On Interest-Bearing Central Bank Digital Currency with Heterogeneous Banks

Rodney Garratt
UCSB

Haoxiang Zhu
MIT

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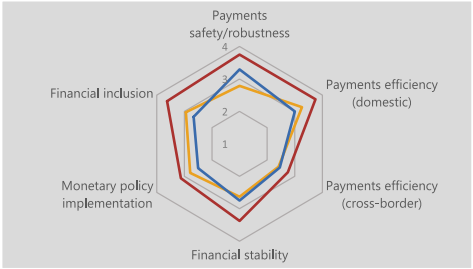
Objectives of CBDC

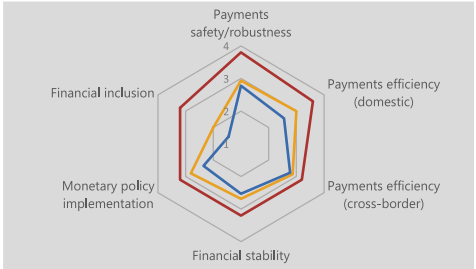
Main motivations of CBDC work by stage

Average importance — Graph 5

Retail CBDC



Wholesale CBDC



(1) = "Not so important"; (2) = "Somewhat important"; (3) = "Important"; (4) = "Very important".

Source: BIS central bank survey on CBDCs.

Past objectives

If all a CBDC did was to substitute for cash – if it bore no interest and came without any of the extra services we get with bank accounts – people would probably still want to keep most of their money in commercial banks.

—Ben Broadbent, Deputy Governor for Monetary Policy of the Bank of England, 2016

- Goal was to minimize impact of CBDC
- Surprising in retrospect
- Now people are looking more toward ways CBDC can be better than cash (improve store of value and medium of exchange aspects).

Banking for All Act

Section 5 (c) Terms Of Digital Dollar Wallets
(1) shall not be subject to any account fees, minimum balances, or maximum balances, and shall pay interest at a rate not below the greater of the rate of interest on required reserves and the rate of interest on excess reserves;
(2) shall provide debit cards, online account access, automatic bill-pay, mobile banking, customer service and other such services as the Board of Governors of the Federal Reserve System determines appropriate in the public interest, provided that digital dollar wallets shall not include overdraft coverage;
(3) shall provide, in conjunction with the Postal Service, access to automatic teller machines
(4) shall be branded in all account statements, marketing materials, and other communications as "FedAccounts"
(5) may not be closed or restricted on the basis of profitability considerations
(6) shall provide account holders with reasonable protection against losses caused by fraud or security breaches.

What do we do this paper?

1. We provide a tractable model of deposit and lending with large and small banks.
   - The large bank has a convenience value and hence more market power in deposit market.
   - Tailored to the U.S. financial system after 2008-09 crisis: banks hold ample reserves that earn interest on reserves (IOR) from the Fed.
   - Banks are not constrained by reserve requirements

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   - CBDC adopts convenience of host bank
   - CBDC has own convenience value
4. Evaluate the trade-offs between interest and convenience (*in progress*).

Preview of Results

Interest-bearing CBDC

- Puts a lower bound on deposit interest rates.
- Improves monetary policy transmission, but further reduces market share of small banks.

A convenient CBDC

- Levels the playing field by increasing the market share of the small bank.
- If the CBDC convenience value is high enough, then it also improves monetary policy transmission.

Long Run Framework

Our work builds on previous literature that has modelled deposit and lending markets in the current regime of large excess reserves.

- Primary references are Martin, McAndrews and Skeie (2013) and Andolfatto (2020)
- Reserves are abundant, lending is determined by the opportunity cost of funds, and banks have monopoly power in lending market.
- A loan is made if its return exceeds the marginal opportunity cost of reserves.

Difference: In our model, deposits generated by loans may be retained, so the opportunity cost of lending is related to deposit market share and differs across banks.

Hot Topic

There are now many CBDC papers: Agur, Ari and Dell'Ariccia (2019); Keister and Sanches (2019); Chiu, Davoodalhosseini, Jiang and Zhu (2019); Andolfatto (2020); Fernández-Villaverde, Sanches, Schilling and Uhlig (2020); Piazzesi and Schneider (2020); Fernández-Villaverde, Schilling and Uhlig (2021)

Conclusions vary and depend upon the level of competition, the interest rate on the CBDC, and other features (eg liquidity properties of CBDC and reserve requirements)

Some derive conditions under which the addition of a CBDC does not affect equilibrium outcomes, e.g., Brunnermeier and Niepelt (2019) and Fernández-Villaverde et al. (2020).

Outline

Model

A large bank (L) and a small bank (S)

Each consumer has a convenience value δ for large bank, independent draws from G

Bank assets are reserves X_L and X_S, exogenous and large (Total reserves $=$ X).

Bank liabilities are existing deposits.

Central bank pays interest on reserves (IOR) f on reserves held by banks.

Interest-bearing CBDC

We model CBDC as the central bank's liability, but various account services such as money transfer are provided by existing commercial banks' infrastructure.

The CBDC is a close substitute for the commercial bank deposit of the same bank, same convenience value.

Interest rate on CBDC is set exogenously to $s \in [0, f]$.

The CBDC interest rate s becomes a lower bound on each bank's deposit interest rate.

Agents: three roles

A unit mass of agents play 3 roles in the model:

- Entrepreneur: Agent i is endowed with a project of quality (success probability) q_i that has a cumulative distribution function Q. Project i requires \$1 of investment and pays $A > 1$ if successful. If the project fails, it pays zero. Agent i can only borrow from the bank where she currently keeps her deposit (the "relationship" bank).
- Worker: If funded, an entrepreneur hires a worker, randomly selected from the population. The worker is paid the full \$1 to work on the project.
- Depositor: Once a worker receives wage (\$1), she deposits it in a bank, chosen endogenously. Choice depends on deposit rates and the worker's "convenience value" δ.

Timeline

- $t = 0$: Banks set deposit interest rates r_L and r_S. Central bank sets IOR rate f and CBDC rate s. Each agent already has an account in either bank.
- $t = 1$: Each agent is endowed with a project and goes to their bank to borrow \$1. The bank prices the loan as a monopolist.
- $t = 2$: If a loan is granted, a funded entrepreneur pays a randomly matched worker \$1 as wage. The worker chooses a bank to deposit the funds.
- $t = 3$: Projects payoff realized.

Bank deposit creation (e.g., large bank)

1. Before lending, the large bank starts with X_L reserves.

Asset	Liability
Reserves X_L	Deposits X_L

2. If the large bank makes a loan of \$1, it immediately creates a deposit of \$1 in the name of the entrepreneur.

Reserves X_L	Deposits X_L
Loans 1	New Deposits 1

3. Eventually, the entrepreneur will spend her money to pay a worker. With probability α_S, the worker deposits at the small bank and her deposit leaves the large bank. With probability $\alpha_L = 1 - \alpha_S$, the deposit stays.

Reserves $X_L - \alpha_S$	Deposits X_L
Loans 1	New Deposits α_L

Marginal profit of lending

If the large bank makes the \$1 loan to entrepreneur i, and charges interest rate R_i, its marginal profit will be

$$\pi_i = \underbrace{q_i(1+R_i)-(1+f)}_{\text{Net profit on the loan}} + \underbrace{\alpha_L(f-r_L)}_{\text{Profit on retained deposit}} .$$

Each \$1 lent out earns NPV of the loan and a part of IOR-deposit rate spread.

Equilibrium

Deposit market at $t = 2$

Faced with the two deposit rates r_L and r_S, an agent with convenience value δ chooses the large bank if and only if

$$r_L + \delta > r_S \Rightarrow \delta > r_S - r_L$$

Therefore, the eventual market shares of the banks are

$$\alpha_L = 1 - G(r_S - r_L)$$
$$\alpha_S = G(r_S - r_L)$$

Loan market at $t = 1$

The large bank makes the loan if and only if

$$q_i A - (1 + f) + \alpha_L (f - r_L) > 0$$

or

$$q_i > q_L^* = \frac{1 + f - \alpha_L (f - r_L)}{A}.$$

The same calculation for the small bank yields a comparable investment threshold

$$q_S^* = \frac{1 + f - \alpha_S (f - r_S)}{A}.$$

Note that banks' lending criteria have nothing to do with existing deposit level.

Choice of deposit rates at $t = 0$

Assume m_L and m_S are initial deposit shares and X is initial total reserves. The large bank's profit from choosing r_L given r_S is

$$\Pi_L = \underbrace{m_L \int_{q_L^*}^{1} [qA - (1+f) + \alpha_L(f - r_L)] dQ(q)}_{\text{Profit from loans}} + \underbrace{[X + m_S(1 - Q(q_S^*))]\alpha_L(f - r_L)}_{\text{Profit from other reserves}}. \quad (1)$$

For simplicity, let $Q(\cdot)$ be the uniform distribution.

And further impose the stationarity condition that the market shares of deposit α_j are identical to the starting market share m_j.

The first-order conditions simplify to

$$0 = \frac{d\Pi_L}{dr_L} = [X + \alpha_L(1 - q_L^*) + \alpha_S(1 - q_S^*)] \cdot [(f - r_L)G'(r_S - r_L) - 1 + G(r_S - r_L)] - \frac{1}{A}\alpha_S\alpha_L(f - r_L)(f - r_S)G'(r_S - r_L), \tag{2}$$

$$0 = \frac{d\Pi_S}{dr_S} = [X + \alpha_L(1 - q_L^*) + \alpha_S(1 - q_S^*)] \cdot [(f - r_S)G'(r_S - r_L) - G(r_S - r_L)] - \frac{1}{A}\alpha_L\alpha_S(f - r_L)(f - r_S)G'(r_S - r_L). \tag{3}$$

Unconstrained equilibrium

Proposition 1

Suppose that the profit function Π_j is quasi-concave in r_j. Let r_L and r_S solve equations (2)–(3). If $r_L > s$ and $r_S > s$, then it is an unconstrained equilibrium that the banks set r_L and r_S as their deposit interest rates. In this equilibrium:

1. *The large bank sets a lower deposit interest rate ($r_L < r_S$) and has a larger market share ($\alpha_L > \alpha_S$) than the small bank.*
2. *The large bank uses a looser lending standard than the small bank does ($q_L^* < q_S^*$).*

CBDC interest rate as a floor on banks' deposit rates

- The lower bound of deposit interest rates is the CBDC interest rate s.
- Since $r_L < r_S$ in the unconstrained equilibrium, by continuity, the large bank's deposit interest rate will hit the lower bound first.
- We look for an equilibrium in which Π_S attains an interior optimum but Π_L attains its maximum at the corner $r_L = s$, i.e.,

$$0 > [X + \alpha_L(1 - q_L^*) + \alpha_S(1 - q_S^*)] \cdot [(f - s)G'(r_S - s) - 1 + G(r_S - s)] - \frac{1}{A}\alpha_S\alpha_L(f - s)(f - r_S)G'(r_S - s), \tag{4}$$

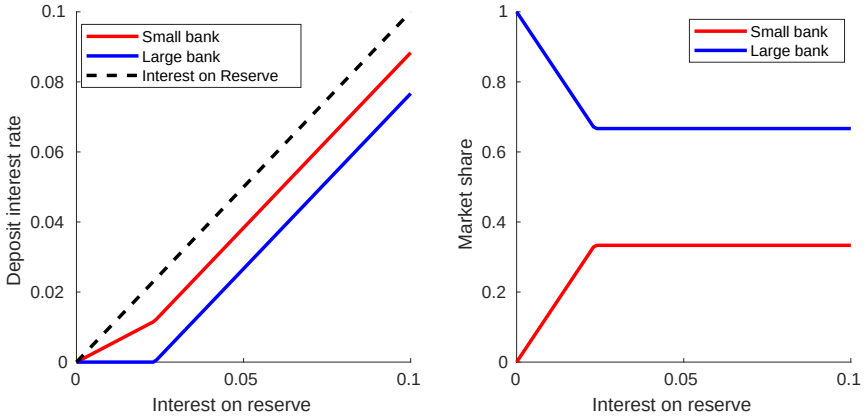
$$0 = [X + \alpha_L(1 - q_L^*) + \alpha_S(1 - q_S^*)] \cdot [(f - r_S)G'(r_S - s) - G(r_S - s)] - \frac{1}{A}\alpha_L\alpha_S(f - s)(f - r_S)G'(r_S - s). \tag{5}$$

Proposition 2

Suppose that the profit function Π_j is quasi-concave in r_j. Let r_S solve equation (5). If, at r_S, equation (4) also holds, then it is a constrained equilibrium that the large bank sets s and the small bank sets r_S as their deposit interest rates. In this equilibrium:

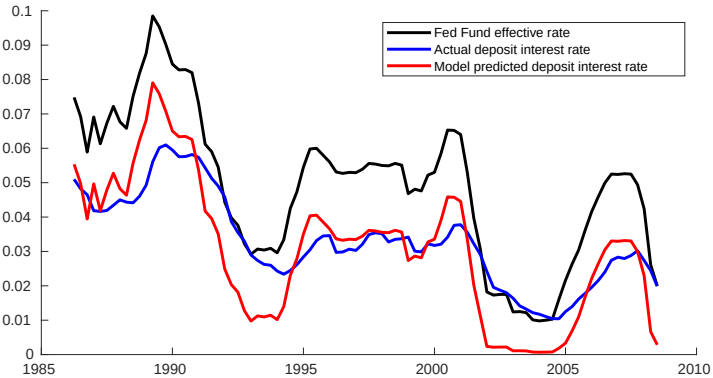
1. *The large bank sets a lower deposit interest rate ($s < r_S$) and has a larger market share ($\alpha_L > \alpha_S$) than the small bank.*
2. *The large bank uses a looser lending standard than the small bank does ($q_L^* < q_S^*$).*

Impact of IOR rate on deposit market ($s = 0$)



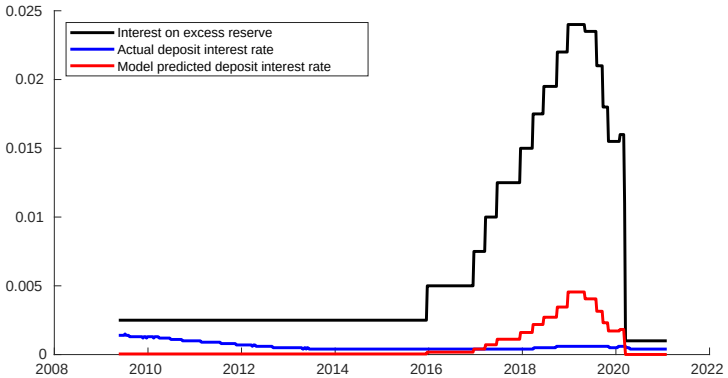
Parameters: $G(\delta) = \delta/0.035$, $A = 1.5$, $X = 10$, $s = 0$.

Fitting U.S. deposit interest rate before 2008



Actual deposit interest rate is from quarterly call report, calculated as quarterly total interest expense divided by total deposit, multiplied by 4. Model-predicted deposit interest rate is $\alpha_L r_L + \alpha_S r_S$. Model parameters: $G(\delta) = \delta/0.035$, $A = 1.5$, $X = 10$, $s = 0$.

Fitting U.S. deposit interest rate after 2009

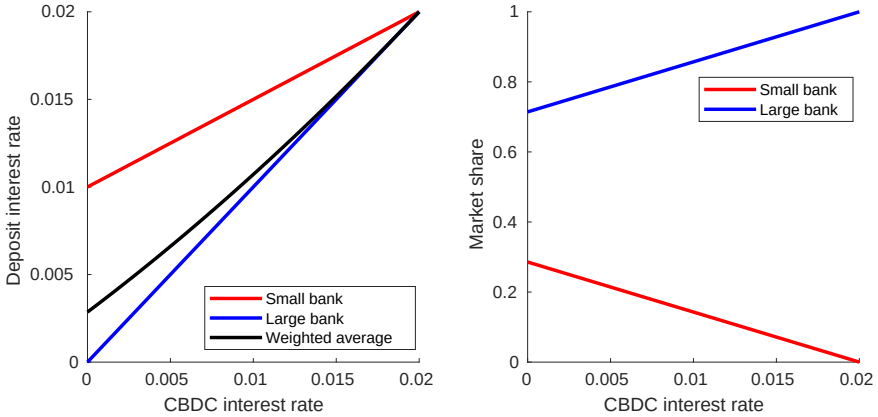


Actual deposit interest rate is non-jumbo (<100K) from FDIC, weekly. Model-predicted deposit interest rate is $\alpha_L r_L + \alpha_S r_S$. Model parameters:

$G(\delta) = \delta/0.035$, $A = 1.5$, $X = 10$, $s = 0$.

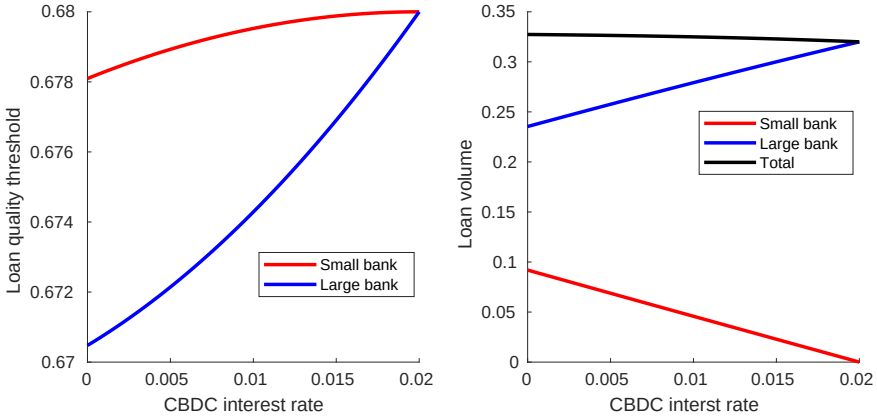
Outine

Impact of the CBDC interest rate s on the deposit market



Parameters: $G(\delta) = \delta/0.035$, $A = 1.5$, $X = 10$, $f = 0.02$.

Impact of the CBDC interest rate s on the loan market



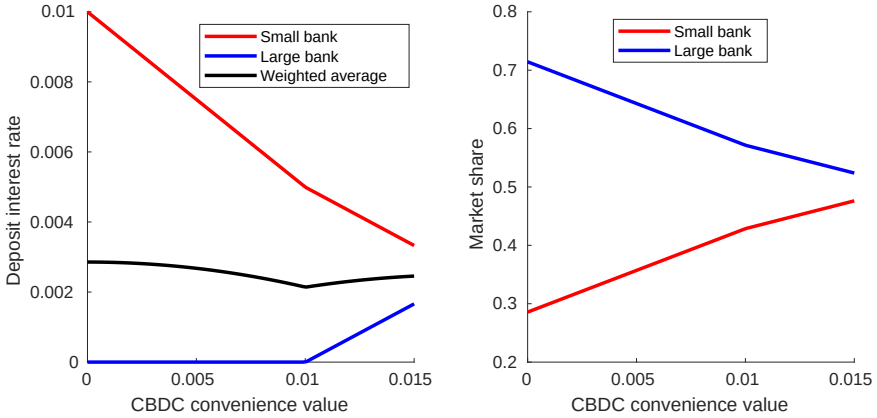
Parameters: $G(\delta) = \delta/0.035$, $A = 1.5$, $X = 10$, $f = 0.02$.

Outline

CBDC with its own convenience value

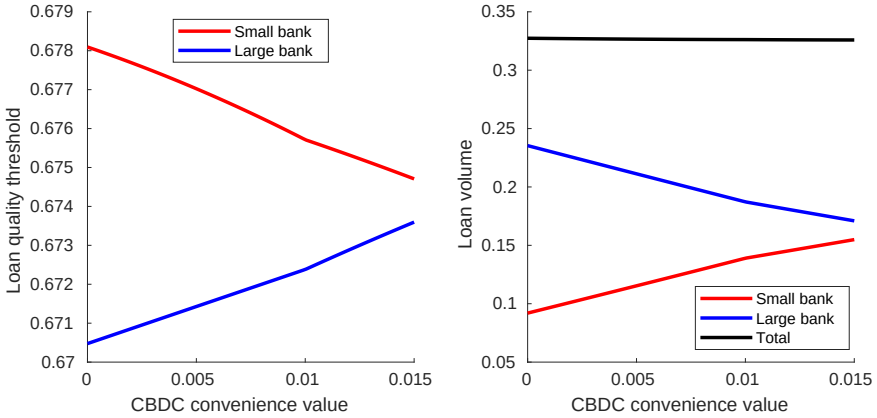
- CBDC convenience value v is same for everyone and in between 0 and the maximum convenience value for the large bank.
- Individual convenience values for large bank deposits still distributed according to G.
- CBDC accounts are still offered by commercial banks, but if a depositor uses a CBDC account hosted by small bank, the convenience value received by the depositor is v and if a depositor uses a CBDC account hosted by large bank, the convenience value received by the depositor is $\max(\delta, v)$.
- Agents with $\delta > r_S - r_L + v$ use the large bank and others use small bank, i.e., $\alpha_S = G(r_S - r_L + v)$.

Impact of CBDC convenience value v on deposit market



Parameters: $G(\delta) = \delta/0.035$, $A = 1.5$, $X = 10$, $f = 0.02$, $s = 0$.

Impact of CBDC convenience value v on loan market

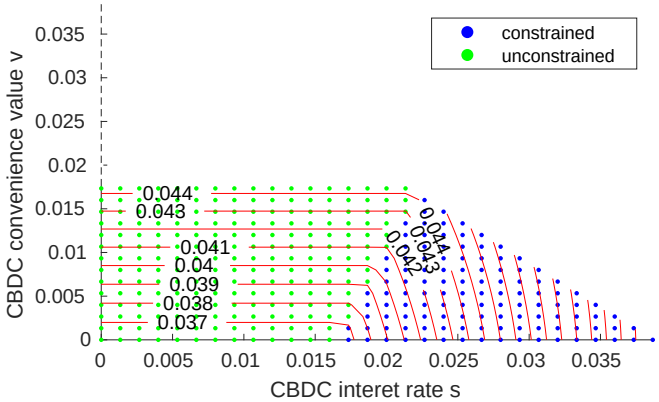


Parameters: $G(\delta) = \delta/0.035$, $A = 1.5$, $X = 10$, $f = 0.02$, $s = 0$.

Outline

The interest-convenience trade-off for depositors

Depositor Welfare (per dollar) $= \alpha_S r_S + \alpha_L r_L + \alpha_S v + \int_{\delta=r_S-r_L+v}^{\infty} \delta dG(\delta)$.



Parameters: $G(\delta) = \delta/0.0035$, $A = 1.5$, $X = 10$, $f = 0.04$.

Conclusions on CBDCs

- CBDC interest rate puts a lower bound on banks' deposit interest rates, limiting their market power.
- A higher CBDC interest rate increases deposit rates and reduces small bank's deposit market share.
- CBDC need not disintermediate banks. Deposits need not flow to CBDC.
- CBDC with own convenience value levels the playing field; it can also enhance monetary policy transmission if the convenience value is large enough to lift the large bank's interest rate from the lower bound.
- The interest-convenience trade-off in CBDC design? Next step.

Thank you!