Unveiling the Interplay between Central Bank Digital Currency and Bank Deposits

Hanfeng Chen Maria Elena Filippin

Uppsala University and CeMoF

May 15th, 2023

Main research question

What is the potential risk of financial instability following the introduction of a Central Bank Digital Currency (CBDC), and how does the substitutability between CBDC and bank deposits impact this risk?

Contribution

We extend the model in Niepelt (2021) incorporating a collateral constraint for central bank lending to banks, key in assessing the implications of CBDC introduction on the banking sector and the broader economy (Burlon et al., 2022; Williamson, 2019).

Also, we extend the literature on different degrees of substitutability between CBDC and deposits (Bacchetta and Perazzi, 2022; Barrdear and Kumhof, 2022; Kumhof and Noone, 2021).

Takeaways

When CBDC and deposits are perfect substitutes, the central bank can offer loans to banks that render the introduction of CBDC neutral to the real economy. The optimal level of loan rate depends on the restrictiveness of the collateral constraint.

When CBDC and deposits are imperfect substitutes, the central bank cannot make banks indifferent to the competition from CBDC, so issuing CBDC has real effects on the economy.

Agenda

- Model
- Equivalence of operating payment systems
- Dynamic effects of households' preferences shocks
- Conclusion
- Future development

Model

RBC model with banks, deposits, government bonds, reserves, and CBDC (Niepelt, 2021; Sidrauski, 1967)

- Households value goods, leisure, and the liquidity services provided by CBDC and deposits. ▸ HHs
- Banks invest in capital, reserves, and government bonds and fund themselves through either deposits or borrowing from the central bank. ▸ Banks
- Firms produce using labor and physical capital. ▸ Firms
- The consolidated government collects taxes, pays deposit subsidies, invests in capital, lends to banks against collateral, and issues CBDC and reserves. ▸ Govt.

Banks' collateral requirement

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

- l_{t+1} and R^l_{t+1} are central bank's loans and rate of return on loans.
- θ_b is the fraction of government bonds required as collateral.
- b_{t+1} are government bonds remunerated at a rate slightly lower than the risk-free rate.

Equivalence of operating payment systems

Proposition (Brunnermeier and Niepelt, 2019; Niepelt, 2021):

Consider a policy implementing an equilibrium with deposits, reserves, no central bank loans, and no government bonds. There exists another policy that in equilibrium guarantees more CBDC, fewer deposits and reserves, central bank loans, government bonds, a different ownership structure of capital, possibly household taxes, but the same equilibrium allocation and price system.

Niepelt (2021) result

The Proposition is verified if the resource cost per unit of effective real balances is the same for CBDC and deposits, and the central bank offers the following loan rate to banks:

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

Niepelt's key result holds with perfect substitutability of payment systems and without a collateral constraint for banks when borrowing from the central bank.

Re-examining the equivalence result

We analyze if issuing CBDC has no real consequences when we introduce a collateral constraint for banks, and consider different degrees of substitutability between payment instruments. This is true when:

1. Modified HHs' portfolio does not alter effective real balances, aggregate capital stock, and reserves-to-deposits ratio. New policy leaves unchanged market values of taxes and of changes in bank profits.
2. Government's budget constraint is satisfied with modified portfolios and policy.
3. Modified banks' portfolio is optimal.

Perfect substitutability between CBDC and deposits

1. Market values of taxes and of changes in bank profits are zero if the central bank offers the following loan rate

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

2. If resource cost per unit of effective real balances is the same for CBDC and deposits, and given equation (1), govt. budget constraint is satisfied with modified portfolios and policy.

3. Equation (1) makes modified banks' portfolio optimal.

Equivalent loan rate

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

The second term at the denominator on the RHS is positive:

- From HHs' problem, assuming the rate of return on capital is not risky, we can approximate $R^k_{t+1} \equiv R^f_{t+1}$.
- Due to the liquidity benefits banks have from holding govt. bonds, $R^b_{t+1} < R^f_{t+1}$.
- Recall that $\theta_b \in [0, 1]$.

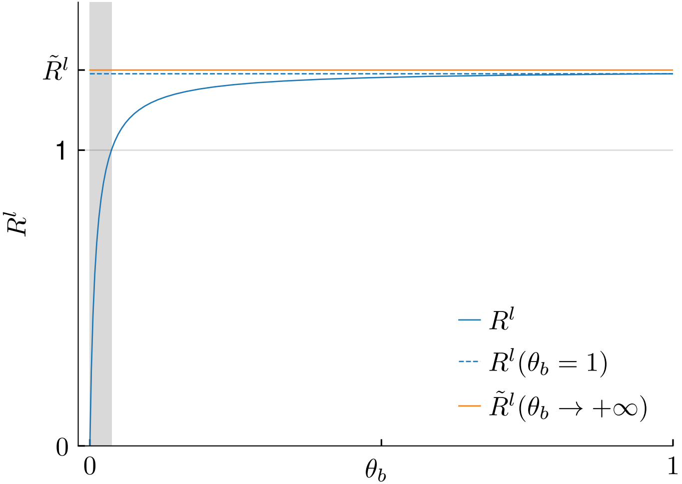
Equivalent loan rate (cont'd)

It follows that

$$R^l_{t+1} < \tilde{R}^l_{t+1}$$

Intuition: When banks are not collateral constrained, they can borrow as much as they want from the central bank. With collateral constraint, the central bank needs to offer lower loan rate to incentivize banks to borrow the same quantity as before, such that their balance sheet remains unaffected.

Relationship between equivalent loan rate and θ_b



Imperfect substitutability between CBDC and deposits

1. There is no loan rate that the central bank can offer such that it makes the change in bank profits zero, implying that banks are not indifferent to the new policy.

Intuition: A change in banks' profitability implies that the new policy does not guarantee same allocations as before, so the introduction of CBDC has real effects on the economy.

Dynamic effects of households' preferences shocks

How does an increase in demand for CBDC affect the real economy, and could it potentially lead to the crowding out of deposits?

We study the economy's responses to changes in households' relative preferences for CBDC over deposits.

Consider an economy in which both CBDC and deposits are held by HHs. ▸ Functional forms

The equilibrium conditions resemble an RBC model augmented with some ”pseudo wedges”. ▸ Equilibrium conditions

CES for effective real balances

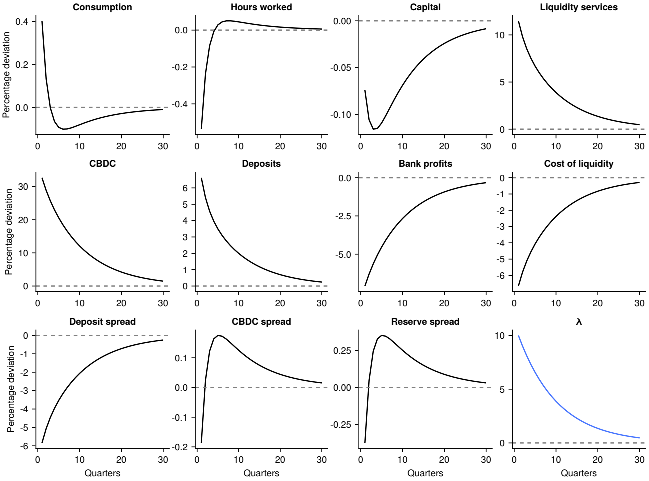
$$z(m_{t+1}, n_{t+1}) = \left(\lambda_t m_{t+1}^{1-\varepsilon_t} + n_{t+1}^{1-\varepsilon_t}\right)^{\frac{1}{1-\varepsilon_t}}$$

- m_{t+1} and n_{t+1} are CBDC and deposits.
- $\lambda_t > 0$ is the liquidity benefit of holding CBDC relative to that of holding deposits.
- $\varepsilon_t > 0$ is the inverse of the elasticity of substitution between payment instruments.

We examine the effects of a positive shock to the liquidity benefit of CBDC, λ_t, assuming it follows a log AR(1) process.

▸ Negative shock to ε_t

Impulse responses to 10% increase in λ_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 banks must respect when borrowing from the central bank, as the central bank's loan rate depends on the constraint's restrictiveness.
- Even if CBDC has real effects on the economy, no crowding out of deposits but negative effects on bank profits.

THANK YOU!

E-mail: *mariaelena.filippin@nek.uu.se*

EXTRA SLIDES

Households

Representative household takes prices, returns, profits, and taxes as given and solves:

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

s.t.

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

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

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

Banks

Bank takes deposit funding schedule, discount factor, and returns as given and solves:

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

s.t.

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

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

$$l_{t+1} \leq \theta_b \frac{b_{t+1}}{R^l_{t+1}}, \qquad n_{t+1}, l_{t+1}, b_{t+1} \geq 0$$

where

$$\zeta_{t+1} \equiv \frac{r_{t+1}}{n_{t+1}}, \text{ and } \bar{\zeta}_{t+1} \equiv \frac{\bar{r}_{t+1}}{\bar{n}_{t+1}}$$

and $\pi^b_{1,t}$, $\pi^b_{2,t+1}$ are cash flow in first and second period of the bank's operations. Back

Firms, Government and Market clearing

Representative firm takes wages, rental rate of capital, and goods price as given and solves:

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

Govt. budget constraint reads:

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

Labor, capital market and market for output good clear. Economy resource constraint is:

$$k_{t+1} = f_t(k_t, 1 - x_t) + k_t(1 - \delta) - c_t\Omega_t^{rc}$$

where we defined $\Omega_t^{rc} = 1 + \frac{m_{t+1}}{c_t}\mu^m + \frac{n_{t+1}}{c_t}(\nu_t(\zeta_{t+1}, \bar{\zeta}_{t+1}) + \zeta_{t+1}\rho)$. Back

Functional forms

We impose the following functional form assumptions for HHs' preferences, real balances, operating costs for deposit-based payments, and firms' production function, respectively:

$$
\begin{aligned}
\mathscr{U}(c_t, x_t, z_{t+1}) &= \frac{\left((1-\upsilon)c_t^{1-\psi} + \upsilon z_{t+1}^{1-\psi}\right)^{\frac{1-\sigma}{1-\psi}}}{1-\sigma} x_t^{\upsilon} \\
z(m_{t+1}, n_{t+1}) &= \left(\lambda_t m_{t+1}^{1-\varepsilon_t} + n_{t+1}^{1-\varepsilon_t}\right)^{\frac{1}{1-\varepsilon_t}} \\
v_t(\zeta_{t+1}, \bar{\zeta}_{t+1}) &= \phi_1 \zeta_{t+1}^{1-\varphi} + \phi_2 \bar{\zeta}_{t+1}^{1-\varphi} \\
f_t(k_t, \ell_t) &= k_t^{\alpha} \ell_t^{1-\alpha}
\end{aligned}
$$

where υ, $\psi \in (0,1)$; $\sigma > 0, \neq 1$; $\varepsilon_t > 0$; $\lambda_t > 0$; $\phi_1 > 0$, $\phi_2 \geq 0$; $\varphi > 1$. Back

Equilibrium conditions

Euler equation, leisure choice and resource constraint are, respectively:

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

where return on capital and real wage are

$$
R_{t+1}^{k} = 1 - \delta + \alpha \left(\frac{k_{t+1}}{1-x_{t+1}} \right)^{\alpha-1}, \qquad w_t = (1-\alpha) \left(\frac{k_t}{1-x_t} \right)^{\alpha}.
$$

Equilibrium conditions (cont'd)

Demand for effective real balances, CBDC, and deposits are, respectively:

$$z_{t+1} = c_t \left(\frac{\upsilon}{1-\upsilon} \frac{1}{\chi_{t+1}} \right)^{\frac{1}{\psi}}, \qquad m_{t+1} = z_{t+1} \left(\lambda_t \frac{\chi_{t+1}}{\chi_{t+1}^m} \right)^{\frac{1}{\varepsilon_t}}, \qquad n_{t+1} = z_{t+1} \left(\frac{\chi_{t+1}}{\chi_{t+1}^n} \right)^{\frac{1}{\varepsilon_t}}.$$

Cost of liquidity reads

$$\chi_{t+1} = \chi_{t+1}^m \chi_{t+1}^n \left(\lambda_t^{\frac{1}{\varepsilon_t}} \left(\chi_{t+1}^n\right)^{\frac{1-\varepsilon_t}{\varepsilon_t}} + \left(\chi_{t+1}^m\right)^{\frac{1-\varepsilon_t}{\varepsilon_t}} \right)^{\frac{-\varepsilon_t}{1-\varepsilon_t}}$$

$$\chi_{t+1}^n - \chi_{t+1}^n \left(\frac{1-s_t}{\psi} + \frac{s_t}{\varepsilon_t} \right)^{-1} = (\phi_1 \varphi + \phi_2) \left(\frac{\chi_{t+1}^r}{\phi_1(\varphi-1)} \right)^{\frac{\varphi-1}{\varphi}} - \theta_t, s_t = \frac{\lambda_t^{\frac{1}{\varepsilon_t}} \left(\chi_{t+1}^n\right)^{\frac{1-\varepsilon_t}{\varepsilon_t}}}{\lambda_t^{\frac{1}{\varepsilon_t}} \left(\chi_{t+1}^n\right)^{\frac{1-\varepsilon_t}{\varepsilon_t}} + \left(\chi_{t+1}^m\right)^{\frac{1-\varepsilon_t}{\varepsilon_t}}}.$$

where χ_{t+1}^i is the spread on the risk free rate for $i \in (m, r)$.

Equilibrium conditions (cont'd)

The auxiliary variables are:

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

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

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

▸ Back

Impulse responses to 10% increase in ε_t ▸ Back