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, Norway, Uruguay, Canada among others
Motivation

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- 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)
Design considerations

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 monies (Cash, CBDC, deposits)

- Network externalities
  - Convenience of a payments method depends on its number of users
  - Cash can endogenously disappear due to CBDC competition

- Bank-based financial intermediation
  - Role of deposit-based intermediation in alleviating financial frictions (Donaldson et al. 2018, JFE; Diamond & Rajan 2001, JPE)
  - Value of intermediation depends on relationship lending frictions
  - CBDC reduces credit when it competes closely with bank deposits

- Analyze optimal (welfare-maximizing) CBDC design, including interest-bearing feature
Related Literature

- Keister & Sanches (2019): CBDC in segregated markets cash/deposits
- Chiu et al. (2019), Andolfatto (2018): CBDC & payment systems

Our contribution

- Impact of network externalities and financial frictions on CBDC design
- Welfare trade-off between variety in payment methods and financial intermediation
- Interest-bearing CBDC as 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 backwards
Model: Firms and banks

- **Firms**
  - Perfectly competitive. Endowment $k_0$ of projects need financing.
  - Use bank loans $l$ to finance portion $k$, yielding
    \[ Y = \left( A - \frac{k}{2} \right) k \]
  - Remaining projects $(k_0 - k)$ liquidated at gross rate of return $0 < \phi < 1$
  - Firm’s profit maximization problem
    \[ \max_{l, k} Y + \phi (k_0 - k) - (1 + R) l \quad s.t. \quad k = l \]
  - Firm loan demand given by FOC:
    \[ 1 + R = A - \phi - l \]
- **Banks**
  - Collect deposits $d$ from households at rate $r_d$
  - Extend loans $l = d$ to firms at rate $R$
  - Perfect competition in deposit and loan markets: $R = r_d$
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

- Hotelling linear-city setup: minimize distance between money properties and preference
  - Key friction: no partial anonymity by mixing payment methods

\[ \Rightarrow \text{Choose between cash } (x_c = 1), \text{ deposit } (x_d = 0) \]
\[ \text{and CBDC located in between } (x_{cbdc} = \theta) \]
Model: Household’s problem

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

s.t.

\[
C_j = 1 + r_j - T + \pi
\]

- \(\eta_j = \max [g(s_j), 0]\) captures network effects, threshold \(s = g^{-1}(0)\)

- Optimal sorting conditions:

  Cash over CBDC: \(1 - i + \eta_c < |\theta - i| - \rho r_{cbdc} + \eta_{cbdc}\)

  Cash over deposits: \(1 - i + \eta_c < i - \rho r_d + \eta_d\)

  CBDC over deposits: \(|\theta - i| - \rho r_{cbdc} + \eta_{cbdc} < i - \rho r_d + \eta_d\)

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

Network effects
Equilibrium: Money shares across $\theta$

- 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 CBDC rate

- 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: no CBDC take up
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Welfare analysis

- Welfare is given by

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

\[ \rho \int_i C_{j^*(i)} \, di - \int_i |x_{j^*(i)} - i| \, di \]

- Trade-off: bank intermediation vs. variety in payment instruments

- Safeguarding bank intermediation favors cash-like design, while variety is best served by intermediate design
Welfare analysis

- Political economy constraints may force central bank to offer non interest-bearing CBDC:
  - Social concerns about negative rates on central bank liabilities, 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 $\theta$ only
  - Then joint optimization with both design and CBDC rate: central bank chooses $(\theta, r_{cbdc})$ to maximize welfare
Optimal design: non interest-bearing CBDC

- CBDC design: more cash-like as bank intermediation more important
- Avoid cash disappearance by distorting design towards deposit-like
- Threshold: let cash disappear, jump up in $\theta$ to offer better substitute
Welfare analysis: role of CBDC interest rate

- Select \((\theta, r_{cbdc})\) optimally to maximize aggregate welfare
- Closed form expression for welfare without network effects:

\[
\frac{1}{8 + 4\rho} \left[ 4\rho \left( A - \phi - \frac{1}{2} \right) \theta + 4(1 - \theta) \theta - 3\rho \theta^2 - (4 + \rho) \rho^2 r_{cbdc}^2 \right] + \text{constants}
\]

- \( r_{cbdc} \) enters negative quadratic: optimally set CBDC rate to zero

- CBDC rate sub-optimal: distorts payment instrument choice
- But: when network effects come into play, central role for \( r_{cbdc} \)
Optimal design: interest-bearing CBDC

- Central bank jointly determines CBDC design and interest rate
- CBDC rate used when network effects bind
- Raises welfare by making it easier to sustain payments variety

![Graph showing the relationship between CBDC design parameters and value of bank intermediation](image)
Welfare analysis: winners & losers

- Optimally designed CBDC raises aggregate welfare, but not all gain.
- Cash holders lose, especially if cash is eliminated.

Non-interest bearing CBDC

\[ \Delta U_i \]

\[ \Delta \pi + \Delta r_d \]

\[ 0 \]

\[ 1 \]

Deposit users

CBDC users

Cash users

Design mistakes
Welfare analysis: winners & losers

- Interest-bearing CBDC redistributes gains from CBDC holders to rest
- Cash holders gain from financial intermediation, and possibly from preserving cash
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Extensions

- Key question: Is it only network effects that make the case for an interest-bearing CBDC?

⇒ No. Optimal to use $r_{cbdc}$ as instrument when central bank has “too many balls to juggle”

1. Bank market power
   - Cournot competition in loans market.
   - Market power distortions interact with CBDC’s effect on deposit base
   - $r_{cbdc}$ varied, optimal responsiveness increases as market power rises

2. Negative externalities from anonymity:
   - Households dislike other households’ use of anonymous means of payment (e.g. illicit activities)
   - $r_{cbdc}$ optimally responds, even without network effects
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 in the face of network effects.
Microfoundations for payment preferences

- Extension in which deposit-based payments processed by monopolistic fintech provider that is also lender
  - Fintech provider uses transactions data to inform credit ratings

- Two types of goods: normal and sin. Households have heterogenous preferred consumption shares of goods types
  - Credit ratings decline in share of sin goods, if using deposit-based payment
  - Cash use avoids transactions data parsing, but only if used for all purchases
  - Using deposits for any share of consumption, always fully reveals household type, as fintech provider infers cash is used for rest

- Pooling equilibrium: some households sort into deposit money, to signal type, while optimally under-consuming sin good. Others sort into cash
  - Endogenous linear-city: highlights demand for intermediate payment instrument
Comparative statics of rise in $\theta$
Preview of Main Results

CBDC design and welfare:

- Optimal design more cash-like when financial frictions are larger
- Lean against disappearance of cash when network effects bind
- CBDC raises aggregate welfare but uneven distributional impact. Depositors and some CBDC holders better off, cash holders worse off.
Preview of Main Results

CBDC design and welfare:

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CBDC interest rate:

- Policy relevance: CBs primarily considering non interest-bearing CBDC
- Distortionary instrument to affect household payment choice
- No (binding) network effects: non-interest bearing CBDC optimal
- Network effects bind: optimally vary CBDC rate to safeguard bank intermediation, payment instrument variety
Design mistakes

- If CBDC design is sub-optimal, perverse outcomes possible:
  - Aggregate welfare effect of CBDC introduction can be negative
  - In addition to cash, deposits can vanish
  - In extremis: Pareto loss with every household worse off due to CBDC