Bank Market Power and Central Bank Digital Currency: *Theory and Quantitative Assessment*[1]

Sam Ng

ANU Macro Study Group, Feb 24, 2021

[1]Authors: Jonathan Chiu (Bank of Canada), Mohammad Davoodalhosseini (Bank of Canada), Janet Jiang (Bank of Canada) and Yu Zhu (Bank of Canada).

Introduction

1. Central banks (e.g., Canada, Sweden, and China) are considering the possibility of issuing central bank digital currency (CBDC).
   - a digital form of fiat money that can be used in retail payments.

2. Financial disintermediation is a concern with issuing CBDC[2]:
   - CBDC competes with commercial banks' deposits as a payment instrument $\Longrightarrow \uparrow$ bank funding costs $\Longrightarrow \downarrow$ bank deposits and loans.

3. This paper:
   - a GE model of payments and bank intermediation;
   - focuses on the effects of CBDC on bank competition;
   - abstracts away from banks' risk taking behavior and financial stability issues (these are also important related to CBDC policy implications).

[2]IMF staff discussion note by Mancini-Griffoli et al. (2018) and, The 2018 report by the Committee on Payments and Market Infrastructures of the Bank of International Settlement.

Empirical evidence: Imperfect Competition in Banking

At the macro-level data:

- For example, U.S. (Corbae and D'Erasmo, 2015; Corbae and D'Erasmo, 2018):
  - High profit margins: Markups (90%);
  - Imperfect interest-rate pass through: Rosse-Panzar H-statistic[3] (50%);
  - High market share of top-3 banks: Portugal (89%), Germany (78%), the United Kingdom (58%), Korea (1998-2006: 80%-100%, post 2007: 50%), Japan (44%), United States (35%).

At the micro-level data:

- Substantial market power (spreads) in the U.S. deposit market controlling for other confounding factors (Drechsler, Savov, and Schnabl, 2017).
- Similar empirical observation (spreads, dispersion) in (consumer/mortgage) loans market (Head, Kam, et al., 2020).
- Data Source:
  - FDIC, Call Reports, U.S. Commercial Banks, 1984-2010;
  - Bankscope;
  - Ratewatch (U.S.), weekly (panel) data on deposit rates over $\sim$ 20 years.
  - Ratewatch (U.S.), monthly (panel) data on loan rates over $\sim$ 20 years.

[3] Sum of the elasticities of a bank's total revenue with respect to that bank's input prices

What Chiu et al. (2020) do I

Question: (CBDC as a policy tool) $\rightarrow$ (banking market power) $\leftrightarrow$ (loans, deposits, output)

Approach (baseline setup):

- Interest-bearing CBDC, perfect substitute for checkable (liquid) deposits as a payment instrument, CBDC is not accessible to banks.
- Assume central bank fixes the CBDC (policy) rate.
- Cournot deposit market and perfectly competitive loan market.
- Banks face a cash reserve requirement.
- Note: In general, the design of CBDC can be universally accessible to all agents, see (Andolfatto, 2020).

What Chiu et al. (2020) do II

More details

Alternative design for CBDC:

- Banks can hold CBDC as interest-bearing reserves (additional cost-saving effect for the banks c.f. holding cash as reserves);
- Non-interest-bearing CBDC (relevant for payment landscape evolves toward a cashless economy, Covid-19 may accelerate this trend..).

Alternative modelling approach for banking competition (see their appendix):

- Imperfectly competitive loan (Cournot, or search and (Kalai) bargaining) and deposit (Cournot) markets - need a perfectly competitive interbank market;
- Noisy-search, price competition in the deposit market; details see (Burdett and Judd, 1983), (Head, Liu, et al., 2012), (Head, Kam, et al., 2020).

Takeaway

1. Introducing an interest-bearing CBDC (i.e., deposit-like) does not necessarily causing financial disintermediation.
   - The main mechanism: CBDC offers an outside option to depositors, which disciplines the banks incentive to increase deposit rate to match with the CBDC rate. Consequently, it has a welfare-improving effect on banking allocation and output even if CBDC may not be used at equilibrium.

   Calibrated model:
   At intermediate range of CBDC interest rate...
   - CBDC induces banks behave more "competitively" to raise the deposit rate.
   - It expands financial intermediation (loans and deposits) and output in equilibrium.

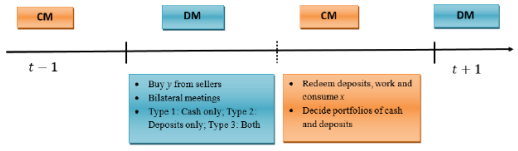
   Sufficiently high CBDC interest rate...
   - It induces higher lending rate to compensate the banks for the interest paid on deposits.
   - Consequently, it causes financial disintermediation.

2. If CBDC serves as interest-bearing reserve, it has stronger effects on intermediation and output in equilibrium.

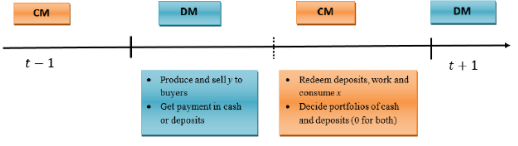
3. Non-interest-bearing CBDC (i.e., cash-like) also improves financial intermediation and output.

Model

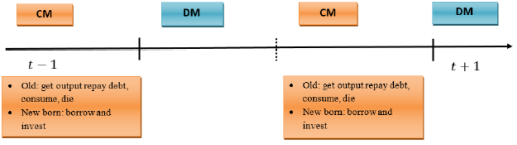
Overview (timing, actions, and payoffs)



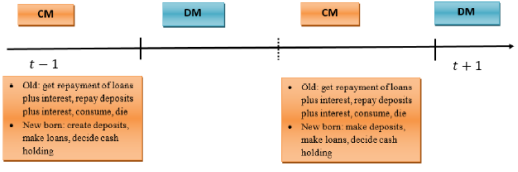
(a) Buyers



(b) Sellers



(c) Entrepreneurs



(d) Bankers

Lagos and Wright (2005)

Economy without CBDC: Households I

Second Market (CM)

A buyer chooses consumption x, labor h, and the cash balance, liquid (checkable) and illiquid (time) deposit balances in the next period, $z^{'}, d^{'}, b^{'}$. The value function is

$$W^B(z,d,b) = \max_{x,h,z^{'},d^{'},b^{'}} \left\{ U(x) - h + \beta V^B(z^{'},d^{'},b^{'}) \right\}$$

$$\text{s.t. } x = h + z + d + b + T - \frac{\phi}{\phi^{'}} z^{'} - \psi d^{'} - \psi_b b^{'} \quad (1)$$

where ϕ is the price of cash balance (in units of CM goods), ψ and ψ_b are prices of future real checkable and time deposit balances.

Note: Linear in wealth, and houseohlds choose the same portfolio $(z^{'}, d^{'}, b^{'})$ at the end of the CM into the beginning of the next DM due to Quasi-lienar preferences in the CM.

Economy without CBDC: Households II

First Market (DM)

An ex-ante buyer (z, d, b) at the opening of the first market has expected lifetime utility

$$V^B(z,d,b) = \alpha_1 \left[u \circ Y(z) - P(z) \right] + \alpha_2 \left[u \circ Y(d) - P(d) \right] + \alpha_3 \left[u \circ Y(z+d) - P(z+d) \right] + W^B(z,d,b) \quad (2)$$

where $Y(\cdot)$ and $P(\cdot)$ are the terms of trade, representing quantity of goods y being traded and payment.

Note: Buyer makes a take-it-or-leave-it offer (y, p) to maximize utility subject to $p \geq y$ and $p \leq \mathcal{L}$. Her optimal demand for liquidity is intertemporal, and usable liquidity varies according to the type of meetings.

Seller's problem is the opposite of the buyers (taking into account bilateral meeting). Details are omitted here for presentation.

Economy without CBDC: bankers

- The N bankers engage in Cournot competition in the deposit market (compete by choosing quantity) and perfect competition in the loan market.
- Take the price of time deposit ($\psi_b = \beta$, derived from household problem), market loan rate (ρ) and other banks' checkable deposit quantity ($D_{-j} = \sum_{i \neq j} d_i$) as given.

Banker j maximization problem (cares consumption when old, i.e., the second CM) is

$$\max_{z_j, l_j, d_j, b_j} \left\{ (1+\rho) l_j + \frac{z_j}{\mu} - d_j - b_j \right\}$$

$$\text{s.t. } \underbrace{l_j + z_j}_{\text{Assets}} = \underbrace{\Psi(D_{-j} + d_j) d_j + \beta b_j}_{\text{Liabilities}}, \text{ and } \underbrace{z_j \geq \chi \Psi(D_{-j} + d_j) d_j}_{\text{reserve requirement}}. \quad (3)$$

Note: $\Psi(d)$ is the inverse total demand function for checkable deposits (derived from households' optimal demand for liquidity).

Economy without CBDC: Entrepreneurs

Entrepreneurs take market loan rate ρ as given and choose loan demand (to finance their endowed project for consumption when old) to solve:

$$\max_{l} \left\{ f(l) - (1+\rho)l \right\} \tag{4}$$

This pins down an (downward sloping) aggregate loan demand function.

$$L^d(\rho) = f'^{-1}(1+\rho). \tag{5}$$

Economy with CBDC I

A baseline design of CBDC:

- It bears interest, perfect substitute for checkable deposits as a means of payment (i.e., in type-2 and type-3 meetings), and it is not accessible to banks.
- Supply of the CBDC grows at a gross rate μ_e and pays a nominal interest i_e.
  - Note: In a stationary monetary equilibrium it would be equivalent to choose the gross growth rare μ_e, or the nominal interest rate i_e as a CBDC policy instrument.

Alternative design of CBDC:

- Banks can hold both the CBDC and cash to satisfy their reserve requirement;
- Non-interest-bearing CBDC, same interest rate as cash (i.e., zero).

Focus on the baseline design in this presentation.

Economy with CBDC II

With the baseline CBDC, entrepreneurs' problem (4) stay the same, but households and bankers are different.

Households problem - with CBDC

- Sellers' problem remain unchanged since they do not need liquidity to produce in the DM.
- Now a buyer (at the end of the CM) also chooses how much CBDC to bring into the next DM to trade, since it is now acceptable in type-2 and type-3 meetings. The CM buyer's problem (1) becomes:

$$W^B(z, z_e, d, b) = z + z_e + d + b + T + \max_x \left[U(x) - x \right]$$
$$+ \max_{z', z_e', d', b'} \left\{ -\frac{\phi}{\phi'} z' - \frac{\phi_e}{\phi_e'} \frac{1}{1+i_e} z_e' - \psi d' - \psi_b b' + \beta V(z', z_e', d', b') \right\} \quad (6)$$

Note: ϕ_e (price of the CBDC in units of CM goods) can be different from ϕ in equilibrium because the CBDC may pay interest or have different growth rate than cash.

Economy with CBDC III

Bank's problem. Replace $\Psi(D)$ in (3) by $\hat{\Psi}(D)$, where $\hat{\Psi}(D)$ is the inverse demand for checkable deposits in an economy with CBDC (derived from households optimal demand for liquidity, more on this later).

Symmetric Stationary Monetary Equilibrium (SME)

SME: Households I

Optimal demand for liquid balances (z, d), (special case: an economy without CBDC)

Given policy (μ):

Money demand:

$$\underbrace{\frac{\mu}{\beta} - 1 \equiv i}_{\text{MC of extra dollar}} = \underbrace{\alpha_1 \lambda(z)}_{\text{[A]: MB in type 1 meeting}} + \underbrace{\alpha_3 \lambda(z+d)}_{\text{[C]: MB in type 3 meeting}} \tag{7}$$

Checkable (liquid) deposit demand:

$$\underbrace{\frac{\psi}{\beta} - 1}_{\text{MC of extra liquid deposit}} = \underbrace{\alpha_2 \lambda(d)}_{\text{[B]: MB in type 2 meeting}} + \underbrace{\alpha_3 \lambda(z+d)}_{\text{[C]: MB in type 3 meeting}}$$

$$\iff \psi = \underbrace{\beta \left[1 + \alpha_2 \lambda(d) + \alpha_3 \lambda(z+d) \right]}_{:=\Psi(d),\ \text{inverse demand for checkable deposit given } z} \tag{8}$$

where $\lambda(\mathcal{L}) = \max\{u'(\mathcal{L}) - 1, 0\}$ is the liquidity premium.

SME: Households II

- Given (7), then (8) pins down a (downward sloping) aggregate inverse demand function for checkable deposits, $\psi = \Psi(d)$.
  - Note: it can show that checkable deposits do not have liquidity premium at the first-best quantity following the property that $\Psi(0) = \infty$, and $\Psi(d) = \beta$ for $d = y^\star$, where $y^\star$ is the first-best quantity.
- From the household's problem, demand for time (illiquid) deposits b is separate from the demand for liquid balances (z, d). This is because b has no liquidity value as it cannot be used in payments across different type of meetings.
  - It can show that the time deposit is priced at fundamental value, i.e., $\psi_b = \beta$ (or, $\underbrace{\frac{1}{\psi_b} - 1}_{\text{return on time deposit}} = \underbrace{\frac{1}{\beta} - 1}_{\text{real interest rate}}$). That means the equilibrium time deposit rate must compensate for agents discounting across t and $t + 1$.

SME: Households III

Optimal demand for liquid balances (z, z_e, d): an economy with CBDC

Given policy (μ, μ_e, i_e):

Money demand:

$$\underbrace{\frac{\mu}{\beta} - 1}_{\text{MC of extra dollar}} = \underbrace{\alpha_1 \lambda(z)}_{\text{[A]: MB in type 1 meeting}} + \underbrace{\alpha_3 \lambda(z + z_e + d)}_{\text{[C*]: MB in type 3 meeting}} \tag{9}$$

Checkable deposit demand:

$$\underbrace{\frac{\psi}{\beta} - 1}_{\text{MC of extra liquid deposit}} \geq \underbrace{\alpha_2 \lambda(d + z_e)}_{\text{[B*]: MB in type 2 meeting}} + \underbrace{\alpha_3 \lambda(z + z_e + d)}_{\text{[C*]: MB in type 3 meeting}} \text{, “ = ” iff } d > 0 \tag{10}$$

CBDC demand:

$$\underbrace{\frac{\mu_e}{\beta(1 + i_e)} - 1}_{\text{MC of extra CBDC}} \geq \underbrace{\alpha_2 \lambda(d + z_e)}_{\text{[B']: MB in type 2 meeting}} + \underbrace{\alpha_3 \lambda(z + z_e + d)}_{\text{[C']: MB in type 3 meeting}} \text{, “ = ” iff } z_e > 0 \tag{11}$$

SME: Households IV

CBDC now competes with banks' checkable deposits as a payment instrument...

- It all depends on the price of bank deposits versus the price of CBDC since they are perfect substitute as a payment instrument. In other words, households only hold the asset with a higher rate of return.
  - Case 1. If $\psi > \frac{\mu_e}{1+i_e}$, $d = 0, z_e > 0$ (uses only CBDC);
  - Case 2. If $\psi < \frac{\mu_e}{1+i_e}$, $d > 0, z_e = 0$ (uses only bank deposits);
  - Case 3. If $\psi = \frac{\mu_e}{1+i_e}$, $d > 0, z_e > 0$ (indifferent, cares about total electronic payment balances)
- Use these information, equations (9), (10) and (11) pin down the inverse demand function for checkable deposits in an economy with CBDC, $\hat{\Psi}(D)$.

SME: Households V

Summary (CBDC limits the banks (deposit) market power)

At certain μ_e or i_e, (total expected) MB [B*]+[C*] can be greater than (or equal to) MB in an economy without CBDC, i.e., $\alpha_2\lambda(d) + \alpha_3\lambda(z+d)$.

- Intuition: CBDC (as an outside option) disciplines the banks incentive to match deposit rate with the CBDC rate. Consequently, it induces banks to create more liquid deposits to meet households' demand for electronic payment balances, and also limit the bank market power in extracting the households share of surplus in monetary trades.

SME: Banks I

Banks optimize (special case: without CBDC)

The equilibrium loan supply of an individual bank is

$$l(\rho) = \begin{cases} 0, \text{ if } 1+\rho < \frac{1}{\mu}, \\ [0, (1-\chi)d(\rho)\Psi(Nd(\rho))], \text{ if } 1+\rho = \frac{1}{\mu}, \\ (1-\chi)d(\rho)\Psi(Nd(\rho)), \text{ if } \frac{1}{\mu} < 1+\rho < \frac{1}{\beta}, \\ [(1-\chi)d_\beta\Psi(Nd_\beta), \infty], \text{ if } 1+\rho = \frac{1}{\beta}, \end{cases} \tag{12}$$

Note: Aggregate loan supply curve, $L^s(\rho) = Nl(\rho)$ can (in principle) be non-monotone at certain range of gross lending rate, $1+\rho \in (\frac{1}{\mu}, \frac{1}{\beta})$. This is because the falling force from $\Psi(Nd(\rho))$ can dominate the rising force in $d(p)$ with ρ. There is a potential soruce for multiple equilibria.

SME: Banks II

Banks optimize (with CBDC)

Using similar techniques from the case without a CBDC, the equilibrium loan supply of an individual bank becomes:

$$\hat{l}(\rho) = \begin{cases} 0, \text{ if } \rho < \underline{\rho}, \\ [0, (1-\chi)\frac{\mu_e}{1+i_e} d_e], \text{ if } \rho = \underline{\rho}, \\ (1-\chi)\frac{\mu_e}{1+i_e} d_e > l(\rho), \text{ if } \rho \in (\underline{\rho}, \bar{\rho}], \\ l(\rho), \text{ if } \rho \in (\bar{\rho}, 1/\beta - 1), \\ l(\rho), \text{ if } \rho = 1/\beta - 1, \end{cases} \tag{13}$$

where $\underline{\rho}$ is the loan rate at which banks stay break-even if the deposit rate equals to the CBDC rate, and $\bar{\rho}$ is the lowest lending rate at which banks offer a real deposit rate equal to $\frac{1+i_e}{\mu_e} - 1$ without CBDC.

SME: Banks III

Notice that $d_e = \hat{d}(\rho)$ (by symmetric optimal strategy of bankers), $Nd_e = D_e$ and $\Psi(D_e) = \frac{\mu_e}{1+i_e}$ (details see section 4.1-4.2 and appendix A.2 of the paper), then the aggregate loan supply function is

$$\hat{L}^s(\rho) = \begin{cases} 0, \text{ if } \rho < \underline{\rho}, \\ [0, (1-\chi)\Psi(D_e)D_e], \text{ if } \rho = \underline{\rho}, \\ (1-\chi)\Psi(D_e)D_e > L^s(\rho), \text{ if } \rho \in (\underline{\rho}, \bar{\rho}], \\ L^s(\rho), \text{ if } \rho \in (\bar{\rho}, 1/\beta - 1), \\ L^s(\rho), \text{ if } \rho = 1/\beta - 1, \end{cases} \tag{14}$$

In words (from a partial equilibrium point of view),

- If $\underline{\rho} \leq \rho \leq \bar{\rho}$, introducing a CBDC can induce banks to supply more loans in aggregate (via creating more checkable deposits) relative to the case without CBDC.
- If $\rho < \underline{\rho}$, or $\rho > \bar{\rho}$, introducing a CBDC does not affect the equilibrium outcome.
- Which branch in the total loan supply function actives at equilibrium will be depending on the CBDC policy rate i_e, since the cut-off values, $\underline{\rho}$ and $\bar{\rho}$ are increasing in i_e, as well as the quantity $(1-\chi)\Psi(D_e)D_e$ (recall the assumption 1 in the paper: $\Psi(D)D$ is increasing).

SME: Markets

market clearing in goods, labor and loan market

- Sellers optimize, DM goods market clears (terms of trade determined by Kalai bargaining).
- Firms optimize, pin down aggregate loan demand curve (monotone decreasing in ρ);
  - banks optimize, pin down aggregate supply of loans, $L^s(\rho)$, or $\hat{L}^s(\rho)$, (monotone increasing in ρ, also need to satisfy households demand for deposits), loan market clears.
  - Note: Monotoncity of total loan supply holds under an assumption that the before-interest value of checkable deposit is increasing in it's after-interest value, i.e., $D\Psi(D)$ increasing in D.
  - Similarly, same assumption for the economy with CBDC.
- CM goods market clears, and labor market clears.

SME: Bank market Power and CBDC I

Summary

Two opposing tensions of (interest-bearing) CBDC on equilibrium outcome (loans, deposits and output):

- A positive effect on financial interemediation. On one hand, $\uparrow$ CBDC rate $\Longrightarrow$ $\uparrow$ banking competition (i.e., CBDC as an outside option restricts banks market power) $\Longrightarrow$ $\uparrow$ checkable deposit rate $\Longrightarrow$ $\uparrow$ supply of loans $\Longrightarrow$ $\uparrow$ loan quantity, and liquid balances (d, z_e) for consumption
  - Note: CBDC may or may not be used at equilibrium depending on policy rate.
- A negative effect on financial intermediation. On the other hand, $\uparrow$ CBDC rate $\Longrightarrow$ $\uparrow$ cost of funds (interest paid to depositors) $\Longrightarrow$ $\uparrow$ loan rate require by banks to stay break-even $\Longrightarrow$ $\downarrow$ loans quantity and consequently, create fewer checkable deposits to finance firms' loans.
- net effect depending on the CBDC policy rate i_e.

SME: Bank market Power and CBDC II

In short, when market power of banks is sensitive to policy.....

- CBDC creates an endogenous policy trade-off between payment efficiency (households' usable liquid balance for payment across α_k meetings) and loan (or firms' investment) quantity!
- Details are summarized in proposition 3 of the paper.

Empirical Validation

Statistical calibration

Model is fitted to

1. empirical money demand;
2. retail markups;
3. banking industry characteristics (e.g., elasticity of commercial loans with respect to the prime rate, non-interest expenditures, average interest rate on transaction accounts, spreads).

Details are omitted here.

Comparative Steady States

Comparative Steady States

- Consider a set of economies, each distinguished by their CBDC policy rates, i_e
- Questions to ask:
  - financial interemediation and output
  - economic welfare

c.f., an economy without CBDC

Note: welfare is measured by the percentage change in consumption that is needed to make an agent indifferent between no CBDC and a CBDC with interest rate i_e. If it is positive, CBDC improves welfare of the agent.

Comparative Steady States

CBDC on Financial intermediation and output

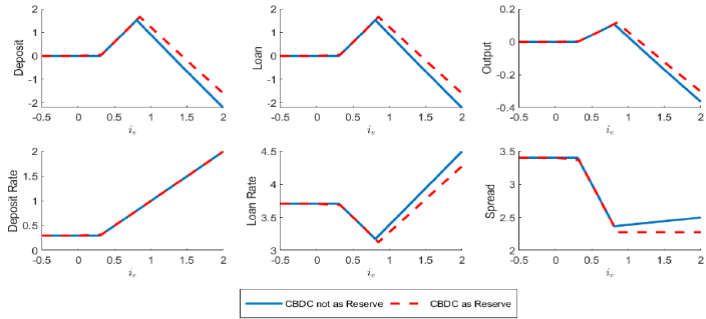
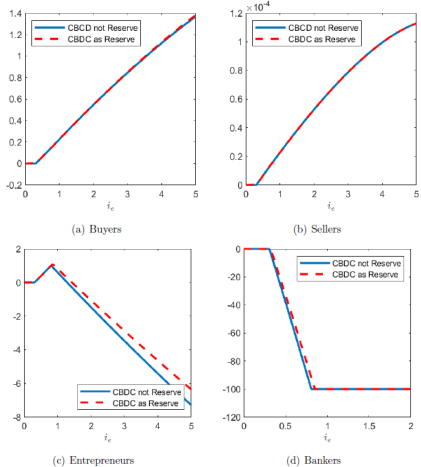


Figure 7: Effects of CBDC Rate

- At intermediate i_e, banks behave more "competitively" to raise the deposit rate and expand financial intermediation.
- At high enough i_e, it induces higher lending rate to compensate the banks for the interest paid on deposits and causes financial disintermediation.

Comparative Steady States

Welfare change: with CBDC vs. without CBDC



- Non-monotone effect of CBDC on welfare for firms and banks. Welfare is increasing for households because more liquid balances available for consumption.

Welfare and Policy Implications

Policy Implications

- Imperfectly competitive banking (without CBDC):
  1. Banks have market power to limit deposit supply $\Longrightarrow$ equilibrium deposit interest rate (or price) lower (higher) than the case with perfectly competitive banking market.
  2. Profits earn by banks are reduction in households surplus in monetary trades due to lower available liquid balance for consumption.

- Imperfectly competitive banks (with CBDC):
  1. CBDC offers an outside option to depositors $\Longrightarrow$ $\downarrow$ banks incentive to limit deposit supply $\Longrightarrow$ $\uparrow$ commercial banks' deposit rate to match with the CBDC rate $\Longrightarrow$ $\uparrow$ financial intermediation.
  2. Banks behave more "competitively" even if CBDC may not be used at equilibrium.
  3. Positive effect of CBDC on financial intermediation outweighs by the negative effect when CBDC interest rate becomes sufficiently high.
- Results are robust to various designs of CBDC (interest-bearing reserves and non-interest bearing cash-like) and various modeling approach for imperfectly competitive banking market.

References I

Andolfatto, David (2020). "Assessing the Impact of Central Bank Digital Currency on Private Banks". In: *The Economic Journal*.

Burdett, Kenneth and Kenneth L. Judd (1983). "Equilibrium Price Dispersion". In: *Econometrica* 51.4, pp. 955–969.

Corbae, Dean and Pablo D'Erasmo (2015). "Discussion of "Large Banks, Loan Rate Markup, and Monetary Policy"". In: *International Journal of Central Banking* June, pp. 1–14.

– (2018). "Capital Requirements in a Quantitative Model of Banking Industry Dynamics". In: *Unpublished*. SED2018.

Drechsler, Itamar, Alexi Savov, and Philipp Schnabl (2017). "The Deposits Channel of Monetary Policy". In: *The Quarterly Journal of Economics* 132.4, pp. 1819–1876.

Head, Allen, Timothy Kam, et al. (2020). "Money, Credit and Equilibrium Imperfectly Competitive Banking". In: *Unpublished*.

Head, Allen, Lucy Qian Liu, et al. (2012). "Sticky prices: A new monetarist approach". In: *Journal of the European Economic Association* 10.5, pp. 939–973. ISSN: 15424766. DOI: 10.1111/j.1542-4774.2012.01081.x. arXiv: arXiv:1011.1669v3.

Lagos, Ricardo and Randall Wright (2005). "A Unified Framework for Monetary Theory and Policy Analysis". In: *Journal of Political Economy* 113.3, pp. 463–484.