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Central Bank Digital Currency, Bank Disintermediation, and Financial Crises

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Abstract

The development of a Central Bank Digital Currency (CBDC) raises concerns about potential bank disintermediation. Especially during financial crises, pessimistic consumers may shift from bank deposits to cash that as a safer store of value. The introduction of a CBDC, viewed as a superior substitute for cash, could amplify this effect. Using the Diamond-Dybvig model with public money as a store of value and a Beta distribution to capture belief dispersion during crises, this thesis analyzes how consumer beliefs drive disintermediation and its implications for financial stability, monetary policy, and the banking sector.

Keywords: financial crisis, central bank, cash, central bank digital currency, bank disintermediation

1 Introduction

In the last few years, the financial sector has experienced significant changes, particularly with the emergence of cryptocurrencies and digital payments. These developments have decreased the role of physical cash and increased the need for central banks to adapt to the digitizing landscape.

In response, the European Central Bank is developing a central bank digital currency. The ECB argues that a CBDC is essential to ensure continued access to central bank money, which is a public good that anchors trust and stability in the financial system. A well-designed CBDC could offer several benefits, including fostering competition with private bank deposits, preserving financial stability, and increasing trust in the currency. However, it also risks financial market structures disrupting commercial banking by reducing bank deposits, limiting lending capacity, and affecting monetary policy.

A CBDC perceived as a safer store of value could lead to bank disintermediation, particularly during financial crises, as consumers transfer their funds from deposits to CBDC (Krogstrup, Sangill, Sicard, 2024).

This thesis investigates the role of CBDC as a store of value during financial crises, drawing on the European Central Bank Working Paper Series titled “Public Money as a Store of Value, Heterogeneous Beliefs, and Banks: Implications of CBDC” by Manuel A. Muñoz and Oscar Soons (2022) that adapts the Diamond and Dybvig model to accommodate heterogeneous beliefs about the probability of bank runs to understand the effects of CBDCs as a store of value. By incorporating an equilibrium selection rule that accounts for the probability of bank runs, the model examines how consumers allocate wealth between CBDCs and bank deposits, as well as how banks adjust their portfolios in response. The representative bank offers a contract that maximizes the expected utility of its depositors, analyzing consumer preferences for cash versus deposits. the expected utility from holding cash must exceed that of deposits for cash to be preferred.

The original model assumes that banks offer contracts that maximize the expected utility of depositors, focusing on consumer decisions to hold cash or make deposits. However, due to the technological advantages of reserves, banks do not offer deposit contracts that are inferior to holding cash.

The model is further adjusted to account for variations in individuals' beliefs about the likelihood of a bank run. These beliefs follow a distribution, reflecting differing consumer perceptions of the probability of a run. As a result, the bank offers a single deposit contract designed to maximize the average expected utility of all depositors, considering this diversity of beliefs.

The analysis incorporates higher standard deviation (σ) distribution to represent the greater dispersion of consumer beliefs during financial crises. This dispersion reflects economic uncertainty, with consumer expectations polarizing—some holding highly optimistic views, while others adopt highly pessimistic ones. Consequently, a larger proportion of consumers tend to hold low expectations.

The analysis is motivated by evidence from the Euro Area during the COVID-19 pandemic, when the demand for cash as a store of value surged, leading individuals to increase their demand for high-denomination banknotes despite the rise of cashless payments. Similar trends were observed during the 2008 financial crisis and the Y2K crisis, when increases in cash demand were noted.

It is crucial for the European Central Bank to design a well-structured Central Bank Digital Currency that maximizes its potential benefits while minimizing its drawbacks, thus promoting financial stability. European central banks have been working on a CBDC design aimed at mitigating any potential bank disintermediation and addressing the extent to which CBDCs are used as a store of value. They have proposed measures to limit CBDC holdings and avoid remuneration to ensure that CBDCs complement rather than replace existing financial instruments. Nonetheless, uncertainties remain regarding the impact of CBDCs on bank deposits, lending, and overall financial stability.

The primary objective of this thesis is to understand whether, during financial crises, a Central Bank Digital Currency would be perceived as a safer and more reliable store of value than bank deposits and the implications for financial stability, monetary policy, and the banking sector.

Literature Review

This thesis builds on the work of Manuel A. Muñoz and Oscar Soons (Public Money as a Store of Value, Heterogeneous Beliefs, and Banks: Implications of CBDC,2023), along with other key studies, to explore the complex effects of Central Bank Digital Currencies. Various research has shown that, though CBDCs are a safe, state-backed asset, they might reduce systemic risks but could highly be deposit-diverting for banks and reduce their lending ability (Andolfatto, 2020; Fernández-Villaverde et al., 2020). Empirical studies, such as those by Bech et al. (2018) and Jobst and Stix (2017), confirm that demand for secure assets surges during crises, emphasizing the importance of policies to manage liquidity risks for banks.

Consumer behavior is thus the decisive force that determines the shape taken by the CBDC influences. Diamond and Dybvig (1983) show how bank runs and liquidity crises are driven by expectations and belief dispersion. More recently, Armantier et al. (2021), reveal that uncertainty during events like the COVID-19 pandemic polarizes consumer expectations, increasing demand for safer assets like CBDCs. This suggests that public perceptions of safety will strongly influence CBDC adoption and its impact on traditional banks.

According to Krogstrup et al. (2024), CBDCs also present opportunities for monetary policy, such as improving liquidity control and enabling negative interest rates, as discussed by. However, excessive dependence on CBDC could weaken the traditional role of banks in monetary transmission. Their design is therefore crucial, with Ashworth and Goodhart (2020) emphasizing limits on holdings and complementarity with existing systems to mitigate risks.

Historical crises, such as the 2008 financial crisis and the COVID-19 pandemic, underscore precautionary shifts in consumer preferences towards safer assets, as highlighted by Baker et al. (2016). These trends suggest that CBDCs could play a significant role during future crises, but they also raise questions about financial inclusion, innovation, and the centralization of financial power within central banks, as explored by Holmström and Tirole (1997). The thesis ultimately emphasizes that careful design and policy measures are essential to harness the benefits of CBDCs while managing their risks.

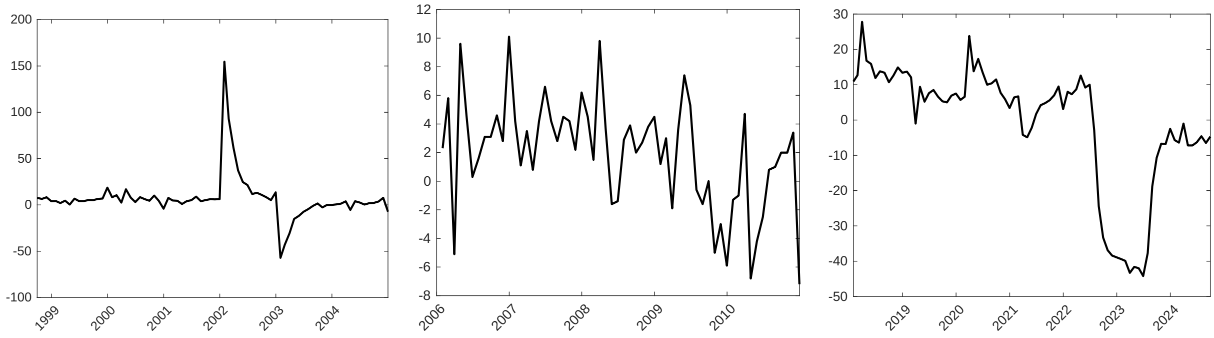
2 Empirical evidence

During times of crises, consumers often transfer resources to safer assets like government bonds and cash, significantly increasing cash demand as a secure, liquid payment option.

Over the past 30 years, the amount of cash in circulation worldwide has grown substantially. For major currencies, cash holdings have risen at a rate that outpaces GDP growth (Jobst and Stix, 2017; Rösl and Seitz, 2021), reflecting its importance during crises.

The COVID-19 pandemic exemplifies this pattern. Even though cashless payments increased during the pandemic, the demand for cash surged to unprecedented levels worldwide. High-denomination banknotes, particularly 50 and 100 notes, accounted for nearly 90 percent of the volume of banknotes issued during this time. In contrast, the issuance of low-value banknotes declined, indicating a reduced use of cash for daily consumer spending and in-person transactions. This dynamic highlights that precautionary motives and the desire for a secure store of value drove this spike in demand (Reserve Bank of Australia, 2021).

Historical events further illustrate this behavior. Crises such as the Y2K crisis, the insolvency of Lehman Brothers in October 2008, and the COVID-19 pandemic have all triggered increases in cash demand as it safeguards against potential disruptions in the financial system. Figure 1 represent the increase in cash demand during these respective crises.



(a) Y2K crisis (b) 2008 Financial Crisis (c) COVID-19 pandemic

Figure 1: Comparison of crises through different time periods.

In the paper "How Economic Crises Affect Inflation Beliefs: Evidence from the COVID-19 pandemic" by Armantier et al., the authors analyze data from the New York Fed's Survey of Consumer Expectations (SCE) to examine how the COVID-19 pandemic affected US households; beliefs about inflation, including their expectations, uncertainty, and levels of disagreement. The study reveals that the pandemic caused an immediate and significant increase in inflation uncertainty. This increase in disagreement indicates a growing polarization, with more respondents shifting toward extreme inflation expectations.

This research illustrates how variations in beliefs intensify during financial crises. Increased uncertainty results in differing interpretations of economic conditions, government actions, and possible recovery scenarios, leading to heightened belief divergence. Several factors, such as access to information, financial literacy, and individual risk perceptions, contribute to this polarization. Some consumers anticipate a swift recovery, while others fear a prolonged economic downturn.

Baker, Bloom, and Davis (2016) developed the Economic Policy Uncertainty Index (EPU), which measures the impact of uncertainty on beliefs and decision making. The index usually spikes during financial crises, highlighting increased belief dispersion. As policy uncertainty escalates, consumers' interpretations of the future diverge, resulting in polarized expectations about economic recovery and inflation. This growing uncertainty further amplifies belief divergence.

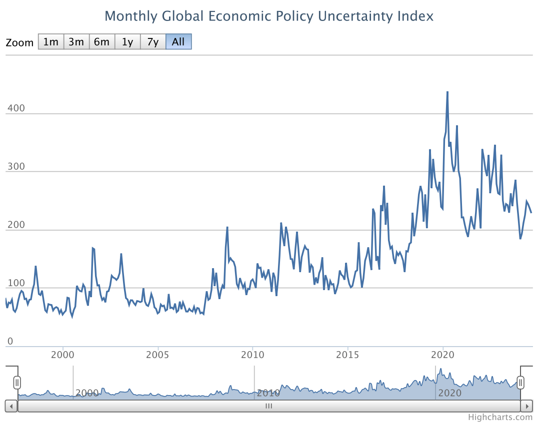


Figure 2: Economic Policy Uncertainty (EPU) Index

The EPU Index shows significant spikes in uncertainty during the 2008 financial crisis, the Y2K crisis, and the COVID-19 pandemic, indicating considerable belief dispersion during these turbulent periods.

3 The baseline Model

The baseline model is based on the Ennis and Keister (2006) model, which is an extension of Cooper and Ross (1998).

3.1 Environment

There is a [0,1] continuum of ex-ante identical consumers, each of whom lives for three periods t= 0,1,2. There is a single good that can be used for investment at t = 0 and consumption at t = 1 and t = 2. Each consumer has an endowment normalized to one in period 0. Consumer preferences are given by

$$U(c_1, c_2, \theta_i) = u(c_1 + \theta_i c_2)$$

where c_t is consumption on date t and the utility function u is strictly increasing, strictly concave, continuously differentiable, and satisfies Inada conditions. The idiosyncratic liquidity shock $\theta_i \in \{0, 1\}$ is realized at $t = 1$ and privately observed by each consumer. If $\theta_i = 0$, consumer i is impatient and wishes to consume only at the interim date, otherwise, the consumer is patient and values consumption at either the interim or final date. The probability that each consumer becomes impatient is constant and denoted by λ.

At $t = 0$, consumers can invest in two types of assets to transfer wealth to the future: retail central bank money (cash) and bank deposits. For simplicity, mixed portfolios are not allowed in this section.

A central bank that exchanges endowments for cash at $t = 0$ and $t = 1$ and provides consumption needed at both $t = 1$ and $t = 2$. The central bank does not incur direct storage costs, but for consumers, holding cash comes with a proportional cost $f > 0$, incurred whenever the cash is exchanged for consumption or any other asset [1]. As a result, a unit of cash has a net exchange value of $1 - f$ when used.

Consumers can pool their resources to form a bank that manages their endowments on their behalf. At $t = 1$, consumers pool resources into banks, which allocate deposits D_0 between

[1] This cost could correspond to resources spent to prevent theft before its conversion, as well as other storage and transportation costs

long-term investments x and central bank reserves $D_0 - x$. Only the bank can access these reserves, and their net exchange value per unit is normalized to one.

There are two types of long-term investment technology: good and bad. One unit invested in the good technology at $t = 0$ yields a return of R units upon maturity at $t = 2$ and has no liquidation value at $t = 1$ (Jacklin and Bhattacharya (1988); Haubrich and King (1990)).This technology provides a larger long-term return than cash or reserves, but it is less liquid because one unit invested in the bad technology yields no return.

It is assumed that the implied adverse selection problem prohibits consumers and the central bank from investing directly or indirectly in the long-term technology (Allen and Gale (1998)). The bank overcomes adverse selection by screening borrowers and identifying good investment opportunities in long-term technology.

So, in this economy, the bank has two functions: (i) act as an intermediary between consumers and investment opportunities, channeling the investment to the good technology while avoiding losses that would arise from a ”bad” investment (ii)provide insurance against idiosyncratic liquidity risk by offering demand deposits to consumers, allowing them to withdraw theirs funds when needed (Diamond and Dybvig (1983))

At $t = 0$, banks promise payments c_1^B for early withdrawals ($t = 1$) and c_2^B for later withdrawals ($t = 2$). If early withdrawals exceed the expected fraction λ, these promises cannot be fulfilled. The bank runs out of reserves and defaults, making a liquidation payment of c_R^B to all consumers attempting to withdraw at $t = 1$, while providing nothing to the rest.

The sequence of events in the baseline model occurs as follows. First, at $t = 0$, each consumer decides whether to hold cash or deposit their funds with the bank. On behalf of its depositors, the bank invests x in long-term technology and the remaining $D_0 - x$ in reserves. At $t = 1$, all impatient consumers attempt to withdraw their bank deposits. Patient consumers´

actions depend on (i) expectations on the other patient consumers´ actions and (ii) the terms of the deposits contract.

To simplify,the model focuses on cases where all consumers choose the same pure strategy. If a patient consumer believes others will not withdraw and the deposit contract is incentive-compatible ($c_B^2 \geq c_B^1$), she will leave her deposits in the bank and will not withdraw early. This behavior sustains a stable, non-run equilibrium. Conversely, if a consumer expects others to withdraw and the bank cannot pay c_B^1 to all depositors, she will also withdraw. If all patient consumers engage in this behavior, it results on a 'bad' bank run equilibrium. If the bank cannot meet the required withdrawals at $t = 1$, the deposit contract is said to be run-prone; this means that banks viability depends on the confidence of depositors. In contrast, if a bank has enough reserves to meet all of its short-term obligations, meeting all the required withdraws and ensuring that the payment at $t = 2$ is higher than at $t = 1$, the deposit is said run-proof as all consumers have a clear incentive to wait until $t = 2$.

To describe the optimal ex-ante deposit contract with the possibility of multiple equilibria, it is followed Cooper and Ross (1998) and Ennis Keister (2006) approaches. If both equilibria exist, a bank run occurs with an exogenous probability q, which is constant and independent of the bank´s reserves. $(1 - q)R > 1$, so waiting until $t = 2$ is more advantageous for consumers than withdrawing early at $t = 1$.

3.2 Optimal cash demand

To determine the demand for cash, it is considered a bank that behaves competitively,and so it offers a contract that maximizes the expected utility of its depositors. $\bar{\lambda}$ represents the fraction of depositors that can be served at the interim date under the given contract, y represents the amount of liquid reserves that the bank needs to hold at $t = 1$ to meet the demands of impatient depositors and y^l is the excess liquidity representing any reserves held above the minimum required to repay impatient depositors. The bank´s problem solves:

$$\max_{c_1^B, c_2^B, c_R^B, x, y, y^l} \left[(1 - q \cdot 1_{\{\bar{\lambda}<1\}}) \Big(\lambda u(c_1^B) + (1-\lambda) u(c_2^B) \Big) + q \cdot 1_{\{\bar{\lambda} <1} u(c_R^B) \right] \tag{A}$$

Subject to:

$$\begin{array}{llll} (1) & x + y + y^l = D_0, & (4) & c_R^B = y + y^l, \\ (2) & \lambda c_1^B = y, & (5) & 0 \leq c_1^B \leq c_2^B, \\ (3) & (1-\lambda) c_2^B = Rx + y^l, & (6) & c_1^B, c_2^B, x, y, y^l \geq 0. \end{array}$$

$1_{\bar{\lambda}<1}$ reflects the equilibrium selection rule, determining whether the good equilibrium (no bank run) or the bad equilibrium (bank run) occurs based on the fraction of impatient depositors, λ. A bank run occurs with probability q if $\bar{\lambda} < 1$ and with probability zero otherwise. The maximum fraction of depositors that can be served at $t = 1$ without causing a default is given by

$$\bar{\lambda} = \frac{y + y^l}{c_1^B} \tag{7}$$

Problem A states that the bank maximizes the expected utility of its depositors subject to the following constraints: (1) the bank invests all its deposits funding; (2) the bank must hold enough reserves to cover the $t = 1$ promised return, the bank knows that a fraction λ of depositors will have liquidity needs; (3) the final payment c_B^2 to depositors who wait until the final date is equal to the sum of the return on long-term lending Rx and the remaining reserves y^l after servicing all the early withdrawals; (4) in the event of a bank run the payment at $t = 1$ is equal to the liquidation value of the bank, which is the sum of y and y^l; (5) incentive compatibility constraint, which ensures that patient consumers have no incentive to withdraw at $t = 1$ in the absence of a bank run. The optimal deposit contract solves problem A by determining the payments (c_1^B, c_2^B, c_R^B) and the bank´s asset allocation (x, y) while considering the deposit funding level (D_0). As a result, this also determines the demand for cash, given by $(M_0 = 1 - D_0)$.

In the baseline model, $M_0 = 0, \forall q \in (0, 1)$. For any value of q, the bank,to maximize depositor utility, can always offer a run-proof contract. A deposit contract that relies only on reserves is the safest option because it eliminates the risk of a bank run. Even though it may offer lower returns compared to contracts that include long-term investments, it still provides more benefits than holding cash. Due to storage value costs and lack of liquidity insurance, cash holdings provide strictly lower utility than a run-proof deposit contract. Consequently, consumers never prefer to hold cash over deposits.

To further characterize the solution to the baseline model, we assume a utility function of the constant-relative-risk-aversion form:

$$u(c) = \frac{c^{1-\gamma}}{1-\gamma}, \quad \text{with } \gamma > 1, \tag{8}$$

where γ is the coefficient of relative risk aversion.

There exists a $\hat{q} \in (0, 1)$ such that: If $q > \hat{q}$, the optimal deposit contract is run-proof and if $q < \hat{q}$, the optimal deposit contract is run-prone.

When $q = 0$, a bank run is impossible, and the bank faces no default risk, allowing it to adopt a run-prone contract, maximizing returns by allocating most deposits to long-term loans (x) and keeping minimal reserves (y). As q rises, the risk of a bank run increases, prompting the bank to substitute long-term loans for reserves to increase liquidation value, reducing potential returns lowering the expected utility from the run-prone contract. Alternatively, the bank can offer a run-proof contract, ensuring sufficient reserves to avoid a run. The expected utility of a run-proof contract is constant and independent of q. For $q > \hat{q}$, the run-proof contract is optimal; for $q < \hat{q}$, the run-prone contract offers higher expected utility.

The baseline model fails to explain the evidence of preference for cash as a store of value under certain conditions. This because it assumes that every individual have the same expectation about the likelihood of a bank run and doesn't account for uncertainty or individual differences in beliefs. It predicts that people will always prefer bank deposits over cash since deposits offer better returns and liquidity insurance and the bank can always offer a deposit that maximizes consumers utility. This means the model can't explain why, in reality, some people hold cash as a safe store of value during uncertain times or crises.

4 Model

This section adapts the original model to take in account consumers´ heterogeneous beliefs about a bank run during financial crisis. Consumers´ beliefs, during financial crises, have a great dispersion.

4.1 Heterogeneous beliefs

The baseline model assumes that if multiple equilibria exist, a bank run occurs with an exogenous probability q that is known ex ante by all consumers at $t = 0$. Based on this information, they decide how to allocate their endowments. This framework introduces belief dispersion between individuals. Consumers hold heterogeneous beliefs about the likelihood of a bank run at $t = 0$, characterized by a probability distribution $F(q, \sigma)$.

A consumer i holds belief q_i at $t = 0$ about the probability of a bank run at $t = 1$, if it exists. At $t = 0$, each consumer draws their belief q_i from a cumulative distribution $F(q, \sigma)$ with support $[0, 1]$ and density $f(q, \sigma)$. Higher σ reflects greater belief dispersion, capturing scenarios where some consumers are highly pessimistic about a bank run while others are optimistic.

For $\sigma_1 > \sigma_2$, it holds that

$$\int_0^1 q_i f(q, \sigma_1) dq = \int_0^1 q_i f(q, \sigma_2) dq,$$

while for any $t > 0$, it holds that

$$\int_0^t F(q, \sigma_1) dq \geq \int_0^t F(q, \sigma_2) dq.$$

Except for their beliefs, consumers remain ex ante identical.

The baseline model can be interpreted as the case for which $\sigma_1 = 0$ as all consumers agree on the probability q of a bank run.

4.2 Optimal cash demand

This part focuses on the banks' dilemma and the household's portfolio decision, attempting to determine under what conditions the optimal demand for cash as a store of value is positive. If the deposit contract chosen is run-proof, individual beliefs q_i become irrelevant, and the results stated in section 3 apply.

If the chosen deposit contract is run-prone, a bank run may occur. The bank is assumed to offer a single deposit contract that is optimized to maximize the expected utility of its depositors. This implies that the bank selects a contract based on the average individual belief of its depositors. In theory, even if consumers' beliefs are private information, the bank could offer a range of deposit contracts, enabling each depositor to select a contract that aligns with her subjective beliefs. In such a system, there would be a reduced but still positive demand for cash, provided that the contracts offered by the bank remain susceptible to runs. It is important to note that, in practice, a representative bank cannot simultaneously offer run-prone and run-proof contracts; it must choose one type of contract to offer to all depositors.

The more pessimist a consumer is about the likelihood of a bank run (higher q_i), the more he believes it would be better with cash instead of a run-prone deposit contract.

If the deposit contract that solves the bank's problem is run-prone, consumers with $q_i > \tilde{q}$ will prefer to place their endowment in cash and a proportion of $(1 - \tilde{q})$ will prefer to hold cash. The threshold value $\tilde{q}$ that defines the set of consumers who prefer to hold public money is given by

$$\tilde{q} = \frac{\lambda u\left(\frac{c_1^B}{D_0}\right) + (1-\lambda)u\left(\frac{c_2^B}{D_0}\right) - u(1-f)}{\lambda u\left(\frac{c_1^B}{D_0}\right) + (1-\lambda)u\left(\frac{c_2^B}{D_0}\right) - u\left(\frac{c_R^B}{D_0}\right)}$$

So the total demand for cash in the economy, is given by: $M_0 = \int_{\tilde{q}}^{1} f(q, \sigma)\, dq$

where $f(q, \sigma)$ is the probability density function of consumers' beliefs about the probability of a bank run, and σ represents the dispersion of consumers´beliefs. This integral calculates the aggregate demand for cash by summing up the choices of consumers who, based on their beliefs q, decide to hold cash instead of deposits.

The bank cannot directly observe each depositor's belief about the probability of a bank run, it can determine the threshold $\tilde{q}$, which defines the fraction of consumers who will place their money in deposits. This fraction depends on the deposit contract the bank offers.

As a result, the bank aims to maximize the expected utility of depositors by solving an optimization problem. The bank's goal is to find the optimal values for the contract terms, such as the amounts paid to depositors who withdraw early (c_1^B), later (c_2^B), or in the case of a bank run (c_R^B). The optimization problem is as follows:

$$\max_{c_1^B, c_2^B, c_R^B, x, y} \int_{\tilde{q}}^{1} f(q, \sigma_1)\, dq \, [\lambda u(c_E) + (1-\lambda)u(c_L)] + \int_{0}^{\tilde{q}} f(q, \sigma_1)\, dq\, u(c_R) \tag{B}$$

The bank must satisfy the same constraints as those in Problem (A), but the key assumption is that individual beliefs about the probability of a bank run do not change based on the deposit contract offered.

The average belief of depositors, denoted by is calculated as the average of the beliefs of depositors who choose to place their money in deposits (those with $q_i \leq \tilde{q}$): $\bar{q} = \int_0^{\tilde{q}} q_i f(q, \sigma_1)\, dq$

Finally, the bank solves for the optimal deposit contract based on the following condition:

$$(1 - \bar{q}) \left[Ru'(c_2^B) - u'(c_1^B) \right] = \bar{q} u'(c_R^B) \tag{9}$$

Figure 5 illustrates how people's beliefs about the likelihood of a bank run impact their decisions on whether to hold cash or keep deposits in a bank. A Beta distribution is employed to represent these beliefs. Depositors who are relatively optimistic about bank stability have an average belief ($\bar{q}$) that is less than the expected value of their beliefs $E[q_i]$.

Consumers with beliefs (q_i) greater than a specific threshold ($\tilde{q}$) perceive a higher likelihood of a bank run and prefer to hold cash, as they believe it is safer. The total demand for cash is represented by the area under the curve beyond this threshold. Conversely, the average belief of those who deposit their money in banks is lower than this threshold ($\bar{q} < \tilde{q}$).

The bank adjusts its deposit contracts based on the average beliefs of its depositors. If depositors are more confident about the bank's stability, the bank can offer contracts that are less vulnerable during a bank run. However, if most depositors are pessimistic, the bank must consider the increased likelihood of withdrawals, necessitating a different type of contract.

There exists a threshold ($\hat{q}$) within the range of $(0, 1)$ such that if $\bar{q} > \hat{q}$, the solution to Problem (B) is a run-proof contract. Conversely, if $\bar{q} < \hat{q}$, it results in a run-prone contract. The difference between $\hat{q}$ and $\tilde{q}$ is caused by the discrepancy between $\bar{q}$ and $E[q_i]$ in the bank's objective function, which is related to the demand for cash and ultimately to the presence of heterogeneous beliefs about bank stability.

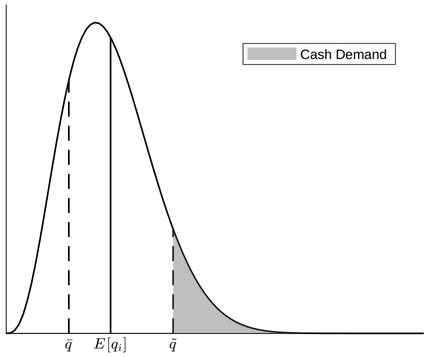


Figure 3: Demand for Cash

Note: The illustration uses $q_i \sim$ Beta$(4, 12)$

4.3 Uncertainty and belief dispersion

The effects of financial crises were incorporated into the model using a Beta distribution with higher σ, reflecting how, there is greater belief dispersion among individuals during financial crises or periods of financial distress. Adjusted α and β parameters represent this higher belief dispersion, with an increased mass of consumers in the tails of the distribution, skewed towards pessimism ($\alpha < \beta$), which is characteristic of financial crisis environments.

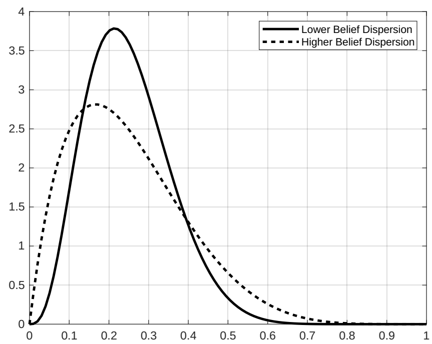


Figure 4: Comparison of lower and higher belief dispersion distributions

Note: The new distribution is modeled as $q_i \sim$ Beta$(2, 6)$, representing a higher Belief Dispersion

Assuming a run-prone deposit contract ($\bar{q} < \hat{\hat{q}}$), higher belief dispersion leads to increased demand for cash – a 'flight to safety'. As a result, the remaining depositors, on average, become more confident about the bank's stability. In response, the bank aims to maximize depositor utility by offering higher payments in the good equilibrium and lower payments otherwise. This is achieved by shifting its asset portfolio towards long-term lending.

As this shift occurs, bank deposits and the average belief of depositors ($\bar{q}$) decrease. The bank reduces its reserve holdings and the share of reserves in its portfolio ($\frac{y}{D_0}$), which in turn causes the threshold bound ($\tilde{q}$) to decrease.

Now, when σ (the volatility or uncertainty measure) increases, all else equal, cash demand also increases. Additionally, cash demand is influenced by the threshold bound $\tilde{q}$. With lower deposit funding (D_0), the average belief of bank depositors ($\bar{q}$) decreases, as only relatively optimistic depositors remain. This leads to a decrease in $\bar{q}$, i.e., $\partial\bar{q} < 0$. The decrease in $\bar{q}$ reduces the optimal reserve ratio y, as determined by $\partial\sigma D_0$, which in turn causes $\tilde{q}$ to decrease. The sign of the change in $\tilde{q}$ depends on $\bar{q}$: when $\bar{q} < \tilde{q}$, the change is negative, and when $\bar{q} > \tilde{q}$, the change is positive. Importantly, only consumers with $q_i < \tilde{q}$ hold bank deposits. Thus, since $\bar{q} < \tilde{q}$, $\partial\tilde{q} < 0$: an increase in σ leads to a decrease in $\tilde{q}$, which further increases cash demand.

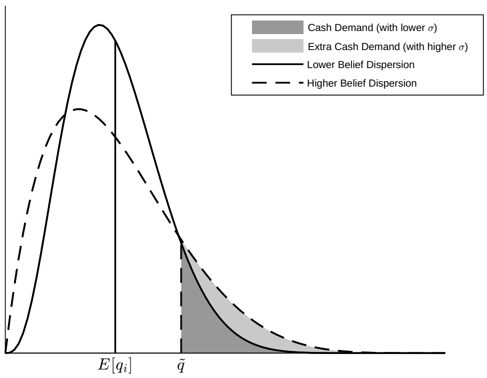


Figure 5: Cash Demand

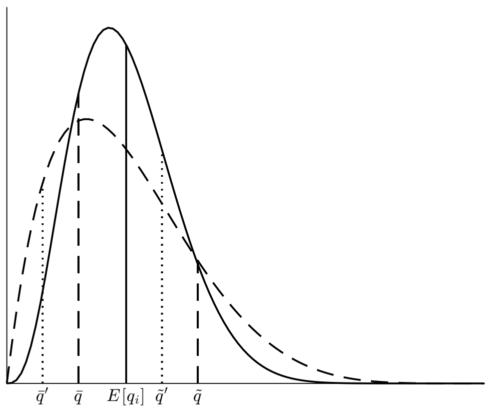


Figure 6: q-values

This adaptation of the Diamond and Dybvig model provides a suitable framework to study the impact of introducing a CBDC on banks and the public money demand during financial crises. The next section explores these implications within the proposed Model.

5 The Model with CBDC

This section expands the Model and incorporates the issue of a Digital Currency by the Central Bank, along with cash and reserves [2]. To simplify the analysis, the introduction of the CBDC is considered to have no effect on the probability of a bank run or individual beliefs about it.

5.1 CBDC vs cash

As for the case of cash, the central bank trades endowment for CBDC at $t = 0$ and $t = 1$ and repays consumption items on demand at $t = 1$.

Three main characteristics set CBDC apart from cash [3]. First, it is a more efficient store of value, benefiting from lower storage costs ($f_{\text{CBDC}} < f$). Then, its interest rate (r_{CBDC}) can be set at zero or even negative, offering flexibility for monetary policy design and the central banks can impose quantity limits on CBDC holdings, allowing them to control its supply and influence how it is used in the financial system.

Under a run-prone deposit contract offered by the bank, a consumer strictly prefers to hold CBDC rather than cash if $(1 - f_{\text{CBDC}} + r_{\text{CBDC}}) > (1 - f)$. By adequately calibrating r_{CBDC}, the central bank can determine whether consumers prefer to hold cash or CBDC as a store of value, and by introducing a limit on CBDC supply $\overline{M}_{\text{CBDC}} < M_0$, where $\overline{M}_{\text{CBDC}}$ denotes the CBDC quantity limit, the central bank can calibrate the amount of CBDC held as a store of value. But if the only difference between CBDC and cash is given by $f > f_{\text{CBDC}}$ (no binding limits on CBDC supply and $r_{\text{CBDC}} = 0$), CBDC fully replaces cash as a safe store of value.

[2] In the Model with CBDC all monetary instruments are only considered as store of value.

[3] This characteristics depend on the design features chosen by the central banks when developing their digital currencies.

5.2 CBDC vs deposits

A CBDC may also impact bank's run-prone contract and, ultimately, in consumers' store of value choices. The introduction of a CBDC in The Model has the potential to alter both cash demand and bank intermediation.

Considering the case in which $f > f_{\text{CBDC}}$, $r_{\text{CBDC}} = 0$, and there are no binding limits on CBDC supply. The threshold for q that characterizes the group of consumers who want to hold public money is no longer provided by $\tilde{q}$ since it now depends on f_{CBDC} rather than f. $\tilde{\tilde{q}}$ is the threshold with CBDC.

Assuming $\bar{q} < \hat{\hat{q}}$, so banks are offering a run-prone deposit contract, and that $f > f_{\text{CBDC}}$. The introduction of CBDC reduces the threshold $\tilde{q}$, which characterizes the group of consumers who prefer to hold public money over bank deposits.

Consider $\tilde{q}$:

$$\tilde{q} = \frac{\lambda u\left(\frac{c_1^B}{D_0}\right) + (1-\lambda)u\left(\frac{c_2^B}{D_0}\right) - u(1-f)}{\lambda u\left(\frac{c_1^B}{D_0}\right) + (1-\lambda)u\left(\frac{c_2^B}{D_0}\right) - u\left(\frac{c_R^B}{D_0}\right)}$$

Holding bank pay-outs and deposits constant, the impact of cash storage cost equals

$$\frac{\partial \tilde{q}}{\partial f} = \frac{u'(1-f)}{\lambda u(c_1^B) + (1-\lambda)u(c_2^B) - u(c_R^B)} > 0 \tag{10}$$

Thus, a decrease in cash storage cost, all else equal, decreases $\tilde{q}$.

As more consumers prefer to hold CBDC, the total demand for public money (M_0) increases. With more consumers moving to CBDC, bank deposits (D_0) decrease, because deposits are now less attractive compared to CBDC. A shift in deposits to CBDC means banks have fewer resources to manage and lend out. Consequently, banks' reserves decrease, which directly impacts their ability to offer loans or engage in long-term lending. As reserves decrease, the share of reserves in the bank's portfolio also declines ($\frac{y}{D_0}$), signaling that banks are adjusting to the reduction in deposits.This adjustment could affect their overall liquidity position.

Intuitively, adopting superior public storage technology lowers the threshold that characterizes the set of consumers who wish to hold public money. A positive fraction of consumers switch from bank deposits to CBDC based on their pré-existent beliefs.

As discussed in point 4.3, belief dispersion during financial crises leads to an increased demand for cash as a store of value, which is reflected in a decrease in the threshold q. The introduction of Central Bank Digital Currency further reduces this threshold, making CBDC a more attractive substitute for cash and deposits, especially during a financial crisis. Figure 7 illustrates the potential increase in the demand for public money, specifically CBDC, during a financial crisis. [4]

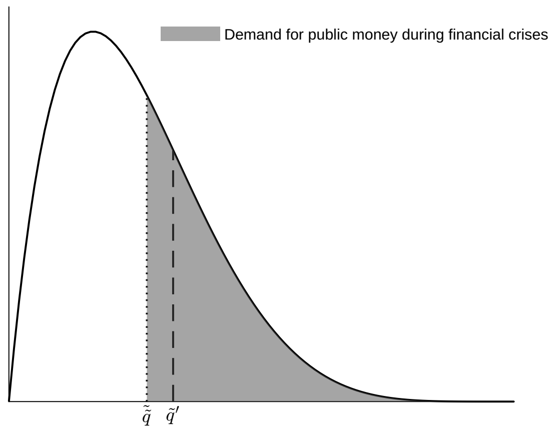


Figure 7: Demand for public money

6 Implications of CBDC on financial stability

This section explores the impact of CBDCs on bank intermediation, including their potential to reduce bank deposits, disrupt credit provision, and affect financial stability, as well as the shift in intermediation from private banks to the central bank.

[4] It´s important to note, that in a real-life situation it would be hard that the CBDC replace fully cash as of some technological constraints, but even though it will have a significant impact

6.1 Bank Disintermediation

In the model with Central Bank digital currency, the conclusion is that their issuance leads to more consumers desiring to hold CBDC rather than bank deposits, as they are perceived as a safer store of value that is not vulnerable to bank runs. During financial crises, as belief in banks declines and more consumers have pessimistic outlooks, the tendency to move from bank deposits to CBDCs will intensify.

Bank disintermediation occurs when CBDC crowds out commercial bank deposits. Deposits are a cheap and stable source of funding for banks, so if CBDC is a too successfully substitute of bank deposits as a store of value, might impact negatively the overall funding and, consequently, the lending capacity of banks. The crowding-out effect of CBDC on deposits can disrupt the credit provision of commercial banks and potentially threaten financial stability. Without sufficient deposits, banks may have to rely on more costly sources of funding. Consequently, it may reduce their ability to grant new credit, leading to lower liquidity and potentially affecting economic growth.

Central Bank digital currencies can shift the dynamic of bank runs of bank runs driven by disintermediation, transforming them from runs between banks to runs between commercial banks and the central bank.(Krogstrup, Sangill,Sicard, 2024)

This effect is magnifies in times of financial crises and distress. Due to this credit contraction, banks may raise interest rates on loans to fill in the gap in lending, discouraging borrowing and spending. Consequently, economic slowdowns could be worsened due to reductions in consumption and investment.

A historical example of this dynamic is the Great Depression, when a shift to cash holdings rather than bank deposits led to a decrease in the money supply, which increased interest rates and subsequently reduced investment. This had negative economic effects, contributing to declines in production and employment. Similarly, during the recent 2008 financial crisis, reduced liquidity in the economy had serious adverse effects, prompting the central bank to implement measures to restore liquidity.

Commercial banks in the Euro area also play a crucial role on saving allocation and financing firms and households. Furthermore, banks' responsiveness to ECB monetary policy actions is an influential channel through which monetary policy affects the economy. Through the interest rate channel, changes in key ECB interest rates affect the general level of interest rates, influencing consumption, investment decisions, real economic activity, and inflation.

The introduction of a central bank digital currency has the potential to alter the operational framework of monetary policy and the conditions in interbank markets, particularly if it leads to a substantial decrease in excess reserves due to reduced bank deposits.

Widespread CBDC adoption could centralize financial intermediation on the Central Bank and thus, alter commercial banks' role and raising concerns about efficiency, innovation, and system resilience.

6.2 Monopolization of Financial Intermediation

With broad diffusion of the Central Bank digital currency, the Central Bank might become, the primary or even the unique intermediary in the financial markets. It can become a monopolist in deposits taking and credit allocation. This situation raises important questions regarding the financial system´s efficiency, stability, and innovation.

Some argue that a CBDC could improve financial stability by removing the risk of bank runs. A digital currency directly backed by the central bank could eliminate liquidity risks that commonly lead to depositor panic. This centralization could also mean a better transmission of monetary policy, allowing central banks to bypass intermediaries and directly manage liquidity, credit, and price stability. It could democratize financial access by providing access to central bank accounts and thus ensure a secure and efficient payment system for undeserved populations.

However, centralization of financial intermediation under a central bank has several significant challenges. Private banks are a key channel for credit allocation, as their knowledge and competitive incentives serve as a means to monitor and allocate resources efficiently. A monopolistic central bank might not have the capacity to perform these functions adequately, potentially leading to suboptimal credit allocation and slower economic growth. Moreover, such lack of competition might also stall financial innovation.

Furthermore, expanding the central´s bank role in financial intermediation can introduce political risks, as external pressures can influence credit allocation, distorting investment priorities. Operational risk could also rise, as concentrating all financial intermediation functions within a central bank could amplify the impact of any system failure.

With CBDC reshaping the financial system, policymakers must carefully balance the benefits of centralization with the critical roles private banks play in promoting competition, innovation, and efficiency. The challenge lies in designing a framework that maximizes the benefits of CBDCs while preserving the dynamic contributions of private banks, ensuring a stable, inclusive, and innovative financial system.

7 Conclusion

This thesis explores the potential role of Central Bank Digital Currencies as a store of value during financial crises.

By adapting the Diamond and Dybvig model to incorporate heterogeneous beliefs about the likelihood of bank runs, this research rationalizes how different consumers choose between bank deposits and cash holdings.

Empirical evidence indicates that during financial crises, consumers often exhibit a flight-to-safety behavior, increasing demand for secure assets such as cash or digital alternatives like CBDC. Viewed as a safer and more efficient store of value,central bank digital currencies could potentially exacerbate bank disintermediation, especially during periods of financial turmoil.

CBDCs offer a reliable, state-backed alternative to traditional deposits. However, widespread adoption could disrupt banking by reducing deposits and credit provision, weakening banks' role in economic growth and monetary policy transmission.

The research also emphasizes the importance of careful CBDC design. Measures such as limiting CBDC holdings, avoiding remuneration, and ensuring that CBDC complement rather than replace existing financial instruments are essential to balance the benefits of a central bank digital currency with their potential risks. Policymakers must consider these design features to mitigate any adverse effects on bank funding and credit markets while maximizing the advantages of digital currency adoption.

The balance between innovation, financial stability, and economic efficiency requires thoughtful policy decisions and continuous assessment of their impact on the broader financial ecosystem. By addressing these challenges, the European Central Bank can leverage the potential of to navigate the evolving financial landscape while safeguarding economic stability and growth.

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