Central Bank Digital Currency and Financial Stability[a]

Toni Ahnert, Peter Hoffmann, Agnese Leonello, and Davide Porcellacchia

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[a]These are our views and not necessarily those of the European Central Bank or the Eurosystem.

Motivation

- Central banks around the globe are researching CBDC (Boar and Wehrli, 2021)
- CBDC is a country's official currency in digital form (digital cash)
  - direct liability of the central bank (rather than of commercial banks)
  - available to the general public (rather than to banks only)
- A response to
  - the declining importance of cash as a means of payment
  - the challenges of the proliferation of new forms of private digital money (stablecoins)

Concerns by policymakers

- How does CBDC affect financial stability?
    - increase the risk of bank runs during crisis episodes (BIS, 2020)
    - safe store of value and potentially positive remuneration
- Should the design of CBDC be adjusted to mitigate this concern?
    1. CBDC remuneration
    2. Holding limits of CBDC
    3. Contingent remuneration of CBDC
- This paper
    - we study the financial stability implications of CBDC
    - we derive consequences for CBDC design

Our paper in one slide

- A parsimonious model of bank runs
    - with a unique equilibrium (global games)
- Remunerated CBDC improves the outside option of investors
    - higher withdrawal incentives: bank fragility $\uparrow$
    - better deposit rates offered: bank fragility $\downarrow$
- Main findings
    - U-shaped relationship between CBDC remuneration and bank fragility
    - A positive remuneration of CBDC improves financial stability
    - Holding limits have an ambiguous impact
    - Contingent remuneration can improve financial stability

Literature

- Overview of recent work in Ahnert et al. (2022)

- CBDC and bank responses in deposit market
  - the same channel in work on the effects of CBDC on the credit supply: Keister and Sanchez (2022), Chiu/Davoodalhosseini/Jiang/Zhu (2022), and Andolfatto (2021)

- CBDC and financial stability
  - In Diamond/Dybvig (1983) setups with bank runs: Fernandez/Schilling/Uhlig (2021,22), Skeie (2020), Keister and Monnet (2022)

- Global games methods
  - Carlsson and van Damme (1993), Morris and Shin (2003), Vives (2005)
  - Goldstein and Pauzner (2005), Vives (2014), Liu (2016), Ahnert/Anand/Gai/Chapman (2019), Carletti/Leonello/Marquez (2023), Liu (2023), Schilling (2023)
  - allows us to study how deposit rates and CBDC design affect bank fragility

A parsimonious model

Key ingredients:

- Withdrawal behaviour of bank depositors
  - an endogenous probability of bank runs
- Bank choices
  - deposit rates
- CBDC design

A parsimonious model

- A single divisible good, three dates, no discounting, universal risk neutrality
- A profit-maximizing bank
- A continuum $i \in [0, 1]$ of investors endowed with 1 unit of funds at date 0 only
- At date 0, the bank raises funds from investors in exchange for a demand-deposit contract (r_1, r_2) and invests in a profitable but risky project
    - the project's liquidation value at date 1 is $L < 1$ and returns $R\theta$ at date 2
    - the variable $\theta \sim U[0, 1]$ represents the fundamentals of the economy
    - $R > 2$ is the return on lending
    - deposit contract with $1 \leq r_1 < r_2$

A parsimonious model

- At date 0, investors decide whether to invest in deposits or CBDC (or cash)
  - CBDC pays $\omega \geq 1$ per period (remuneration)
  - Cash pays 1, so it is dominated ($\omega = 1$ is an economy without CBDC)
- At date 1, investors decide whether to withdraw their funds based on a noisy private signal:

$$s_i = \theta + \epsilon_i$$

- The bank satisfies early withdrawals n by partially liquidating the risky investment
  - thresholds for insolvency $\hat{n}$ and illiquidity $\overline{n}$
- Two simplifying assumptions:
  - Vanishing private noise
  - Full bankruptcy costs

Equilibrium

We work backwards to solve for

- Withdrawal behaviour of investors and the probability of a run θ^*
- Bank choice of deposit contract (r_1^*, r_2^*)
- Impact of CBDC remuneration ω
- Evaluate various CBDC design options

Investor withdrawal decisions

Lower dominance	Intermediate region	Upper dominance

$\underline{\theta}$ θ^* $\overline{\theta}$

investors withdraw as low θ — fundamental runs	investors withdraw because of θ and n — panic runs	no investor withdraws — no runs

where the fundamental run threshold $\underline{\theta}$ solves

$$R\theta = r_2$$

and the bank failure threshold θ^* solves

$$\underbrace{\int_0^{\widehat{n}(\theta^*)} r_2(\omega)dn}_{\textit{Expected payoff at date 2}} = \underbrace{\omega \int_0^{\overline{n}} r_1(\omega)dn}_{\textit{Expected payoff at date 1}}$$

A unique failure threshold

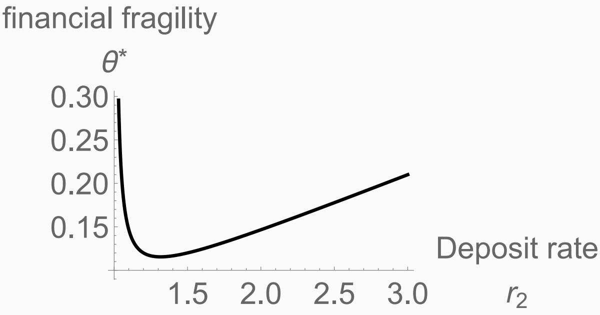
Proposition 1 (Failure threshold.)

In the unique equilibrium, each investors withdraws whenever

$$\theta < \theta^* = \frac{r_2}{R} \cdot \frac{r_2 - \omega \cdot L}{r_2 - \omega \cdot r_1}.$$

- Higher bank fragility (higher θ^*) if
  - higher CBDC remuneration: $\frac{\partial \theta^*}{\partial \omega} > 0$ (direct effect)
  - higher short-term deposit rate r_1
  - worse investment characteristics L, R

Higher long-term deposit rates and bank fragility



- Impact of higher long-term deposit rates ambiguous
  - lower incentives to withdraw at interim date
  - higher risk of insolvency at final date
- In equilibrium, the economy is on the downward-sloping part
  - we focus on appropriate parameters
  - bank chooses to be fragile

Bank fragility and CBDC remuneration

- θ^* is the ex-ante probability of a bank run (our measure of bank fragility)
- What is the effect of CBDC remuneration ω on θ^*?

$$\frac{\mathrm{d}\theta^*}{\mathrm{d}\omega} = \underbrace{\frac{\partial\theta^*}{\partial\omega}}_{\text{Direct effect}} + \underbrace{\sum_{t=1}^{2} \frac{\partial\theta^*}{\partial r_t} \cdot \frac{\mathrm{d}r_t}{\mathrm{d}\omega}}_{\text{Indirect effect}}.$$

- Indirect effect runs through the deposit contract

Bank choice of deposit rates

- Bank sets deposit rates to maximize expected profits subject to investor participation in the deposit market:

$$\Pi = \int_{\theta^*}^{1} (R\theta - r_2)\, d\theta \quad \text{s.t.} \quad \int_{\theta^*}^{1} r_2 d\theta \geq \omega^2$$

- We assume that the return on the bank's project is high enough and on CBDC is low enough:

$$R > \underset{\sim}{R} \text{ and } \omega < \widetilde{\omega}$$

Proposition 2 (Deposit Contract.)

The deposit rates are $r_1^* = 1$ and $r_2^* < r_2^{max}$ that solves a binding participation constraint. Higher CBDC remuneration increases the deposit rate, $\mathrm{d}r_2^*/\mathrm{d}\omega > 0$.

Two effects of CBDC remuneration on financial stability

- $$\frac{d\theta^*}{d\omega} = \frac{\partial\theta^*}{\partial\omega} + \frac{\partial\theta^*}{\partial r_2}\frac{dr_2}{d\omega}$$
- The direct effect is positive $\left(\frac{\partial\theta^*}{\partial\omega} > 0\right)$
- The indirect effect is negative $\left(\frac{\partial\theta^*}{\partial r_2}\frac{dr_2}{d\omega} < 0\right)$
- When does the indirect effect dominate?

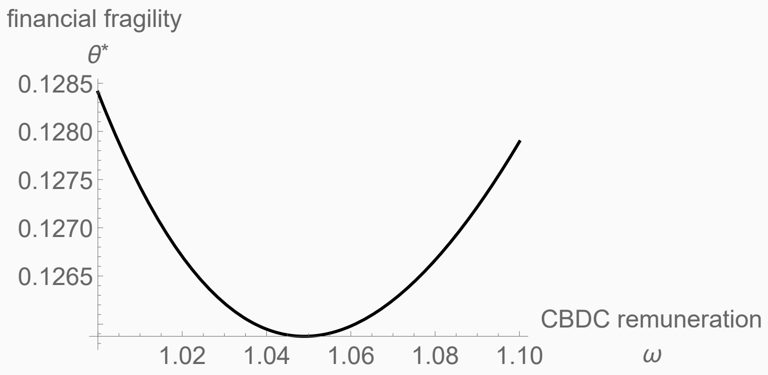
Lemma 1 (Elasticity of the failure threshold.)

Denote $\eta \equiv -\frac{\partial\theta^*}{\partial r_2} \cdot \frac{r_2^*}{\theta^*}$. Then, $\frac{\mathrm{d}\theta^*}{\mathrm{d}\omega} < 0$ if and only if $\eta > 1$.

The total effect

Proposition 3 (CBDC remuneration and bank fragility.)

Fragility is U-shaped in CBDC remuneration with a unique minimum $\omega_{min} > 1$.



CBDC design and financial stability

1. CBDC remuneration
2. Limits on CBDC holdings
3. Contingent remuneration

Objective function

- The central bank as a constrained planner
  - CB takes as given the informational friction (dispersed private information) and the privately optimal behaviour of consumers and the bank
  - Formally, $\theta^*(r_1, r_2)$ (Proposition 1) and r_1^* and r_2^* (Proposition 2)
- The central bank maximizes utilitarian welfare

$$W \equiv \int_{\theta^*}^{1} (R\theta - r_2) d\theta + \int_{\theta^*}^{1} r_2 d\theta = \frac{R}{2}\left[1 - (\theta^*)^2\right].$$

  - expected bank profits + payments to consumers
  - equivalent to minimizing fragility in our economy

Design option 1: CBDC remuneration

- The central bank can freely set ω

Proposition 4 (Optimal CBDC remuneration.)

The central bank sets ω_{min}.

- Increasing CBDC remuneration from 1 (digital cash) ω_{min}
  - consumers benefit from higher deposit rates and lower fragility (net positive)
  - bank benefits from lower fragility but incurs higher deposit rates (net negative)
  - redistribution, with a net gain in welfare: higher CBDC remuneration limits the effective market power of the bank in the deposit market

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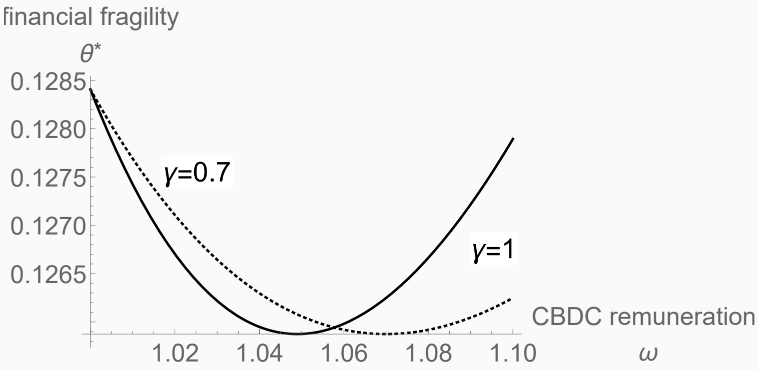
  - redistribution, with a net gain in welfare: higher CBDC remuneration limits the effective market power of the bank in the deposit market
- CB may not be able to freely set CBDC remuneration for financial stability purposes (previous commitment; monetary policy implementation)

Design option 2: Holding limits

- CBDC remuneration can reduce bank stability
- Motivated policy proposals aimed at reducing the appetite for CBDC
  - reduce the outflow of funds from banks when bad news about fundamentals arrive
  - One proposal is the introduction of holding limits (Bindseil et al., 2021)
- Our model is suited to study the implications of this measure
  - a proportion γ of consumer wealth can be held as CBDC

Holding limits can exacerbate bank fragility

- Caution for policymakers: holding limit interacts with CBDC remuneration
- Effective CBDC remuneration $\omega^{HL} \equiv \gamma\omega + (1-\gamma)$



Holding limits: understanding the result

Proposition 5 (Holding limits.)

(a) Positive: Holding limits, $\gamma < 1$, increase (reduce) bank fragility for low (high) levels of CBDC remuneration ω.

(b) Normative: The central banks optimally sets holding limits depending on (exogenous) CBDC remuneration: $\gamma^* = 1$ if $\omega \leq \omega_{min}$ and $\gamma^* = \frac{\omega_{min}-1}{\omega-1}$ otherwise.

- Two opposing effects on bank fragility
  - lower expected payoff from withdrawing (less fragility)
  - lower outside option and lower deposit rate (more fragility)

Design option 3: Contingent remuneration

- Based on a Panetta / Bindseil proposal

- CBDC remuneration depends on the state of the financial system
    - Lower remuneration of CBDC amidst financial turmoil
    - To mitigate the withdrawal incentives of depositors

- Suppose $\omega_1 \equiv \omega$ and

$$\omega_2(n) = \begin{cases} \omega & \text{if } 0 \leq n \leq \widetilde{n} \\ \underline{\omega} & \text{if } \widetilde{n} < n \leq 1, \end{cases}$$

- $\widetilde{n}$ and $\underline{\omega} \in [1, \omega]$ are policy parameters

- a stricter intervention is captured by lower values of $\widetilde{n}$ and $\underline{\omega}$

Contingent remuneration is effective

- CR is effective at reducing *direct* withdrawal incentives

- CR has limited indirect effect because the participation constraint of investors changes less (than with e.g. holding limits)

$$V_{CR} = r_2(1 - \theta^*_{CR}) - \omega[\underline{\omega}\theta^*_{CR} + \omega(1 - \theta^*_{CR})]$$

Proposition 6 (Contingent remuneration.)

CR is effective at improving financial stability: $\frac{d\theta^*_{CR}}{d\tilde{n}} > 0$ and $\frac{d\theta^*_{CR}}{d\underline{\omega}} \lesseqgtr 0$.

- Contingent remuneration seems more promising than holding limits.

Extensions

- Risk-taking on the asset side
- Competition in the market for bank deposits
- Our results are generally robust to these changes in the model.

Conclusion

- A parsimonious model on the financial stability implications of CBDC
  - endogenous withdrawal incentives and deposit rates
  - evaluate the efficacy of CBDC design options
- CBDC remuneration improves outside option of investors
  - more runs, given a deposit contract
  - higher deposit rates, lowering bank fragility
- Overall, U-shape between bank fragility and CBDC remuneration
  - a positive level of CBDC remuneration maximizes financial stability
- Implications for CBDC holding limits and contingent remuneration