and bond borrowing, it follows that $r_\ell = r$.

Appendix C Equilibrium

As described in Definition 1, we have the following endogenous variables: Consumption C, deposits D, government money M, stablecoins S, bonds held by households B_H, final goods output Y, output, capital, investment and relative prices by corporate and small non-corporate firms $y_X, K_X, I_X, p_X \ \forall X \in \{C, N\}$, loans ℓ, bonds held by banks B_B, bonds held by stablecoin suppliers B_S, deposit r_D and loan interest rate r_ℓ, taxes T and the Lagrange multipliers for the leverage constraint μ and the bond holdings ζ. As mentioned in Section 2.6, we focus on steady state equilibria with a positive loan rate spread, $s_\ell > 0$, such that banks do not hold bonds $B_B = 0$ and $\zeta > 0$.

Furthermore, there are three exogenous interest rates r_M, r and r_S, where r is determined by the agent's discount factor $\beta = (1 + r)^{-1}$. In the base case, the interest rate on stablecoins is equal to the public money rate, $r_S = r_M$. The equilibrium equations are shown below. From the household problem we have the deposit and money demand equations, and the budget constraint:

$$D = L \left(\frac{s_D}{s_L}\right)^{-1/\varepsilon}, \tag{C.1}$$

$$M = \omega_M L \left(\frac{s_M}{s_L}\right)^{-1/\varepsilon}, \tag{C.2}$$

$$S = \omega_S L \left(\frac{s_S}{s_L}\right)^{-1/\varepsilon} \tag{C.3}$$

$$C = \Pi + r_D D + r B_H, \tag{C.4}$$

where the last equation imposes the government budget constraint and the fact that the stablecoin suppliers profit also drops out since only government bonds are held and the profit is distributed to households. Total liquidity L, the spread s_L and overall profit Π, composed of bank and firm profits, are given by:

$$L = \min\{L^*, \nu s_L^{-1/\eta}\} \tag{C.5}$$

$$s_L = \left(\omega_M s_M^{\frac{\varepsilon-1}{\varepsilon}} + s_D^{\frac{\varepsilon-1}{\varepsilon}} + \omega_S s_S^{\frac{\varepsilon-1}{\varepsilon}}\right)^{\frac{\varepsilon}{\varepsilon-1}} \tag{C.6}$$

$$\Pi = \underbrace{\Pi_B}_{\text{Bank}} + \underbrace{p_N y_N - I_N(1+r_\ell)}_{\text{Non-corporate Firm}} + \underbrace{p_C y_C - I_C(1+r)}_{\text{Corporate Firm}} \tag{C.7}$$

From the bank problem, we get the deposit supply equation, the profit equation, the balance sheet identity and the complementary slackness condition:

$$s_D = \varepsilon_D^{-1} + \kappa - s_\ell, \tag{C.8}$$

$$\Pi_B = \ell(1+r_\ell) - D(1+r_D) \tag{C.9}$$

$$\ell = D, \tag{C.10}$$

$$0 = \mu(\phi(\Pi_B) - D), \tag{C.11}$$

where the elasticity of deposit demand ε_D and the deposit market share ω_D is defined by:

$$\varepsilon_D^{-1} = \frac{s_D}{\varepsilon^{-1}(1-\omega_D) + \eta^{-1}\omega_D}, \tag{C.12}$$

$$\omega_D = \frac{D s_D}{D s_D + M s_M + S s_S}. \tag{C.13}$$

From the final goods producer we have the production function and the two first order conditions with respect to the two inputs:

$$Y = \left[y_N^{\frac{\rho-1}{\rho}} + y_C^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}, \tag{C.14}$$

$$y_C = Y p_C^{-\rho}, \tag{C.15}$$

$$y_N = Y p_N^{-\rho}. \tag{C.16}$$

From the intermediate goods producers we have two production functions, two capital evolution equations and the two first order conditions:

$$y_C = A_C K_C^{\alpha}, \tag{C.17}$$

$$y_N = A_N K_N^{\alpha}, \tag{C.18}$$

$$\delta K_N = I_N, \tag{C.19}$$

$$\delta K_C = I_C, \tag{C.20}$$

$$\alpha p_C A_C K_C^{\alpha-1} = r + \delta, \tag{C.21}$$

$$\alpha p_N A_N K_N^{\alpha-1} = (1 + s_\ell)(r + \delta). \tag{C.22}$$

Lastly, we have market clearing in the goods and lending market

$$Y = C + I_C + I_N, \tag{C.23}$$

$$I_C = B_H, \tag{C.24}$$

$$I_N = \ell, \tag{C.25}$$

$$B_P = B_{S,P} + B_{H,P}, \tag{C.26}$$

and the definitions for the spreads:

$$s_D = \frac{r - r_D}{1 + r},, \tag{C.27}$$

$$s_M = \frac{r - r_M}{1 + r},, \tag{C.28}$$

$$s_S = \frac{r - r_S}{1 + r},, \tag{C.29}$$

$$s_\ell = \frac{r_\ell - r}{1 + r},. \tag{C.30}$$

To solve the model numerically, we apply the following algorithm depicted below. If the algorithm converges, the values determined in the last iteration represent the model solution.

Algorithm 1 Solve model numerically

Input: Initial guess s_0^D and $\{\beta, \nu, \eta, \omega_M, \omega_S, s_M, s_S, \varepsilon, \rho, \phi, \alpha, A_N, A_C, \delta, L^*\}$
Output: s_D

1: $s_D \leftarrow s_0^D$
2: Calculate $s_L, L, D, M, S, \omega_D, \varepsilon_D$ using (C.6), (C.5), (C.1), (C.2), (C.3), (C.13) and (C.12).
3: Set $\mu = \kappa = 0$. ▷ Assuming unconstrained region.
4: Calculate s_ℓ using (C.8).
5: Calculate ℓ and Π_B using (C.10) and (C.9).
6: **if** $D > \phi(\Pi_B)$ **then** ▷ Constrained region.
7: $\quad \Pi_B = \phi^{-1}(D)$ ▷ Leverage constraint binding.
8: $\quad$ Calculate s_ℓ using (C.10) and (C.9).
9: $\quad$ Calculate κ using (C.8).
10: **end if**
11: Calculate I_N, K_N, y_N, p_N using (C.25), (C.19), (C.18) and (C.22).
12: $p_C = (1 - p_N^{1-\rho})^{1/(1-\rho)}$ ▷ Price level for CES-function.
13: Calculate K_C, y_C, Y using (C.21), (C.17) and (C.14).
14: **if** $y_C \neq Y p_C^{-\rho}$ **then** ▷ Use Equation (C.15).
15: $\quad$ Choose different s_D in line 1
16: **end if**
17: **return** s_D

Appendix D Data

The model is calibrated to the US economy spanning from 1987 to 2007. We obtain data on the federal funds rate from FRED. To calculate real interest rates, we utilize inflation expectations measured by the Federal Reserve Bank of Cleveland, also obtained from FRED. Our measure for M is derived from the currency component of M1. Additionally, we incorporate estimates from Judson (2017) to account for US-dollar holdings abroad.

Table D.1: FRED and FDIC call report data.

Variable	**Source**	**Mnemonic**
Federal Funds Rate	FRED	DFF
Expected Inflation	FRED	EXPINF1YR
Currency component of M1	FRED	WCURRNS
Transaction Deposit Expense	FDIC	ETRANDEP; RIAD4508
Transaction Deposit Amount	FDIC	TRN; RCON2215
Savings Deposit Expense	FDIC	ESAVDP; RIAD0093
Savings Deposit Amount	FDIC	AVSAVDP; RCONB563
Loan Income	FDIC	ILN; RIAD4010
Loan Amount	FDIC	AVLN; RCON3360
Total Equity	FDIC	EQ; RCFD3210

The first set of FDIC mnemonics (e.g. ETRANDEP) are the ones used in the bulk download data. The second set of FDIC mnemonics are the ones that are used in the call reports (e.g. RIAD4508). A mapping can be found here: `https://www7.fdic.gov/DICT/app/templates/Index.html#!/Main`

All other data required for the calibration is derived from FDIC call reports, obtained via bulk download from `https://www.fdic.gov/foia/ris/`. For each quarter spanning from 1987 to 2007, our initial step involves computing a banking-sector interest rate by aggregating the expenses of all banks on transaction and saving deposits, which is then divided by the aggregated amounts of transaction and saving deposits. Subsequently, we compute the spread between the banking-sector interest rate and the federal funds rate to get s_D. We proceed analogously for the loan rate spread. To obtain estimates for the steady state, we calculate the time series' average. To compute the banking sector's leverage, we utilize total equity. For the measurement of total deposit holdings D, we consider transaction and savings deposits. The data points used are presented in Table D.1.

Appendix E Calibration

First, we set the parameters that match value found in the literature: $\beta, \delta, \rho, \varepsilon$.

To compute ω_M and ω_S, we divide Equation (C.2) and (C.3) by Equation (C.1) and rearrange the expressions as follows:

$$\omega_M = \frac{M}{D}\left(\frac{s_D}{s_M}\right)^{-1/\varepsilon}$$
$$\omega_S = \frac{S}{D}\left(\frac{s_D}{s_S}\right)^{-1/\varepsilon}$$

We determine ω_M and ω_S using the steady-state values of M/D, S/D, s_D, s_M and s_S.

As discussed in Section 3.2.1, we first assume, and then check, that banks' leverage constraints are not binding in steady state and the deposit spread arises exclusively due to the market power of banks on deposits. Thus, η is chosen such that the spreads in Equation (22) match the data moments, utilizing $\mu = \kappa = 0$ in the unconstrained case. By combining Equations (22) and (23), i.e.,

$$\frac{s_D}{s_D + s_\ell} = \left[\varepsilon^{-1}\left(1 - \frac{s_D}{s_M M/D + s_D + s_S S/D}\right) + \eta^{-1}\left(\frac{s_D D}{s_M M/D + s_D + s_S S/D}\right)\right]$$

we can pin down η, using ε and the steady state values of s_D, s_M, s_ℓ, M/D and S/D.

Next, calculate relative prices. Combine equations (C.16) and (C.15) and use the definition of relative prices given that the aggregate price level is set to $P = 1$, i.e., $p_C = (1 - p_N^{1-\rho})^{\frac{1}{1-\rho}}$. This yields:

$$\frac{y_C}{y_N} = \left(\frac{(1 - p_N^{1-\rho})^{\frac{1}{1-\rho}}}{p_N}\right)^{-\rho}$$

Using this we can caculate p_N given ρ and the data moment of $p_C y_C/(p_N y_N)$. Now calculate $p_C = (1 - p_N^{1-\rho})^{\frac{1}{1-\rho}}$.

Calculate Y, i.e.,

$$Y = \left[y_N^{\frac{\rho-1}{\rho}} + y_C^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}}$$

by normalizing $y_C = 1$ and using the data moment for y_C/y_N.

Calculate D using the data moment for D/Y. Then calculate ν by combining (C.1) and (C.5), i.e.,

$$\nu = s_D^{1/\varepsilon} D s_L^{1/\eta - 1/\varepsilon}$$

where s_L is defined by (C.6) and use the data moments for s_D, s_M and s_S.

Next, calculate $I_N = \ell = D$ and $K_N = I_N/\delta$. Given Equations (C.18) and (C.22) from the small firm's problem, we can pin down α and A_N solving the system of equations.

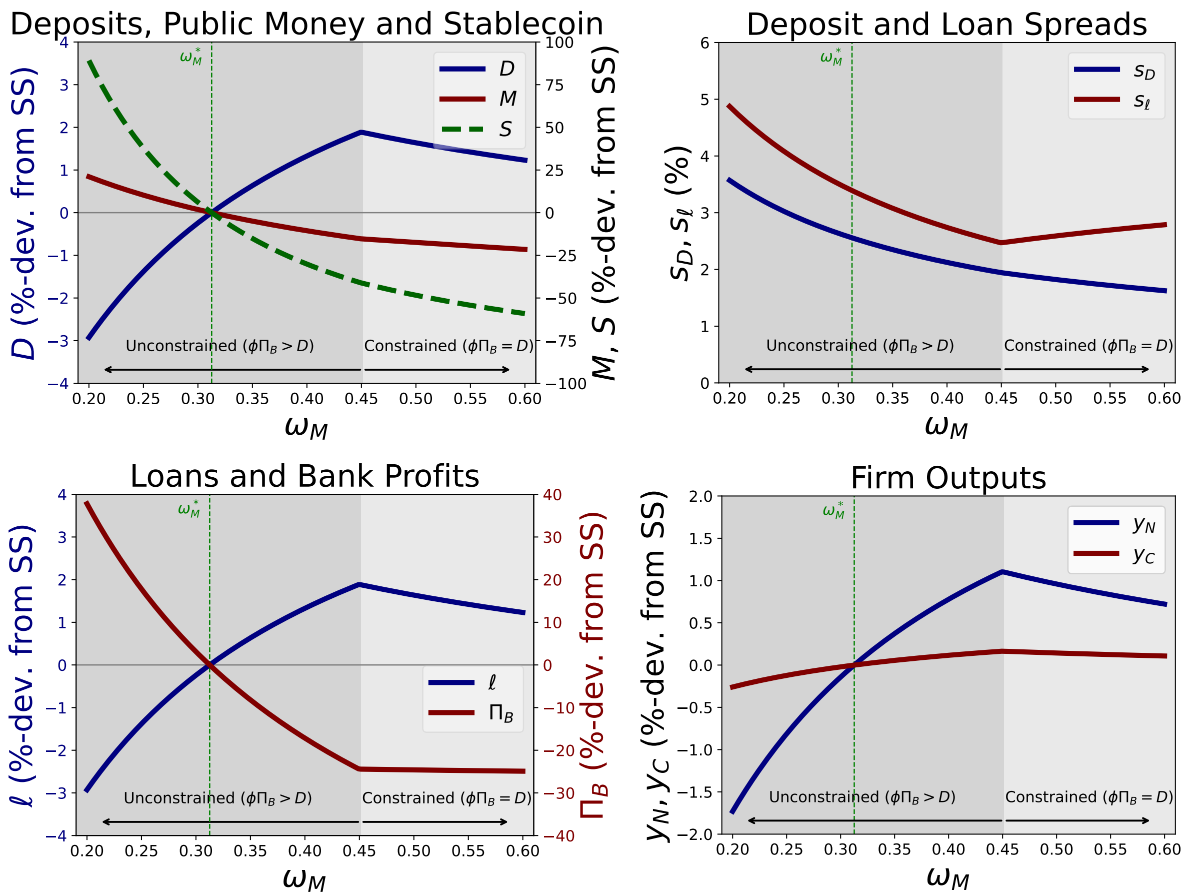
Pin down A_C using the first order condition of the corporate sector:

$$A_C = \left(\frac{r + \delta}{\alpha p_C y_C^{\frac{\alpha-1}{\alpha}}} \right)^{\alpha}$$

Lastly, we pin down the parameter ϕ for the leverage constraint. As discussed in Appendix A.4, we can rearrange the standard leverage constraint including equity, i.e. $D \leq \psi e$, to $D \leq \Pi_B \psi/\gamma$. As discussed in Section 3.2.1, for the standard leverage constraint we choose $\psi = 10$. For γ we aim to match $\gamma = \Pi_B/e$ in the data. Since in our model, the only profit the banks make is due to the interest rate spread between loans and deposits, we use the FDIC data to calculate the income from the net interest margin and relate it to equity. This yields a steady state value of $\gamma = 0.45$. Thus it follows, $\phi = \psi/\gamma = 10/0.45 = 22.3$.

Appendix F Introducing CBDC

Figure F.1: Effects of improving public money (ω_M).



Note: The figure shows the steady-state equilibrium outcomes for different values of the quality of public money (ω_M) in our calibrated economy. The unconstrained region refers to steady states such that $D < \phi \cdot \Pi_B$; the constrained regions to those with $D = \phi \cdot \Pi_B$.

Figure F.1 illustrates the effects of improving the quality of public money through the introduction of a CBDC. The qualitative effects mirror those of an improvement in stablecoin quality shown in Figure 1. The quantitative responses of deposit holdings and loan issuance are also similar. However, two important differences emerge. First, the deposit spread responds more strongly than in the stablecoin case. Second, holdings of public money, M, decline despite the increase in its quality.

In the model, this outcome arises because the larger decline in the deposit spread s_D

induces a stronger reduction in the liquidity spread s_L, which more than offsets the direct increase in the quality parameter ω_M. Intuitively, the result highlights that improvements in money quality can reduce money demand: higher-quality money delivers the same liquidity services with lower nominal holdings.