Designing Central Bank Digital Currencies

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Motivation

- What is a central bank digital currency (CBDC)?
  - Digital CB liability, available to the public for peer-to-peer transactions
  - Many central banks considering introducing a CBDC
  - e.g. China, Sweden, Uruguay, Canada among others

Motivation

- What is a central bank digital currency (CBDC)?
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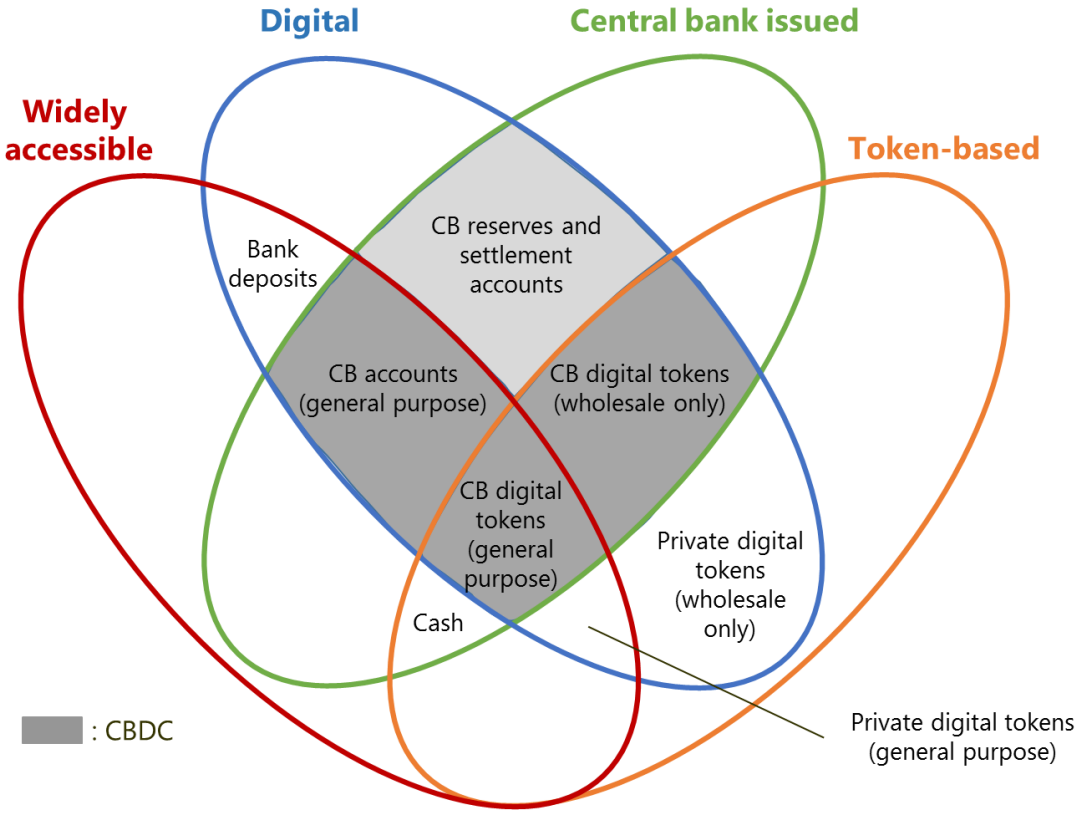
  - Many central banks considering introducing a CBDC
  - e.g. China, Sweden, Uruguay, Canada among others
- Why introduce a CBDC?
  - Privacy concerns due to private payments providers (e.g., China)
  - Maintaining cash-like attributes when cash vanishes (e.g., Sweden)
  - Public access to CB liabilities when cash vanishes (e.g., Sweden)
  - Limiting cash maintenance costs (e.g., Uruguay)
  - Financial inclusion (e.g., Uruguay)
  - Payments efficiency

Design considerations

Money flower (BIS, 2018)



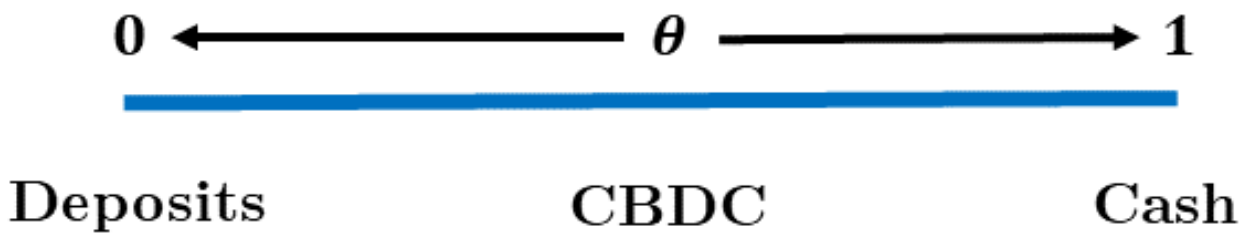
We focus on:

- Cash-like (token-based) or deposit-like (account-based)
- Interest-bearing vs non-interest bearing

Nature & implications of a CBDC

Blended nature of a CBDC:

- Cash: completely anonymous but not secure
- Deposits: completely secure but not anonymous
- CBDC: design can blend features of cash/deposits, i.e. extent of anonymity (to which parties; size limits; "unwatched" until suspicion)



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Open Questions:

- Will there be demand for CBDC?
- Implications for financial intermediation (bank deposits & credit)?
- Impact on cash usage and those dependent on cash?

This paper

- Households with heterogeneous preferences, endogenously sort into different moneys (Cash, CBDC, deposits)
- Network externalities
  - Convenience of a payments method depends on its number of users
  - Cash can endogenously disappear
  - Implications for CBDC design
- Bank-based financial intermediation
  - Role of deposit-based intermediation in alleviating financial frictions (Donaldson et al. 2018, JFE; Diamond & Rajan 2001, JPE)
  - CBDC reduces credit when it competes closely with bank deposits
  - Value of intermediation depends on relationship lending frictions
- Analyze optimal (welfare-maximizing) CBDC design, including interest-bearing feature

Preview of Main Results

- Welfare analysis
  - Always optimal to introduce CBDC, but leads to design trade-off
  - Deposit-like design: depressing bank credit and output vs.
  - Cash-like design: worsening network effects on cash
- Optimal design: more cash-like when financial frictions are larger
- CBDC interest rate:
  - Central banks are primarily considering non-interest bearing CBDC
  - Non-interest bearing: cash may disappear if financial frictions are large
  - Interest-bearing: optimally set CBDC rate alleviates trade-off, safeguards bank credit and cash never disappears in equilibrium

Related Literature

- Keister & Sanches (2018): CBDC in segregated markets cash/deposits
- Chiu et al. (2018), Andolfatto (2018): CBDC & payment system contestability under bank market power
- Kim and Kwon (2019): CBDC and bank runs in DD model
- Davoodalhosseini (2018): CBDC vs. cash $\rightarrow$ monetary transmission
- Agarwal & Kimball (2015), Assenmacher & Knogstrup (2018): ELB

Our contribution

- Impact of network externalities and financial frictions on CBDC design
- Co-existence of cash, money and CBDC depends on design choice
- Welfare trade-off between variety in payment methods and financial intermediation
- Interest-bearing CBDC provides a second design instrument

Roadmap

1. Introduction
2. **Model**
3. CBDC design
4. Extensions
5. Conclusion

Model

- Agents: households, banks, firms, and central bank
- Stages
  1. Central bank determines CBDC design, interest rate
  2. Households sort into deposits, cash and CBDC according to heterogeneous preferences over anonymity/security
  3. Banks collect deposits and extend credit to non-financial firms
  4. Firms produce consumption good
- We solve backward

Model: Firms and banks

- Firms
  - Produce consumption good Y with production technology:

$$f(k) = \left(A - \frac{k}{2}\right) k$$

  - Working capital financed by bank loan L at market rate R

$$\max_{L} \left\{ \left(A - \frac{L}{2}\right) L - (1+R) L \right\}$$

- Banks
  - Perfect competition on both loan and deposit markets

$$\max_{L,d} \{(1+R) L - (1+r_d) d\}$$

$$s.t. \quad L = d$$

  - First order condition: $R = r_d$

Model: Household preferences

- Transaction demand for money. Decide which form of money to hold
- Preference for anonymity relative to security:
  - i uniformly distributed on $[0, 1]$
  - Higher i: more anonymous, less secure
- Utility cost of distance between money properties and preference
- Key friction: no partial anonymity by mixing payment methods

$\Rightarrow$ Choose between cash ($x_c = 1$), deposit ($x_d = 0$) and CBDC located in between ($x_{cbdc} = \theta$)

Model: Household problem

$$\max_{j \in \{c,d,cbdc\}} U_i(j) = C_j - |x_j - i| - \eta_j$$

s.t.

$$C_j = 1 + r_j - T + \pi + k + \phi(k_0 - k)$$

- η_i captures network effects, ϕ (inverse) financial frictions

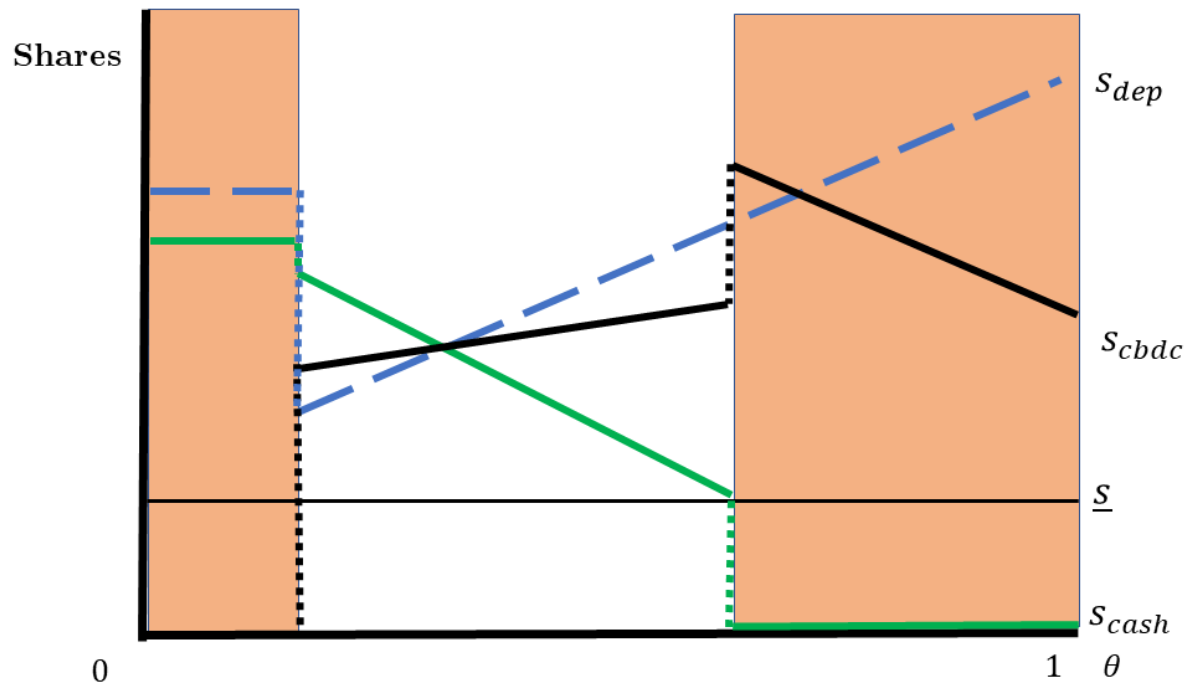
- Optimal sorting conditions:

$$\text{Cash over CBDC: } 1 - i + \eta_c < |\theta - i| - r_{cbdc} + \eta_{cbdc}$$
$$\text{Cash over deposits: } 1 - i + \eta_c < i - r_d + \eta_d$$
$$\text{CBDC over deposits: } |\theta - i| - r_{cbdc} + \eta_{cbdc} < i - r_d + \eta_d$$

- Depends on CBDC design. Use uniform distribution properties to solve for shares of money types

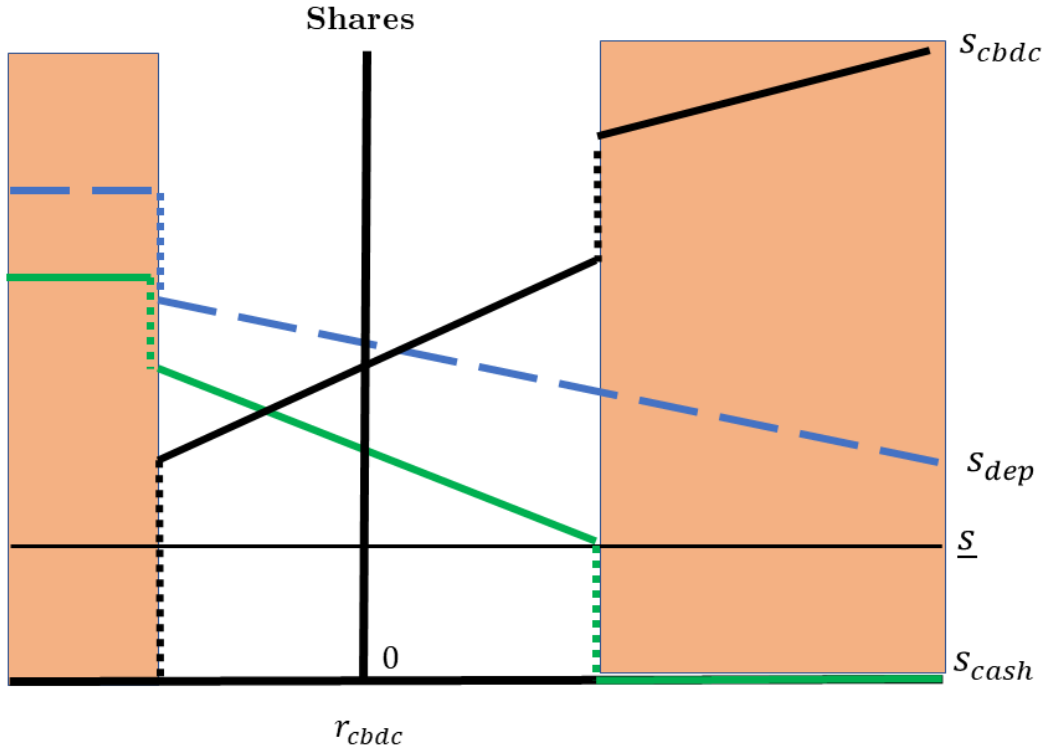
Equilibrium: Money shares across θ

- More cash-like CBDC: cash use falls, deposits rise
- Rise in deposits also curtails fall in credit due to CBDC
- Network effects: cash use drops to zero as it falls below critical mass



Equilibrium: Money shares across r_{cbdc}

- Different to θ: cash use and deposits both fall as r_{cbdc} rises
- Lower CBDC rates can raise both bank credit and cash demand
- CBDC rates too negative: strictly dominated by deposits/cash



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Welfare analysis

- Welfare is given by

$$W(\theta, r_{cbdc}) = \int_i U(j^*(i))\, di =$$

$$\underbrace{\int_i C_{j^*(i)} di}_{\textit{bank intermediation}} - \underbrace{\int_i \left| x_{j^*(i)} - i \right| di}_{\textit{variety}}$$

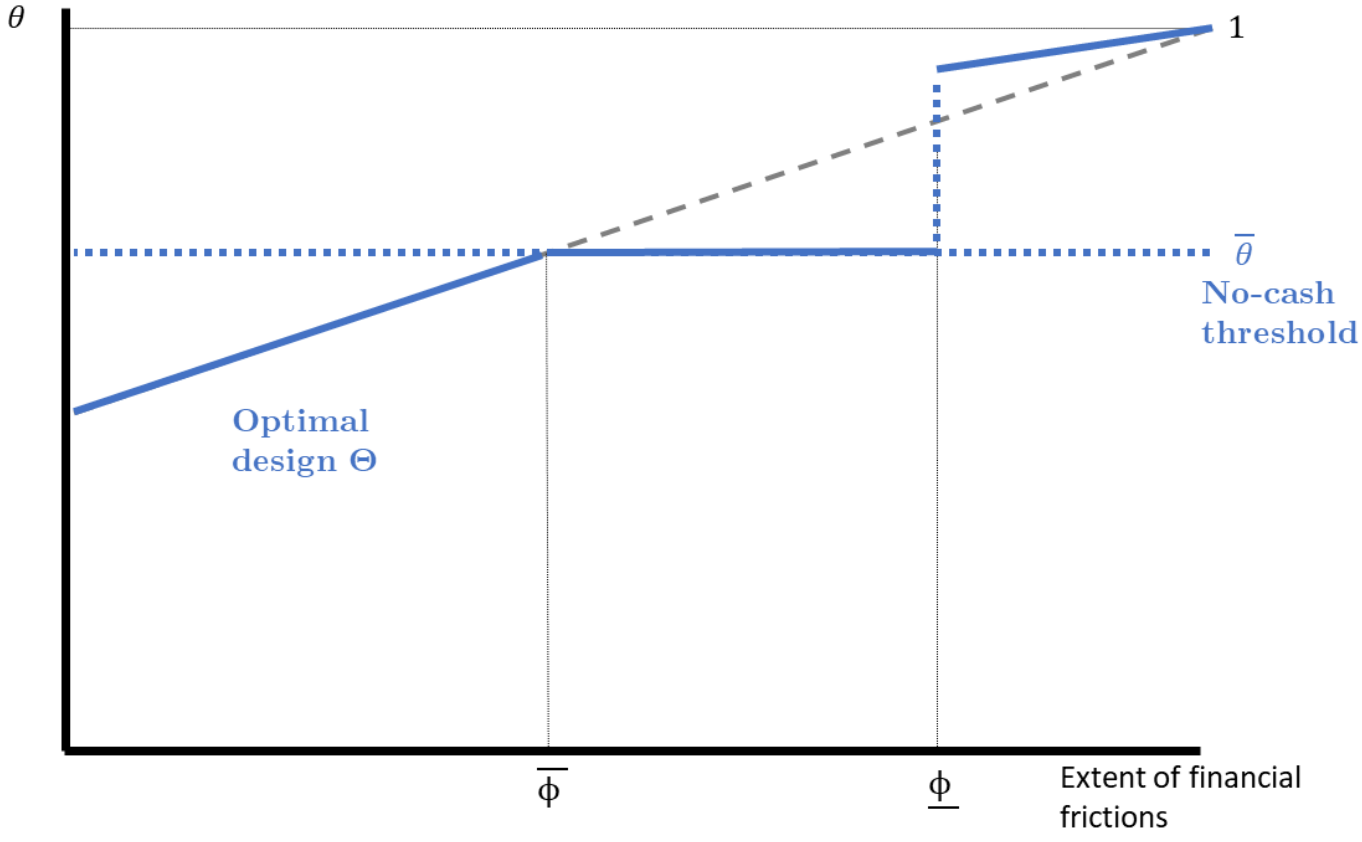
- Trade off bank intermediation and variety in payment instruments
- Safeguarding intermediation favors cash-like design, while variety best served by intermediate design

Welfare analysis

- Political economy constraints may force central bank to offer non interest-bearing CBDC, e.g.:
  - Social concerns about negative rates on central bank liability, held by the general public
  - Link between interest payments and taxation
- Question: how costly is that constraint in terms of impact on bank intermediation and maintaining cash usage?
  - First consider one-tool case: welfare maximization using θ only
  - Then joint optimization with both design and CBDC rate: central bank chooses (θ, r_{cbdc}) to maximize welfare

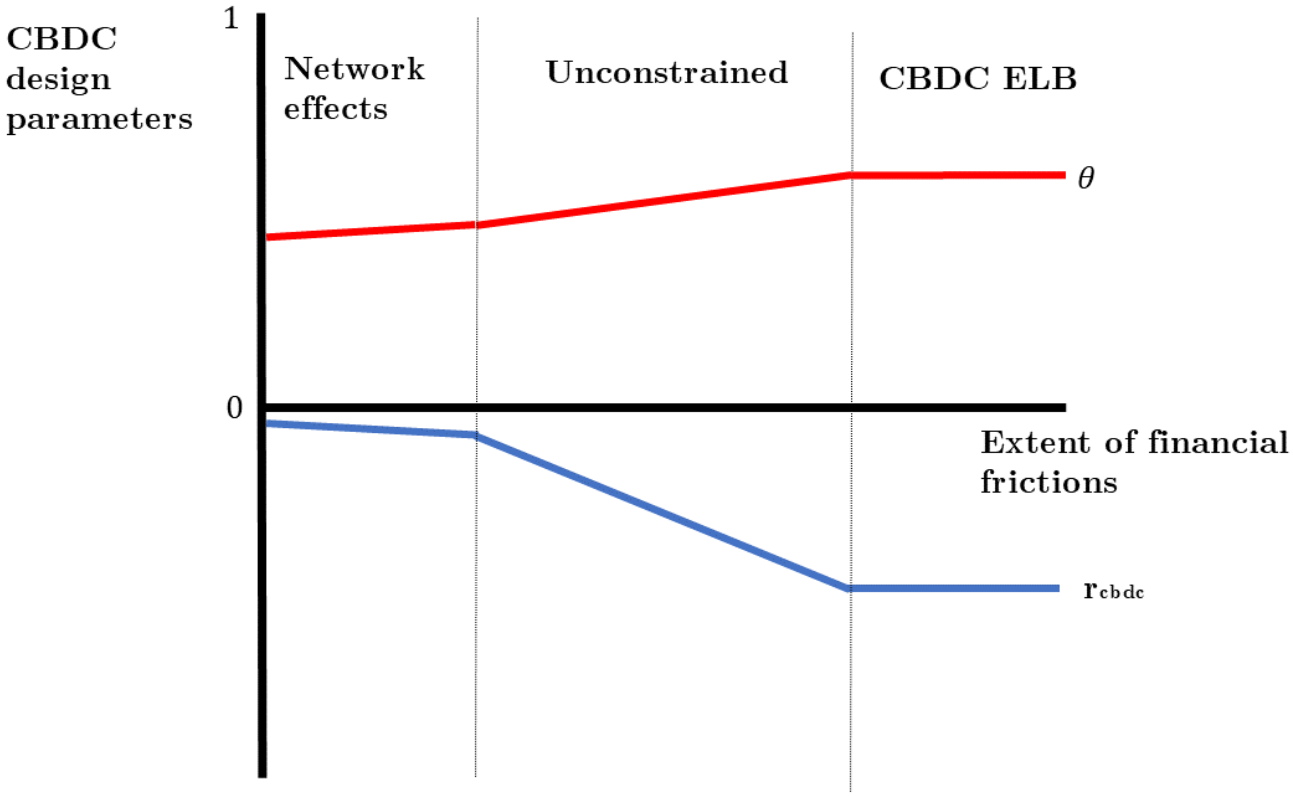
Optimal design with non interest-bearing CBDC

- CBDC design: more cash-like as bank intermediation more important
- Avoid cash disappearance by distorting design towards deposit-like
- $\phi < \overline{\phi}$: let cash disappear, jump up in θ to offer better substitute



Optimal design with interest-bearing CBDC

- Central bank jointly determines CBDC design and interest rate
- Cash never disappears when CBDC is interest-bearing
- Optimally compensate for more cash-like design by reducing r_{cbdc}



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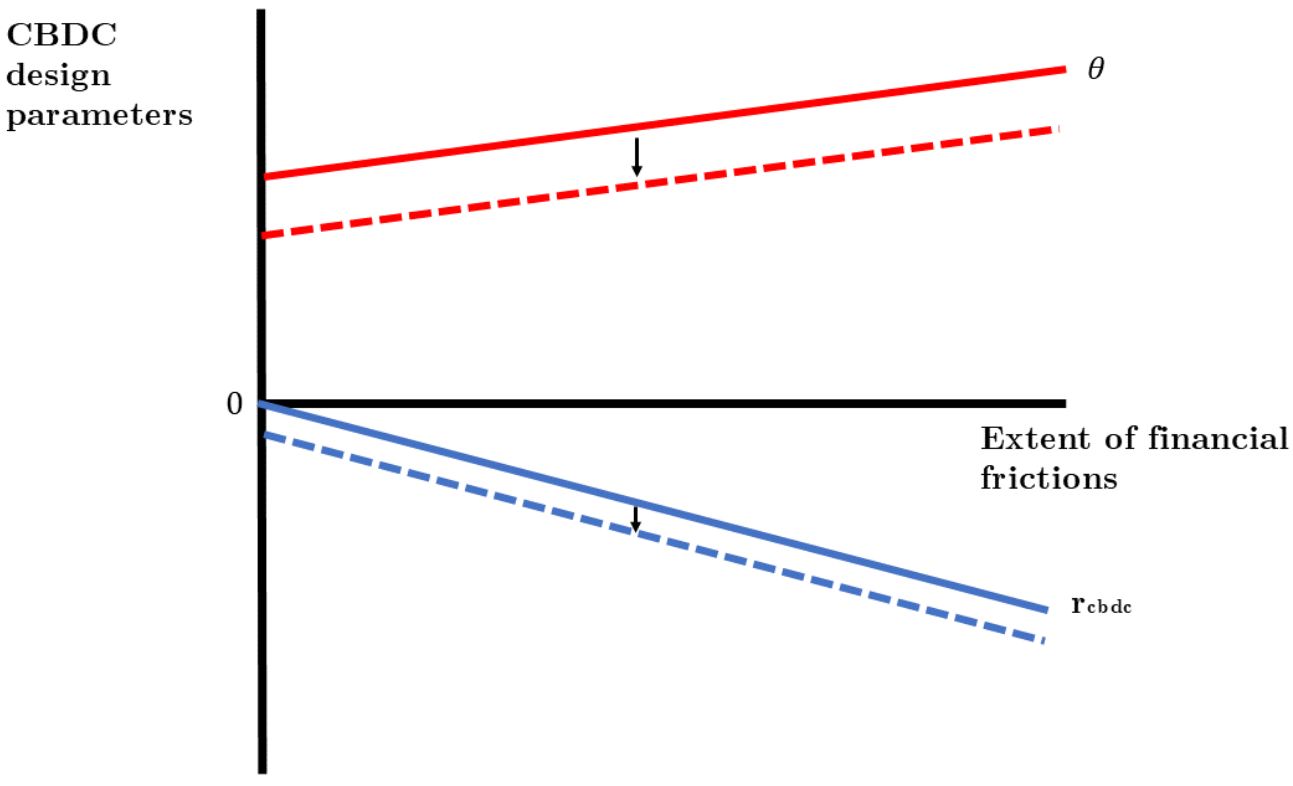
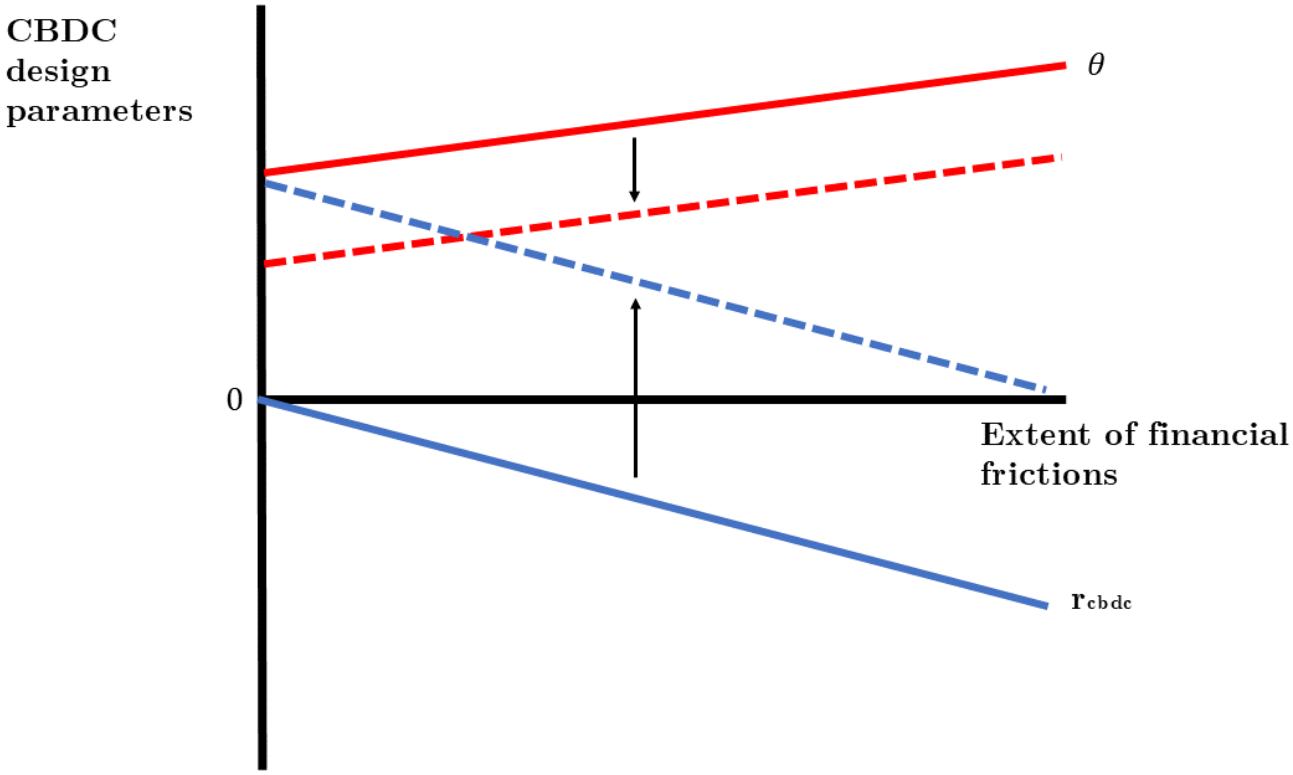
Bank market power

- Banks have market power in loans market (Cournot)
- Impact of CBDC on credit supply softened as market power rises
- Optimal design shifts towards deposit-like



Money multiplier

- Bank loans partially feed back into more deposits
- With increased level of loans, optimal to shift CBDC to greater competition with deposits: lower θ and higher r_{cbdc}



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Conclusion

- Many central banks considering CBDCs. We analyze CBDC design tradeoffs, in the presence of network effects and financial frictions
- CBDC causes bank disintermediation, but extent depends on design: optimal design more cash-like when financial frictions higher
- Tradeoff between disintermediation and drop in cash use: variety in payments creates value, but also constraints through network effects
- Political economy bent against rate-bearing CBDC. But offers key advantages: maintain payments variety and limit disintermediation.

Backup slide: modeling of network effects