Monetary Policy Transmission, Central Bank Digital Currency, and Bank Market Power

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Motivation: some developments

- Central bank digital currency (CBDC)
  - many central banks have publicly communicated research or development effort
  - interest-bearing CBDC would compete with commercial bank deposits
- Bank market power and concentration
  - banking industry consolidation has softened competitive pressure (Wang et al., 2020)
  - deposit market share of the top U.S. banks has grown substantially (Corbae and D'Erasmo, 2020)
  - U.S. deposit spread suggest bank market power (Wang et al., 2020)

Questions

- Does bank market power influence the transmission of interest rate on CBDC?
    - amplification, dampening or no effect?
- Does bank market power influence the government's optimal policy?
    - policy instruments: CBDC rate, reserve rate and deposit subsidy

Related work

- CBDC
  - Commercial banks' intermediation (Andolfatto, 2021)
  - Financial stability (Williamson, 2021)
  - Pass-through of interest rates on CBDC (Jiang and Zhu, 2021)
  - Macroeconomic impact (Barrdear and Kumhof (2021) and Niepelt (2021))
    - Niepelt (2021) first to embed non-competitve banks, deposits, reserves and CBDC into the baseline real business cycle (RBC) model
- Bank market power and policy transmission
  - Deposit channel of monetary policy (Drechsler et al., 2017)
  - Regulatory vs. market-power transmission channels (Wang et al., 2020)
  - Heterogeneous banks and market power (Bellifemine et al. (2022) and Jamilov (2021))

Our contribution

- Extend the Niepelt (2021) RBC model
    - banks compete by offering deposits to the household which values a variety of differentiated deposit products
    - assume CBDC and deposits are imperfect substitutes
- Incorporate mechanisms akin to the deposit channel into the RBC model
- Analyze the extent to which deposit market concentration has impact on macroeconomic fluctuations

Summary of results

- Deposit market concentration *amplifies* fluctuations caused by shocks to CBDC rate
  - changes in CBCD rate not only affects the household's opportunity cost of CBDC but also the opportunity cost of deposits
  - link between the two costs relies on market concentration and bank market power in general
- Optimal policy equalizes opportunity costs of holding liquid assets to the societal costs of supplying them
  - bank market power does not affect optimal CBDC rate
  - optimal reserve rate decreases with deposit market concentration
- Optimal policy corrects for bank market power
  - optimal subsidy increases with market concentration

Model in the nutshell

- Households
  - households value liquidity services provided by CBDC and bank deposits
  - interest-bearing CBDC and deposits are imperfect substitutes
  - households value a variety of differentiated deposit products
- Banks
  - banks borrow deposits from the households and invest in capital and reserves
  - banks have market power due to deposit market concentration and imperfect substitutability between banks' deposit products
- Firms
  - competitive firms produce a common consumption good using capital and labor
- Government
  - consolidated fiscal/monetary authority collects taxes and issues CBDC and reserves

Some definitions

- Risk-free rate

$$R^f_{t+1} \equiv \frac{1}{\mathbb{E}_t[\Lambda_{t+1}]}$$

- CBDC spread

$$\chi^m_{t+1} \equiv 1 - \frac{R^m_{t+1}}{R^f_{t+1}}$$

- Reserve spread

$$\chi^r_{t+1} \equiv 1 - \frac{R^r_{t+1}}{R^f_{t+1}}$$

Equilibrium conditions

- Three core conditions that parallels baseline RBC

$$
\begin{aligned}
\text{Euler equation :} \quad & c_t^{-\sigma} x_t^{\upsilon} \Omega_t^c = \beta \mathbb{E}_t \left[R_{t+1}^k c_{t+1}^{-\sigma} x_{t+1}^{\upsilon} \Omega_{t+1}^c \right] \\
\text{Leisure choice :} \quad & \frac{c_t^{1-\sigma}}{1-\sigma} \upsilon x_t^{\upsilon-1} \Omega_t^x = w_t c_t^{-\sigma} x_t^{\upsilon} \Omega_t^c \\
\text{Resource constraint :} \quad & k_{t+1} = a_t k_t^{\alpha} (1 - x_t)^{1-\alpha} + k_t (1 - \delta) - c_t \Omega_t^{rc}
\end{aligned}
$$

- $\Omega^c(\chi^z)$, $\Omega^x(\chi^z)$ and $\Omega^{rc}(\chi^z)$ summarize the impact of household's preference for liquidity, and depend on the *average cost of liquidity*, χ^z

Cost of liquidity

- Cost of liquidity

$$\chi^z_{t+1} = \frac{\chi^m_{t+1}\chi^n_{t+1}}{\left((1-\gamma)^{\frac{1}{\epsilon}}\left(\chi^n_{t+1}\right)^{\frac{1-\epsilon}{\epsilon}} + \gamma^{\frac{1}{\epsilon}}\left(\chi^m_{t+1}\right)^{\frac{1-\epsilon}{\epsilon}}\right)^{\frac{\epsilon}{1-\epsilon}}}$$

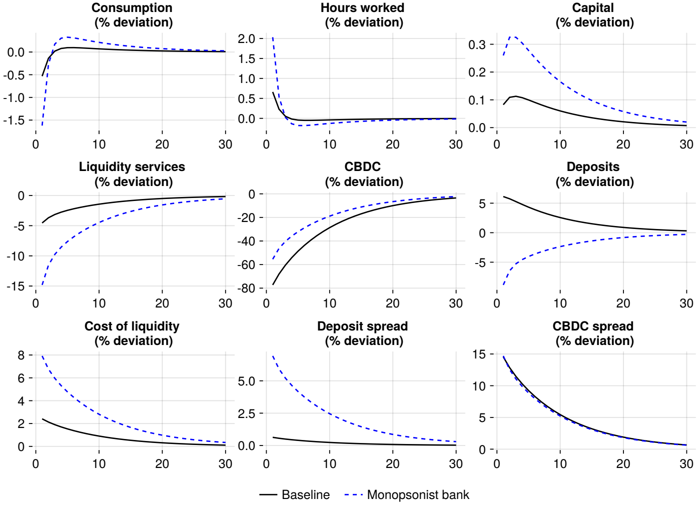
- CBDC spread is determined by the government

- Deposit spread is determined by the banking sector

$$\chi^n_{t+1} = \underbrace{MU(\chi^m_{t+1}; N)}_{\text{mark-up}} + \underbrace{MC(\chi^r_{t+1})}_{\text{marginal cost}}$$

Impulse responses

Impulse responses to 25 basis points decrease in CBDC rate

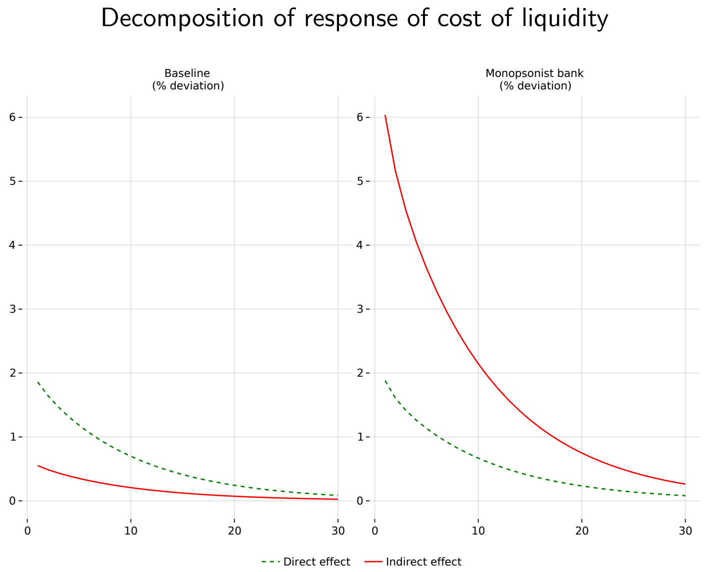


Decomposition

$$\begin{tikzcd}
\text{Shock to CBDC rate} \arrow[d] & \\
\text{Cost of CBDC} \arrow[r] \arrow[d, "direct"] & \text{Cost of deposits} \arrow[dl, "indirect"] \\
\text{Average cost of liquidity} &
\end{tikzcd}$$

$$\frac{\partial \chi^z_{t+1}}{\partial \chi^m_{t+1}} = \underbrace{\left((1-\gamma)\frac{\chi^z_{t+1}}{\chi^m_{t+1}}\right)^{\frac{1}{\epsilon}}}_{\text{direct effect}} + \underbrace{\left(\gamma\frac{\chi^z_{t+1}}{\chi^n_{t+1}}\right)^{\frac{1}{\epsilon}} \overbrace{\frac{\partial \chi^n_{t+1}}{\partial \chi^m_{t+1}}}^{\text{deposit channel}}}_{\text{indirect effect}}$$

Decomposition



Impact of CBDC on banks: bank market power matters

- Competitve banking sector implies no indirect effect since $\frac{\partial \chi^n_{t+1}}{\partial \chi^m_{t+1}} = 0$

$$\underbrace{\chi^n_{t+1} = MC}_{\text{competitve}} \quad \text{or} \quad \underbrace{\chi^n_{t+1} = \frac{MC}{1-\eta}}_{\text{monopsonistically competitve}}$$

- In more general cases, χ^n_{t+1} depends on a weighted average of $1/\psi$ and $1/\epsilon$

$$\frac{1 - s(\chi^m_{t+1})}{\psi} + \frac{s(\chi^m_{t+1})}{\epsilon}, \quad s(\chi^m_{t+1}) \in [0, 1]$$

- Banking sector faces competition from CBDC ($1/\epsilon$) and consumption ($1/\psi$), and the CBDC spread only influences the relative importance of these two sources of deposits outflow

Impact of CBDC on banks: bank market power matters

- Suppose CBDC spread increases

$$\frac{\partial s(\chi_{t+1}^m)}{\partial \chi_{t+1}^m} < 0$$

- Demand for deposits becomes less elastic and the banks increase their deposit spread. Deposit market concentration, $1/N$, amplifies this mechanism through elasticity of demand for deposits

$$-\frac{1}{N}\left(\frac{1-s(\chi_{t+1}^m)}{\psi}+\frac{s(\chi_{t+1}^m)}{\epsilon}\right)-\left(1-\frac{1}{N}\right)\frac{1}{\eta}<0$$

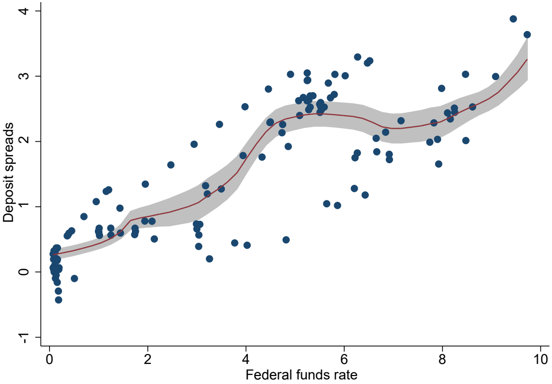
- *Intuition*: when the market is more concentration, banks compete less with each other and more with the household's alternative source of liquidity, CBDC. They are more responsive to the competitive pressure from CBDC and the deposit spread is more sensitive to changes in the CBDC spread

Conclusions

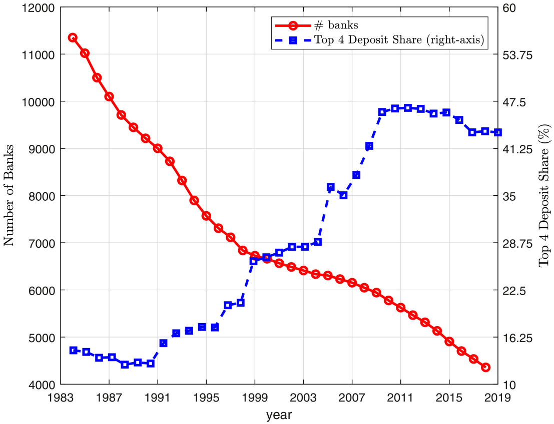
- Higher deposit market concentration amplifies fluctuations caused by shocks to the CBDC rate
  - shock to CBDC rate generate fluctuations because it affects the household's average cost of liquidity
  - decrease in CBDC rate 1) directly increases the cost of liquidity and 2) indirectly affects this cost through its influence on the cost of holding deposits (similar to the deposit channel)
  - indirect effect of CBDC rate relies on deposit market concentration (and bank market power in general)
- Optimal policy
  - equalizes opportunity costs of holding CBDC and reserves to the societal costs of supplying them
  - optimal reserve rate decreases with market concentration
  - corrects for bank market power using deposit subsidy, which size increases with deposit market concentration

Appendix: figures

U.S. deposit spread (Wang et al., 2020)



U.S. bank concentration (Corbae and D'Erasmo, 2020)



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Appendix: household problem

- Households value consumption (c), leisure (x) and liquidity services (z)

$$u(c_t, z_{t+1}, x_t) = \frac{\left((1-\upsilon)c_t^{1-\psi} + \upsilon z_{t+1}^{1-\psi}\right)^{\frac{1-\sigma}{1-\psi}}}{1-\sigma} x_t^{\upsilon}$$

- Liquidity composes of CBDC (m) and bank deposits (n)

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

- Bank deposits are themselves a composite good issued by a set of N banks

$$n_{t+1} = \left(\frac{1}{N}\sum_{i=1}^{N}\left(n_{t+1}^{i}\right)^{1-\eta}\right)^{\frac{1}{1-\eta}}$$

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Appendix: household problem

- Household's budget constraint

$$c_t + k^h_{t+1} + m_{t+1} + \sum_{i=1}^{N} \frac{n^i_{t+1}}{N} + \tau_t = w_t(1 - x_t) + \pi_t + k^h_t R^k_t + m_t R^m_t + \sum_{i=1}^{N} \frac{n^i_t R^{n,i}_t}{N}$$

- Household chooses $\{c_t, x_t, k^h_{t+1}, m_{t+1}, n^i_{t+1}\}_{t=0}^{\infty}$ to maximize

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(c_t, z_{t+1}, x_t)$$

subject to budget constraint

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Appendix: bank problem

- Each bank i issues deposits (n^i) to fund investments in capital (k^i) and reserves (r^i)

$$r^i_{t+1} + k^i_{t+1} = n^i_{t+1}$$

- Bank i faces a demand schedule for its deposits

$$n^i_{t+1} = n_{t+1} \left(\frac{\chi^{n,i}_{t+1}}{\chi^n_{t+1}} \right)^{-\frac{1}{\eta}}$$

where

$$\chi^{n,i}_{t+1} \equiv 1 - \frac{R^{n,i}_{t+1}}{R^f_{t+1}}, \quad \chi^n_{t+1} = \left(\frac{1}{N} \sum_{i=1}^{N} \left(\chi^{n,i}_{t+1} \right)^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}$$

back

Appendix: bank problem

- Maturity transformation is costly and imposes a cost per unit of deposit issued

$$\nu_t^i = \phi \left(\frac{r_{t+1}^i}{n_{t+1}^i} \right)^{1-\varphi}$$

- Each bank solves a sequence of two-period problems by choosing its deposit rate and reserve holdings

$$\max_{r_{t+1}^i, R_{t+1}^{n,i}} \quad - n_{t+1}^i \nu_t^i + \mathbb{E}_t \left[\Lambda_{t+1} \left(k_{t+1}^i R_{t+1}^k + r_{t+1}^i R_{t+1}^r - n_{t+1}^i R_{t+1}^{n,i} \right) \right]$$

subject to the balance sheet constraint and deposit demand schedule

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Appendix: firms

- Representative firm solves a profit maximization problem

$$\max_{k_t, l_t} \quad a_t k_t^{\alpha} l_t^{1-\alpha} - k_t \left(R_t^k - 1 + \delta \right) - w_t l_t$$

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Appendix: consolidated government

- Government collects taxes, invests in capital (k^g), and issues CBDC and reserves

$$k^g_{t+1} - m_{t+1}(1-\mu) - \sum_{i=1}^{N} \frac{r^i_{t+1}(1-\rho)}{N} = k^g_t R^k_t + \tau_t - m_t R^m_t - \sum_{i=1}^{N} \frac{r^i_t R^r_t}{N}$$

back

Appendix: market clearing

- Labor and capital market clearing

$$l_t = 1 - x_t, \quad k_t = k_t^h + \frac{1}{N}\sum_{i=1}^{N}\left(n_t^i - r_t^i\right) + k_t^g$$

- Total profits

$$\pi_t = \frac{1}{N}\sum_{i=1}^{N}\left(-n_{t+1}^i \nu_t^i + k_t^i R_t^k + r_t^i R_t^r - n_t^i R_t^{n,i}\right) + a_t k_t^\alpha l_t^{1-\alpha} - k_t\left(R_t^k - 1 + \delta\right) - w_t l_t.$$

Appendix: full set of equilibrium conditions

- Household's demand for liquidity services and their composition

$$z_{t+1} = c_t \left(\frac{\upsilon}{1-\upsilon} \frac{1}{\chi^z_{t+1}} \right)^{\frac{1}{\psi}}, \quad m_{t+1} = z_{t+1} \left((1-\gamma) \frac{\chi^z_{t+1}}{\chi^m_{t+1}} \right)^{\frac{1}{\epsilon}}, \quad n_{t+1} = z_{t+1} \left(\gamma \frac{\chi^z_{t+1}}{\chi^n_{t+1}} \right)^{\frac{1}{\epsilon}}$$

- Average cost of liquidity

$$\chi^z_{t+1} = \frac{\chi^m_{t+1} \chi^n_{t+1}}{\left((1-\gamma)^{\frac{1}{\epsilon}} \left(\chi^n_{t+1} \right)^{\frac{1-\epsilon}{\epsilon}} + \gamma^{\frac{1}{\epsilon}} \left(\chi^m_{t+1} \right)^{\frac{1-\epsilon}{\epsilon}} \right)^{\frac{\epsilon}{1-\epsilon}}}$$

back

Appendix: full set of equilibrium conditions

- Euler equation

$$c_t^{-\sigma} x_t^{\upsilon} \Omega_t^c = \beta \mathbb{E}_t \left[R_{t+1}^k c_{t+1}^{-\sigma} x_{t+1}^{\upsilon} \Omega_{t+1}^c \right]$$

- Leisure choice condition

$$\frac{c_t^{1-\sigma}}{1-\sigma} \upsilon x_t^{\upsilon-1} \Omega_t^x = w_t c_t^{-\sigma} x_t^{\upsilon} \Omega_t^c$$

- Aggregate resource constraint

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

back

Appendix: full set of equilibrium conditions

- Factor prices

$$R_t^k = 1 - \delta + a_t \alpha \left(\frac{k_t}{1 - x_t} \right)^{\alpha - 1}, \quad w_t = a_t (1 - \alpha) \left(\frac{k_t}{1 - x_t} \right)^{\alpha}$$

- Bank optimality condition

$$\chi_{t+1}^n + \chi_{t+1}^n \left(\frac{1}{N} \left(-\frac{1 - s_t}{\psi} - \frac{s_t}{\epsilon} \right) - \left(1 - \frac{1}{N} \right) \frac{1}{\eta} \right)^{-1} = \varphi \phi \zeta_{t+1}^{1-\varphi},$$

where

$$s_t = (1 - \gamma)^{\frac{1}{\epsilon}} \left(\frac{\chi_{t+1}^z}{\chi_{t+1}^m} \right)^{\frac{1-\epsilon}{\epsilon}}, \quad \zeta_{t+1} = \left(\frac{\chi_{t+1}^r}{\phi(\varphi - 1)} \right)^{-\frac{1}{\varphi}}$$

back

Appendix: full set of equilibrium conditions

- CBDC and reserve spread

$$\chi^m_{t+1} = 1 - \frac{R^m_{t+1}}{R^f_{t+1}}, \quad \chi^r_{t+1} = 1 - \frac{R^r_{t+1}}{R^f_{t+1}}$$

- Risk-free rate

$$R^f_{t+1} = \frac{1}{\mathbb{E}_t[\Lambda_{t+1}]}$$

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Appendix: full set of equilibrium conditions

- Auxiliary variables

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

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

$$\Omega_t^{rc} = 1 + \left(\frac{\upsilon}{1-\upsilon}\frac{1}{\chi_{t+1}^z}\right)^{\frac{1}{\psi}} \left(\left((1-\gamma)\frac{\chi_{t+1}^z}{\chi_{t+1}^m}\right)^{\frac{1}{\epsilon}} \mu + \left(\gamma\frac{\chi_{t+1}^z}{\chi_{t+1}^n}\right)^{\frac{1}{\epsilon}} \left(\phi\zeta_{t+1}^{1-\varphi} + \zeta_{t+1}\rho\right)\right)$$

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Appendix: predefined parameters

Predefined parameters

	Value	Source/motivation
β	$(1.03)^{-1/4}$	Steady state annual risk-free rate 3%
γ	0.5	
ϵ	1/6	Bacchetta and Perazzi (2021)
η	1/6	
σ	0.5	Niepelt (2021)
υ	0.85	Steady state labor supply $\approx 1/3$
ψ	0.6	$\psi > \sigma$
α	1/3	
δ	0.025	
ρ	0.01	Niepelt (2021)

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Appendix: calibrated parameters

Calibrated parameters

	Baseline $\frac{1}{N} = 1/3$	Alternative $\frac{1}{N} = 1.0$
υ	0.02368	0.02368
ϕ	0.00526	0.00267
φ	1.24806	1.39707
μ	0.00992	0.00714

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Social planner problem

- Social planner maximizes the household's utility subject to the aggregate resource constraint

$$
\begin{aligned}
\max_{\{c_t, x_t, k_{t+1}, m_{t+1}, n^i_{t+1}, r^i_{t+1}\}_{t=0}^{\infty}} \quad & \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(c_t, z_{t+1}, x_t) \\
\text{s.t.} \quad k_{t+1} = a_t k_t^{\alpha} (1 - x_t)^{1-\alpha} + k_t(1-\delta) - \ldots \\
& \ldots c_t - m_{t+1}\mu - \sum_{i=1}^{N} \frac{n^i_{t+1}\nu^i_t}{N} - \sum_{i=1}^{N} \frac{r^i_{t+1}\rho}{N}
\end{aligned}
$$

back

Optimal policy

- Consolidated government can implement the social planner solution by choosing policy instruments, CBDC rate, R^m_{t+1}, reserve rate, R^r_{t+1}, and bank subsidy, θ_t, that support the optimal equilibrium

- We restrict ourselves to a "first-order approach", i.e. policy instruments can be set in way such that the relevant first-order conditions in the competitive equilibrium are equivalent to the corresponding conditions in the social planner solution

back

Optimal policy

- In order to replicate the social planner condition, the government should keep the CBDC spread equal to the government's per unit cost of issuing (and managing) CBDC

$$\chi^{m*}_{t+1} = \mu, \quad R^{m*}_{t+1} = R^{f}_{t+1}(1-\mu)$$

- Similarly, the government should ensure that the reserve spread equals the government's per unit cost of issuing (and managing) reserves

$$\chi^{r*}_{t+1} = \frac{1}{N}\rho, \quad R^{r*}_{t+1} = R^{f}_{t+1}\left(1 - \frac{1}{N}\rho\right)$$

- Lastly, to correct for bank market power, the deposit subsidy should be

$$\theta^*_t = \chi^{n*}_{t+1}\left(\frac{1}{N}\left(\frac{1-s(\chi^{m*}_{t+1})}{\psi} + \frac{s(\chi^{m*}_{t+1})}{\epsilon}\right) + \left(1-\frac{1}{N}\right)\frac{1}{\eta}\right)^{-1}$$

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