

How CBDC Design Choices Impact Monetary Policy Pass-Through and Market Composition

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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).

Current objectives

Banking for All Act of U.S. Congress (2020): 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...

ECB's digital euro report (2020)

Requirement 1 (R1): enhanced digital efficiency. The digital euro should keep pace with state-of-the-art technology at all times in order to best address the needs of the market as regards, among other attributes, usability, convenience, speed, cost efficiency and programmability.

Requirement 4 (R4): monetary policy option. If considered to be a tool for improving the transmission of monetary policy, the digital euro should be remunerated at interest rate(s) that the central bank can modify over time.

This paper

Consider two key design features that relate to store of value and medium of exchange functions.

Interest-bearing

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

Payment convenience

- ▶ 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.

Also contribute to the 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.

CBDC Literature

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).

Model

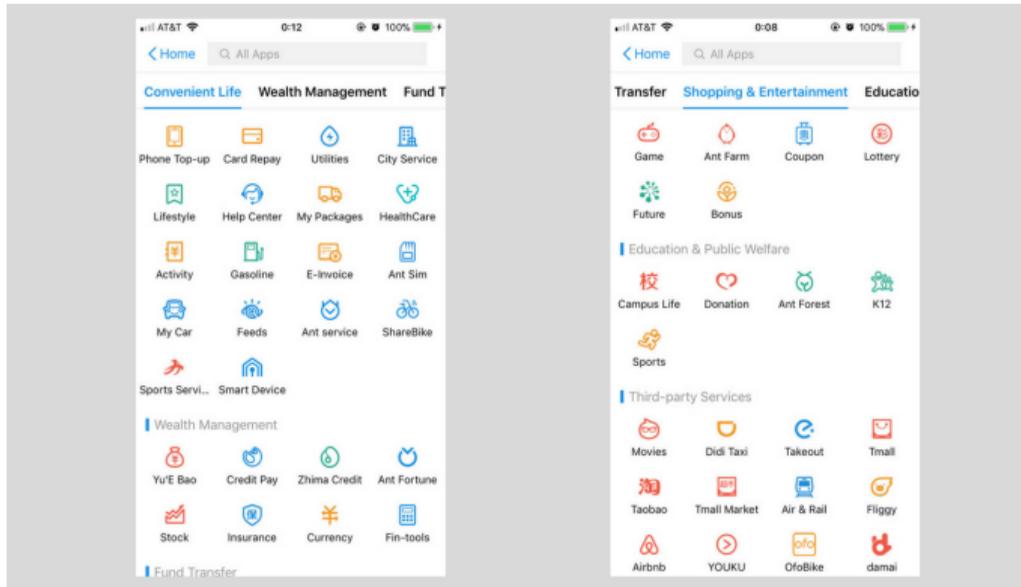
- ▶ A large bank (L) and a small bank (S)
- ▶ Bank assets are reserves X_L and X_S , exogenous and large (Total reserves = X).
- ▶ Bank liabilities are existing deposits.

Asset	Liability
Reserves X_L	Deposits X_L

- ▶ Central bank pays interest on reserves (IOR) f to banks.
- ▶ Banks set deposit interest rates r_L and r_S .

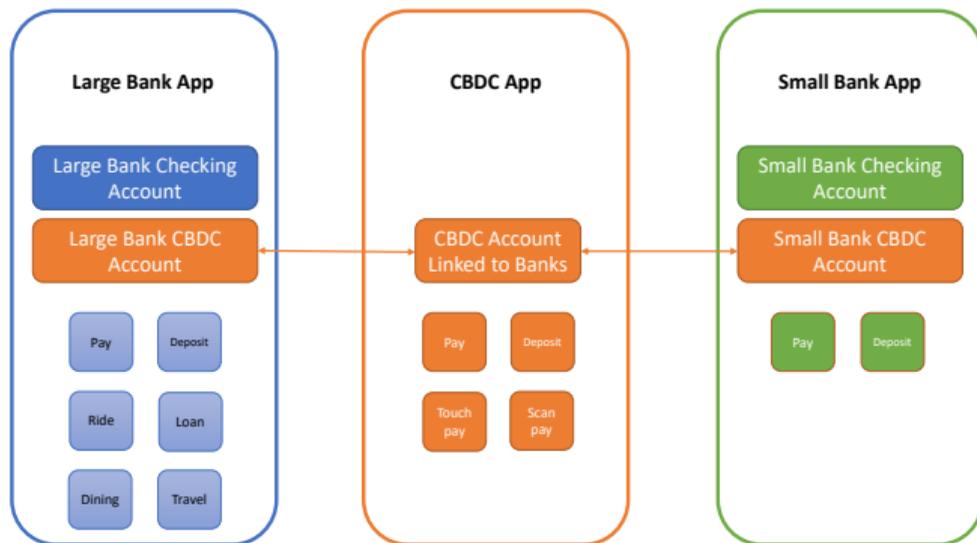
Payment convenience

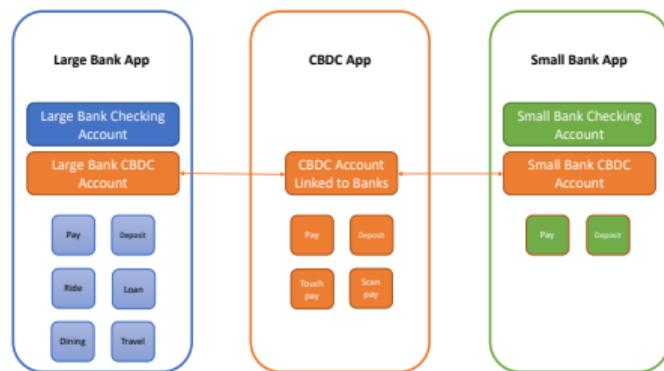
- ▶ Each depositor has a convenience value $\delta \geq 0$ for large bank deposit, independent draws from G . Small bank deposit has convenience value 0.
- ▶ Convenience value: extensive bank branches, better Apps, other services, etc.



CBDC

- ▶ CBDC is the central bank's liability, but offered through commercial banks to depositors.
- ▶ CBDC offers its own convenience value $v \geq 0$.
 - ▶ Better mobile App, lower fees, available in all ATMs...





- ▶ A depositor's total convenience value for using the large bank is $\max(\delta, v)$, and small bank $\max(v, 0) = v$.
- ▶ Within each bank, deposits in checking account and CBDC account receive the same services.
- ▶ CBDC pays interest rate $s \in [0, f]$, and s is a lower bound of bank deposit interest rates. Thus, $r_L \geq s$, $r_S \geq s$.

Timeline

A unit mass of agents play three roles: entrepreneurs, workers, depositors.

- $t = 0$ Banks set deposit interest rates r_L and r_S . Central bank sets IOR f , CBDC interest rate s , and CBDC convenience v . Each agent already has an account with a commercial bank.
- $t = 1$ Each agent is endowed with a project and goes to their bank to borrow \$1. Project i has expected payoff $q_i A$, where A is a constant and q_i has distribution Q . Agent i can only borrow from her current deposit bank, which prices the loan as a monopolist. If a loan is granted, a funded entrepreneur pays a randomly matched agent (worker) \$1 as wage.
- $t = 2$ Worker chooses a bank to deposit the wage, based on interest rate and convenience value.
- $t = 3$ Projects payoff realized. Banks receive interests on reserves and pay interests to depositors.

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 pays a worker \$1. 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 lends \$1 and charges interest rate R_i , its total expected profit is

$$\underbrace{(X_L - \alpha_S)f}_{\text{Interest on reserves}} + \underbrace{[q_i(1 + R_i) - 1]}_{\text{Profit on the loan}} - \underbrace{(X_L + \alpha_L)r_L}_{\text{Cost of deposits}}.$$

- ▶ If the large bank does not make the loan, its total profit is

$$X_L(f - r_L).$$

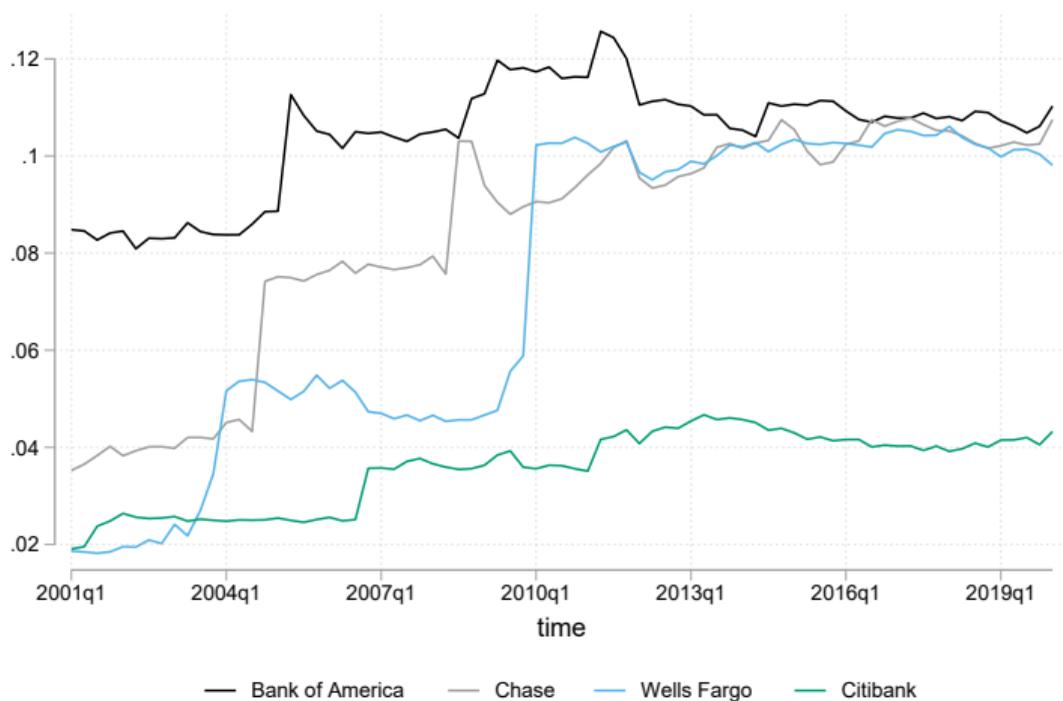
- ▶ The large bank's marginal profit from making the loan is

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

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

Concentration of deposits in U.S. banks (call reports)

Large bank concentration \implies Part of lent money comes back to large banks as deposit



Equilibrium

Deposit market at $t = 2$

Depositor choices	Large bank		Small bank	
	Deposit	CBDC	Deposit	CBDC
Convenience value	$\max(\delta, v)$	$\max(\delta, v)$	v	v
Interest rate	r_L	s	r_S	s

- ▶ We focus on parameters that lead to $r_S > r_L$, so depositor with $\delta \leq v$ chooses small bank.
- ▶ Depositor chooses large bank if and only if $\delta > r_S - r_L + v$.
- ▶ The eventual market shares of the banks are

$$\alpha_L = 1 - G(r_S - r_L + v)$$

$$\alpha_S = G(r_S - r_L + v)$$

Loan market at $t = 1$

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

- ▶ The large bank makes the loan if and only if

$$q_i A - (1 + f) + \alpha_L(f - r_L) > 0 \implies q_i > q_L^* = \frac{1 + f - \alpha_L(f - r_L)}{A} .$$

- ▶ The small bank's lending standard is

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

- ▶ Banks' lending criteria have nothing to do with existing deposit level.
- ▶ Large bank uses a lower lending standard than small bank.

Choice of deposit rates at $t = 0$

- ▶ Let m_L and $m_S = 1 - m_L$ be initial deposit market shares and X is initial total reserves.
- ▶ The large bank's profit from choosing r_L given r_S is

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

- ▶ The small bank's profit from choosing r_S given r_L is

$$\Pi_S = m_S \int_{q_S^*}^1 [qA - (1 + f) + \alpha_S(f - r_S)] dQ(q) + [X + m_L(1 - Q(q_A^*))]\alpha_S(f - r_S).$$

- ▶ For simplicity, let $Q(\cdot)$ be the uniform distribution.
- ▶ Further impose the stationarity condition $\alpha_j = m_j$.

Two cases of equilibrium

- ▶ Unconstrained equilibrium: CBDC interest rate s is not binding, $r_L > s$.
- ▶ Constrained equilibrium: CBDC interest rate s is binding: $r_L = s$.

In both cases, the large bank:

- ▶ sets a lower deposit interest rate, $r_L < r_S$;
- ▶ has a larger market share, $\alpha_L > \alpha_S$;
- ▶ has a lower lending standard, $q_L^* < q_S^*$;
- ▶ has a higher profit, $\Pi_L > \Pi_S$.

In equilibrium, the CBDC is not held by agents and does not disintermediate banks. CBDC works as a viable outside option.

Long-run framework

Set $s = v = 0$ (ie no CBDC)

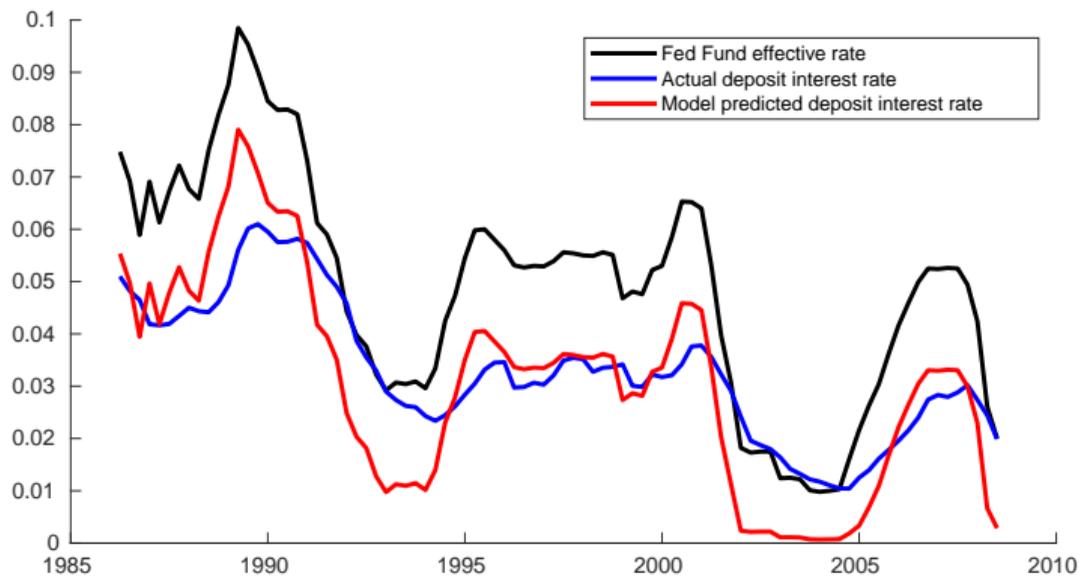
Our model describes deposit and lending markets in the current regime of large excess reserves.

- ▶ Reserves are abundant, lending is determined by the opportunity cost of funds (not the level of reserves), and banks have monopoly power in lending market.
- ▶ A loan is made if its return exceeds the marginal opportunity cost of reserves.
- ▶ Opportunity costs are lower for large banks
- ▶ For low values of IOR, large bank will be at corner solution

Impact of IOR

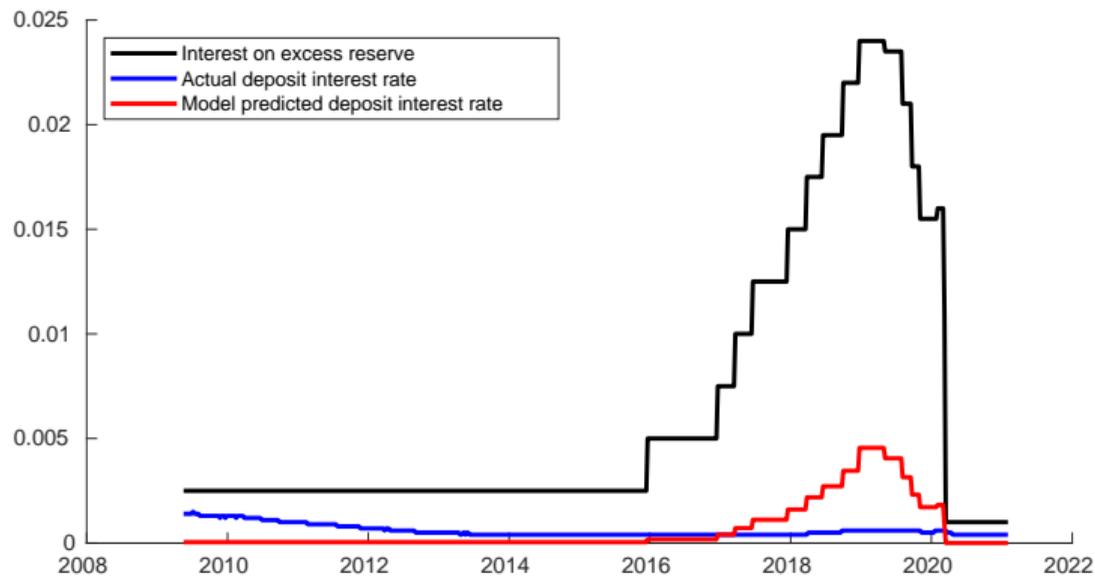
For an increase in f	Constrained		Unconstrained	
	Large	Small	Large	Small
Deposit interest rates r_L and r_S	Flat	↑	↑	↑
Deposit market shares α_L and α_S	↓	↑	Flat	Flat
Weighted average deposit interest rate		↑		↑
Loan quality thresholds q_L^* and q_S^*	↑	unclear	↑	↑
Loan volume $\alpha_L(1 - q_L^*)$ and $\alpha_S(1 - q_S^*)$	↓	unclear	↓	↓
Total loan volume, i.e., total deposit created		↓		↓

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

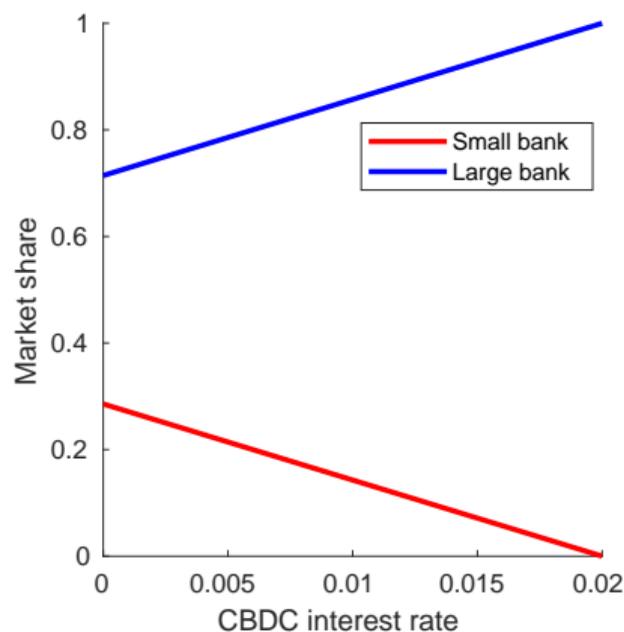
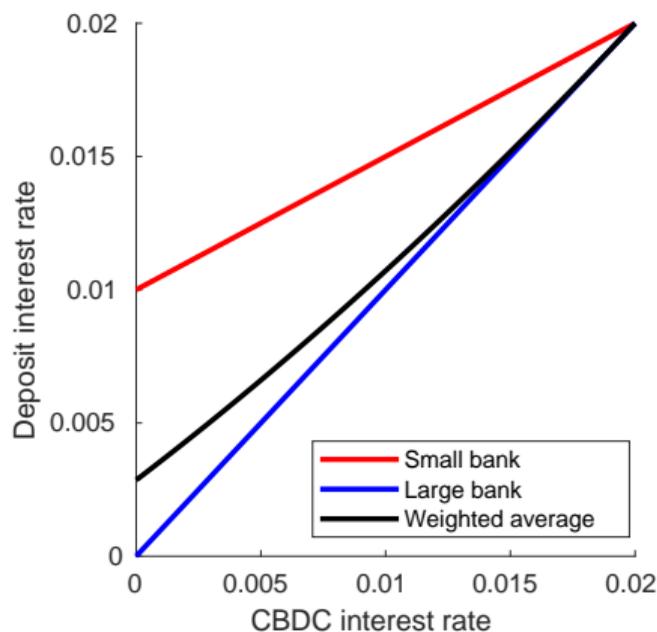


Actual deposit interest rate is non-jumbo (<100K) from FDIC, weekly. Model-predicted deposit interest rate is $\alpha_L r_L + \alpha_S r_S$. Model parameters:

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

Impact of the CBDC interest rate s on the deposit market

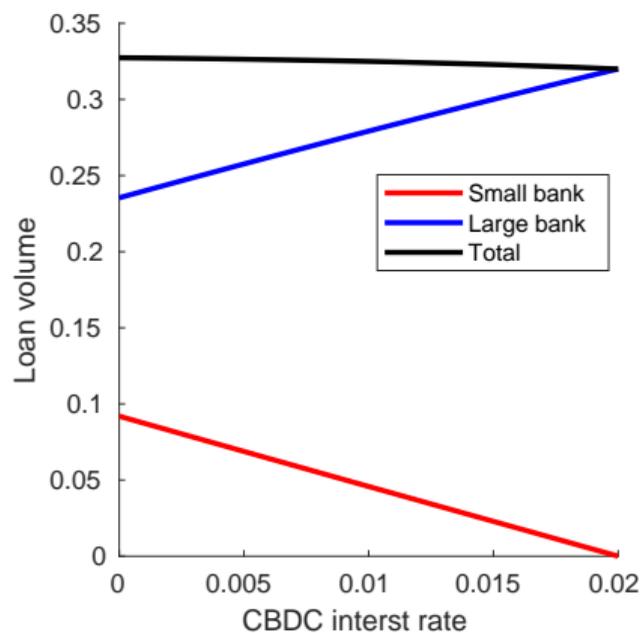
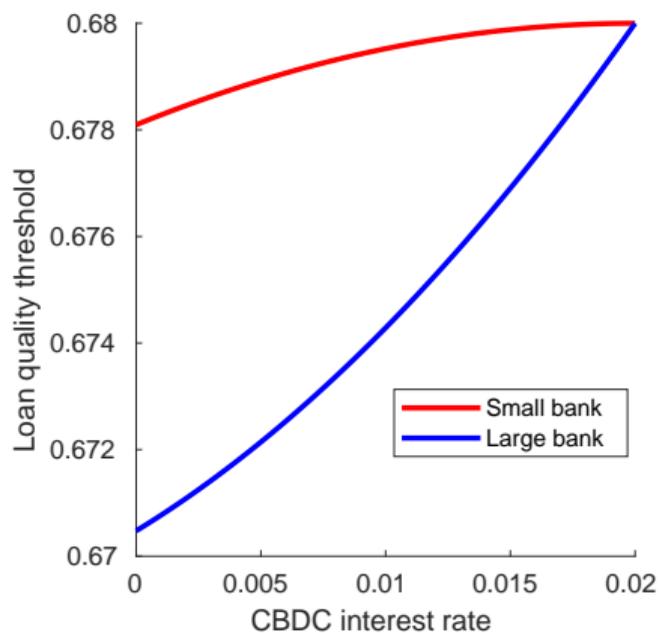
$$f = 2\%, v = 0$$



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

Impact of the CBDC interest rate s on the loan market

$$f = 2\%, v = 0$$



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

Proposition 1

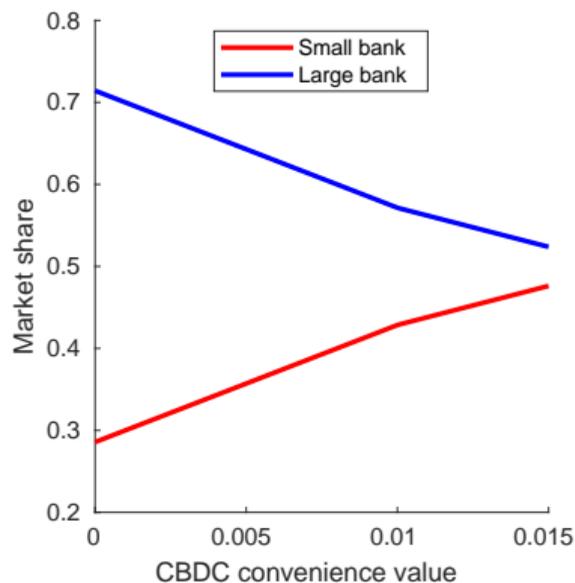
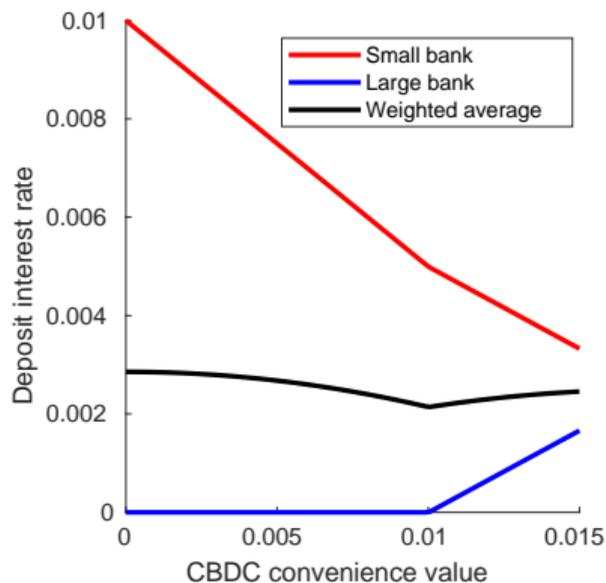
Suppose that $G''(\delta) < G'(\delta)/f$ for any $\delta \in [0, f]$. Then, in the constrained equilibrium, for a sufficiently large X , an increasing CBDC interest rate has the following impact:

As s increases	Constrained equilibrium	
	Large	Small
Deposit interest rates r_L and r_S	↑	↑
Deposit market shares α_L and α_S	↑	↓
Weighted average deposit interest rate		↑
Loan quality thresholds q_L^* and q_S^*	↑	↑
Loan volume $\alpha_L(1 - q_L^*)$ and $\alpha_S(1 - q_S^*)$	unclear	↓
Total loan volume, i.e., total deposit created	↓ if $G'' \leq 0$	

Impact of CBDC convenience value v on deposit market

Weighted average interest rate is decreasing in constrained equilibrium and increasing in unconstrained one \implies Total bank profit has the approximate opposite pattern.

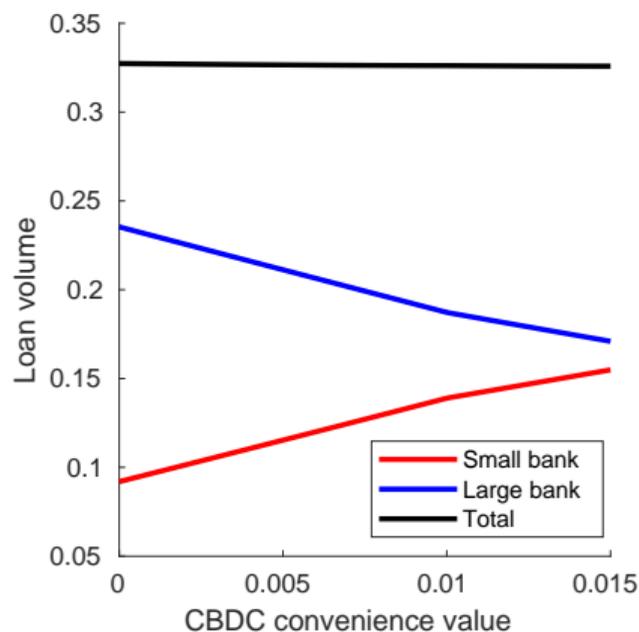
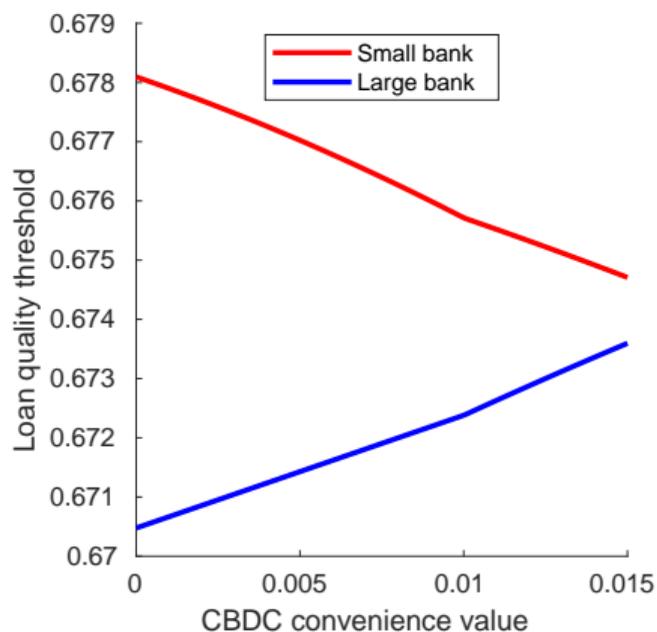
$$f = 2\%, s = 0$$



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

Impact of CBDC convenience value v on loan market

$$f = 2\%, s = 0$$



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

Proposition 2

Suppose that G satisfies $-G'(\delta)/f < G''(\delta) < G'(\delta)/f$ for any $\delta \in [0, f - s + v]$. For sufficiently large X , the impacts of increasing v are given in the following table:

As v increases	Constrained		Unconstrained	
	Large	Small	Large	Small
Deposit interest rates r_L and r_S	Flat(=s)	↓	↑	↓
Deposit market shares α_L and α_S	↓	↑	↓	↑
Weighted average deposit interest rate	↓ if $G'' \leq 0$		↑ if $G'' \geq 0$	
Loan quality thresholds q_L^* and q_S^*	↑	↓	↑	↓
Loan volume $\alpha_L(1 - q_L^*)$ and $\alpha_S(1 - q_S^*)$	↓	↑	↓	↑
Total loan volume, i.e., total deposit created	unclear		↓ if $G'' \geq 0$	

Conclusions on CBDCs

- ▶ Either interest or convenience value can be used to increase pass-through (raised weight deposit rates associated with any IOR rate)
- ▶ ↑ CBDC interest rate raises deposit rates, but causes deposit shares to diverge
- ▶ ↑ CBDC convenience value raises deposit rates and causes deposit shares to converge, but only if convenience value is high
- ▶ Need to pay attention to all design aspects and how they interact

Thank you!

Appendix: Additional results on IOR Pass-Through

Proposition 3

For a sufficiently large X :

1. In the unconstrained equilibrium, r_L and r_S move one-for-one with f ;
2. In the constrained equilibrium, $\frac{dr_S}{df}$ decreases with s and increases with v if $\frac{G''(\delta)}{G'(\delta)}$ is increasing in δ and $-G'(\delta)/f \leq G''(\delta) < G'(\delta)/f$, for any $\delta \in [0, f - s + v]$; and
3. f^* increases with s . f^* decreases with v if $0 \leq G''(\delta) < G'(\delta)/f$ for any $\delta \in [0, f - s + v]$.