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Central Bank Digital Currency and Bank Stability: Does a No Bailout Policy Suffice?

Chakshu Jain
ISI DELHI

Subhadeep Halder
ISI DELHI & NYU ABU DHABI

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Chakshu Jain
ISI Delhi

Subhadeep Halder
ISI Delhi & NYU Abu Dhabi

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Abstract

We study how retail central bank digital currency (CBDC) interacts with bailout policy in a Diamond–Dybvig–style model with sequential service, sunspot runs, taxes financing a public good, and a CBDC available to movers and non-movers. We compare four regimes—bailouts vs. no bailouts, each with and without CBDC—and characterize fragility, illiquidity, taxes, and welfare. Bailouts induce generous early payouts and expand the run set; adding CBDC further lowers the withdrawal threshold by providing a safe outside option. Under a credible no-bailout commitment, CBDC essentially stabilizes the system via insurance substitution: banks promise less first-period liquidity, maturity mismatch falls, and tax needs decline. Within fragile equilibria, no-bailout policies dominate bailout policies for welfare, both with and without CBDC; with CBDC, the welfare gap is U-shaped in crisis probability. Taken together, the results suggest that combining CBDC with a credible no-bailout stance can enhance financial stability, contain fiscal costs, and improve welfare.

JEL Classification: E43, E61, E58, G21, G28
Keywords: CBDC, Digital Currency, Financial Stability, No-Bailout Commitment, Welfare

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Jain: Indian Statistical Institute - Delhi. Email: chakshujain9@gmail.com.
Halder: Indian Statistical Institute- Delhi and New York University Abu Dhabi. Email: sh7991@nyu.edu

1 Introduction

Central Bank Digital Currencies (CBDCs) have moved from thought experiment to near-universal exploration. Recent surveys show that most central banks are now evaluating or testing CBDCs, and a growing number have entered pilots or live issuance. As of 2024, 91% of 93 central banks surveyed by the BIS reported working on some form of CBDC.[1] By 2025, independent trackers counted roughly 137 countries and currency unions—covering about 98% of global GDP—engaged in CBDC projects, with more than seventy in advanced stages (development, pilot, or launch), and three (the Bahamas, Jamaica, Nigeria) fully functional.[2] These initiatives reflect a broad policy agenda—improving retail payments, expanding financial access, and modernizing public money—yet they also raise a core financial-stability question: how does a widely accessible, safe outside asset interact with the stability of the financial system?

An important challenge highlighted in the literature is that CBDCs could, in fact, increase fragility. In the event of a crisis, the presence of a safe and convenient form of money may encourage depositors to withdraw from banks and shift their funds into CBDC, creating the risk of self-fulfilling runs (Keister and Monnet, 2022; Williamson, 2022b). Some proponents argue that this drawback might be mitigated if CBDCs were paired with active policy interventions, such as bailouts of distressed banks informed by real-time flows into CBDC (Keister and Monnet, 2022). The central question, however, is whether CBDCs can be designed and implemented in a way that preserves their benefits without undermining financial stability.

This paper builds a model of financial intermediation in the spirit of Diamond and Dybvig (1983) and Keister (2016), where agents pool resources in banks to insure against idiosyncratic liquidity risk. A fraction of depositors face relocation shocks before their deposits mature; because relocation status is private information, some may withdraw early even if they do not need to. Banks provide liquidity by promising first-period payouts, but this creates a maturity mismatch, making them vulnerable to runs. Policymakers can observe the true state of the economy only with a lag, and in a "bad" state, they may choose to bail out intermediaries once withdrawals cross a threshold. Bailouts reallocate resources ex post, but they weaken ex-ante incentives by encouraging banks to rely more heavily on short-term liabilities, thereby raising fragility.

In this environment, we introduce a CBDC as a safe alternative available to all

[1] See BIS 2024 Report for details.

[2] Refer to the CBDC tracker for the recent developments in CBDC adoption by Central Banks around the world.

depositors. CBDCs affect outcomes through two main channels. First, an *insurance-substitution* channel: because depositors can turn to CBDC if needed, banks can promise less first-period liquidity, reducing maturity mismatch. Second, a *run-to-CBDC* channel: when CBDC offers a return above outside alternatives, even patient depositors may withdraw in bad states, making runs on the bank more likely, which we define as the fragility of the financial system. Our contribution is to map how these forces interact under four regimes—bailout vs. no-bailout, each with and without CBDC—and to evaluate their consequences for fragility, illiquidity, taxes (used to finance the public good), and the overall welfare.

Our analysis yields three main sets of findings. First, on fragility and illiquidity, where we define financial fragility as the range of conditions under which runs on banks can occur, and illiquidity as the extent to which banks rely on short-term liabilities that leave them exposed when shocks arrive, we show that bailout policies encourage banks to offer generous early payouts, which in turn expand the range of conditions under which runs can occur as the probability of a bad state rises. Introducing a CBDC into a bailout regime reinforces this tendency: because depositors face both high first-period payouts and a safe outside option, fragility emerges at lower thresholds of early withdrawals. In contrast, when policymakers commit to no bailouts, CBDC essentially stabilizes the system. Substituting for part of the insurance role of banks allows intermediaries to decrease their short-term liabilities, thereby shrinking maturity mismatch. Although we find a narrow region at low crisis probabilities where the run-to-CBDC margin can generate fragility, across most of the parameter space, the combination of no bailouts and CBDC delivers the most stable outcome.

Turning to the tax rates imposed under the different regimes, the results are unambiguous. Bailout regimes require higher expected transfers and therefore higher tax rates, with the bailout–CBDC combination producing the most considerable fiscal burden and the no-bailout–no-CBDC regime the smallest. In the presence of CBDC, the tax differential between bailout and no-bailout regimes follows a kinked, nonlinear pattern as the economy crosses into run regions, while without CBDC, the gap increases more smoothly with the probability of a bad state. These differences have implications not only for fiscal policy but also for the allocation of resources between public and private consumption, providing a comprehensive understanding of the broader economic impact.

Finally, in terms of welfare, no-bailout policies dominate bailout policies within fragile equilibria. By limiting maturity mismatch, they preserve more resources for second-period consumption. The presence of CBDC magnifies this effect as crises become more likely. Still, when the probability of a crisis is low, the temptation to run into CBDC makes the welfare advantage of no bailouts smaller. As the likelihood of a bad state rises, however, the maturity-mismatch correction dominates and the welfare gap widens. Taken together, these results suggest that combining CBDC with a credible no-bailout commitment produces the strongest overall performance in terms of stability, fiscal outcomes, and welfare.

Our results show how the effects of CBDCs interact with the broader financial-stability framework. When the probability of a bad state (a sunspot-driven crisis) is nontrivial, pairing a retail CBDC with a *credible no-bailout commitment* is stabilizing: intermediaries rely less on short-term liabilities, maturity mismatch shrinks, and the set of parameters that admit runs narrows. By contrast, combining CBDC with bailouts expands fragility because large first-period payouts meet a safe outside option, pulling non-movers into early withdrawal. These differences have fiscal consequences. Bailout regimes require higher taxes to finance expected transfers, which diverts resources from private consumption and public-good provision, whereas no-bailout regimes—especially with CBDC—reduce the tax burden associated with crisis support. In short, the stability benefits of CBDC hinge on the surrounding policy regime: CBDC changes the trade-off, and the sign of that change depends on whether bailouts are part of the toolkit.

The broader lesson is forward-looking. As the use of digital money expands—through CBDCs, stablecoins, and faster-payment rails—policymakers face a world where safe, immediately accessible outside assets are increasingly pervasive. Our analysis suggests that credibility on no bailouts becomes more, not less, important in such an environment. A credible commitment disciplines intermediaries ex ante and limits the run margins that a widely available digital asset can activate ex post. In practice, this commitment can be complemented by CBDC design choices (for example, remuneration tiers or holding limits) that dampen run incentives at very low crisis probabilities without undoing the *insurance-substitution channel* that stabilizes the system when the likelihood of a bad state rises. The remainder of the paper lays out the model, characterizes fragility and tax patterns across regimes, and then turns to welfare and extensions, including how CBDC design and simple regulatory constraints interact with these mechanisms.

Introduction of CBDC also has implications for the competitive landscape faced by banks. A readily available public outside option tightens competition for retail funding, making deposit rates and payout promises more sensitive to policy and market conditions. This can improve discipline and reduce maturity mismatch, but it can also compress intermediation margins and shift risk toward asset–liability management if banks respond by searching for yield. The recent experience with rapid deposit outflows at regional institutions—facilitated by digital banking, social networks, and real-time transfers—illustrates how funding can reprice and reallocate quickly even without a CBDC. A retail CBDC would strengthen this channel unless design features and the broader policy regime (in particular, a credible no-bailout stance) temper the incentives to move early. Taken together, these considerations suggest that CBDC policy, bank competition, and crisis management should be analyzed jointly: design choices that preserve the insurance–substitution benefit while limiting run-to-CBDC behavior can enhance stability without unduly weakening the intermediation capacity of banks.

Related Literature: This paper builds on a growing literature that develops models to analyze how bailouts affect risk-taking incentives and financial stability (Allen et al., 2018; Calomiris, 1990; Chari and Kehoe, 2016; Gropp et al., 2014; Panageas, 2010).[3] Farhi and Tirole (2012) show that bailouts can generate incentives to align risks, increasing instability, and argue that preemptive regulation is needed to avoid bailouts in equilibrium. Bianchi (2016) provide a quantitative framework to measure how bailouts affect stability, finding that the expectation of bailouts raises ex-ante risk-taking, which in turn makes the system more fragile. Similarly, Keister (2016) shows that the overall effect of bailouts depends on the balance between the insurance they provide and the additional risk they encourage: in some cases bailouts can eliminate runs, while in others they can make crises more likely.[4]

Our framework adapts Keister (2016), introducing ex-ante bailouts but also adding a new investment option for depositors in the form of CBDC. This setup allows us to directly compare the interaction of CBDC and bailout policy, focusing on how the two together shape stability and incentives.

This paper is also connected to the growing theoretical work on CBDC and its impact on banking system fragility, efficiency, and broader macroeconomic outcomes.[5] Williamson (2022b) models an environment in which depositors cannot perfectly identify whether their own bank is distressed. In such cases, a CBDC may be more attractive

[3] See also Burnside et al. (2001), Diamond and Rajan (2012), Keister and Narasiman (2011), Pasten (2020), and Stavrakeva (2020), who study the link between bailouts and financial fragility.

[4] A related strand of the literature studies how limited government commitment to ex-post optimal policies shapes banks' ex-ante behavior, often amplifying fragility (Acharya and Yorulmazer, 2007; Bianchi and Mendoza, 2018; Holmström and Tirole, 1998; Nosal and Ordonez, 2016; Schneider and Tornell, 2004). Dávila and Walther (2020) show that bank size matters: optimal regulation imposes size-dependent restrictions on leverage, which disproportionately constrain larger banks.

[5] For recent contributions, see Brunnermeier and Niepelt (2019), Carapella and Flemming (2020), Williamson (2022a), Keister and Monnet (2022), Davoodalhosseini (2022), Chiu and Keister (2022), and Keister and Sanches (2023). A comprehensive review is provided in Infante et al. (2022).

than cash because it is more widely usable, but this advantage can make runs more likely. Keister and Monnet (2022) extend this framework to include bailouts, showing that CBDC can generate an "information effect": by accelerating the recognition of weak banks, CBDC can reduce run incentives. Our contribution differs in that we also consider the possibility of no bailouts in this setting, asking whether the incentives created by withholding bailouts can replicate or even improve upon the outcomes with CBDC.

Our work is also distinct from Kim and Kwon (2023), who adapt the framework of Champ et al. (1996) to study how CBDC affects fragility through banks' asset portfolios. We instead focus on the liabilities side, as in Keister and Monnet (2022), abstracting from monetary policy and concentrating on the role of government guarantees—or their absence—in shaping fragility. Finally, there is a related literature emphasizing the efficiency gains from CBDC (Allen et al., 2022; Chiu et al., 2023; Williamson, 2022a), as well as a parallel strand highlighting that CBDC may raise banks' risk-taking incentives and thus increase fragility (Agur et al., 2022; Auer et al., 2022; Keister and Sanches, 2023; Minesso et al., 2022).

The remainder of the paper proceeds as follows. Section 2 sets out the model. Section 3 analyzes equilibria under bailout regimes, both with and without a CBDC, while Section 4 examines the corresponding no-bailout cases. Section 5 then compares stability outcomes across all policy combinations. Section 6 studies how the optimal tax rate behaves, and Section 7 evaluates aggregate welfare under different regimes. Finally, Section 8 discusses the broader implications of our findings and Section 9 concludes.

2 Model

The model builds on Keister (2016), augmented to include a central bank digital currency (CBDC). This section describes the main elements of the model and defines financial fragility in this setting.

2.1 The environment

There are three periods, $t = 0, 1, 2$, and a continuum of investors, indexed by $i \in [0, 1]$, located in a continuum of regions indexed by $j \in [0, 1]$. The economy has one private consumption good and a public good, the latter of which is produced at $t = 1$. Each depositor is initially endowed with one unit of the private good and desires consumption only at $t = 2$. Preferences are given by

$$u(c_i^j) + v(g) = \frac{(c_i^j)^{1-\sigma}}{1-\sigma} + \delta \frac{g^{1-\sigma}}{1-\sigma},$$

where c_i^j denotes the private consumption of depositor i in location j and g is the level of the public good, which is common across locations. The parameter δ measures the relative weight of public consumption in preferences, and $\sigma > 1$ is the coefficient of relative risk aversion.

Banks allow each depositor to withdraw in either period $t \in \{1, 2\}$. Goods not withdrawn at $t = 1$ earn a gross return $R > 1$ between periods. A fraction π of depositors in each location learn that they will be relocated at the end of $t = 1$. Relocating depositors cannot contact their original bank after moving and therefore must withdraw at $t = 1$. They then earn an idiosyncratic return ρ_i on the goods they carry to the new location, distributed according to a continuous cumulative distribution function F on $[\underline{\rho}, \bar{\rho}]$ with $\bar{\rho} \leq R$. Non-relocating depositors earn a fixed return ρ_N on any goods withdrawn at $t = 1$.

Unlike the classic Diamond and Dybvig (1983) model, where impatient investors consume immediately at $t = 1$, here we follow Champ et al. (1996) and assume movers consume at $t = 2$. Once relocation shocks are realized, each depositor must decide whether to withdraw in period 1 or leave funds until period 2. Withdrawals at $t = 1$ take place in sequence: depositors arrive at the bank according to their index i and are served in that order, as in Wallace (1988). For instance, the depositor with $i = 0$ knows she will be the very first in line, while the depositor with $i = 1$ knows he will be last. Each depositor's position in line is private information, but whether or not they choose to withdraw is publicly observed. At $t = 2$, whatever resources remain are divided among those who chose to wait. Figure 1 shows the balance sheet of a bank in our model.

2.2 Financial crises

Investors coordinate their actions on an extrinsic "sunspot" signal. Let $S = \{\alpha, \beta\}$ denote the possible states, occurring with probabilities $\{1-q, q\}$ respectively. Investor i chooses a strategy that assigns an action depending on her type (mover or non-mover) and the state:

$$\omega_i \in \{mo, nm\}, \quad y_i : \omega_i \times S \to \{0, 1\},$$

where $y_i = 0$ means withdrawing early and $y_i = 1$ means waiting until $t = 2$.

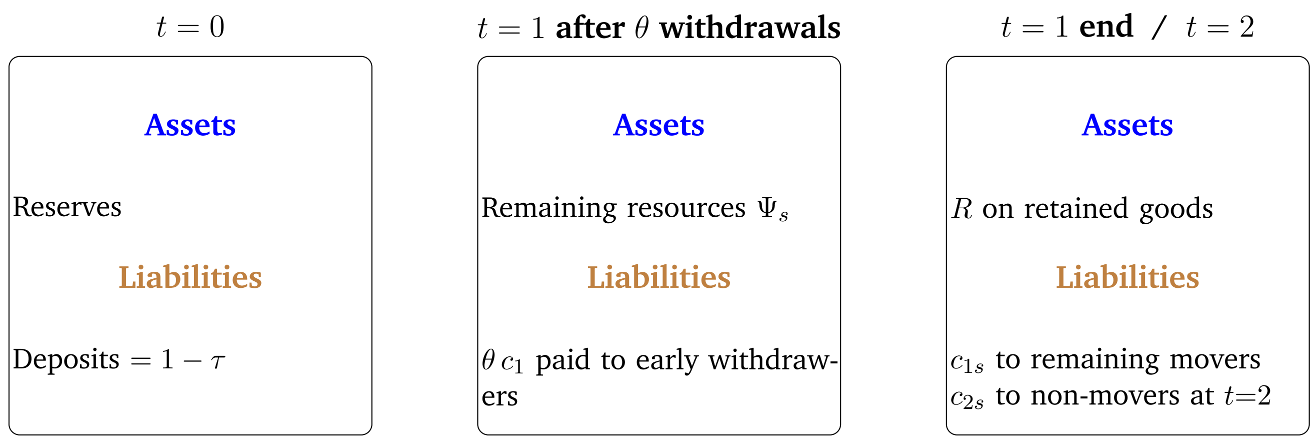

Figure 1: Bank's balance sheet before the introduction of CBDC

2.3 Timeline

The sequence of decisions is illustrated in Figure 2. At $t = 0$, investors deposit their endowments with intermediaries, and the policymaker collects a fraction τ of total deposits as taxes. At $t = 1$, investors observe their type ω_i and the sunspot state s, and decide whether to withdraw. Those who withdraw arrive sequentially, in order of index i. The state s is realized at the start of $t = 1$, but intermediaries and policymakers observe it with a lag—only after a fraction $\theta \in (0, \pi]$ of investors have withdrawn. If $s = \beta$ and a crisis is underway, policymakers may choose to provide a bailout. By the end of $t = 1$, all early withdrawals have been served, and the remaining resources are used to finance the public good. At $t = 2$, the remaining depositors withdraw from their intermediaries.

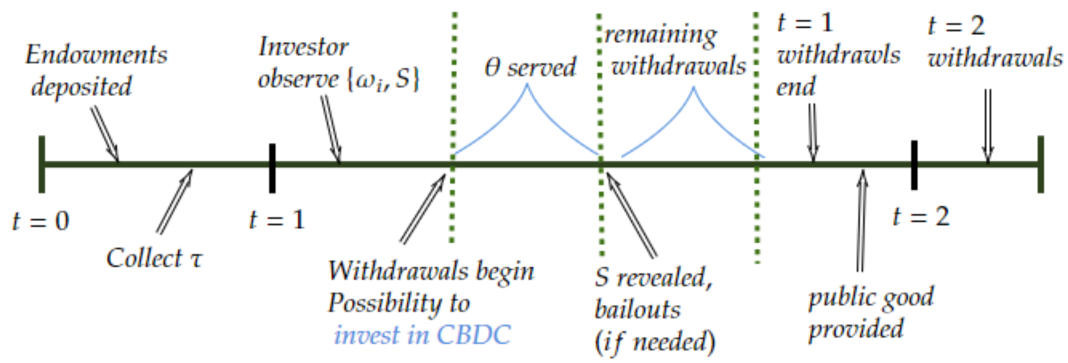

Figure 2: Timeline.

3 Equilibrium with Bailouts.

We begin by examining equilibrium outcomes when the policymaker faces no restrictions on providing bailout payments. Specifically, we study the conditions under which the financial system becomes more fragile—both with and without a CBDC—under such a bailout regime. We then derive the equilibrium allocation of resources for each case. In the following section, we contrast this with the situation where the policymaker can credibly commit to a no-bailout policy, and analyze how fragility depends on the presence of a CBDC in that setting.

3.1 Case 1: No CBDC.

We first consider the equilibrium without a central bank digital currency. The analysis proceeds by backward induction. Initially, the policymaker selects a tax rate in period 0. Anticipating the possibility of bailouts, intermediaries adjust their behavior as the first fraction θ of investors withdraw. If a crisis emerges once the state is revealed, the policymaker chooses bailout transfers. Finally, given the state and any bailouts received, intermediaries decide how to allocate their remaining resources across movers and non-movers. To keep the analysis tractable, we assume that the idiosyncratic return follows a uniform distribution, $\rho_i \sim U(\underline{\rho}, \bar{\rho})$.

3.1.1 *The allocation of remaining private consumption*

First, consider the last decision (d) for intermediary j to consider how much to give to each remaining movers in period 1, c_{1s}^j, and a common amount c_{2s}^j to each of the remaining non-movers in period 2. Notice that the intermediary could take this decision only after knowing that a fraction θ of the investors have already withdrawn, the state s have been revealed, and if any bailout payment has been made. Based on this information, the intermediary considers the payments out of the remaining resources Ψ_s^j. If we let $\hat{\pi}_s$ be the fraction of remaining investors who are movers and will withdraw in period 1, which is either,

$$\hat{\pi}_\alpha \equiv \frac{\pi - \theta}{1 - \theta} \qquad \text{or} \qquad \hat{\pi}_\beta \equiv \pi.$$

The payment will be chosen to solve,

$$V(\Psi_s^j; \hat{\pi}_s) = \max_{\{c_{1s}^j, c_{2s}^j\}} \; (1-\theta)\left[\hat{\pi}_s \int_{\underline{\rho}}^{\bar{\rho}} u\left(\rho_i c_{1s}^j\right)\, F(\rho_i) + (1-\hat{\pi}_s) u\left(c_{2s}^j\right)\right], \tag{1}$$

subject to the feasibility constraint,

$$(1-\theta)\left[\hat{\pi}_s c_{1s}^j + (1-\hat{\pi}_s)\frac{c_{2s}^j}{R}\right] = \Psi_s^j. \tag{2}$$

Let μ_s^j denote the multiplier on the constraint, the optimal solution to the above problem is characterized by,

$$\frac{(\bar{\rho}-\underline{\rho})^{1-\sigma}}{2-\sigma}u'(c^j_{1s}) = Ru'(c^j_{2s}) = \mu^j_s. \tag{3}$$

It is easy to show that $\frac{\partial c^j_{is}}{\partial \hat{\pi}_s} < 0 \;\forall\; i \in \{1,2\}$ if $R > (2-\sigma)^{\frac{1}{\sigma-1}}(\bar{\rho}-\underline{\rho})$ which is true given our assumption that $\sigma > 1$.[6] This condition implies that as the fraction of remaining investors who are movers rises, fewer resources are left invested to realize the return R. As a result, the allocations to both movers and non-movers must fall.

3.1.2 *Bailout Policy*

We now turn to stage (c), where the policymaker decides on the size of the bailout when the state of the economy is $S = \beta$. In this state, the sunspot shock triggers a run, and some of the early withdrawals by the first θ investors include non-movers. As a result, a larger fraction of the remaining investors, $\hat{\pi}_\beta$, are movers. These additional early withdrawals reduce the available resources, leading to lower values of $\{c^j_{1s}, c^j_{2s}\}$.

To offset this decline, the policymaker can transfer bailout funds to intermediaries facing distress. Suppose a payment b^j is made to intermediary j. Total bailout spending is financed from the tax revenue collected at $t = 0$. Let $\Theta(j)$ denote the distribution of investors across intermediaries; then aggregate bailout payments satisfy

$$b \equiv \int b^j d\Theta(j)$$

Bailout payments are chosen to maximize

$$\max_{\{b^j\}} \int V(\Psi^j_\beta; \hat{\pi}_\beta) d\Theta(j) + v(\tau - b)$$

subject to the resource constraint

$$\Psi^j_\beta = 1 - \tau - \theta c^j_1 + b^j \;\; \forall j$$

FOC of the problem will give us

$$v'(\tau - b) = \mu^j_\beta \;\; \forall j \tag{4}$$

[6] Suppose, by contradiction $R < (2-\sigma)^{\frac{1}{\sigma-1}}(\bar{\rho}-\underline{\rho})$. Because $\bar{\rho} \leq R$, this implies $R < (2-\sigma)^{\frac{1}{\sigma-1}}(R-\underline{\rho})$; $\underline{\rho}(2-\sigma)^{\frac{1}{\sigma-1}} < R((2-\sigma)^{\frac{1}{\sigma-1}} - 1)$. This inequality will never hold because $((2-\sigma)^{\frac{1}{\sigma-1}} - 1) < 0$ as $\sigma > 1$.

For a given size of bailout package b per investor, this will mean that

$$b^j = b + \theta[c_1^j - \bar{c}_1] \tag{5}$$

with $\bar{c}_1$ being the economy wide average payment c_1^j to those investors already withdrawn. The remainder of the resources under this state will be

$$\Psi_\beta^j = 1 - \tau - \theta\bar{c}_1 + b \tag{6}$$

3.1.3 *Choosing consumption before observing the state*

Moving backward to decision (b), to ascertain the amount of consumption chosen by the intermediary to give to each of the θ fraction of investors before observing the state. Intermediary j will choose c_1^j to maximize

$$\max_{\{c_1^j\}} \ \theta \left[\int_{\underline{\rho}}^{\bar{\rho}} u\left(\rho_i c_1^j\right)\ F(\rho_i) \right] + (1-q)V(\Psi_\alpha^j; \hat{\pi}_\alpha) + qV(\Psi_\beta^j; \hat{\pi}_\beta)$$

s.t.

$$\Psi_\alpha^j = 1 - \tau - \theta c_1^j,$$

$$\Psi_\beta^j = 1 - \tau - \theta\bar{c}_1 + b.$$

The first order condition for this problem is,

$$\frac{(\bar{\rho} - \underline{\rho})^{1-\sigma}}{2-\sigma}(c_1^j)^{-\sigma} = (1-q)\mu_\alpha^j, \tag{7}$$

The intermediary chooses c_1^j to equate the marginal value of resources before the state is known to the expected shadow value of resources in the no-run state, ignoring the value of resources in the event of a run. This condition represents incentive distortions. This condition is optimal because the resources available to the intermediary in the run state will be independent of its own choice of c_1^j.

3.1.4 *Tax Rate*

Finally, we need to find the optimal tax rate τ in decision (a) that the policy maker will choose to maximize ex-ante welfare, which is given by,

$$\theta \left[\int_{\underline{\rho}}^{\bar{\rho}} u\left(\rho_i c_1(\tau)\right)\ F(\rho_i) \right] + (1-q)[V(\Psi_\alpha^j; \hat{\pi}_\alpha) + v(g_\alpha)] + q[V(\Psi_\beta^j; \hat{\pi}_\beta) + v(g_\beta)] \tag{8}$$

subject to resource constraints,

$$\Psi_\alpha = 1 - \tau - \theta c_1(\tau) \tag{9}$$

$$\Psi_\beta = 1 - \tau - \theta c_1(\tau) + b(\tau) \tag{10}$$

and the government budget constraints,

$$g_\alpha = \tau \tag{11}$$

$$g_\beta = \tau - b(\tau) \tag{12}$$

where we have omitted the j superscript of the intermediaries since all of them face the same problem.

Taking the FOC with respect to τ will give us,

$$\theta \frac{(\bar{\rho} - \underline{\rho})^{1-\sigma}(c_1)^{-\sigma}}{(2-\sigma)} \frac{\partial c_1}{\partial \tau} + (1-q)V'(\Psi^j_\alpha; \hat{\pi}_\alpha)\Big(- 1 - \theta \frac{\partial c_1}{\partial \tau}\Big) + (1-q)v'(\tau)$$
$$+ qv'(\tau - b(\tau))(1 - b'(\tau)) + qV'(\Psi^j_\beta; \hat{\pi}_\beta)\Big(- 1 - \theta \frac{\partial c_1}{\partial \tau} + b'(\tau)\Big) = 0$$

$$\implies \theta \left(\frac{(\bar{\rho} - \underline{\rho})^{1-\sigma}(c_1)^{-\sigma}}{(2-\sigma)} - (1-q)\mu_\alpha - q\mu_\beta \right) \frac{\partial c_1}{\partial \tau} = (1-q)[\mu_\alpha - v'(\tau)] + q[\mu_\beta - v'(\tau - b(\tau))]b'(\tau) \tag{13}$$

Combining (4) and (7) we get,

$$v'(\tau) = \mu_\alpha + \frac{q}{1-q}\mu_\beta \theta \frac{dc_1}{d\tau}. \tag{14}$$

If q, the probability of crisis is zero, the tax rate is set to be equal to the marginal value of the public good in state α. When q is positive, the policymaker recognizes that τ affects intermediaries' choice of c_1 and hence can be used to correct the distortions created by bailout policy.

3.2 Case2: With CBDC.

3.2.1 Introducing CBDC.

We now introduce a central bank that issues a digital currency (CBDC), which provides depositors with an alternative means of transferring funds from $t = 1$ to $t = 2$. The central bank operates in all locations of the model. Following Keister and Monnet (2022), we assume the CBDC accepts deposits in period $t = 1$ and pays a return $\rho^C \in [\underline{\rho}, \bar{\rho}]$

at $t = 2$. Importantly, depositors can access their CBDC balances from any location at $t = 2$. This feature makes CBDC particularly valuable for movers, since it does not require them to transport goods across locations. In equilibrium, the central bank itself does not need to transport goods: withdrawals by movers arriving in a location can be covered by deposits of movers who exited from that same location.

Whether a mover finds CBDC attractive depends on how her individual return ρ_i compares to the CBDC return ρ^C. We interpret these returns as capturing how well different payment methods serve an investor's needs. Movers with relatively high ρ_i benefit sufficiently from carrying goods themselves and have little incentive to use CBDC, whereas those with low ρ_i will prefer the convenience of depositing into CBDC. Non-movers also have the option to use CBDC, though their incentives differ. In normal times, a patient depositor strictly prefers to leave funds with the intermediary until $t = 2$, since the return R exceeds ρ^C. If the bad state occurs and she decides to withdraw early, her choice between CBDC and holding cash depends on whether the outside option ρ^N is lower or higher than ρ^C. For tractability, we assume $\rho^N = 1$. Figure 3 shows the decision tree of an investor after the introduction of CBDC.

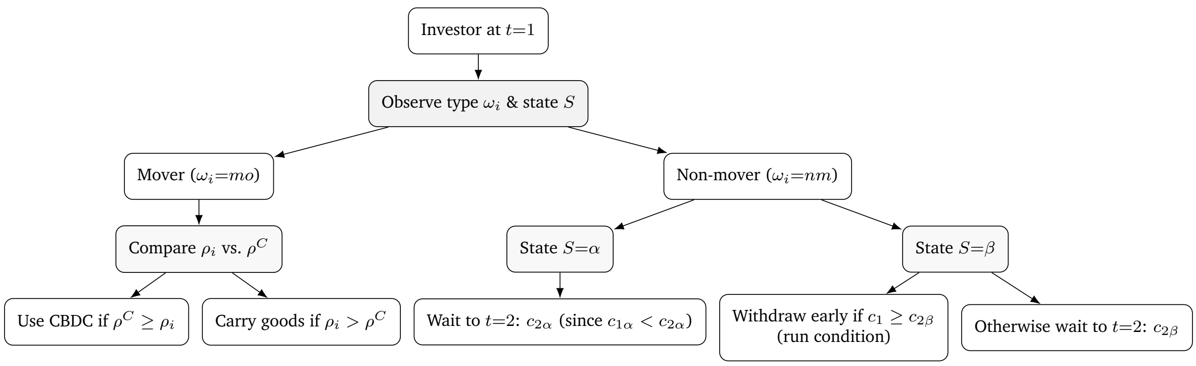

Figure 3: Decision tree for Investor choices at t=1.

Because relocation status is private information, the central bank cannot initially distinguish whether deposits into CBDC come solely from movers or from a mix of movers and non-movers. Our aim is to assess whether introducing a CBDC alongside a bailout policy reduces fragility in the financial system, as discussed in Allen et al. (2022); Fernández-Villaverde et al. (2021). Figure 4 represents the balance sheet of the bank after the introduction of CBDC.

Introducing a CBDC affects behavior through two broad channels. First, an *insurance substitution* effect: because some depositors can earn the CBDC return ρ^C after withdrawing at $t = 1$, the banking system needs to provide less liquidity insurance. In terms of allocations, this tilts the constrained–efficient outcome toward smaller early

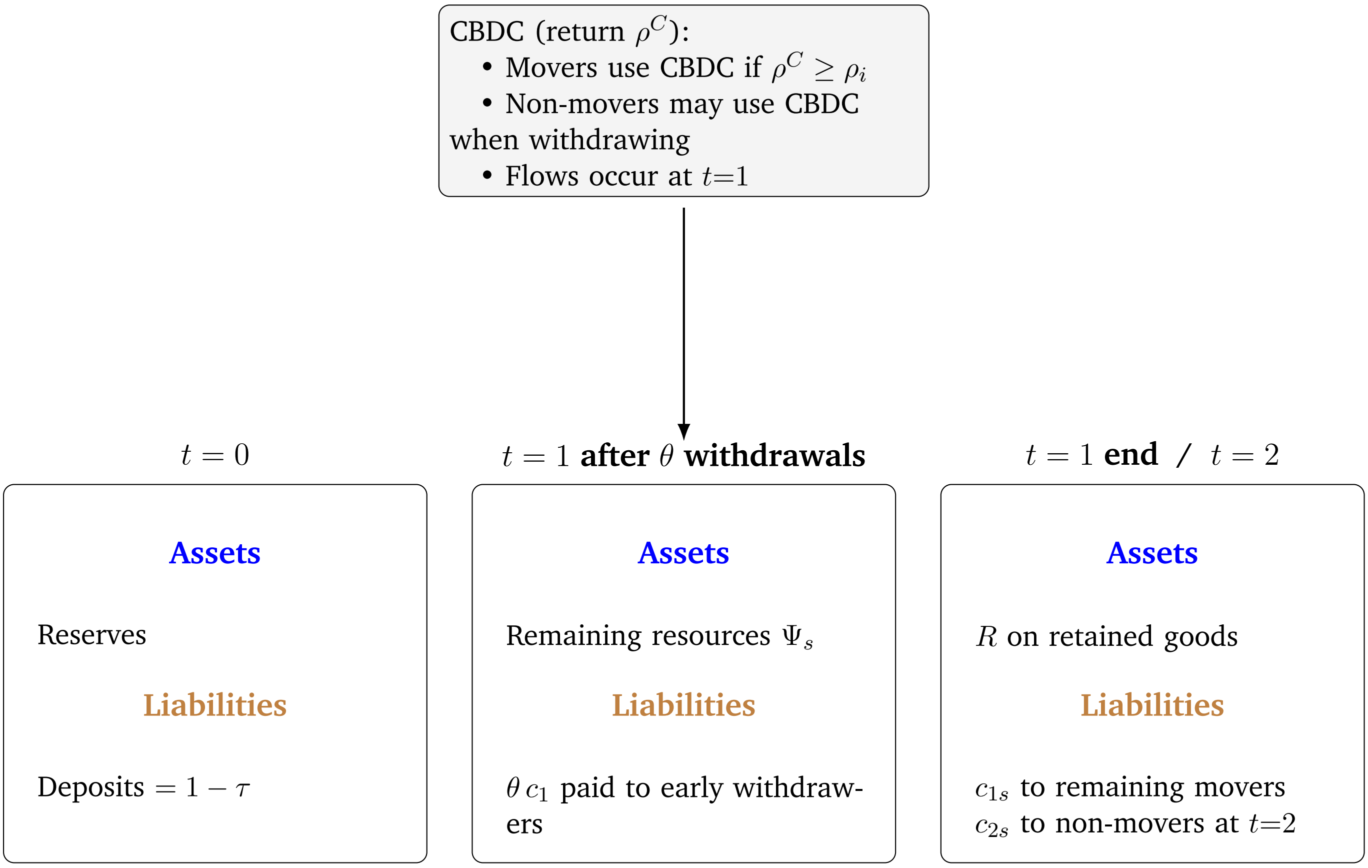

Figure 4: Bank's balance sheet after CBDC.

payouts to movers and larger late payouts to non-movers (recall the standard Diamond and Dybvig (1983) logic with $c_1^* > 1$). Second, a *run-to-CBDC* effect: if $\rho^C > \rho^N$, non-movers have a stronger incentive to withdraw in the bad state and place funds into CBDC, making runs more likely—especially under bailout regimes. With these mechanisms in place, we next study equilibrium under bailouts with CBDC and solve jointly for the intermediaries' policies and the government's choice of taxes and transfers.

3.2.2 *The allocation of remaining private consumption*

Similar to the previous case, we solve the game backwards, starting with decision (d) in the Figure 2, with intermediary choosing the consumption allocation contingent on the state of the economy. The intermediary will choose the payments to maximize its value,

$$V(\Psi_s^j; \hat{\pi}_s) = \max_{\{c_{1s}^j, c_{2s}^j\}} (1-\theta) \left[\hat{\pi}_s \left[\int_{\underline{\rho}}^{\rho^C} u\left(\rho_i c_{1s}^j\right) + \int_{\rho^C}^{\bar{\rho}} u\left(\rho_i c_{1s}^j\right) \right] F(\rho_i) + (1-\hat{\pi}_s) u\left(c_{2s}^j\right) \right], \tag{15}$$

where the distribution function is

$$F(\rho_i;\rho^C) \equiv \begin{cases} 0 & \text{for } \rho_i < \underline{\rho} \\ F(\rho_i) & \text{for } \rho_i \geq \bar{\rho} \end{cases}$$

to incorporate the return from CBDC, and subject to feasibility constraint,

$$(1-\theta)\left[\hat{\pi}_s c_{1s}^j + (1-\hat{\pi}_s)\frac{c_{2s}^j}{R}\right] = \Psi_s^j.$$

The first term in the bracket of the value function reflects that movers with idiosyncratic returns $\rho_i < \rho^c$ place their funds in the CBDC and earn the fixed return ρ^c, while those with $\rho_i \geq \rho^c$ continue to earn their own idiosyncratic return. The remaining non-movers simply receive their respective payoffs. The Lagrangian for this problem is

$$\begin{aligned}\mathcal{L} = (1-\theta)\Bigg(\frac{\hat{\pi}_s (c_{1s}^j)^{1-\sigma}}{1-\sigma}\Bigg(\frac{(\rho^C-\underline{\rho})(\rho^C)^{1-\sigma}}{\bar{\rho}-\underline{\rho}} + \frac{(\bar{\rho}-\rho^C)^{2-\sigma}}{(2-\sigma)(\bar{\rho}-\underline{\rho})}\Bigg) + \frac{(1-\pi_s)(c_{2s}^j)^{1-\sigma}}{(1-\sigma)}\Bigg) \\ + \mu_s^j\left(\Psi_s^j - (1-\theta)\left(\hat{\pi}_s c_{1s}^j + (1-\hat{\pi}_s)\frac{c_{2s}^j}{R}\right)\right),\end{aligned}$$

that gives the following first-order condition,

$$(c_{1s}^j)^{-\sigma} A = R(c_{2s}^j)^{-\sigma} = \mu_s^j, \tag{16}$$

where,

$$A = \left(\frac{(\rho^C-\underline{\rho})(\rho^C)^{1-\sigma}}{\bar{\rho}-\underline{\rho}} + \frac{(\bar{\rho}-\rho^C)^{2-\sigma}}{(2-\sigma)(\bar{\rho}-\underline{\rho})}\right).$$

Like in the case under no CBDC but with a bailout mechanism, the intermediaries will equate the marginal utility of consumption in both the periods to the shadow price of consumption. Further, it can be shown that $\frac{\partial c_{is}^j}{\partial \hat{\pi}_s} < 0 \ \forall\ i \in \{1,2\}$ implying that the consumption allocated to depositors declines as the fraction of movers left to be served increases once the intermediary learns the state of the economy. Notice how the marginal utility in period 1 is augmented by the returns,A, from both the idiosyncratic returns earned by withdrawing as well as from investment in a CBDC. The optimal solution to the problem is characterized by,

$$c_{2s}^j = \frac{\Psi_s^j}{(1-\theta)\left(\pi^s\left(\frac{A}{R}\right)^{\frac{1}{\sigma}} + \frac{(1-\pi^s)}{R}\right)},$$

$$c_{1s}^j = \left(\frac{A}{R}\right)^{\frac{1}{\sigma}} \frac{\Psi_s^j}{(1-\theta)\left(\pi^s\left(\frac{A}{R}\right)^{\frac{1}{\sigma}} + \frac{(1-\pi^s)}{R}\right)}.$$

we can see $(c_{2s}^j)'(\rho^C) > 0$ and $(c_{1s}^j)'(\rho^C) < 0$ as $\frac{dA}{d\rho^C} < 0$[7], which is similar to as mentioned in Keister and Monnet (2022). This implies that when CBDC is introduced, the constrained efficient allocation gives a smaller payment to movers $\left(c_{1s}^j(\rho^C)\right)$ and a larger payment to non-movers $\left(c_{2s}^j(\rho^C)\right)$. In other words, CBDC reduces the need for banks to issue short-term liabilities and, equivalently, lessens the extent of maturity transformation in the system.

3.2.3 *Bailout Policy*

The conditions for the optimal bailout package are qualitatively similar to those in the no-CBDC case. However, both the value of remaining resources and the size of the bailout package now depend on the return offered by the CBDC. If the CBDC return is sufficiently high such that $\rho^c > \rho^N$, movers have an additional incentive to withdraw early when the state is β. This behavior reduces the resources available for the remaining investors and therefore necessitates a larger bailout package to restore stability.

3.2.4 *Choosing consumption before observing the state.*

Moving backward to decision (b), to ascertain the amount of consumption chosen by the intermediary to give to each of the θ fraction of investors before observing the state.

[7]We know, $A = \left(\frac{(\rho^C - \underline{\rho})(\rho^C)^{1-\sigma}}{\bar{\rho}-\underline{\rho}} + \frac{(\bar{\rho}-\rho^C)^{2-\sigma}}{(2-\sigma)(\bar{\rho}-\underline{\rho})}\right)$,

$$\frac{dA}{d\rho^C} = \frac{(\rho^C)^{1-\sigma}}{\bar{\rho}-\underline{\rho}}\left[1 + (1-\sigma)\left(\frac{\rho^C - \underline{\rho}}{\rho^C}\right) - \left(\frac{\bar{\rho}-\rho^C}{\rho^C}\right)^{1-\sigma}\right]$$

The term in the braces is negative as we can see,

$$1 < (\sigma - 1)\left(\frac{\rho^C - \underline{\rho}}{\rho^C}\right) + \left(\frac{\bar{\rho}-\rho^C}{\rho^C}\right)^{1-\sigma};$$

Using, $R > \frac{(\bar{\rho}-\underline{\rho})^{1-\sigma}}{2-\sigma}$,

$$\frac{1}{R} < \left(\frac{\bar{\rho}-\rho^C}{\rho^C}\right)^{1-\sigma},$$

$$\left(\frac{1}{R}\right)^{\frac{1}{\sigma-1}} < \frac{\rho^C}{\bar{\rho}-\rho^C},$$

$$1 < \frac{\bar{\rho}}{\rho^C} < \left(\frac{1+\left(\frac{1}{R}\right)^{\frac{1}{\sigma-1}}}{\left(\frac{1}{R}\right)^{\frac{1}{\sigma-1}}}\right).$$

This is true; $\frac{dA}{d\rho^C} < 0$.

Intermediary j will choose c_1^j to maximize

$$\max_{\{c_1^j\}} \quad \theta \left[\left[\int_{\underline{\rho}}^{\rho^C} u\left(\rho_i c_1^j\right) + \int_{\rho^C}^{\bar{\rho}} u\left(\rho_i c_1^j\right) \right] F(\rho_i) \right] + (1-q)V(\Psi_\alpha^j; \hat{\pi}_\alpha) + qV(\Psi_\beta^j; \hat{\pi}_\beta)$$

subject to

$$\Psi_\alpha^j = 1 - \tau - \theta c_1^j$$

$$\Psi_\beta^j = 1 - \tau - \theta \bar{c}_1 + b$$

$$L = \left[\frac{\theta (c_1^j)^{1-\sigma}}{1-\sigma} \left(\frac{(\rho^C - \underline{\rho})(\rho^C)^{1-\sigma}}{\bar{\rho} - \underline{\rho}} + \frac{(\bar{\rho} - \rho^C)^{2-\sigma}}{(2-\sigma)(\bar{\rho} - \underline{\rho})} \right) \right] + (1-q)V(\Psi_\alpha^j; \hat{\pi}_\alpha) + qV(\Psi_\beta^j; \hat{\pi}_\beta)$$

The FOC of the problem is given by,

$$\frac{dL}{dc_1^j} = (c_1^j)^{-\sigma} A = (1-q)\mu_\alpha^j, \tag{17}$$

$$(c_1^j)^{-\sigma} = (1-q)(c_{1\alpha}^j)^{-\sigma}.$$

3.2.5 *Tax Rate*

Finally, we need to find the optimal tax rate τ, decision (a). The condition for the optimal tax rate remains the same as no CBDC case, that is,

$$v'(\tau) = \mu_\alpha + \frac{q}{1-q} \mu_\beta \theta \frac{dc_1}{d\tau}.$$

3.3 Equilibrium Characterization

The analysis above implies that, under a bailout regime, the best responses of intermediaries and the policymaker can be summarized by the allocation vectors

$$\mathbf{c}^{BN} \equiv \left\{ c_1^{BN}, \, \{ c_{1s}^{BN}, \, c_{2s}^{BN}, \, g_s^{BN} \}_{s \in \{\alpha, \beta\}} \right\}, \qquad \mathbf{c}^{BC} \equiv \left\{ c_1^{BC}, \, \{ c_{1s}^{BC}, \, c_{2s}^{BC}, \, g_s^{BC} \}_{s \in \{\alpha, \beta\}} \right\},$$

where BN denotes bailouts without CBDC and BC denotes bailouts with CBDC. Here c_1^m is the early payment promised to the first θ investors before the state is observed, while c_{1s}^m and c_{2s}^m are the post–state allocations to the remaining movers and non-movers, respectively, for $s \in \{\alpha, \beta\}$.

In equilibrium, the strategy profile we focus on has movers withdrawing at $t = 1$ in both states, non-movers waiting until $t = 2$ in the good state α, and (when a run occurs) non-movers with indices $i \leq \theta$ joining the first-period queue in the bad state β. This is one admissible run equilibrium consistent with our fragility notion.

To verify that non-movers wait in state α, we require $c^m_{1\alpha} < c^m_{2\alpha}$. From the first-order conditions in (3) and the period–0 choice condition (denoted (7)) in the no-CBDC case, we obtain

$$\frac{u'(c_1^{BN})}{u'(c_{2\alpha}^{BN})} = \frac{(1-q)R(2-\sigma)}{(\bar{\rho}-\underline{\rho})^{1-\sigma}},$$

so $c_1^{BN} < c_{2\alpha}^{BN}$ whenever

$$q \ < \ \frac{R - \dfrac{(\bar{\rho}-\underline{\rho})^{1-\sigma}}{2-\sigma}}{R}.$$

Similarly, combining the CBDC first-order condition (16) with its period–0 counterpart (17) gives

$$\frac{u'(c_1^{BC})}{u'(c_{2\alpha}^{BC})} = \frac{(1-q)R}{A},$$

so $c_1^{BC} < c_{2\alpha}^{BC}$ whenever

$$q \ < \ \frac{R-A}{R}.$$

Because $u'(\cdot)$ is strictly decreasing, a ratio greater than one implies the early payment is lower than the late payment, hence non-movers prefer to wait in state α.[8]

The remaining incentive to check is for non-movers in the bad state β. A run equilibrium (fragility) under regime $m \in \{BN, BC\}$ requires that non-movers with $i \leq \theta$ prefer to join the queue at $t = 1$. Using our earlier fragility definition, this is equivalent to

$$c_1^{BN} \ \geq \ c_{2\beta}^{BN} \quad \text{and} \quad c_1^{BC} \ \geq \ c_{2\beta}^{BC}.$$

Hence, the non-movers will exert a run on the system under bailouts without CBDC iff $c_1^{BN} \geq c_{2\beta}^{BN}$, and under bailouts with CBDC iff $c_1^{BC} \geq c_{2\beta}^{BC}$. In the next sections, we analyze the corresponding equilibria when the policymaker can commit to *no* bailouts.

4 Equilibrium with No bailouts.

In this section, we consider the case in which the government commits not to provide bailouts to intermediaries in the event of a run, that is, $b^j = 0 \ \ \forall j$ in all states of nature. A no-bailout policy has been shown to improve incentives and act as a regulatory device against distortions (Acharya and Mora, 2015; Allen et al., 2018; Calomiris, 1990; Demirgüç-Kunt and Detragiache, 1998; Gropp et al., 2014). As in the bailout case, we

[8] For the no-CBDC case, combining (3) and (7) yields $\dfrac{(\bar{\rho}-\underline{\rho})^{1-\sigma}}{2-\sigma} u'(c_1) = (1-q)R\, u'(c_{2\alpha})$. Thus $\dfrac{u'(c_1)}{u'(c_{2\alpha})} = \dfrac{(1-q)R(2-\sigma)}{(\bar{\rho}-\underline{\rho})^{1-\sigma}}$, which exceeds one iff $q < (R - \dfrac{(\bar{\rho}-\underline{\rho})^{1-\sigma}}{2-\sigma})/R$. The CBDC case is analogous using A in place of $\dfrac{(\bar{\rho}-\underline{\rho})^{1-\sigma}}{2-\sigma}$.

derive the best responses of intermediaries and the policymaker to the possibility of a run following the realization of the state of the economy, both with and without a CBDC.

4.1 Case 1: No CBDC.

Decision (d) is unchanged; intermediaries will still allocate their remaining resources according to equation (1). Decision (c) is now trivial, since $b^j = 0$, The analysis for this case begins, therefore, with decision (b) in which intermediary choose the amount of consumption c_1^j that will be allocated to the depositors by the intermediaries before observing the state.

4.1.1 *Choosing consumption before observing the state.*

As in the previous case without CBDC, intermediary j chooses c_1^j to solve

$$\max_{\{c_1^j\}} \theta \left[\int_{\underline{\rho}}^{\bar{\rho}} u\big(\rho_i c_1^j\big) \; F(\rho_i) + (1-q)V(\Psi_\alpha^j; \hat{\pi}_\alpha) + qV(\Psi_\beta^j; \hat{\pi}_\beta) \right]$$

subject to the resource constraints

$$\Psi_\alpha^j = \Psi_\beta^j = 1 - \tau - \theta c_1^j,$$

Since no bailout scheme is available, and the same resource constraint applies under both states.

The corresponding first-order condition is

$$\frac{(\bar{\rho} - \underline{\rho})^{1-\sigma}(c_1^j)^{-\sigma}}{2-\sigma} = (1-q)\mu_\alpha + q\mu_\beta, \tag{18}$$

which highlights the change in incentives relative to the bailout case. Now the intermediary equates the marginal value of resources before the state is observed with the expected marginal value across both states, explicitly weighting the probabilities of α and β. This feature illustrates one potential advantage of a no-bailout policy: intermediaries internalize both possible outcomes when setting c_1^j.

At the final stage (a), the policymaker chooses the tax rate τ to maximize equation (8), subject to the resource constraint $b(\tau) = 0$. This yields the allocation

$$g_\alpha = g_\beta = \tau,$$

with first-order condition

$$v'(\tau) = (1-q)\mu_\alpha + q\mu_\beta. \tag{19}$$

Hence, the tax rate is pinned down as a constant fraction of period-1 consumption chosen before the state is realized. Because all tax revenues are used to finance the public good in both states, the government equates the marginal value of taxes to the expected marginal value of consumption. We now turn to the economy with a CBDC introduced under a no-bailout commitment.

4.2 Case 2: With CBDC.

Decision (d) is unchanged; intermediaries will still allocate their remaining resources according to equation (1). Decision (c) is now trivial, since $b^j = 0$, The analysis for this case begins, therefore, with decision (b) in which intermediary choose the amount of consumption c_1^j that will be allocated to the depositors by the intermediaries before observing the state.

4.2.1 Choosing Consumption before the State

Like in previous case with CBDC, intermediary j will choose c_1^j to solve,

$$\max_{\{c_1^j\}} \ \theta \left[\left[\int_{\underline{\rho}}^{\rho^C} u\left(\rho_i c_1^j\right) + \int_{\rho^C}^{\bar{\rho}} u\left(\rho_i c_1^j\right) \right] F(\rho_i) \right] + (1-q)V(\Psi_\alpha^j; \hat{\pi}_\alpha) + qV(\Psi_\beta^j; \hat{\pi}_\beta)$$

subject to

$$\Psi_\alpha^j = 1 - \tau - \theta c_1^j$$

$$\Psi_\beta^j = 1 - \tau - \theta c_1^j$$

Note that in the absence of a bailout policy, the resources available to the intermediaries are the same in both states of the world. Forming the Lagrangian as

$$\mathcal{L} = \left[\frac{\theta (c_1^j)^{1-\sigma}}{1-\sigma} \left(\frac{(\rho^C - \underline{\rho})(\rho^C)^{1-\sigma}}{\bar{\rho} - \underline{\rho}} + \frac{(\bar{\rho} - \rho^C)^{2-\sigma}}{(2-\sigma)(\bar{\rho} - \underline{\rho})} \right) + (1-q)V(1-\tau-\theta c_1^j; \hat{\pi}_\alpha) \right. \\ \left. + qV(1-\tau-\theta c_1^j; \hat{\pi}_\beta) \right.$$

FOC with respect to c_1^j will give us

$$Au'(c_1^j) = (1-q)\mu_\alpha + q\mu_\beta \tag{20}$$

In the last decision (a), the policymaker will choose the tax rate τ and the equation is equivalent to previous case with no CBDC, that is,

$$v'(\tau) = (1-q)\mu_\alpha + q\mu_\alpha$$

The above analysis establishes that the best responses of intermediaries and the policy maker under the no-bailout regime with and without CBDC can be summarized by a vector

$$c^{NN} \equiv \{c_1^{NN}, \{c_{1s}^{NN}, c_{2s}^{NN}, g_s^{NN}\}_{s=\alpha,\beta}\},$$

where NN represents the case with No Bailout and No CBDC.

$$c^{NC} \equiv \{c_1^{NC}, \{c_{1s}^{NC}, c_{2s}^{NC}, g_s^{NC}\}_{s=\alpha,\beta}\},$$

where NC represents the case with No Bailout and CBDC. As in the previous section, comparing two elements of the vector yields a necessary and sufficient condition for the existence of any equilibrium in which some investors choose to run in state β. We will make use of this definition to talk about how fragile the economic system is under each policy regime.

5 Fragility

5.1 Comparing the Degree of Illiquidity

A key part of the analysis is to compare the effects of different policy combinations on how intermediaries behave when faced with the initial fraction of investors who withdraw their deposits. This behavior, in turn, determines whether or not a run will occur. To capture this, following Keister (2016), we define the degree of illiquidity in the financial system as

$$\varrho^m = \frac{\theta c_1^m}{1-\tau^m} \quad \text{for } m \in \{NN, NC, BC, BN\}, \tag{21}$$

where NN, NC, BC, BN represent, respectively, the cases of no-bailout policy with no CBDC, no-bailout policy with a CBDC, bailout policy with a CBDC, and bailout policy with no CBDC.

Intuitively, the numerator captures the size of short-term liabilities: a fraction θ of investors withdraw an amount c_1 before intermediaries or regulators can react to a crisis. The denominator reflects the value of assets still held by intermediaries at the end of the first period. Taken together, ϱ^m gives us a measure of illiquidity, and hence maturity mismatch, under a given policy arrangement.

Proposition 1. *For a given value of δ, the following ranking is preserved across the four regimes:*

$$\varrho^{BN} > \varrho^{BC} > \varrho^{NN} > \varrho^{NC}$$

for all $q > 0$.

Proof. See Appendix A □

Proposition 1 shows that illiquidity is highest when bailouts are in place and no CBDC is available (BN), and lowest under the combination of no bailouts with CBDC (NC). The intuition runs as follows. A no-bailout regime makes intermediaries more cautious, since they cannot rely on external support in the bad state. As a result, they hold more reserves, which lowers the first-period payout c_1^m. The presence of CBDC adds another layer: because depositors already have access to a safe outside option, the need for intermediaries to provide liquidity insurance falls. This further reduces the size of c_1^m. Together, the two forces mean that under the NC regime, intermediaries take on less short-term liability, lowering maturity mismatch and reducing the incentive for non-movers to run.

At the same time, as discussed earlier, a no-bailout policy is not costless. On the one hand, it encourages intermediaries to hold larger reserves, which strengthens stability. On the other hand, it also gives non-movers—who would otherwise prefer to consume in the second period—a stronger incentive to withdraw early at the first sign of trouble. In this respect, the presence of CBDC plays a corrective role. Since CBDC provides a reliable outside option, intermediaries need to provide less insurance through deposits. That relaxes the pressure on them to create large early payouts, leaving more resources available for the second period. In equilibrium, this means lower short-term liabilities and a smaller degree of maturity mismatch.

Overall, the ranking in Proposition 1 highlights how the interaction between bailouts and CBDC shapes the extent of illiquidity in the system. Bailouts without CBDC leave intermediaries with the most substantial incentive to create a maturity mismatch. In contrast, the combination of no bailouts and CBDC produces the opposite outcome: fewer short-term liabilities, more second-period resources, and a less fragile system.

Though the presence of a no-bailout policy can potentially reduce the maturity mismatch faced by the intermediaries, it does not guarantee that the economy is going to be secluded from a run on the banking system. Next, we characterize which among the regimes is more likely to face the possibility of a run, and therefore deemed to be more fragile.

5.2 Fragility

Before comparing run outcomes across policy regimes, we first define fragility in the model. Following Keister (2016), we say:

Definition. *An economy is fragile if a positive mass of non-movers withdraw in the first period in state β.*

The idea is straightforward. A sunspot shock can cause both movers and non-movers to panic. In state β, any non-mover with index $i \leq \theta$ will choose to withdraw in the first period and take c_1^m rather than wait until the second period for $c_{2\beta}^m$, for $m \in \{NN, NC, BC, BN\}$. In other words, the economy is fragile when non-movers behave like movers in state β and withdraw early.[9] Formally, the condition for fragility under regime m is

$$c_1^m \geq c_{2\beta}^m, \qquad m \in \{NN, NC, BC, BN\}.$$

In state α, non-movers strictly prefer to leave funds with the intermediary until the second period. As shown earlier, $c_{1s} < c_{2s}$ for $s \in \{\alpha, \beta\}$, so the only case where a run can arise is in state β. Let

$$\mathbf{c}^m \equiv \{c_1^m, \{c_{1s}^m, c_{2s}^m, g_s^m\}_{s=\alpha,\beta}\}$$

denote the set of equilibrium allocations under regime m, and define Φ^m as the set of economies that are fragile under m.

The introduction of a CBDC adds two opposing forces. On one side, if the CBDC return ρ^C exceeds the individual outside return ρ_i, then depositors have less need for the intermediary to provide liquidity insurance. This lowers the degree of maturity mismatch chosen in equilibrium and works to reduce fragility. On the other hand, when ρ^C is higher than the usual outside option ρ^N, non-movers prefer to take out their funds early in state β and move them into CBDC. This behavior makes the system more fragile. The overall outcome then depends on the specific parameter values and the policy regime.

In what follows, we solve the model numerically and, for each regime, identify the parameter regions in which the economy is fragile. We then compare these regimes to assess how bailouts and CBDC affect fragility.

[9] We assume fragility never occurs in state α.

5.3 Fragility under a No-CBDC Policy

We begin with the case without CBDC, which is qualitatively similar to Keister (2016). Figure 5 plots the sets of fragile economies under no bailouts (Φ^{NN}), under bailouts (Φ^{BN}), and their overlap on the (θ, q) plane for three values of δ (the weight on the public good)[10].

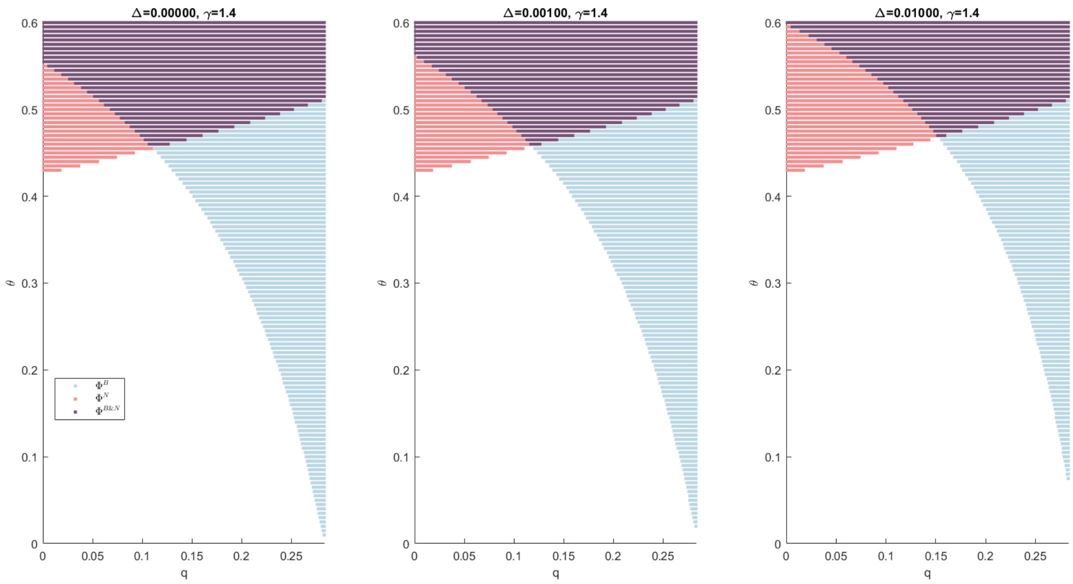

Figure 5: Fragile economies under a no-CBDC policy

Two patterns stand out. First, under bailouts (BN) the fragility threshold for θ falls as q rises (downward-sloping boundary). A higher probability of the bad state induces intermediaries to promise larger early payouts, which encourages non-movers to join the first-period queue and makes fragility occur even at lower θ. Second, under no bailouts (NN) the relationship reverses: as q increases, the threshold θ for fragility rises (upward-sloping boundary). Without public support, intermediaries self-insure by holding more liquid reserves, lowering c_1 and making runs less attractive.

When q is small, however, the no-bailout regime can be *more* fragile than the bailout regime (the medium-shaded region at low q). With crises unlikely, bailout-induced distortions are modest, so early payouts look similar across regimes; but with no transfers in a bad state, the payoff from waiting is lower under NN, which nudges patient depositors to withdraw early and shifts the fragility threshold downward.

The role of δ is straightforward across the three panels. Larger δ implies larger bailout needs (via higher tax resources available to support intermediaries). Removing

[10]The other parameter values used in this figure are $R = 2, \pi = 0.5, \gamma = 1.4$, $\bar{\rho} = 1.8$, $\underline{\rho} = 0.3$

those transfers in NN therefore has a bigger effect on incentives: the upward shift in the no-bailout boundary is more pronounced at higher δ. As q grows, the bailout distortion dominates and Φ^{BN} expands while Φ^{NN} contracts, reflecting the same two forces emphasized throughout: bailouts raise run incentives by supporting large early payouts, whereas no bailouts push intermediaries to self-insure and reduce maturity mismatch.

5.4 Fragility under a CBDC policy

Figure 6 reports the fragile sets under CBDC for the two regimes: no bailouts with CBDC (Φ^{NC}) and bailouts with CBDC (Φ^{BC}). As before, the panels plot the loci on the (θ, q) plane for three values of δ (the weight on public good provision)[11]. Dark shading indicates the overlap where both regimes are fragile; the light areas mark fragility under a single regime.

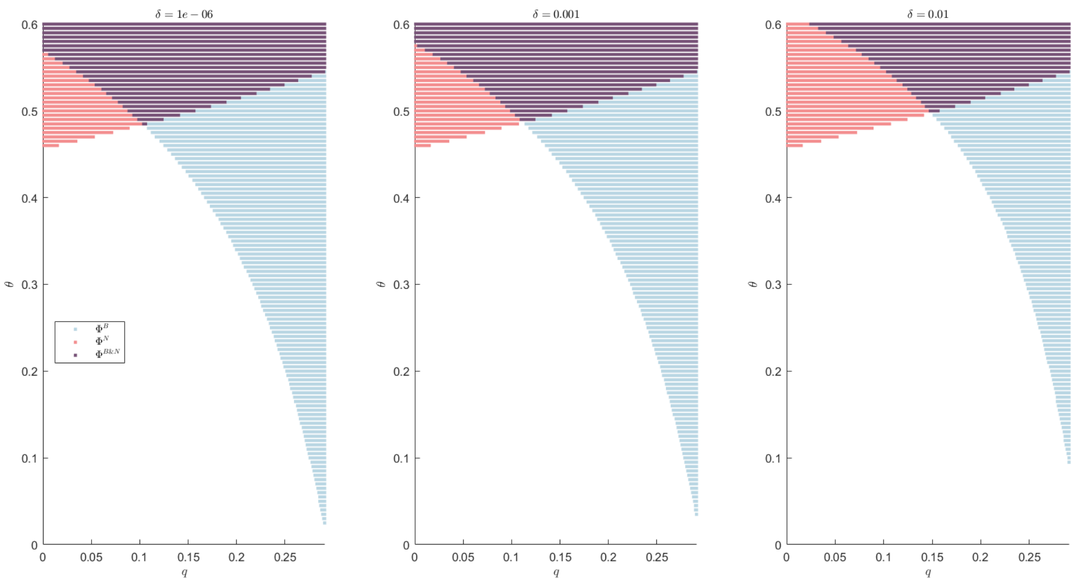

Figure 6: Fragile economies under a CBDC policy

Three features stand out. *First*, with CBDC the bailout frontier (Φ^{BC}) shifts down relative to its no-CBDC counterpart: for a given q, fragility under BC appears at lower θ. The reason is straightforward. Bailouts support large early payouts, and the availability of CBDC gives non-movers a clean outside option; together they amplify the incentive to join the first-period queue. *Second*, the (Φ^{NC}) boundary is visibly non-monotone in q, with a kink. At very low q, CBDC's appeal nudges patient depositors toward early withdrawal even without bailouts, pulling the threshold down. Past an intermediate value of q, the effect reverses: intermediaries in NC self-insure and, because CBDC

[11] The value of CBDC return, ρ_c is assumed to be 1.5.

substitutes for part of the liquidity insurance, choose a lower c_1. That reduces maturity mismatch and pushes the fragility threshold up. *Third*, increasing δ widens the region where BC is fragile relative to NC. A higher δ raises fiscal capacity and the scale of state-contingent support under bailouts, which makes large early payouts easier to sustain and thus expands Φ^{BC}; by contrast, under NC the insurance-substitution channel of CBDC keeps the rise in fragility in check.

Introduction of a CBDC has two competing effects on fragility. The benefit is the *insurance-substitution* channel: because CBDC offers a safe return, banks need not promise as much first-period liquidity, so c_1 is lower and maturity mismatch shrinks—this stabilizes the system, especially as q grows. The drawback is the *run-to-CBDC* channel: when CBDC's return compares favorably with the outside option, non-movers are more willing to exit early, which raises fragility at low q. The kinked frontier in Φ^{NC} is exactly where the balance tilts from the drawback to the benefit.

Comparison with the no-CBDC regime. Relative to Figure 5, the main difference is the shape and placement of the no-bailout frontier. Without CBDC, the bailout set (Φ^{BN}) slopes down in q while the no-bailout set (Φ^{NN}) slopes up, and the thresholds move smoothly. With CBDC, (Φ^{BC}) expands (downward shift) because bailouts plus a ready outside option encourage early withdrawals; meanwhile (Φ^{NC}) becomes *non-monotone* in q, reflecting the insurance-substitution benefit at higher q and the run-to-CBDC temptation at lower q. Put simply: CBDC alone does not uniformly stabilize the system—it changes the trade-off. It curbs maturity mismatch, but it also makes it easier for non-movers to join the run, and which force dominates depends on the parameter values of q, θ, and δ.

5.5 Comparing between cross-policy regimes

5.5.1 Under a Bailout Policy

Figure 7 compares fragility sets when bailouts are in place, with and without a CBDC. The light green region marks fragility under bailouts with CBDC (Φ^{BC}), the blue region marks fragility under bailouts without CBDC (Φ^{BN}), and the purple area is their overlap. Each panel plots the (θ, q) plane for a different value of δ (left to right: higher weight on public good provision).

Two facts are immediate. *First*, for a given q, the *no-CBDC* bailout frontier (blue) typically lies below the CBDC frontier (green): the economy becomes fragile at a lower value of θ without CBDC. Intuitively, with bailouts in place banks are comfortable promising high early payouts c_1. If there is no CBDC, depositors lack a safe outside

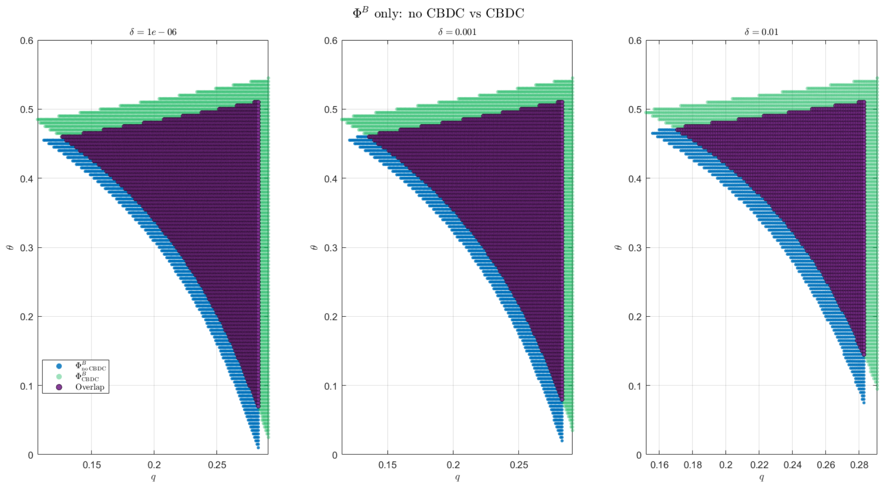

Figure 7: Fragile economies under bailouts-only policy: CBDC vs. no CBDC

option, so banks must do even more of the insurance "in house," which pushes c_1 up and increases maturity mismatch. That combination (bailouts + no CBDC) makes it easier for non-movers to join the first-period queue; hence fragility arrives "sooner" in θ under BN. By contrast, introducing a CBDC allows some of the insurance burden to shift away from banks. Intermediaries can set a lower c_1, which raises the θ threshold for fragility under BC—even though CBDC also creates a potential run-to-CBDC margin.

Second, the shape of the green and blue frontiers differs across q. At very low q, the run-to-CBDC motive is visible in the BC set: CBDC offers a clean outside option, so some patient depositors are tempted to exit early. But as q increases, the insurance-substitution channel dominates under BC: lower c_1 reduces maturity mismatch and the fragility boundary shifts up relative to BN. This is why the green region tends to sit above the blue region for moderate and high q.

The role of δ can be read across the panels. A higher δ means more fiscal capacity and larger state-contingent support when bailouts are used. That expands fragility in both BC and BN, but the expansion is stronger under BN, where banks rely more on large early payouts to provide insurance. Under BC, CBDC takes part of the burden off bank balance sheets, so the shift in the frontier with δ is comparatively muted. The growing purple overlap as δ rises reflects parameter combinations where both regimes are fragile, but the ordering of thresholds—BN becoming fragile at lower θ than BC—remains visible.

In short, within a bailouts-only world, CBDC changes the mix of forces. It introduces a new route for runs (depositors can flee to CBDC), but it also lets banks promise less first-period liquidity. In the region that matters for policy—moderate to high q—the insurance-substitution effect dominates, so CBDC *raises* the θ threshold for fragility relative to no-CBDC bailouts. Without CBDC, the system leans more heavily on bank-provided insurance, and fragility arrives sooner.

5.5.2 Under a No-Bailout Policy

Figure 8 compares fragility when bailouts are ruled out, with and without a CBDC. The orange region marks economies that are fragile under no bailouts without CBDC (Φ^{NN}), the pink region marks fragility under no bailouts with CBDC (Φ^{NC}), and the violet area is the overlap. Each panel maps the (θ, q) plane for a different value of δ (left to right: higher weight on public good provision).

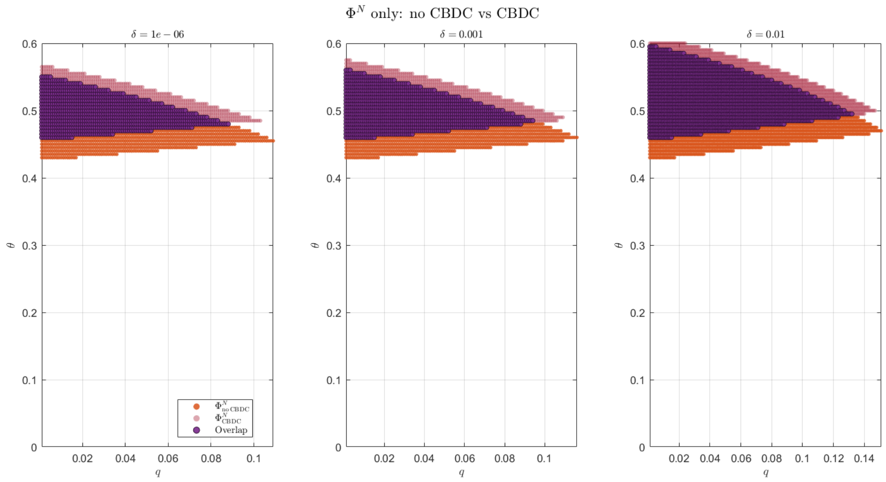

Figure 8: Fragile economies under no-bailouts only policy: CBDC vs. no CBDC

Three observations stand out.

First, across most of the plotted range the pink frontier (CBDC) sits *above* the orange frontier (no CBDC): for a given q, fragility under NC typically requires a *higher* θ than under NN. The mechanism is the insurance–substitution effect. With no bailouts, intermediaries already self-insure. Introducing a CBDC lets them lean less on large early payouts, so they choose a lower c_1; maturity mismatch shrinks and runs are harder to trigger, which raises the θ threshold for fragility.

Second, very close to the origin (low q) the picture tightens and the pink region occasionally pushes *down* toward the orange boundary. This captures the run-to-CBDC margin: when the bad state is unlikely, the appeal of a safe CBDC can pull some patient depositors into the first-period queue even without bailouts, making fragility appear at slightly lower θ than otherwise. In other words, CBDC trims maturity mismatch overall, but at very low q it can also create a small pocket where the economy is *more* prone to runs.

Third, moving rightward across panels (higher δ) expands the set of fragile economies for both NN and NC, and the violet overlap widens. Larger δ increases public-good spending financed in period 0, tightening budget constraints in the bad state and making early withdrawals more consequential. Even so, the ordering noted above largely survives: for most (θ, q), NC needs a higher θ to become fragile than NN, reflecting that CBDC allows intermediaries to promise less first-period liquidity when bailouts are off the table.

Taken together, in a no-bailouts environment, the main effect of CBDC is stabilizing—by reducing c_1 and maturity mismatch—while its downside shows up in a narrow low-q region where the ready outside option encourages early exit. The figure makes both forces visible: a higher fragility threshold with CBDC in most of the domain, and a small low-q wedge where the CBDC margin binds.

5.6 Extreme cross–regime comparisons

We now compare the two extreme pairs of regimes. The first figure contrasts *Bailout without CBDC* (Φ^{BN}) with *No Bailout with CBDC* (Φ^{NC}), and the second compares *No Bailout without CBDC* (Φ^{NN}) with *Bailout with CBDC* (Φ^{BC}). In each panel the horizontal axis is the probability of the bad state q and the vertical axis is the speed or scale of early withdrawals θ. Panels move left to right with higher δ, i.e., a greater weight on public good provision.

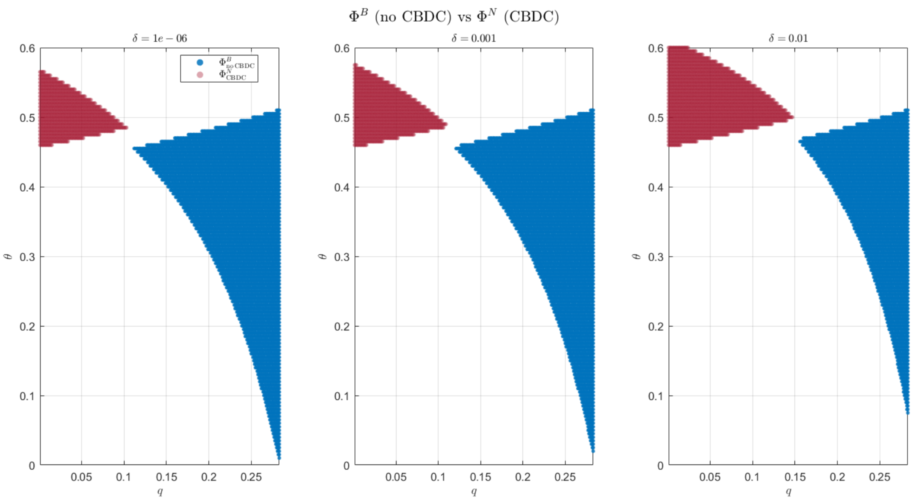

Figure 9: Φ^{BN} vs. Φ^{NC}

In Figure 9, the blue area (fragility under BN) covers most of the (θ, q) space, while the maroon area (fragility under NC) shows up mainly as a small wedge at low q and high θ. In general, runs start sooner under BN: the blue frontier sits well below the maroon one, meaning a smaller θ is enough to trigger fragility when bailouts are in place and there is no CBDC. The logic is direct. Bailouts sustain generous first-period payouts c_1; without a CBDC outside option, banks provide more of the insurance within deposits, raising maturity mismatch and inviting early withdrawals. The maroon NC wedge is the exception that proves the rule: when crises are very unlikely, a safe CBDC tempts some patient depositors into the first period even without bailouts. As δ increases across panels, the blue BN region expands—larger state-contingent support makes big c_1 easier to maintain—while the maroon NC wedge retreats slightly toward the upper left as self-insurance combined with CBDC keeps maturity mismatch contained.

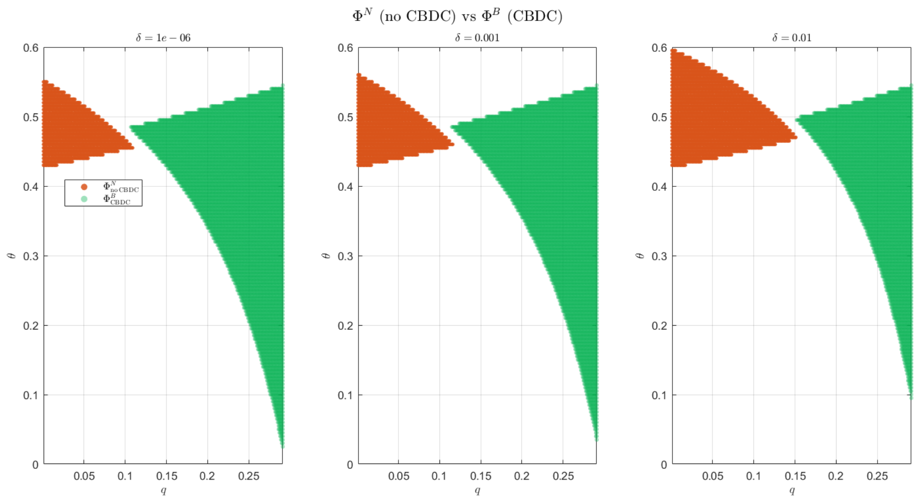

Figure 10: Φ^{NN} vs. Φ^{BC}

Figure 10 flips the policy mix. Here the green BC region occupies most of the domain once q is moderate, whereas the orange NN region is confined to the low-q, high-θ corner. When bailouts are combined with CBDC, two forces stack up: fiscal support allows high c_1 and CBDC offers a clean outside option; together they pull non-movers into the early queue and broaden the fragile set. Under NN, intermediaries self-insure and, with no CBDC, depositors lack an easy outside asset; runs are therefore harder to trigger except in that narrow low-q/high-θ region. As δ rises, the green BC set expands further, the orange NN region shrinks, and the crossing point between their frontiers shifts right and down.

Taken together, the two figures deliver a consistent message. With bailouts in place, fragility expands as the crisis probability q rises, and the trade-off between θ and q is inverse: higher q lowers the θ needed to spark a run because generous early payouts become more attractive. A higher δ amplifies this by enlarging the fiscal capacity behind bailouts. CBDC adds a cushion by letting banks promise less first-period liquidity (the insurance-substitution channel). However, at very low q it can open a small region where runs to CBDC appear. These forces imply that the ranking of fragility depends on q: at low q, the run-to-CBDC wedge can bring no-bailout configurations close to fragility in the high-θ corner, while at higher q the bailout frontiers dominate and the *No Bailout + CBDC* arrangement remains the most resilient over a wide range of parameters.

Proposition 2. *For a given δ, there exists a cutoff $\tilde{q}$ such that the ordering of fragility sets switches at $q = \tilde{q}$. For low crisis probability $(q < \tilde{q})$,*

$$\Phi^{NN} > \Phi^{NC} > \Phi^{BN} > \Phi^{BC},$$

so fragility is largest under No Bailout + No CBDC and smallest under Bailout + CBDC. For high crisis probability $(q > \tilde{q})$,

$$\Phi^{BN} > \Phi^{BC} > \Phi^{NN} > \Phi^{NC},$$

so fragility is largest under Bailout + No CBDC and smallest under No Bailout + CBDC.

The fragility results also carry over to the fiscal side. When runs become more likely—either because bailouts support high c_1 or because CBDC encourages non-movers to exit early—the government ends up needing more resources in the bad state. Under bailouts, this appears as direct transfers to the financial sector, whereas under no bailouts, the link is through the amount of insurance banks must build into deposits and the size of early payouts. In both cases, the government's budget constraint ties these choices to the tax rate τ and to what remains for the public good g. This makes it natural to turn next to the behavior of taxes: how they differ across regimes, how they move with q, and how CBDC and bailouts shape the patterns we see.

6 Taxes Across Policy Regimes

This section looks at how the equilibrium tax rate τ^m varies across policy regimes and how those differences move with the probability of the bad state q. The basic forces are familiar. Bailouts require fiscal resources ex ante (they must be credibly financed) and ex post (when the bad state hits), which pushes up τ. A CBDC changes how much liquidity insurance banks need to provide and therefore affects maturity mismatch and the size of early payouts; that channel also shows up in taxes through the resources the government must raise.

Proposition 3. *For a given value of δ, taxes are highest under a bailout with CBDC and lowest under no bailouts without CBDC. The ranking is*

$$\tau^{BC} > \tau^{BN} > \tau^{NC} > \tau^{NN} \quad \text{for all } q > 0.$$

Figures 11 and 12 plot tax differentials between pairs of regimes. The first compares bailouts with CBDC to no bailouts with CBDC, $\tau^{BC} - \tau^{NC}$. The second compares bailouts without CBDC to no bailouts without CBDC, $\tau^{BN} - \tau^{NN}$.

Bailouts vs. no bailouts with CBDC (BC vs. NC). Figure 11 shows that $\tau^{BC} - \tau^{NC}$ is always positive, consistent with Proposition 3, but it is not monotone in q. The gap declines at low q, then turns up; there is a noticeable kink around an intermediate value of q. The mechanism follows the competing effects of CBDC. With a CBDC in place, depositors have a safe outside option. Under NC, intermediaries rely less on large early payouts and choose a smaller c_1, keeping τ^{NC} low. Under BC, expected bailout needs are financed through taxes, so τ^{BC} embeds the state-contingent fiscal cost of support.

For very small q, expected bailout outlays under BC are limited, and the main difference comes from how CBDC lets banks under NC substitute away from insurance—τ^{NC} is especially low, so the gap starts out relatively high and then narrows. Once q passes a threshold $\bar{q}$, expected bailout needs under BC rise quickly with q, while NC continues to restrain maturity mismatch; the differential then widens. The kink reflects a change in equilibrium constraints (entry into a fragile region for one regime), which shifts how strongly these forces load into τ.

Bailouts vs. no bailouts without CBDC (BN vs. NN). Figure 12 is more linear. Without CBDC, there is no extra outside option pulling non-movers into the first period, so bank behavior varies more smoothly with q. The difference $\tau^{BN} - \tau^{NN}$ rises steadily with q. Under BN, taxes must cover expected bailout payments, which scale with the probability of the bad state and the associated shortfall. Under NN there are no bailout transfers to fund, so τ^{NN} mainly reflects public-good financing and standard distortions. As q increases, expected fiscal needs under BN rise one-for-one, and the gap widens accordingly.

What happens to the provision of public goods that depend on the amount of taxes raised under each regime? Because the government budget constraint links taxes to spending on the public good g and to any state-contingent support to banks, higher τ

tends to crowd resources away from private consumption and/or compress g unless offset elsewhere. In the CBDC cases, the insurance-substitution channel (smaller c_1 under NC) reduces the need to raise taxes for financial support, helping preserve resources for g and second-period private consumption. In contrast, bailout regimes—especially BC—load more of the adjustment onto τ as q rises, which puts pressure on these same components of the allocation.

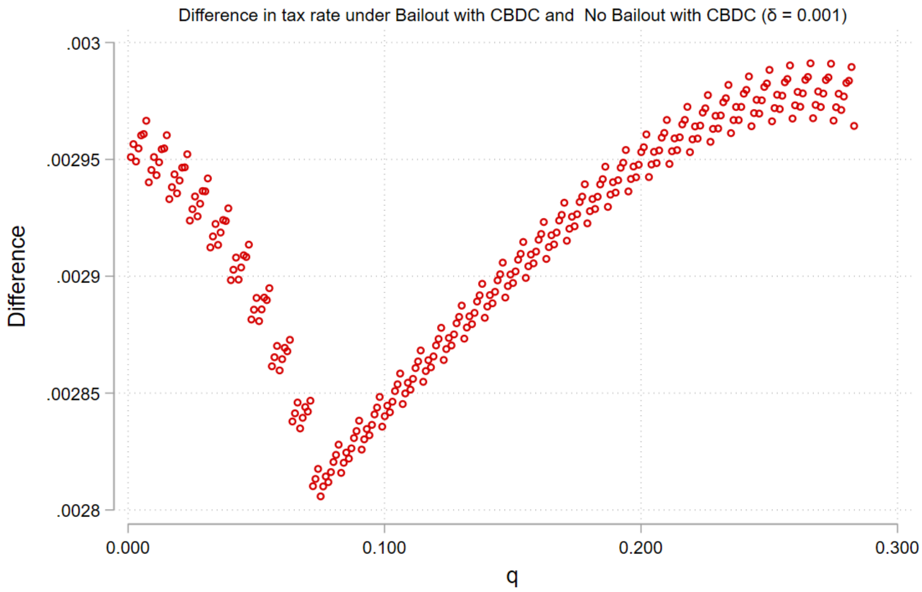

Figure 11: Tax differential with CBDC: $\tau^{BC} - \tau^{NC}$.

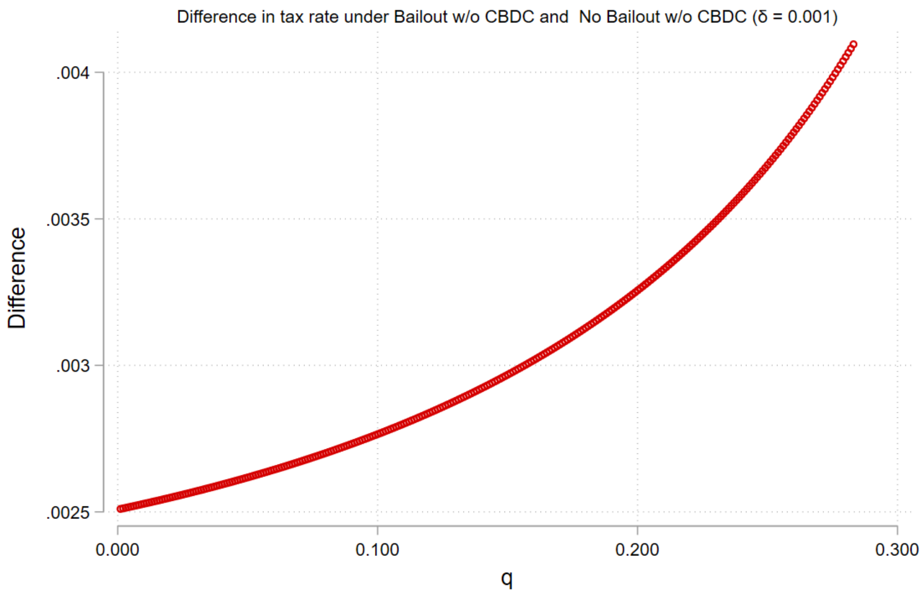

Figure 12: Tax differential without CBDC: $\tau^{BN} - \tau^{NN}$.

7 Welfare

Welfare in the model is defined as the equal-weighted average of investors' expected utilities under a given policy regime m:

$$W^m = \int_0^1 \mathbb{E}[U(c_1^m(i), c_2^m(i), g^m, \tau^m)]\, di,$$

where $m \in \{NN, NC, BC, BN\}$.

For each regime, we use the same parameter values that generate the equilibrium allocations. The comparison across regimes is carried out by first ruling out those that are fragile relative to the others. If both regimes are fragile, welfare is compared directly across the two run equilibria—W^j versus W^m. Depending on the parameterization, one can dominate the other.

Different instruments work through competing forces. Bailouts encourage intermediaries to push too much consumption toward the first θ investors who withdraw, while the presence of a CBDC—depending on its relative return—can induce non-movers to also withdraw in the first period. On the other hand, removing bailouts corrects this distortion, but at the cost of reducing risk-sharing between public and private consumption, which again creates incentives for premature withdrawals. CBDC reduces the extent of insurance provision required from intermediaries and lowers measured illiquidity, but it can simultaneously raise fragility by increasing the incentive to run.

We first look at bailouts versus no-bailouts in a world without CBDC, and then repeat the comparison in a CBDC setting.

Proposition 4. *For any $q > 0$ and for economies in the fragile region, welfare is always higher under a no-bailout policy, both with and without CBDC:*

$$W^{NN} > W^{BN} \quad \forall q > 0,$$

$$W^{NC} > W^{BC} \quad \forall q > 0.$$

Figure 13 shows the difference in welfare between a no-bailout/no-CBDC regime (NN) and a bailout/no-CBDC regime (BN). The gap widens as the probability of the bad state q increases. The mechanism is straightforward: with no bailouts, intermediaries take on less maturity mismatch, and this effect more than offsets the incentive distortion faced by non-movers and the distortion introduced by bailouts. In short, without CBDC, no-bailouts dominate bailouts, and the advantage grows as the probability of a bad state rises.

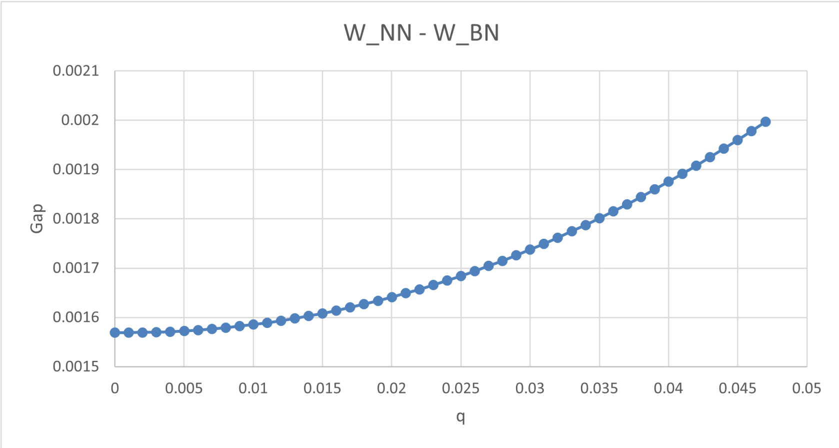

Figure 13: Welfare under a no CBDC regime

A similar pattern appears under a CBDC regime, but with some differences. Figure 14 plots the welfare gap between no-bailouts (NC) and bailouts (BC). The gap is always positive, but now the relationship with q is U-shaped. At low values of q, the advantage of no-bailouts is small, since the joint effect of CBDC and no-bailouts induces non-movers to withdraw early, increasing fragility. Once q exceeds a threshold $\bar{q}$, the picture reverses: less maturity mismatch by intermediaries dominates, more resources remain for the second period, and welfare rises more quickly under no-bailouts than bailouts.

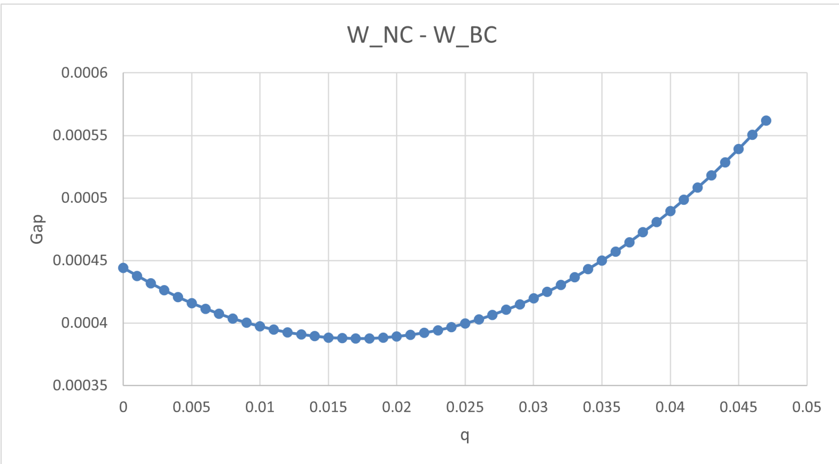

Figure 14: Welfare under a CBDC regime

The other cases are reported in Appendix C. Comparing bailout regimes (BC vs. BN) or no-bailout regimes (NC vs. NN) shows that introducing a CBDC improves welfare relative to no-CBDC, though the gain falls as q increases. The downward-sloping curves point to the incentive distortion from CBDC: as the probability of the bad state rises, more non-movers withdraw early, reducing welfare.

Taken together, two conclusions stand out. First, no bailouts raise welfare regardless of whether CBDC is present. The correction of incentives dominates, leaving more resources for second-period consumption and public goods, and therefore higher welfare overall. Second, the combination of no-bailouts and CBDC delivers the highest welfare relative to the extreme cases, although the gains are nonlinear in q. In fact, the welfare advantage of combining no-bailouts with CBDC becomes stronger as the probability of a bad state rises.

8 Discussion

The results point to a clear organizing principle: the interaction between CBDC and bailout policy determines whether the system tilts toward maturity mismatch and runs, or toward self–insurance and stability. Three findings are central. First, on illiquidity (Proposition 1), the ordering $\varrho^{BN} > \varrho^{BC} > \varrho^{NN} > \varrho^{NC}$ shows that bailouts push banks toward higher early payouts c_1 and larger short–term liabilities, and that CBDC—when paired with no bailouts—allows banks to scale back c_1 the most. Second, on fragility, the maps of Φ^m show that bailouts expand the run set as q rises, while CBDC reshapes incentives in two ways: it substitutes for deposit insurance (stabilizing, because c_1 falls) but also opens a margin to run into CBDC at very low q. The net effect is non–linear in q and depends on δ, with a clean threshold pattern summarized in Proposition 2. Third, on taxes, the ranking $\tau^{BC} > \tau^{BN} > \tau^{NC} > \tau^{NN}$ links these private choices to fiscal pressure: expected transfers under bailouts and larger c_1 show up in higher τ, whereas CBDC under no bailouts keeps both maturity mismatch and the tax burden comparatively low.

Taken together, these arguments support the policy combination that our figures emphasize: *No Bailout + CBDC* emerges as the most resilient configuration over a wide part of the parameter space. In the fragility diagrams, Φ^{NC} is smallest once q is moderate or high; in the tax plots, τ^{NC} stays below its bailout counterparts; and in the welfare comparisons, $W^{NC} > W^{BC}$ within the fragile region, with the gap widening again as q grows. The mechanism is the same in each domain. Removing bailouts eliminates the incentive to promise excessive early liquidity, and the presence of CBDC lets banks rely less on deposit–based insurance, lowering c_1 without making the system illiquid. Resources saved in period 0 carry forward into higher second–period consumption and public–good provision g, while the fiscal authority faces smaller state–contingent needs.

At the same time, the model is explicit about the drawback that comes with CBDC. When the bad state is unlikely, the CBDC return can attract patient depositors into the first period, creating the narrow low–q wedge where Φ^{NC} expands and the tax gap $\tau^{BC} - \tau^{NC}$ briefly narrows. This is the same force behind the kink in Figure 11 and the non–monotonic Φ^{NC} boundary. The policy implication is straightforward: ρ^{C} should not dominate the standard outside option ρ^{N} at low q. Tiered remuneration or quantity frictions on CBDC balances are natural design tools to mute the run–to–CBDC margin without undoing the insurance–substitution benefit.

Comparisons within a fixed bailout stance sharpen the message. With bailouts, adding CBDC does *not* guarantee more stability: the green regions in Figure 10 expand quickly as q rises because bailout support and an easy outside option together pull non–movers into the queue. Without bailouts, by contrast, adding CBDC is mostly stabilizing: the pink regions in Figure 8 sit above the orange ones for most (θ, q), reflecting smaller c_1 and less maturity mismatch. This asymmetry explains why the cross–pair comparison $(BN$ vs $NC)$ is so stark in Figure 9: the blue area dominates except for the tiny low–q wedge where run–to–CBDC appears, and that wedge shrinks as δ or q increase.

The fiscal patterns line up one–for–one with the run maps. As q increases, bailout regimes load more adjustment onto taxes to finance expected support, which is why $\tau^{BN} - \tau^{NN}$ rises roughly linearly with q. With CBDC in place, the early–payout schedule under NC is flatter precisely because insurance is partly offloaded to the public option; that is why $\tau^{BC} - \tau^{NC}$ dips at low q, kinks, and then climbs—once bad states are sufficiently likely, bailout promises dominate again. Because g shares the same budget, these differences in τ also translate into concrete trade–offs for public–good provision and private consumption across regimes.

Welfare results follow the same ordering within the fragile region. When CBDC is absent, $W^{NN} > W^{BN}$ because removing bailouts curbs maturity mismatch and the gain grows with q. With CBDC, $W^{NC} > W^{BC}$ for all $q > 0$, but the gap is U–shaped: small at low q when run–to–CBDC trims the advantage, and increasing once q passes the internal threshold $\bar{q}$ as the insurance–substitution channel dominates. This mirrors the movement of the Φ^{NC} boundary and the tax differentials, and it underlines why the *No Bailout + CBDC* mix is the natural benchmark in our environment.

Two practical implications follow. First, credibility of the no–bailout commitment is central. The improvements we document—smaller ϱ^{m}, a smaller Φ^{NC}, lower τ, and higher W—all rely on banks internalizing the absence of transfers in bad states. Second, CBDC design should target the margin that matters in our model: keep ρ^{C} below ρ^{N} in normal times to avoid the low–q run wedge, while allowing CBDC to substitute for deposit insurance when stress rises. Either tiered remuneration, ceilings on remunerated balances, or state–contingent adjustments to ρ^C would be consistent with that objective.

Across episodes in which the perceived probability of crisis rises, the model yields clear empirical implications. Under bailout regimes, one should observe a steeper increase in tax pressure and an earlier shift of non-movers into the withdrawal queue. By contrast, in systems with a credible no-bailout commitment and a well-designed CBDC, early-payout schedules should be flatter, maturity mismatch lower, and expected taxes more stable. While the framework abstracts from monetary-policy feedbacks, the two central margins—insurance substitution versus run-to-CBDC, and the fiscal footprint of bailouts—offer a disciplined way to interpret policy choices in environments considering digital public money.

Work in progress. The next part of the paper will capture issues that go beyond the current setup. One direction is to examine different design choices for CBDC—such as limits on holdings or alternative remuneration rules—that may reduce the incentive for depositors to shift funds into CBDC during good times, while still maintaining its stabilizing role when the probability of a crisis is higher. Another direction introduces differences across intermediaries, for example, by allowing banks of different sizes or balance sheet structures. This will help us see whether the advantage of combining no bailouts with CBDC continues to hold once some institutions are viewed as "too big to fail" and bailout expectations are unevenly spread across the system.

A third avenue will study the role of credibility and political constraints by embedding limited commitment into the no-bailout promise. This will allow us to quantify how deviations from full credibility shift fragility regions Φ^m, equilibrium taxes τ, and welfare W. Finally, we are also extending the framework to connect more directly with macro-financial policy. In particular, we examine how the model interacts with standard monetary policy tools, such as interest rate rules, and with prudential regulations, including the Liquidity Coverage Ratio, which requires banks to hold liquid assets sufficient to withstand short-term funding pressures. This will map the theoretical insights about c_1 and maturity mismatch into implementable tools for policymakers.

9 Conclusion

Our analysis shows that the stability impact of CBDC depends critically on the policy regime in which it is introduced. Bailouts, by sustaining large early payouts, expand the range of run-prone economies; when paired with a CBDC, this tendency intensifies because depositors face both generous first-period liquidity and a safe outside option. By contrast, a credible no-bailout commitment changes the calculus. Banks hold back on short-term liabilities, maturity mismatch declines, and—when a CBDC is available as an alternative store of value—fragility is sharply reduced. Across a wide range of parameters, the combination of CBDC and no bailouts delivers the most favorable outcomes in terms of financial stability, fiscal costs, and welfare. Our welfare analysis shows that commiting credibly to a no-bailout policy can actually provide higher welfare as compared to the scenario of introducing a CBDC when the possibility of a crisis is high enough.

CBDCs cannot be assessed in isolation from the broader framework of crisis management. Recent episodes of rapid deposit withdrawals—accelerated by digital banking, social networks, and real-time transfers—show how fragile funding can become even without a CBDC in place. The introduction of a retail CBDC would intensify these pressures unless it were accompanied by a credible commitment to limit bailouts. Our results indicate that pairing CBDC with such a commitment, alongside design features that reduce incentives for runs at very low crisis probabilities, allows the stabilizing insurance-substitution role of CBDC to dominate while containing the run-to-CBDC risk. This combination strengthens financial resilience and reduces the fiscal burden associated with bailouts, ultimately supporting a more stable and efficient system.

Looking forward, the expansion of digital money—whether through CBDCs, stablecoins, or fast-payment systems—will only make the question more pressing. As safe, liquid outside options become more widely available, the credibility of no-bailout policies grows in importance rather than receding. Policymakers weighing CBDC adoption should therefore view it as part of a broader financial-stability architecture: one that emphasizes ex-ante discipline, minimizes reliance on fiscal transfers, and strengthens the resilience of intermediaries in the face of sudden shocks.

References

Acharya, Viral V and Nada Mora, "A crisis of banks as liquidity providers," *The journal of Finance*, 2015, *70* (1), 1–43.

— **and Tanju Yorulmazer**, "Too many to fail—An analysis of time-inconsistency in bank closure policies," *Journal of financial intermediation*, 2007, *16* (1), 1–31.

Agur, Itai, Anil Ari, and Giovanni Dell'Ariccia, "Designing central bank digital currencies," *Journal of Monetary Economics*, 2022, *125*, 62–79.

Allen, Franklin, Elena Carletti, Itay Goldstein, and Agnese Leonello, "Government guarantees and financial stability," *Journal of Economic Theory*, 2018, *177*, 518–557.

— **, Xian Gu, and Julapa Jagtiani**, "Fintech, cryptocurrencies, and CBDC: Financial structural transformation in China," *Journal of International Money and Finance*, 2022, *124*, 102625.

Auer, Raphael, Jon Frost, Leonardo Gambacorta, Cyril Monnet, Tara Rice, and Hyun Song Shin, "Central bank digital currencies: motives, economic implications, and the research frontier," *Annual review of economics*, 2022, *14* (1), 697–721.

Bianchi, Javier, "Efficient bailouts?," *American Economic Review*, 2016, *106* (12), 3607–3659.

— **and Enrique G Mendoza**, "Optimal time-consistent macroprudential policy," *Journal of Political Economy*, 2018, *126* (2), 588–634.

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

Burnside, Craig, Martin Eichenbaum, and Sergio Rebelo, "Hedging and financial fragility in fixed exchange rate regimes," *European Economic Review*, 2001, *45* (7), 1151–1193.

Calomiris, Charles W, "Is deposit insurance necessary? A historical perspective," *The Journal of Economic History*, 1990, *50* (2), 283–295.

Carapella, Francesca and Jean Flemming, "Central bank digital currency: A literature review," 2020.

Champ, Bruce, Bruce D Smith, and Stephen D Williamson, "Currency elasticity and banking panics: Theory and evidence," *Canadian Journal of Economics*, 1996, pp. 828–864.

Chari, Varadarajan V and Patrick J Kehoe, "Bailouts, time inconsistency, and optimal regulation: A macroeconomic view," *American Economic Review*, 2016, *106* (9), 2458–2493.

Chiu, Jonathan and Todd Keister, "The economics of digital currencies: Progress and open questions," *Journal of Economic Dynamics and Control*, 2022, *142*, 104496.

_ , Seyed Mohammadreza Davoodalhosseini, Janet Jiang, and Yu Zhu, "Bank market power and central bank digital currency: Theory and quantitative assessment," *Journal of Political Economy*, 2023, *131* (5), 1213–1248.

Dávila, Eduardo and Ansgar Walther, "Does size matter? Bailouts with large and small banks," *Journal of Financial Economics*, 2020, *136* (1), 1–22.

Davoodalhosseini, Seyed Mohammadreza, "Central bank digital currency and monetary policy," *Journal of Economic Dynamics and Control*, 2022, *142*, 104150.

Demirgüç-Kunt, Asli and Enrica Detragiache, "The determinants of banking crises in developing and developed countries," *Staff Papers*, 1998, *45* (1), 81–109.

Diamond, Douglas W and Philip H Dybvig, "Bank runs, deposit insurance, and liquidity," *Journal of political economy*, 1983, *91* (3), 401–419.

_ and Raghuram G Rajan, "Illiquid banks, financial stability, and interest rate policy," *Journal of Political Economy*, 2012, *120* (3), 552–591.

Farhi, Emmanuel and Jean Tirole, "Collective moral hazard, maturity mismatch, and systemic bailouts," *American Economic Review*, 2012, *102* (1), 60–93.

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

Gropp, Reint, Christian Gruendl, and Andre Guettler, "The impact of public guarantees on bank risk-taking: Evidence from a natural experiment," *Review of Finance*, 2014, *18* (2), 457–488.

Holmström, Bengt and Jean Tirole, "Private and public supply of liquidity," *Journal of political Economy*, 1998, *106* (1), 1–40.

Infante, Sebastian, Kyungmin Kim, André F Silva, and Robert J Tetlow, "The macroeconomic implications of CBDC: A review of the literature," 2022.

Keister, Todd, "Bailouts and financial fragility," *The Review of Economic Studies*, 2016, *83* (2), 704–736.

— **and Cyril Monnet**, “Central bank digital currency: Stability and information,” *Journal of Economic Dynamics and Control*, 2022, *142*, 104501.

— **and Daniel Sanches**, “Should central banks issue digital currency?,” *The Review of Economic Studies*, 2023, *90* (1), 404–431.

— **and Vijay Narasiman**, “Expectations versus fundamentals: Does the cause of banking panics matter for prudential policy?,” *FRB of New York Staff Report*, 2011, (519).

Kim, Young Sik and Ohik Kwon, “Central bank digital currency, credit supply, and financial stability,” *Journal of Money, Credit and Banking*, 2023, *55* (1), 297–321.

Minesso, Massimo Ferrari, Arnaud Mehl, and Livio Stracca, “Central bank digital currency in an open economy,” *Journal of Monetary Economics*, 2022, *127*, 54–68.

Nosal, Jaromir B and Guillermo Ordonez, “Uncertainty as commitment,” *Journal of Monetary Economics*, 2016, *80*, 124–140.

Panageas, Stavros, “Bailouts, the incentive to manage risk, and financial crises,” *Journal of Financial Economics*, 2010, *95* (3), 296–311.

Pasten, Ernesto, “Prudential policies and bailouts–a delicate interaction,” *Review of Economic Dynamics*, 2020, *38*, 181–197.

Schneider, Martin and Aaron Tornell, “Balance sheet effects, bailout guarantees and financial crises,” *The Review of Economic Studies*, 2004, *71* (3), 883–913.

Stavrakeva, Vania, “Optimal bank regulation and fiscal capacity,” *The Review of Economic Studies*, 2020, *87* (2), 1034–1089.

Wallace, Neil, “Another attempt to explain an Illiquid banking system: With sequential service taken seriously,” *Federal Reserve Bank Minneapolis Quarterly Review*, 1988, pp. 3–15.

Williamson, Stephen, “Central bank digital currency: Welfare and policy implications,” *Journal of Political Economy*, 2022, *130* (11), 2829–2861.

Williamson, Stephen D, “Central bank digital currency and flight to safety,” *Journal of Economic Dynamics and Control*, 2022, *142*, 104146.

Central Bank Digital Currency and Bank Stability: Does a No Bailout Policy Suffice?

Online Appendix

A Model Solution

A.1 Solution for the case of Bailout and No CBDC.

$$V(\Psi_s^j;\hat{\pi}_s) = \max_{\{c_{1s}^j, c_{2s}^j\}} \ (1-\theta)\left[\hat{\pi}_s \int_{\underline{\rho}}^{\bar{\rho}} u\left(\rho_i c_{1s}^j\right)\, F(\rho_i) + (1-\hat{\pi}_s) u\left(c_{2s}^j\right)\right],$$

subject to feasibility constraint

$$(1-\theta)\left[\hat{\pi}_s c_{1s}^j + (1-\hat{\pi}_s)\frac{c_{2s}^j}{R}\right] = \Psi_s^j.$$

Assuming uniform distribution,

$$\mathcal{L} = (1-\theta)\left[\hat{\pi}_s\left(\frac{(\bar{\rho}-\underline{\rho})^{1-\sigma}\left(c_{1s}^j\right)^{1-\sigma}}{(2-\sigma)(1-\sigma)}\right) + (1-\hat{\pi}_s)\frac{\left(c_{2s}^j\right)^{1-\sigma}}{1-\sigma}\right] + \mu_s^j\left[\Psi_s^j - (1-\theta)\left[\hat{\pi}_s c_{1s}^j + (1-\hat{\pi}_s)\frac{c_{2s}^j}{R}\right]\right].$$

F.O.C with respect to c_{1s} and c_{2s} is given by,

$$\frac{(\bar{\rho}-\underline{\rho})^{1-\sigma}(c_{1s}^j)^{-\sigma}}{2-\sigma} = \mu_s^j, \tag{A1}$$

$$R\left(c_{2s}^j\right)^{-\sigma} = \mu_s^j, \tag{A2}$$

Combining (A1) and (A2),

$$\frac{c_{2s}^j}{c_{1s}^j} = \left(\frac{R(2-\sigma)}{(\bar{\rho}-\underline{\rho})^{1-\sigma}}\right)^{\frac{1}{\sigma}},$$

Using resource constraint,

$$c_{1s}^j = \frac{\Psi_s^j}{(1-\theta)\left[\hat{\pi}_s + \frac{(1-\hat{\pi}_s)}{R}\left(\frac{R(2-\sigma)}{(\bar{\rho}-\underline{\rho})^{1-\sigma}}\right)^{\frac{1}{\sigma}}\right]}, \tag{A3}$$

$$c_{2s}^j = \frac{\Psi_s^j}{(1-\theta)\left[\hat{\pi}_s + \frac{(1-\hat{\pi}_s)}{R}\left(\frac{R(2-\sigma)}{(\bar{\rho}-\underline{\rho})^{1-\sigma}}\right)^{\frac{1}{\sigma}}\right]} \times \left(\frac{R(2-\sigma)}{(\bar{\rho}-\underline{\rho})^{1-\sigma}}\right)^{\frac{1}{\sigma}}. \tag{A4}$$

Bailout Policy:

$$b^j = b + \theta[c_1^j - \bar{c}_1];$$

$$\Psi_\beta^j = 1 - \tau - \theta\bar{c}_1 + b.$$

With no CBDC intermediary j will choose c_i^j to solve ,

$$\max_{\{c_1^j\}} \quad \theta \left[\int_{\underline{\rho}}^{\bar{\rho}} u\left(\rho_i c_1^j\right)\ F(\rho_i) \right] + (1-q)V(\Psi_\alpha^j;\hat{\pi}_\alpha) + qV(\Psi_\beta^j;\hat{\pi}_\beta),$$

subject to

$$\Psi_\alpha^j = 1 - \tau - \theta c_1^j,$$

$$\Psi_\beta^j = 1 - \tau - \theta \bar{c}_1 + b.$$

F.O.C w.r.t to c_1 is given by,

$$\frac{(\bar{\rho}-\underline{\rho})^{1-\sigma}(c_1^j)^{-\sigma}}{(2-\sigma)} = (1-q)\mu_\alpha^j, \tag{A5}$$

Combining (A1), (A3) for state α and (A5) we get,

$$(c_1^j) = \frac{(1-q)^{-1/\sigma}\Psi_\alpha^j}{(1-\theta)\left[\hat{\pi}_\alpha + \frac{(1-\hat{\pi}_\alpha)}{R}\left(\frac{R(2-\sigma)}{(\bar{\rho}-\underline{\rho})^{1-\sigma}}\right)^{\frac{1}{\sigma}}\right]},$$

$$c_1^j = \frac{1-\tau}{(1-q)^{1/\sigma}(1-\theta)\left[\hat{\pi}_\alpha + \frac{(1-\hat{\pi}_\alpha)}{R}\left(\frac{R(2-\sigma)}{(\bar{\rho}-\underline{\rho})^{1-\sigma}}\right)^{\frac{1}{\sigma}}\right] + \theta} \tag{A6}$$

Optimal Tax rate: $\tau = g_\alpha$ where,

$$v'(\tau) = \mu_\alpha + \frac{q}{1-q}\theta\mu_\beta\frac{dc_1}{d\tau}.$$

A.2 Solution for the case of Bailout and CBDC.

$$V(\Psi_s^j;\hat{\pi}_s) = \max_{\{c_{1s}^j, c_{2s}^j\}} \quad (1-\theta)\left[\hat{\pi}_s\left[\int_{\underline{\rho}}^{\rho^C} u\left(\rho_i c_{1s}^j\right) + \int_{\rho^C}^{\bar{\rho}} u\left(\rho_i c_{1s}^j\right)\right] F(\rho_i) + (1-\hat{\pi}_s)u\left(c_{2s}^j\right)\right],$$

subject to feasibility constraint,

$$(1-\theta)\left[\hat{\pi}_s c_{1s}^j + (1-\hat{\pi}_s)\frac{c_{2s}^j}{R}\right] = \Psi_s^j.$$

The Lagrangian for the problem is

$$\mathcal{L} = (1-\theta)\Bigg(\frac{\hat{\pi}_s (c_{1s}^j)^{1-\sigma}}{1-\sigma}\Bigg(\frac{(\rho^C-\underline{\rho})(\rho^C)^{1-\sigma}}{\bar{\rho}-\underline{\rho}}+\frac{(\bar{\rho}-\rho^C)^{2-\sigma}}{(2-\sigma)(\bar{\rho}-\underline{\rho})}\Bigg)+\frac{(1-\pi_s)(c_{2s}^j)^{1-\sigma}}{(1-\sigma)}\Bigg)$$
$$+\mu_s^j\left(\Psi_s^j-(1-\theta)\left(\hat{\pi}_s c_{1s}^j+(1-\hat{\pi}_s)\frac{c_{2s}^j}{R}\right)\right),$$

that gives the following first-order condition,

$$(c_{1s}^j)^{-\sigma}A = R(c_{2s}^j)^{-\sigma} = \mu_s^j, \tag{A7}$$

where,

$$A = \Bigg(\frac{(\rho^C-\underline{\rho})(\rho^C)^{1-\sigma}}{\bar{\rho}-\underline{\rho}}+\frac{(\bar{\rho}-\rho^C)^{2-\sigma}}{(2-\sigma)(\bar{\rho}-\underline{\rho})}\Bigg).$$

$$(c_{1s}^j)^{-\sigma}A = R(c_{2s}^j)^{-\sigma},$$

$$c_{1s}^j = \left(\frac{A}{R}\right)^{1/\sigma}(c_{2s}^j),$$

$$c_{2s}^j = \frac{\Psi_s^j}{(1-\theta)\left(\pi^s\left(\frac{A}{R}\right)^{\frac{1}{\sigma}}+\frac{(1-\pi^s)}{R}\right)}, \tag{A8}$$

$$c_{1s}^j = \left(\frac{A}{R}\right)^{\frac{1}{\sigma}}\frac{\Psi_s^j}{(1-\theta)\left(\pi^s\left(\frac{A}{R}\right)^{\frac{1}{\sigma}}+\frac{(1-\pi^s)}{R}\right)}. \tag{A9}$$

Bailout Policy:

$$b^j = b+\theta[c_1^j-\bar{c}_1];$$

$$\Psi_\beta^j = 1-\tau-\theta\bar{c}_1+b.$$

With CBDC intermediary j will choose c_i^j to solve ,

$$\max_{\{c_1^j\}}\ \theta\left[\left[\int_{\underline{\rho}}^{\rho^C}u\left(\rho_i c_1^j\right)+\int_{\rho^C}^{\bar{\rho}}u\left(\rho_i c_1^j\right)\right]F(\rho_i)\right]+(1-q)V(\Psi_\alpha^j;\hat{\pi}_\alpha)+qV(\Psi_\beta^j;\hat{\pi}_\beta),$$

subject to

$$\Psi_\alpha^j = 1-\tau-\theta c_1^j,$$

$$\Psi_\beta^j = 1-\tau-\theta\bar{c}_1+b.$$

$$L = \Bigg[\frac{\theta(c_1^j)^{1-\sigma}}{1-\sigma}\Bigg(\frac{(\rho^C-\underline{\rho})(\rho^C)^{1-\sigma}}{\bar{\rho}-\underline{\rho}}+\frac{(\bar{\rho}-\rho^C)^{2-\sigma}}{(2-\sigma)(\bar{\rho}-\underline{\rho})}\Bigg)+(1-q)V(\Psi_\alpha^j;\hat{\pi}_\alpha)+qV(\Psi_\beta^j;\hat{\pi}_\beta),$$

Taking the FOC of the problem we have,

$$\frac{dL}{dc_1^j} = (c_1^j)^{-\sigma} A = (1-q)\mu_\alpha^j,$$

$$(c_1^j)^{-\sigma} = (1-q)(c_{1\alpha}^j)^{-\sigma},$$

$$c_1^j = \frac{c_{1\alpha}^j}{(1-q)^{1/\sigma}}.$$

The optimal value of $c_{1\alpha}^j$ is given by and using value of $\hat{\pi}_\alpha$,

$$c_{1\alpha}^j = \left(\frac{A}{R}\right)^{\frac{1}{\sigma}} \left[\frac{1-\tau-\theta c_1^j}{(\pi-\theta)\left(\frac{A}{R}\right)^{\frac{1}{\sigma}} + \frac{(1-\pi)}{R}}\right].$$

$$c_1^j = \frac{1}{(1-q)^{1/\sigma}} \left(\frac{A}{R}\right)^{\frac{1}{\sigma}} \frac{1-\tau-\theta c_1^j}{(\pi-\theta)\left(\frac{A}{R}\right)^{\frac{1}{\sigma}} + \frac{(1-\pi)}{R}}.$$

$$c_1^j = \frac{1-\tau}{\frac{(\pi-\theta)\left(\frac{A}{R}\right)^{\frac{1}{\sigma}} + \frac{(1-\pi)}{R}}{\left(\frac{A}{R(1-q)}\right)^{1/\sigma}} + \theta}.$$

Optimal Tax rate: $\tau = g_\alpha$ where,

$$v'(\tau) = \mu_\alpha + \frac{q}{1-q}\theta\mu_\beta\frac{dc_1}{d\tau}.$$

A.3 Solution for the case of No Bailout and No CBDC.

Similar to previous case with no CBDC, assuming uniform distribution,

$$\mathcal{L} = (1-\theta)\left[\hat{\pi}_s\left(\frac{(\bar{\rho}-\underline{\rho})^{1-\sigma}\left(c_{1s}^j\right)^{1-\sigma}}{(2-\sigma)(1-\sigma)}\right) + (1-\hat{\pi}_s)\frac{\left(c_{2s}^j\right)^{1-\sigma}}{1-\sigma}\right] + \mu_s^j\left[\Psi_s^j - (1-\theta)\left[\hat{\pi}_s c_{1s}^j + (1-\hat{\pi}_s)\frac{c_{2s}^j}{R}\right]\right]$$

F.O.C with respect to c_{1s} and c_{2s} and the optimal solution to c_{1s} and c_{2s} is given by (A1), (A2), (A3) and (A4),

No bailout: $b = 0$.

With no CBDC intermediary j will choose c_i^j to solve ,

$$\max_{\{c_1^j\}} \quad \theta\left[\int_{\underline{\rho}}^{\bar{\rho}} u\left(\rho_i c_1^j\right) F(\rho_i) + (1-q)V(\Psi_\alpha^j; \hat{\pi}_\alpha) + qV(\Psi_\beta^j; \hat{\pi}_\beta)\right],$$

F.O.C is given by,

$$\frac{(\bar{\rho}-\underline{\rho})^{1-\sigma}(c_1^j)^{-\sigma}}{(2-\sigma)} = (1-q)\mu_\alpha + q\mu_\beta \tag{A10}$$

Combining (A1), (A2) and (A10),

$$\left(c_1^j\right)^{-\sigma} = (1-q)\left(c_{1\alpha}^j\right)^{-\sigma} + q\left(c_{1\beta}^j\right)^{-\sigma},$$

Using (A3) and (A4),

$$\left(\frac{1-\tau-\theta c_1^j}{c_1^j}\right)^\sigma = (1-q)\left[(\pi-\theta) + \frac{(1-\pi)}{R}\left(\frac{R(2-\sigma)}{(\bar{\rho}-\underline{\rho})^{1-\sigma}}\right)^{\frac{1}{\sigma}}\right]^\sigma + q\left[(\pi)(1-\theta) + \frac{(1-\pi)(1-\theta)}{R}\left(\frac{R(2-\sigma)}{(\bar{\rho}-\underline{\rho})^{1-\sigma}}\right)^{\frac{1}{\sigma}}\right]^\sigma;$$

$$c_1^j = \frac{1-\tau}{\left[(1-q)\left[(\pi-\theta) + \frac{(1-\pi)}{R}\left(\frac{R(2-\sigma)}{(\bar{\rho}-\underline{\rho})^{1-\sigma}}\right)^{\frac{1}{\sigma}}\right]^\sigma + q\left[(\pi)(1-\theta) + \frac{(1-\pi)(1-\theta)}{R}\left(\frac{R(2-\sigma)}{(\bar{\rho}-\underline{\rho})^{1-\sigma}}\right)^{\frac{1}{\sigma}}\right]^\sigma\right]^{\frac{1}{\sigma}} + \theta}. \tag{A11}$$

We know optimal tax rate is given by,

$$v'(\tau) = u'(c_1^j),$$

$$\tau = [\delta]^{\frac{1}{\sigma}}\left(c_1^j\right) \tag{A12}$$

Combining (A11) and (A12),

$$c_1^j = \left[\left[(1-q)\left[(\pi-\theta) + \frac{(1-\pi)}{R}\left(\frac{R(2-\sigma)}{(\bar{\rho}-\underline{\rho})^{1-\sigma}}\right)^{\frac{1}{\sigma}}\right]^\sigma + q\left[(\pi)(1-\theta) + \frac{(1-\pi)(1-\theta)}{R}\left(\frac{R(2-\sigma)}{(\bar{\rho}-\underline{\rho})^{1-\sigma}}\right)^{\frac{1}{\sigma}}\right]^\sigma\right]^{\frac{1}{\sigma}} + \theta + \delta^{1/\sigma}\right]^{-1} \tag{A13}$$

A.4 Solution for the case of No Bailout and CBDC.

Similar to previous case of CBDC, assuming uniform distribution, Lagrangian is given by,

$$L = (1-\theta)\left[\frac{\hat{\pi}_s (c_{1s}^j)^{1-\sigma}}{1-\sigma}\left(\frac{(\rho^C - \underline{\rho})(\rho^C)^{1-\sigma}}{\bar{\rho}-\underline{\rho}} + \frac{(\bar{\rho}-\rho^C)^{2-\sigma}}{(2-\sigma)(\bar{\rho}-\underline{\rho})}\right) + \frac{(1-\pi_s)(c_{2s}^j)^{1-\sigma}}{(1-\sigma)}\right] \\ + \mu_s^j \left(\Psi_s^j - (1-\theta)\left(\hat{\pi}_s c_{1s}^j + (1-\hat{\pi}_s)\frac{c_{2s}^j}{R}\right)\right),$$

FOCs and the optimal value of c_{1s}^j and c_{2s}^j is given by (A7), (A8) and (A9).

No bailout: $b = 0$.

With no CBDC intermediary j will choose c_i^j to solve ,

$$\max_{\{c_1^j\}} \ \theta \left[\left[\int_{\underline{\rho}}^{\rho^C} u\left(\rho_i c_1^j\right) + \int_{\rho^C}^{\bar{\rho}} u\left(\rho_i c_1^j\right)\right] F(\rho_i)\right] + (1-q)V(\Psi_\alpha^j; \hat{\pi}_\alpha) + qV(\Psi_\beta^j; \hat{\pi}_\beta),$$

subject to

$$\Psi_\alpha^j = 1 - \tau - \theta c_1^j,$$

$$\Psi_\beta^j = 1 - \tau - \theta c_1^j.$$

The Lagrangian is given by,

$$\mathcal{L} = \left[\frac{\theta (c_1^j)^{1-\sigma}}{1-\sigma}\left(\frac{(\rho^C - \underline{\rho})(\rho^C)^{1-\sigma}}{\bar{\rho}-\underline{\rho}} + \frac{(\bar{\rho}-\rho^C)^{2-\sigma}}{(2-\sigma)(\bar{\rho}-\underline{\rho})}\right) + (1-q)V(1-\tau-\theta c_1^j; \hat{\pi}_\alpha) \\ + qV(1-\tau-\theta c_1^j; \hat{\pi}_\beta),$$

FOC with respect to c_1^j will give us

$$Au'(c_1^j) = (1-q)\mu_\alpha + q\mu_\beta \tag{A14}$$

$$\left(\frac{1-\tau-\theta c_1^j}{c_1^j}\right)^\sigma = (1-q)\left[(\pi-\theta) + \frac{(1-\pi+\theta)}{R}\left(\frac{R}{A}\right)^{\frac{1}{\sigma}}\right]^\sigma + \\ q\left[(\pi)(1-\theta) + \frac{(1-\pi)(1-\theta)}{R}\left(\frac{R}{A}\right)^{\frac{1}{\sigma}}\right]^\sigma$$

$$\frac{1-\tau}{c_1^j} = \left[(1-q)\left[(\pi-\theta) + \frac{(1-\pi+\theta)}{R}\left(\frac{R}{A}\right)^{\frac{1}{\sigma}}\right]^{\sigma} + q\left[(\pi)(1-\theta) + \frac{(1-\pi)(1-\theta)}{R}\left(\frac{R}{A}\right)^{\frac{1}{\sigma}}\right]^{\sigma}\right]^{\frac{1}{\sigma}} + \theta$$

$$c_1^j = \frac{1-\tau}{\left[(1-q)\left[(\pi-\theta) + \frac{(1-\pi)}{R}\left(\frac{R}{A}\right)^{\frac{1}{\sigma}}\right]^{\sigma} + q\left[(\pi)(1-\theta) + \frac{(1-\pi)(1-\theta)}{R}\left(\frac{R}{A}\right)^{\frac{1}{\sigma}}\right]^{\sigma}\right]^{\frac{1}{\sigma}} + \theta} \tag{A15}$$

We know optimal tax rate is given by,

$$v'(\tau) = u'(c_1^j),$$

$$\tau = [\delta]^{\frac{1}{\sigma}}(c_1^j); \tag{A16}$$

$$c_1^j = \frac{1}{\left[(1-q)\left[(\pi-\theta) + \frac{(1-\pi+\theta)}{R}\left(\frac{R}{A}\right)^{\frac{1}{\sigma}}\right]^{\sigma} + q\left[(\pi)(1-\theta) + \frac{(1-\pi)(1-\theta)}{R}\left(\frac{R}{A}\right)^{\frac{1}{\sigma}}\right]^{\sigma}\right]^{\frac{1}{\sigma}} + \theta + \delta^{1/\sigma}}$$

A.5 Proof of Proposition 1

In this section, we will prove the rankings obtained under the Proposition 1. In order to do so, we will proceed in parts, taking different cases and finding the rankings between them, and then combining them to get the final rankings.

First, we will compare between Φ^{NN} and Φ^{BN}. We will show that $\Phi^{NN} < \Phi^{BN}$ holds for all $q > 0$

Proof. To prove it, note that given the multipliers μ_α^{NN} and μ_β^{NN} are always strictly positive, thus we can write

$$(1-q) + q\frac{\mu_\beta^{NN}}{\mu_\alpha^{NN}} > (1-q)$$

which we can write as

$$\frac{(1-q)\mu_\alpha^{NN} + q\mu_\beta^{NN}}{\mu_\alpha^{NN}} > \frac{(1-q)\mu_\alpha^{BN}}{\mu_\alpha^{BN}}$$

Using the FOC in Equation 3, and in Equation (A10) we can write

$$\frac{\frac{(\bar{\rho}-\rho)^{1-\sigma}u'(c_1^{NN})}{(2-\sigma)}}{Ru'(c_{2\alpha}^{NN})} > \frac{\frac{(\bar{\rho}-\rho)^{1-\sigma}u'(c_1^{BN})}{(2-\sigma)}}{Ru'(c_{2\alpha}^{BN})}$$

$$\implies \frac{u'(c_1^{NN})}{u'(c_{2\alpha}^{NN})} > \frac{u'(c_1^{BN})}{u'(c_{2\alpha}^{BN})}$$

applying homotheticity of preferences, we can write the above inequality as

$$\frac{c_1^{NN}}{c_{2\alpha}^{NN}} < \frac{c_1^{BN}}{c_{2\alpha}^{BN}} \tag{A17}$$

Now, using the definitions of the resource constraints in the two states, given in Equations (9) and (10), together with the government spending in the two states given by Equations (11) and (12) along with the fact that for the given CRRA utility we have

$$c_{2s}^j = \left(\frac{R(2-\sigma)}{(\bar{\rho}-\underline{\rho})^{1-\sigma}} \right)^{\frac{1}{\sigma}} c_{1s}^j$$

the resource constraint can be written for any state as

$$\theta c_1 + \left[(1-\theta) \left(\hat{\pi}_\alpha R^{\left(\frac{\sigma-1}{\sigma}\right)} \left(\frac{(\bar{\rho}-\underline{\rho})^{1-\sigma}}{(2-\sigma)} \right)^{\frac{1}{\sigma}} + 1 - \hat{\pi}_\alpha \right) \right] \frac{c_{2\alpha}}{R} + g_\alpha = 1 \tag{A18}$$

Using the definition of Φ and the fact that $g_\alpha = \tau$, we have

$$\Phi^{-1} = \frac{1-g_\alpha}{\theta c_1} = 1 + \frac{(1-\theta)}{\theta} \left(\hat{\pi}_\alpha R^{\left(\frac{\sigma-1}{\sigma}\right)} \left(\frac{(\bar{\rho}-\underline{\rho})^{1-\sigma}}{(2-\sigma)} \right) + 1 - \hat{\pi} \right) \frac{1}{R} \left(\frac{c_{2\alpha}}{c_1} \right) \tag{A19}$$

which along with Equation (A17) implies

$$\Phi^{NN} < \Phi^{BN}$$

□

Next, we take the cases under the CBDC regime and compare Φ^{NC} and Φ^{BC}. We will proceed similarly as in the proof for the previous case, using Equations A7 and A14 together with the homotheticity of preferences and the resource constraint.We assert that $\Phi^{NC} < \Phi^{NN}$ holds for all $q > 0$. In order to show this, we will use a contradiction.

Proof.

$$\Phi^{NC} = \frac{\theta c_1^{NC}}{1-\tau^{NC}},$$

where,

$$\tau^{NC} = \delta^{1/\sigma} c_1^{NC}.$$

$$\Phi^{NN} = \frac{\theta c_1^{NN}}{1-\tau^{NN}},$$

where,

$$\tau^{NN} = \delta^{1/\sigma} c_1^{NN}.$$

$$c_1^{NN} < or > c_1^{NC} implies$$

$$\Phi^{NN} < or > \Phi^{NC}$$

$$c_1^{NN} = \frac{1}{\left[(1-q)\left[(\pi-\theta)+\frac{(1-\pi+\theta)}{R}\left(\frac{R(2-\sigma)}{(\bar{\rho}-\underline{\rho})^{1-\sigma}}\right)^{\frac{1}{\sigma}}\right]^{\sigma}+q\left[(\pi)(1-\theta)+\frac{(1-\pi)(1-\theta)}{R}\left(\frac{R(2-\sigma)}{(\bar{\rho}-\underline{\rho})^{1-\sigma}}\right)^{\frac{1}{\sigma}}\right]^{\sigma}\right]^{\frac{1}{\sigma}}+\theta+\delta^{1/\sigma}}$$

$$c_1^{NC} = \frac{1}{\left[(1-q)\left[(\pi-\theta)+\frac{(1-\pi+\theta)}{R}\left(\frac{R}{A}\right)^{\frac{1}{\sigma}}\right]^{\sigma}+q\left[(\pi)(1-\theta)+\frac{(1-\pi)(1-\theta)}{R}\left(\frac{R}{A}\right)^{\frac{1}{\sigma}}\right]^{\sigma}\right]^{\frac{1}{\sigma}}+\theta+\delta^{1/\sigma}}$$

where, $A = \left(\frac{(\rho^C-\underline{\rho})(\rho^C)^{1-\sigma}}{\bar{\rho}-\underline{\rho}} + \frac{(\bar{\rho}-\rho^C)^{2-\sigma}}{(2-\sigma)(\bar{\rho}-\underline{\rho})}\right)$. We have to check whether

$$\frac{2-\sigma}{(\bar{\rho}-\underline{\rho})^{1-\sigma}} > or < \frac{1}{A}$$

Suppose that $\frac{2-\sigma}{(\bar{\rho}-\underline{\rho})^{1-\sigma}} < \frac{1}{\left(\frac{(\rho^C-\underline{\rho})(\rho^C)^{1-\sigma}}{\bar{\rho}-\underline{\rho}} + \frac{(\bar{\rho}-\rho^C)^{2-\sigma}}{(2-\sigma)(\bar{\rho}-\underline{\rho})}\right)}$

$$\left(\frac{(\rho^C-\underline{\rho})(\rho^C)^{1-\sigma}}{\bar{\rho}-\underline{\rho}} + \frac{(\bar{\rho}-\rho^C)^{2-\sigma}}{(2-\sigma)(\bar{\rho}-\underline{\rho})}\right) < \frac{(\bar{\rho}-\underline{\rho})^{1-\sigma}}{2-\sigma},$$

$$\left(\underbrace{\frac{(\rho^C-\underline{\rho})(\rho^C)^{1-\sigma}}{1}}_{\text{positive}} + \frac{(\bar{\rho}-\rho^C)^{2-\sigma}}{(2-\sigma)}\right) < \frac{(\bar{\rho}-\underline{\rho})^{2-\sigma}}{2-\sigma},$$

$$(\bar{\rho}-\rho^C)^{2-\sigma} < (\bar{\rho}-\underline{\rho})^{2-\sigma},$$

$$\implies \underline{\rho} < \rho^C.$$

This is indeed true by our assumption, which means that

$$c_1^{NN} > c_1^{NC};$$

$$\Phi^{NN} > \Phi^{NC}.$$

as required. □

Next, we have to show that $\Phi^{BC} >$ or $< \Phi^{NN}$ holds.

Proof. To prove it, note that given the multipliers μ_α^{NN} and μ_β^{NN} are always strictly positive, thus we can write

$$(1-q) + q\frac{\mu_\beta^{NN}}{\mu_\alpha^{NN}} > (1-q)$$

which we can write as

$$\frac{(1-q)\mu_\alpha^{NN} + q\mu_\beta^{NN}}{\mu_\alpha^{NN}} > \frac{(1-q)\mu_\alpha^{BC}}{\mu_\alpha^{BC}}$$

Using (19), (26) and F.O.C

$$\frac{u'(c_1^{NN})}{u'(c_{1\alpha}^{NN})} > \frac{u'(c_1^{BC})}{u'(c_{1\alpha}^{BC})}$$

$$\frac{c_1^{NN}}{c_{1\alpha}^{NN}} < \frac{c_1^{BC}}{c_{1\alpha}^{BC}}$$

$$\frac{c_{1\alpha}^{BC}}{c_1^{BC}} < \frac{c_{1\alpha}^{NN}}{c_1^{NN}}$$

Now, using the definitions of the resource constraints in the two states, given in equations (9) and (10), together with the government spending in the two states given by equations (11) and (12) along with the fact that for the given CRRA utility we have

$$c_{2\alpha}^{NN} = \left(\frac{R(2-\sigma)}{(\bar{\rho}-\underline{\rho})^{1-\sigma}}\right)^{\frac{1}{\sigma}} c_{1\alpha}^{NN}$$

$$c_{2\alpha}^{BC} = \left(\frac{R}{A}\right)^{\frac{1}{\sigma}} c_{1\alpha}^{BC}$$

where as proved above, $\left(\frac{R(2-\sigma)}{(\bar{\rho}-\underline{\rho})^{1-\sigma}}\right)^{\frac{1}{\sigma}} < \left(\frac{R}{A}\right)^{\frac{1}{\sigma}}$ the resource constraint can be written for any state as

$$\Phi^{-1} = \frac{1-g_\alpha}{\theta c_1^{NN}} = 1 + \left[(1-\theta)\left(\hat{\pi}_\alpha + (1-\hat{\pi}_\alpha)\left(\frac{R(2-\sigma)}{(\bar{\rho}-\underline{\rho})^{1-\sigma}}\right)^{\frac{1}{\sigma}}\left(\frac{1}{R}\right)\right)\right]\frac{c_{1\alpha}^{NN}}{\theta c_1^{NN}}$$

Similarly, for BC,

$$\Phi^{-1} = \frac{1-g_\alpha}{\theta c_1^{BC}} = 1 + \left[(1-\theta)\left(\hat{\pi}_\alpha + (1-\hat{\pi}_\alpha)\left(\frac{R}{A}\right)^{\frac{1}{\sigma}}\left(\frac{1}{R}\right)\right)\right]\frac{c_{1\alpha}^{BC}}{\theta c_1^{BC}};$$

$$\Phi^{NN} < \text{ or } > \Phi^{BC}$$

□

Based on the figures we determine the final rankings.

B Taxes

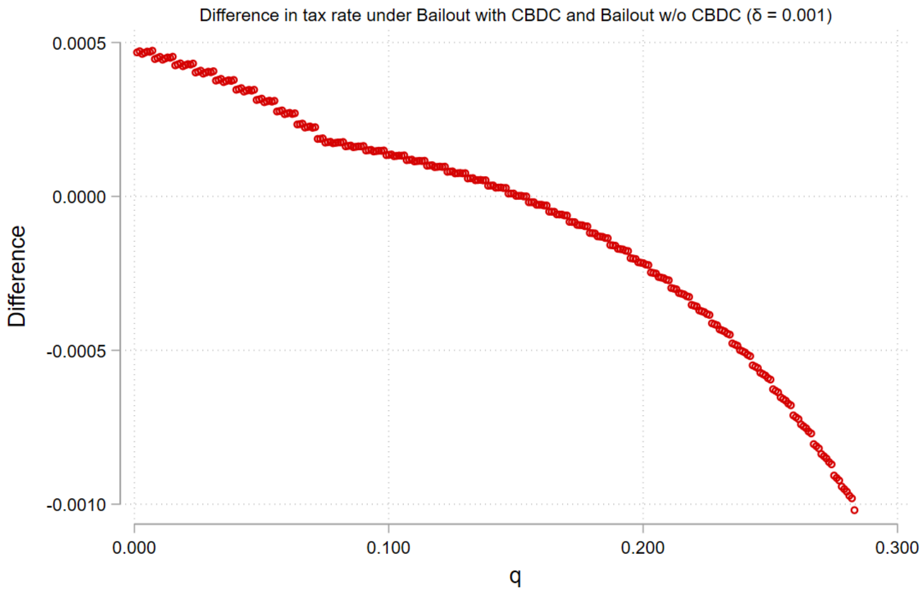

Figure A1: τ^{BC} vs τ^{BN}

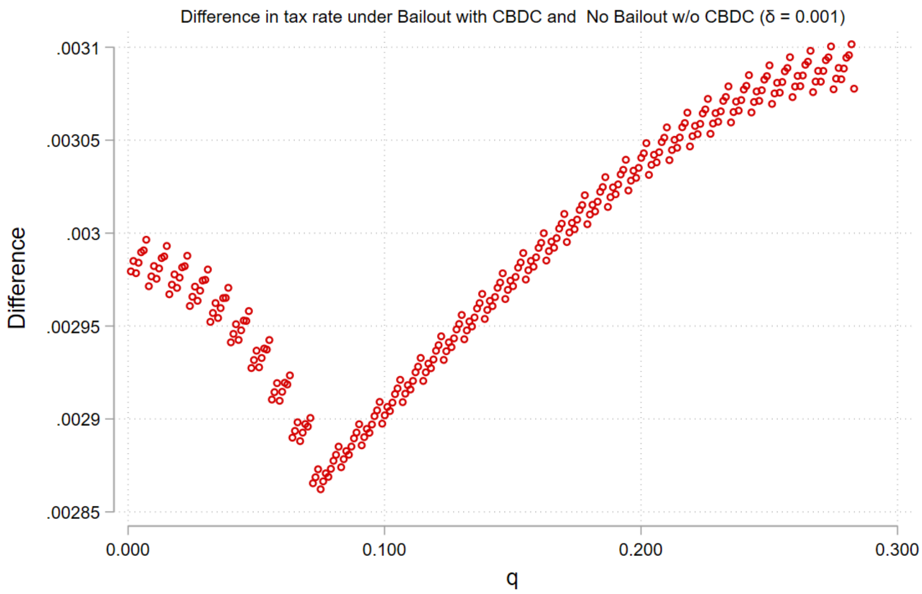

Figure A2: τ^{BC} vs τ^{NN}

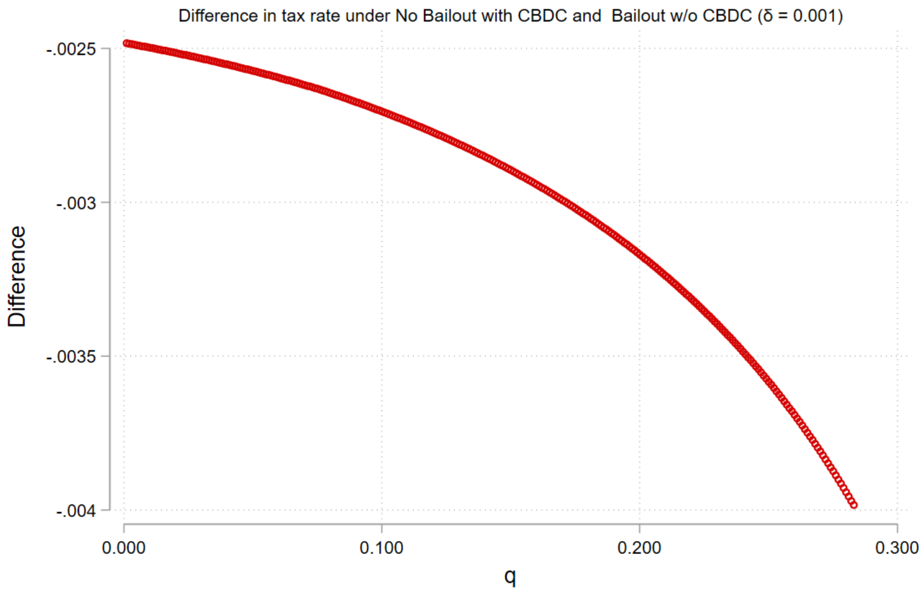

Figure A3: τ^{NC} vs τ^{BN}

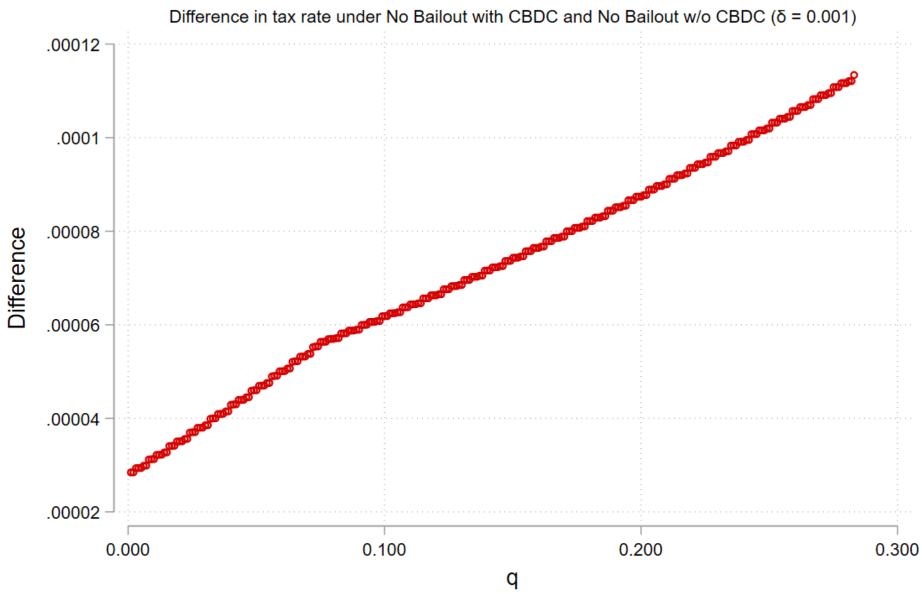

Figure A4: τ^{NC} vs τ^{NN}

C Welfare

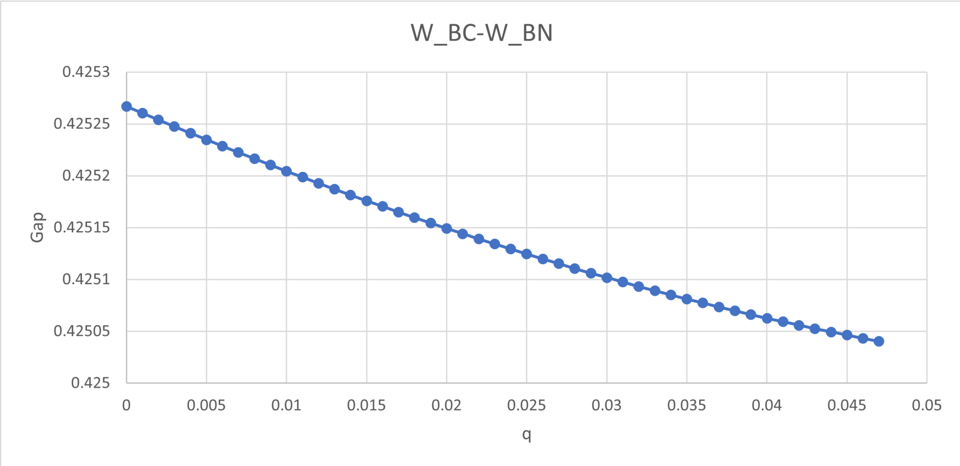

Figure A5: Welfare under Bailout policy

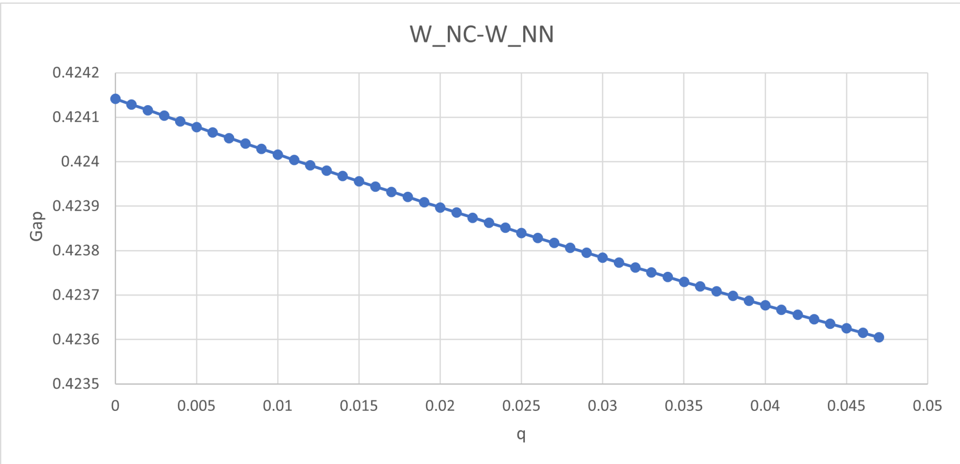

Figure A6: Welfare under No-Bailouts policy

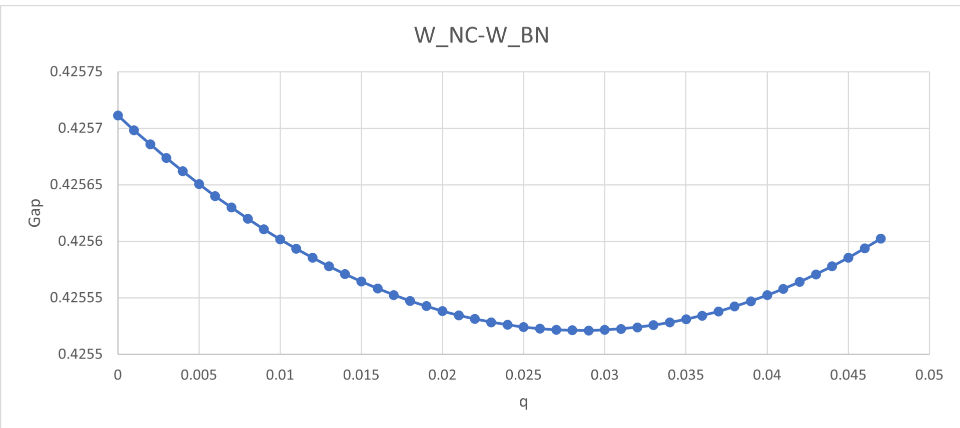

Figure A7: Welfare under W^{NC} and W^{BN}

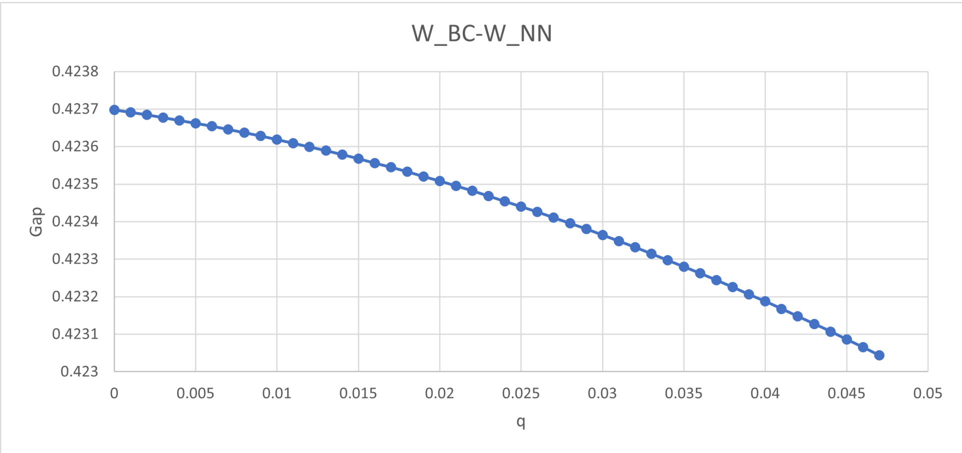

Figure A8: Welfare under W^{BC} and W^{NN}