

Designing Central Bank Digital Currencies

Itai Agur Anil Ari Giovanni Dell'Ariccia

International Monetary Fund

November, 2019

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

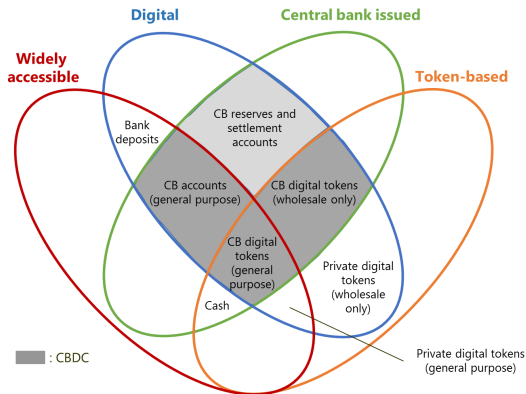
Motivation

- 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

- 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

Money flower (BIS, 2018)



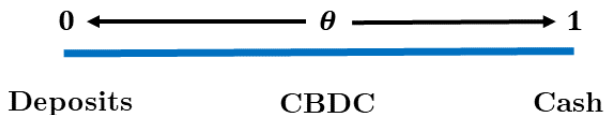
We focus on:

- 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)



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)

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
- Brunnermeier & Niepelt (2019), Kim & Kwon (2019): banking panics
- Agarwal & Kimball (2015), Barrdear & Kumhof (2016), Meaning et al. (2018), Assenmacher & Knogstrup (2018): Monetary policy transmission, ELB

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 $\underline{s} = g^{-1}(0)$

• Optimal sorting conditions:

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

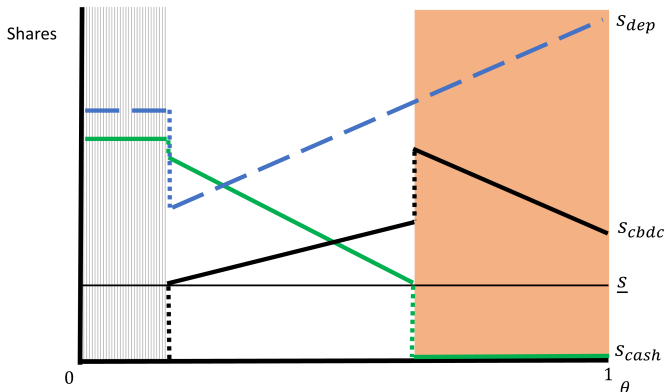
$$\text{Cash over deposits: } 1 - i + \eta_c < i - \rho r_d + \eta_d$$

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

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

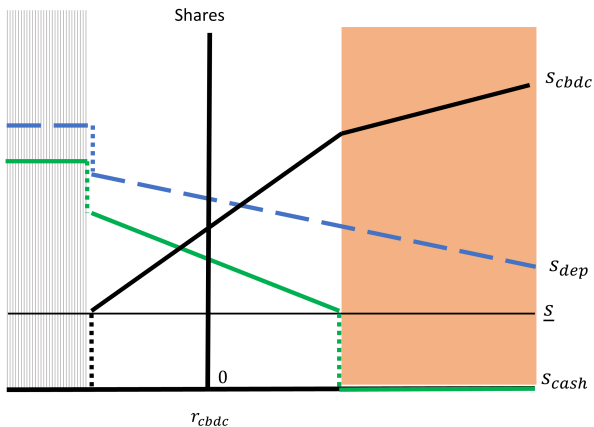
Equilibrium: Money shares across θ

- 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 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



Roadmap

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

Welfare analysis

- Welfare is given by

$$W(\theta, r_{cbdc}) = \int_i U(j^*(i)) di =$$
$$\underbrace{\rho \int_i C_{j^*(i)} di}_{\text{bank intermediation}} - \underbrace{\int_i |x_{j^*(i)} - i| di}_{\text{variety}}$$

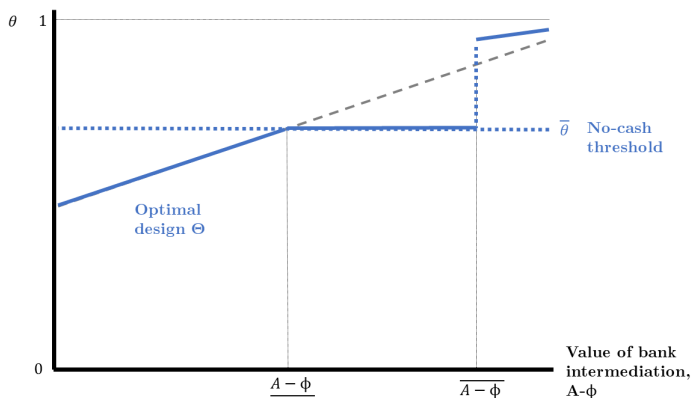
- Trade-off: bank intermediation vs. variety in payment instruments
- Safeguarding bank intermediation favors cash-like design, while variety is best served by intermediate design

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 θ only
 - Then joint optimization with both design and CBDC rate: central bank chooses (θ, 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 θ to offer better substitute



Welfare analysis: role of CBDC interest rate

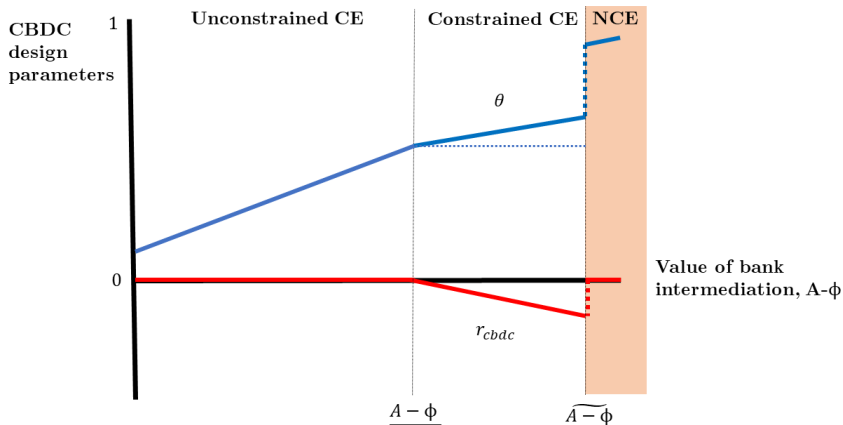
- Select (θ, r_{cbdc}) optimally to maximize aggregate welfare
- Closed form expression for welfare without network effects:

$$\frac{1}{8+4\rho} \left[\underbrace{4\rho \left(A - \phi - \frac{1}{2} \right) \theta}_{\text{bank intermediation}} + \underbrace{4(1-\theta)\theta - 3\rho\theta^2}_{\text{variety}} - \underbrace{(4+\rho)\rho^2 r_{cbdc}^2}_{\text{CBDC interest rate}} \right] + \text{constants}$$

- 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}

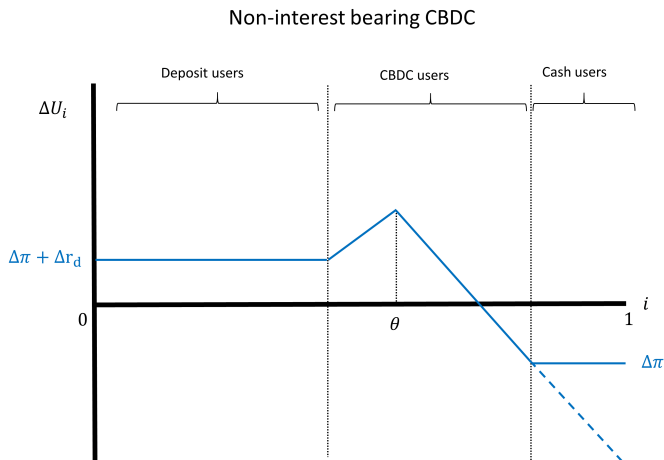
Optimal design: interest-bearing CBDC

- 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



Welfare analysis: winners & losers

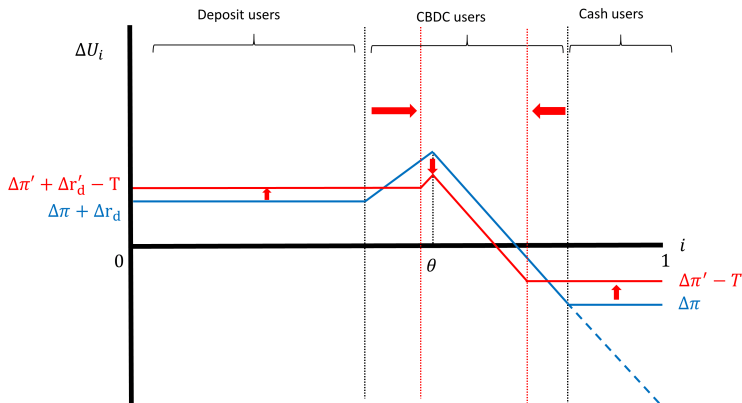
- Optimally designed CBDC raises aggregate welfare, but not all gain
- Cash holders lose, especially if cash is eliminated



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

Comparative statics of reduction in CBDC rate



Roadmap

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

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

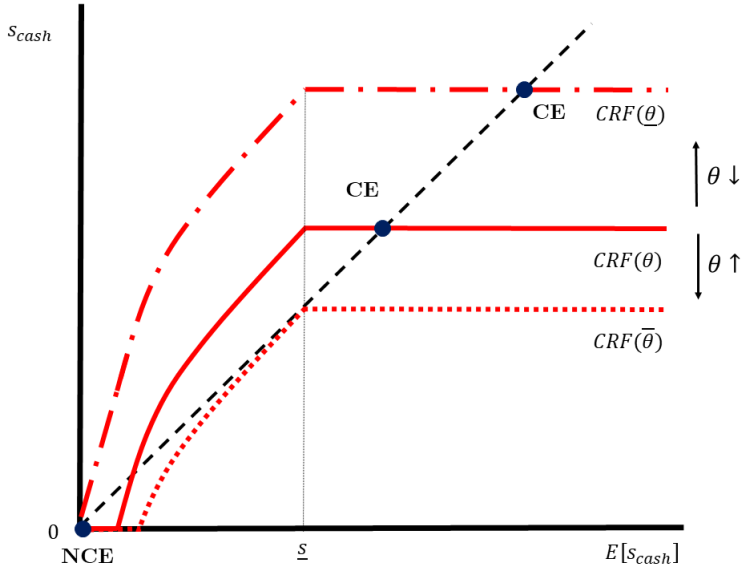
Conclusion

- 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.

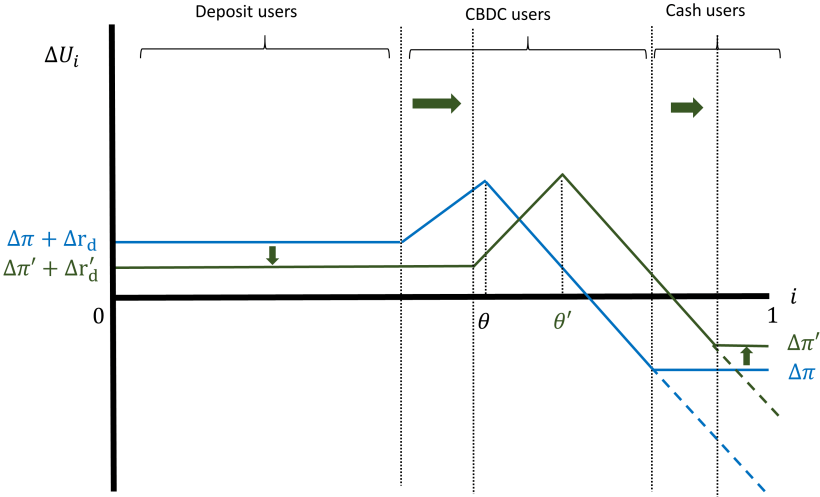
Microfoundations for payment preferences

- 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 heterogeneous 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 θ



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:

- 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.

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 households worse off due to CBDC