Central Bank Digital Currency and Financial Stability[a]

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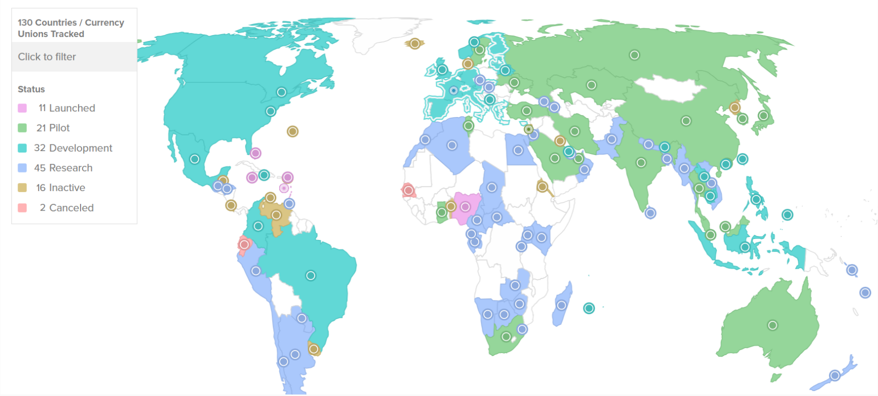
[a]The views expressed are our own and not necessarily those of the European Central Bank or the Eurosystem. The authors are not part of the digital euro project.

Motivation

- Among surveyed central banks, 90% are actively researching the merits of CBDC (Kosse and Mattei, 2022)
  - few CBDCs are "live", but the pipeline is growing fast



Motivation

- A widespread CBDC adoption could entail major changes for the financial system
  - it is essential to understand the potential side effects
- How does CBDC affect financial stability?
  - "ultimate" store of value (potentially remunerated)
  - concern: CBDC amplifies the risk of bank runs (BIS, 2020)
- Can appropriate CBDC design mitigate such concerns?
  - remuneration, holding limits, contingent remuneration

Our paper in a nutshell

- We incorporate CBDC into a parsimonious model of bank runs
  - unique equilibrium (global games), endogenous deposit rates set by monopoly bank
- Main result: The relationship between CBDC remuneration and bank fragility is U-shaped
- This overall effect is the result of two opposing forces
  - direct effect: for a given deposit contract, higher CBDC remuneration increases withdrawal incentives (bank fragility $\nearrow$)
  - indirect effect: an improvement in depositors' outside option induces the bank to offer more attractive terms (bank fragility $\searrow$)

Our paper in a nutshell

- We explore different CBDC design proposals
  - holding limits have an ambiguous impact
  - contingent remuneration can improve financial stability
- Our results are robust to
  - imperfect competition in deposit markets
  - risk-taking on the asset side

Literature

- Survey of recent work in Ahnert et al. (2022)
- CBDC and bank responses in deposit market
    - the effects of CBDC on bank credit supply: Keister and Sanchez (2022), Chiu et al. (2022), and Andolfatto (2021)
- CBDC and financial stability
    - Fernandez-Villaverde et al. (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 et al. (2019), Carletti et al. (2023), Liu (2023), Schilling (2023)
    - enables us to study how deposit contract and CBDC design affect bank fragility

The model

- A single divisible good, three dates ($t = 0, 1, 2$), no discounting, risk neutrality
- A profit-maximizing bank
- A continuum $i \in [0, 1]$ of investors endowed with 1 unit of funds
- At $t = 0$, 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 returns $R\theta$ at maturity ($t = 2$), liquidation at $t = 1$ yields $L < 1$
  - $\theta \sim U[0, 1]$ represents the "fundamentals" of the economy
  - $R > 2$ is the return on lending

The model

- At $t = 0$, 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 $t = 1$, investors decide whether to withdraw funds based on a noisy private signal:

$$s_i = \theta + \epsilon_i$$

- The bank satisfies early withdrawals $n \in [0, 1]$ by partially liquidating the risky investment
- We assume vanishing noise ($\epsilon \to 0$) and full bankruptcy costs

Solving for the equilibrium

We work backwards

1. For a given deposit contract, solve for the probability of a bank run $\theta^*(\omega, r_1, r_2)$
2. Solve for the bank contract as a function of CBDC remuneration $(r_1^*(\omega),\ r_2^*(\omega))$
3. Impact of CBDC remuneration ω on equilibrium bank fragility $\theta^*(\omega, r_1^*(\omega), r_2^*(\omega))$

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

Investor withdrawal decisions

- The global games methodology establishes a unique failure threshold θ^* and a unique signal threshold s^*
  - depositors withdraw if and only if $s_i < s^*$
  - the bank fails if and only if $\theta < \theta^*$

- For $s_i = s^*$, depositors are indifferent between withdrawing at $t = 1$ and keeping their funds in the bank until $t = 2$.

- Using that $s^* \to \theta^*$ for vanishing private noise ($\epsilon \to 0$), θ^* solves

$$\underbrace{\omega \int_0^{\overline{n}} r_1 \, dn}_{\text{withdraw at } t=1} = \underbrace{\int_0^{\widehat{n}(\theta^*)} r_2 \, dn}_{\text{stay until } t=2}$$

where $\overline{n}$ and $\widehat{n}$ denote the thresholds for illiquidity and insolvency

A unique failure threshold

Proposition 1 (Failure threshold.)

In the unique equilibrium, all investors withdraw whenever

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

- The direct effect is positive: $\frac{\partial \theta^*}{\partial \omega} > 0$
- For a fixed deposit contract, higher CBDC remuneration raises bank fragility
- Note that $\frac{\partial \theta^*}{\partial r_2} < 0$ for $r_2^* < r_2^{max}$ (which will be the case in equilibrium).

Bank choice of deposit rates

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

$$\max_{r_1, r_2} \int_{\theta^*}^{1} (R\theta - r_2)\, d\theta \quad \text{s.t.} \quad \int_{\theta^*}^{1} r_2 d\theta \geq \omega^2$$

- 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 bank sets $r_1^* = 1$ and $r_2^* < r_2^{max}$ such that the participation constraint is binding. Higher CBDC remuneration increases the deposit rate, $\mathrm{d}r_2^*/\mathrm{d}\omega > 0$.

Two effects of CBDC remuneration on financial stability

- Recall: The total effect is

$$\frac{d\theta^*}{d\omega} = \frac{\partial\theta^*}{\partial\omega} + \frac{\partial\theta^*}{\partial r_2}\frac{dr_2}{d\omega}$$

- 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?

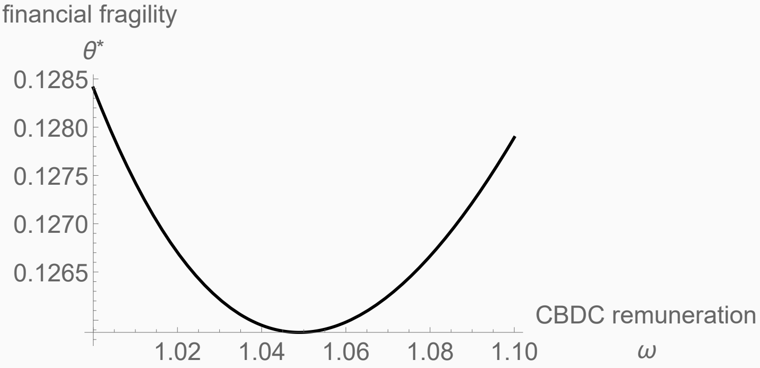
Lemma 1 (Elasticity of the failure threshold.)

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

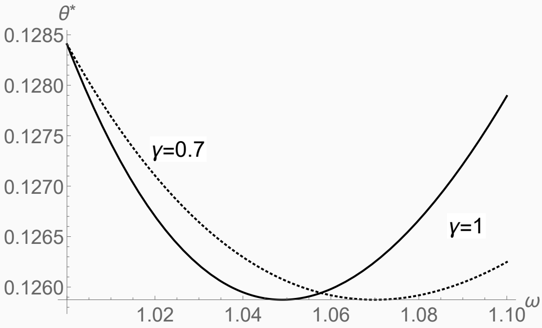
Proposition 3 (CBDC remuneration and bank fragility.)

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



CBDC design

- We examine two CBDC design proposals aimed at financial stability objectives
- Holding limits: investors can only hold wealth $\gamma < 1$ in CBDC (remainder in cash)
  - reduces effective "outside option" to $\omega^{HL} \equiv \gamma\omega + (1-\gamma)$
  - lower financial instability for high remuneration ω (counterproductive otherwise)



- Appropriately calibrated contingent remuneration can improve financial stability

Extension - Risk-taking on the asset side

- The bank chooses monitoring effort $q \in [0,1]$ with cost $\frac{c}{2}q^2$
- The project yields $R\theta$ with probability q (and zero otherwise)
- Full model is untractable, so we consider an exogenous deposit contract (r_1, r_2).
- Our measure of financial stability is $\Phi^* \equiv q^* \left(1 - \theta_q^*\right)$.

Proposition 8 (Risk taking on the asset side.)

Higher CBDC remuneration increases fragility, $\frac{d\theta_q^*}{d\omega} > 0$, but improves monitoring, $\frac{dq^*}{d\omega} > 0$.

- Can show numerical example for $\frac{d\Phi^*}{d\omega} > 0$ (hard to find sufficient conditions)

Conclusion

- A parsimonious model on the financial stability implications of CBDC
  - endogenous withdrawal incentives and deposit rates
  - CBDC remuneration improves investors' "outside option"
- U-shaped relationship between bank fragility and CBDC remuneration
  - "direct effect": for a given deposit contract, a higher CBDC rate makes it more attractive to run (fragility $\nearrow$)
  - "indirect effect": the bank responds by offering a more attractive deposit contract (fragility $\searrow$)
- Implications for CBDC design