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)
  - Payments efficiency
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
  - 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

Design trade-off:

- Deposit-like design: depresses bank credit and output
- Cash-like design: worsens network effects on cash
- Optimal design: more cash-like when financial frictions are larger, but 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.

CBDC interest rate:

- 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

Policy relevance: CBs primarily considering non interest-bearing CBDC
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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
    \[ \max_{l,k} Y + \phi (k_0 - k) - (1 + R)l \quad \text{s.t.} \quad k = l \]
  - 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

⇒ Choose between cash ($x_c = 1$), deposit ($x_d = 0$) 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
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
  \[
  W(\theta, r_{cbdc}) = \int U(j^*(i)) di = \\
  \rho \int iC_{j^*(i)} di - \int i|\chi_{j^*(i)} - i| di
  \]

  \( \underbrace{\text{bank intermediation}}_{\text{bank intermediation}} - \underbrace{\text{variety}}_{\text{variety}} \)

- 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

- Closed form expression for welfare in a given equilibrium:

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

- $r_{cbdc}$ enters negative quadratic: optimally set CBDC rate to zero

- Select $\theta$ optimally to address variety and bank intermediation tradeoff

- 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
Welfare analysis: winners & losers

- Optimally designed CBDC raises aggregate welfare, but not all gain
- Cash holders lose, especially if cash is eliminated
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
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 households worse off due to CBDC
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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. Alternative production functions
   - CRS or generalized quadratic functions do not change $r_{cbdc}$ results

2. 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

3. 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
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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 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
Modeling of network effects
Comparative statics of rise in $\theta$