Unveiling the Interplay between Central Bank Digital Currency and Bank Deposits

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Motivation

- Rising interest in Central Bank Digital Currencies (CBDCs)
  - Growing demand for digital payment methods for retail purposes
  - Gradual decline of the use of cash for transactions in many economies
- Risk of households substituting bank deposits for CBDC
  $\Rightarrow$ CBDC disintermediating the banking sector
  $\Rightarrow$ Reduced bank profits and negative real effects on the economy
  $\Rightarrow$ Financial instability

This paper

- What is the potential risk of financial instability following the introduction of a CBDC?
  - RBC model with CBDC and bank deposits (Niepelt 2022)
  - Revisit equivalence result in the literature
    1. Financial friction for CB lending to banks (i.e., collateral requirement)
    2. Different degrees of substitutability between CBDC and deposits (i.e., imperfect substitutability)
- How does the substitutability between CBDC and bank deposits impact this risk?
  - Dynamic effects of shifts in households' preferences

Literature

- Impact of the introduction of CBDC on commercial banks (Assenmacher et al. 2021, Burlon et al. 2022, Chiu et al. 2019, Whited, Wu, and Xiao 2023, Williamson 2022)
- Equivalence of payment systems (Brunnermeier and Niepelt 2019, Niepelt 2022, Piazzesi and Schneider 2021)
- Relationship between CBDC and bank deposits (Andolfatto 2021, Agur, Ari, and Dell'Ariccia 2022, Bacchetta and Perazzi 2022, Barrdear and Kumhof 2022, Keister and Sanches 2022, Kumhof and Noone 2021)

Takeaways

- CBDC and deposits perfect substitutes: CB can replace lost funding for the bank under more restrictive conditions
  $\Rightarrow$ No effects on financial instability
- CBDC and deposits imperfect substitutes: CB loan rate cannot make the bank indifferent to the competition from CBDC
  $\Rightarrow$ Real effects in the economy
  - CBDC demand increases but limited crowding out of deposits
  - Bank profits drop due to reduced market power
- Substitutability between CBDC and deposits key for real effects of introducing CBDC

Agenda

- Model with CBDC and collateral-constrained banks
- Revisit the equivalence of payment systems
- Dynamic effects of shifts in households' preferences
- Conclusion

Model with CBDC and collateral-constrained banks

- Non-competitive banks invest in capital, reserves, and government bonds and fund themselves through deposits or borrowing from the CB subject to a collateral requirement (i.e., discount window lending)

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$$l_{t+1} \leq \theta_b \frac{b_{t+1}}{R^l_{t+1}}$$

  - l_{t+1} and R^l_{t+1} are CB loans and interest rate on CB loans
  - θ_b is the fraction of government bonds required as collateral
  - b_{t+1} are government bonds remunerated at a rate lower than the risk-free rate (i.e., convenience yield)

Model with CBDC and collateral-constrained banks

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- Households value goods, leisure, and the liquidity services provided by CBDC and deposits

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- Firms produce using labor and physical capital

Model with CBDC and collateral-constrained banks

- Non-competitive banks invest in capital, reserves, and government bonds and fund themselves through deposits or borrowing from the CB subject to a collateral requirement (i.e., discount window lending) ▸ Banks
- Households value goods, leisure, and the liquidity services provided by CBDC and deposits ▸ HHs
- Firms produce using labor and physical capital ▸ Firms
- Consolidated government collects taxes, pays deposit subsidies, invests in capital, lends to banks against collateral, and issues CBDC and reserves ▸ Govt.

Revisit the equivalence of payment systems

Proposition 1 (Brunnermeier and Niepelt 2019, Niepelt 2022)

- Consider a policy implementing an equilibrium with deposits and reserves
- There exists another policy and equilibrium with less deposits and reserves, more CBDC, CB loans, government bonds, a different ownership structure of capital, additional taxes on the household, but the same equilibrium allocation and price system

Perfect substitutability with collateral requirement

- Household's real balances

$$z_{t+1} = \lambda_t m_{t+1} + n_{t+1}$$

  - m_{t+1} and n_{t+1} are CBDC and deposits
  - $\lambda_t \geq 0$ is the liquidity benefits of CBDC relative to deposits

- CB can pass back lost funding from deposits to the bank offering the loan rate

$$R^l_{t+1} = \frac{R^n_{t+1} + \left(\nu_t(\zeta_{t+1}, \bar{\zeta}_{t+1}) - \theta_t\right) R^f_{t+1} - \zeta_{t+1} R^r_{t+1}}{(1 - \zeta_{t+1})\left(1 + \frac{R^k_{t+1} - R^b_{t+1}}{\theta_b}\right)}$$

CB equivalent loan rate

Denote with $\tilde{R}^l_{t+1}$ the CB equivalence loan rate w/o collateral requirement (Niepelt 2022)

$$R^l_{t+1} \simeq \frac{\tilde{R}^l_{t+1}}{\left(1 + \frac{R^k_{t+1} - R^b_{t+1}}{\theta_b}\right)}$$

$\Rightarrow$ Denominator on the RHS is positive

- From HH's problem, if rate of return on capital is not risky $\rightarrow R^k_{t+1} \simeq R^f_{t+1}$
- From convenience yield $\rightarrow R^b_{t+1} < R^f_{t+1}$
- Recall $\theta_b \in [0, 1]$

CB equivalent loan rate (cont'd)

It follows that

$$R^{l}_{t+1} < \tilde{R}^{l}_{t+1}$$

Intuition

- When the bank is not collateral-constrained, it can borrow as much as it wants from the CB
- With collateral constraint, the CB needs to offer lower loan rate to incentivize the bank to borrow the same quantity as before $\Rightarrow$ Bank profits unaffected
  $\Rightarrow$ No real effects of introducing CBDC

Note: CB loan rate is lower with tighter collateral constraint

Imperfect substitutability with collateral requirement

- Household's real balances

$$z_{t+1} = \left(\lambda_t m_{t+1}^{1-\varepsilon_t} + n_{t+1}^{1-\varepsilon_t}\right)^{\frac{1}{1-\varepsilon_t}}$$

  - $\varepsilon_t > 0$ $(\forall t)$ is the inverse elasticity of substitution between CBDC and deposits

- CB loan rate does not make the bank profits unchanged

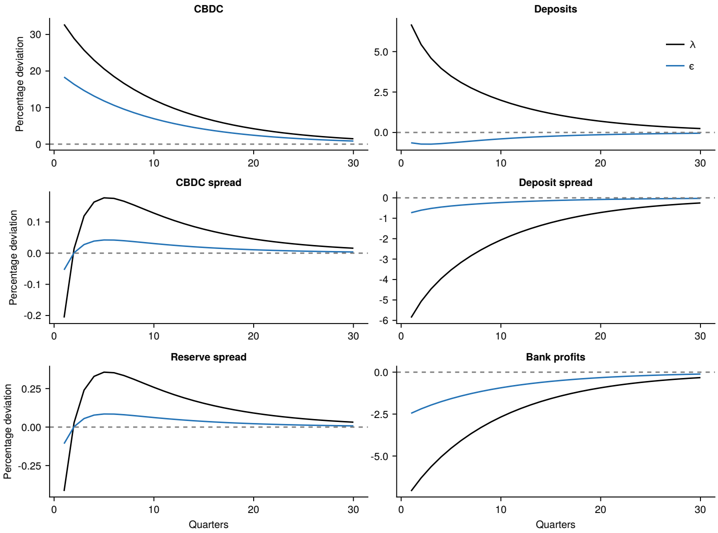
Intuition

- Change in bank's profitability implies that the new policy does not guarantee the same allocations as before $\Rightarrow$ Bank not indifferent to competition from CBDC $\Rightarrow$ Real effects in the economy

Dynamic effects of shifts in household's preferences

- How does an increase in CBDC demand affect the real economy and financial stability?
- CBDC and deposits as imperfect substitutes (Bacchetta and Perazzi 2022, Barrdear ans Kumhof 2022, Kumhof and Noone 2021) Functional forms and equilibrium
- Responses to changes in households' relative preferences for CBDC over deposits Calibration
  - Positive shock to the liquidity benefit of CBDC, λ_t
  - Negative shock to the substitutability between CBDC and deposits, $1/\varepsilon_t$

IRFs to 10% increase in λ_t and ε_t



Conclusion

- Important to consider the degree of substitutability between CBDC and deposits when evaluating the consequences of issuing CBDC
- Accounting for the collateral requirement the bank must respect when borrowing from the CB is key, as the CB loan rate depends on the constraint's restrictiveness
- Even if CBDC has real effects on the economy and negative effects on bank profits, the effects seem limited

Thank you!!

EXTRA SLIDES

Households

$$\max_{\{c_t, x_t, k^h_{t+1}, m_{t+1}, n_{t+1}\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \mathscr{U}(c_t, x_t, z_{t+1})$$

s.t.

$$c_t + k^h_{t+1} + m_{t+1} + n_{t+1} + \tau_t = w_t(1 - x_t) + \Pi_t + k^h_t R^k_t + m_t R^m_t + n_t R^n_t$$

$$k^h_{t+1}, m_{t+1}, n_{t+1} \geq 0$$

- $\beta \in (0, 1)$ is the positive discount factor
- c_t, x_t and k^h_{t+1} are consumption, leisure and capital
- z_{t+1} are effective real balances function of CBDC, m_{t+1}, and deposits, n_{t+1}

Back

Banks

$$\max_{n_{t+1}, l_{t+1}, r_{t+1}, b_{t+1}} \left\{ \Pi^b_{1,t} + \mathbb{E}_t \left[\Lambda_{t+1} \Pi^b_{2,t+1} \right] \right\}$$

s.t.

$$\Pi^b_{1,t} = -n_{t+1} \left(\nu_t(\zeta_{t+1}, \bar{\zeta}_{t+1}) - \theta_t \right)$$

$$\Pi^b_{2,t+1} = (n_{t+1} + l_{t+1} - r_{t+1} - b_{t+1}) R^k_{t+1} + r_{t+1} R^r_{t+1} + b_{t+1} R^b_{t+1} - n_{t+1} R^n_{t+1} - l_{t+1} R^l_{t+1}$$

$$l_{t+1} \leq \theta_b \frac{b_{t+1}}{R^l_{t+1}}$$

$$R^n_{t+1}, R^l_{t+1} \text{ perceived endogenous,} \qquad n_{t+1}, l_{t+1}, b_{t+1} \geq 0$$

- $\zeta_{t+1} \equiv \frac{r_{t+1}}{n_{t+1}}$, and $\bar{\zeta}_{t+1} \equiv \frac{\bar{r}_{t+1}}{\bar{n}_{t+1}}$
- $\Pi^b_{1,t}$, $\Pi^b_{2,t+1}$ are cash flow in the first and second periods of the bank's operations

Back

Firms and consolidated government

Firm's problem

$$\max_{k_t,\ell_t} f(k_t,\ell_t) - k_t(R_t^k - 1 + \delta) - w_t\ell_t$$

Government budget constraint

$$k_{t+1}^g + l_{t+1} - b_{t+1} - m_{t+1} - r_{t+1} = k_t^g R_t^k + l_t R_t^l - b_t R_t^b - m_t R_t^m - r_t R_t^r + \tau_t - n_{t+1}\theta_t - m_{t+1}\mu^m + r_{t+1}\rho$$

▸ Back

Functional forms

$$z_{t+1}(m_{t+1}, n_{t+1}) = \left(\lambda_t m_{t+1}^{1-\varepsilon_t} + n_{t+1}^{1-\varepsilon_t}\right)^{\frac{1}{1-\varepsilon_t}}, \qquad \lambda_t, \varepsilon \geq 0$$

$$\mathscr{U}(c_t, x_t, z_{t+1}) = \frac{\left((1-\upsilon)c_t^{1-\psi} + \upsilon z_{t+1}^{1-\psi}\right)^{\frac{1-\sigma}{1-\psi}}}{1-\sigma} x_t^{\upsilon}, \qquad \upsilon, \psi \in (0,1); \sigma > 0, \neq 1$$

$$v_t(\zeta_{t+1}, \bar{\zeta}_{t+1}) = \phi_1 \zeta_{t+1}^{1-\varphi} + \phi_2 \bar{\zeta}_{t+1}^{1-\varphi}, \qquad \phi_1 > 0; \phi_2 \geq 0; \varphi > 1$$

$$f(k_t, \ell_t) = k_t^{\alpha} \ell_t^{1-\alpha}$$

Equilibrium conditions

Euler equation, leisure choice, and resource constraint

$$
\begin{aligned}
c_t^{-\sigma} x_t^{v} &= \beta \mathbb{E}_t \left[c_{t+1}^{-\sigma} x_{t+1}^{v} R_{t+1}^{k} \frac{\Omega_{t+1}^{c}}{\Omega_t^{c}} \right] \\
\frac{c_t^{1-\sigma}}{1-\sigma} v x_t^{v-1} &= w_t c_t^{-\sigma} x_t^{v} \frac{\Omega_t^{c}}{\Omega_t^{x}} \\
k_{t+1} &= k_t^{\alpha} (1 - x_t)^{1-\alpha} + k_t (1-\delta) - c_t \Omega_t^{rc}
\end{aligned}
$$

Equilibrium conditions (cont'd)

Auxiliary variables

$$\Omega_t^c = (1-\upsilon)^{\frac{1-\sigma}{1-\psi}} \left(1 + \left(\frac{\upsilon}{1-\upsilon}\right)^{\frac{1}{\psi}} \chi_{t+1}^{1-\frac{1}{\psi}}\right)^{\frac{\psi-\sigma}{1-\psi}}$$

$$\Omega_t^x = (1-\upsilon)^{\frac{1-\sigma}{1-\psi}} \left(1 + \left(\frac{\upsilon}{1-\upsilon}\right)^{\frac{1}{\psi}} \chi_{t+1}^{1-\frac{1}{\psi}}\right)^{\frac{1-\sigma}{1-\psi}}$$

$$\Omega_t^{rc} = 1 + \frac{m_{t+1}}{c_t}\mu^m + \frac{n_{t+1}}{c_t}\left((\phi_1+\phi_2)\left(\frac{\chi_{t+1}^r}{\phi_1(\varphi-1)}\right)^{\frac{\varphi-1}{\varphi}} + \left(\frac{\chi_{t+1}^r}{\phi_1(\varphi-1)}\right)^{-\frac{1}{\varphi}}\rho\right)$$

Equilibrium conditions (cont'd)

Demand for effective real balances, CBDC, and deposits

$$z_{t+1} = c_t \left(\frac{\upsilon}{1-\upsilon} \frac{1}{\chi_{t+1}} \right)^{\frac{1}{\psi}}$$

$$m_{t+1} = z_{t+1} \left(\lambda_t \frac{\chi_{t+1}}{\chi^m_{t+1}} \right)^{\frac{1}{\varepsilon_t}}$$

$$n_{t+1} = z_{t+1} \left(\frac{\chi_{t+1}}{\chi^n_{t+1}} \right)^{\frac{1}{\varepsilon_t}}$$

Household's average cost of liquidity

$$\chi_{t+1} = \chi^m_{t+1} \chi^n_{t+1} \left(\lambda_t^{\frac{1}{\varepsilon_t}} \left(\chi^n_{t+1}\right)^{\frac{1-\varepsilon_t}{\varepsilon_t}} + \left(\chi^m_{t+1}\right)^{\frac{1-\varepsilon_t}{\varepsilon_t}} \right)^{\frac{-\varepsilon_t}{1-\varepsilon_t}}$$

Equilibrium conditions (cont'd)

Return on capital and real wages

$$R^k_{t+1} = 1 - \delta + \alpha \left(\frac{k_{t+1}}{1 - x_{t+1}} \right)^{\alpha - 1}$$
$$w_t = (1 - \alpha) \left(\frac{k_t}{1 - x_t} \right)^{\alpha}$$

Deposit spread

$$\chi^n_{t+1} - \chi^n_{t+1} \left(\frac{1 - s_t}{\psi} + \frac{s_t}{\varepsilon_t} \right)^{-1} = (\phi_1 \varphi + \phi_2) \left(\frac{\chi^r_{t+1}}{\phi_1 (\varphi - 1)} \right)^{\frac{\varphi - 1}{\varphi}} - \theta_t$$

where

$$s_t = \frac{\lambda_t^{\frac{1}{\varepsilon_t}} \left(\chi^n_{t+1} \right)^{\frac{1 - \varepsilon_t}{\varepsilon_t}}}{\lambda_t^{\frac{1}{\varepsilon_t}} \left(\chi^n_{t+1} \right)^{\frac{1 - \varepsilon_t}{\varepsilon_t}} + \left(\chi^m_{t+1} \right)^{\frac{1 - \varepsilon_t}{\varepsilon_t}}}$$

and χ^i_{t+1} is the spread on the risk free rate for $i \in (m, r, n)$ Back

Calibration ▸ Back

Parameter	Value	Source
λ	1	Assumption
β	0.99	Standard
ε	$1/6$	Bacchetta and Perazzi (2022)
σ	0.5	Assumption
υ	0.85	Assumption (Match steady-state labor supply $\approx 1/3$)
ψ	0.6	Assumption (Ensure $\psi > \sigma$)
α	$1/3$	Standard
δ	0.025	Standard
θ_t	0	Assumption
ρ	0.0004	Niepelt (2022)
$\rho^{\varepsilon}, \rho^{\lambda}$	0.9	Standard
ϕ	0.00061	Model
φ	2.00924	Model
ϖ	0.01200	Model
μ	0.00745	Model