Designing Central Bank Digital Currencies

Itai Agur Anil Ari Giovanni Dell'Ariccia

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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

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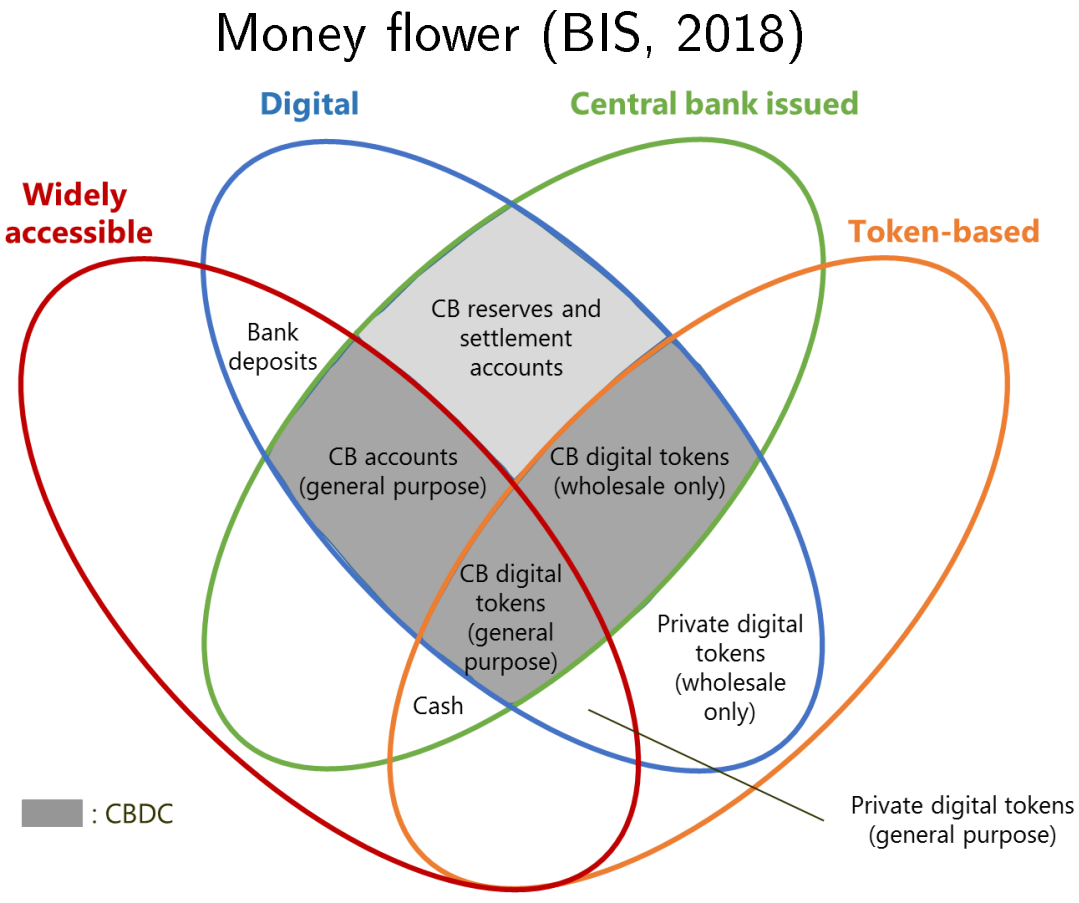
  - Many central banks considering introducing a CBDC
  - e.g. China, Sweden, Norway, Uruguay, Canada among others
- Why introduce a CBDC?
  - Privacy concerns due to private payments providers (e.g. China)
  - Maintaining cash-like attributes when cash vanishes (e.g. Sweden)
  - Public access to CB liabilities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

Design considerations



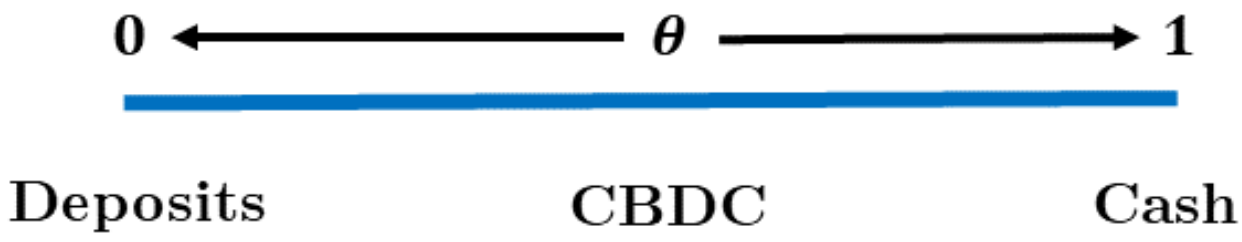
We focus on:

- 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
  - 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.

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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

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), Assenmacher & Knogstrup (2018): 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

$$\max_{l,k} \; Y + \phi\,(k_0 - k) - (1 + R)\,l \quad s.t. \;\; k = l$$

  - 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

  $\Rightarrow$ 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:

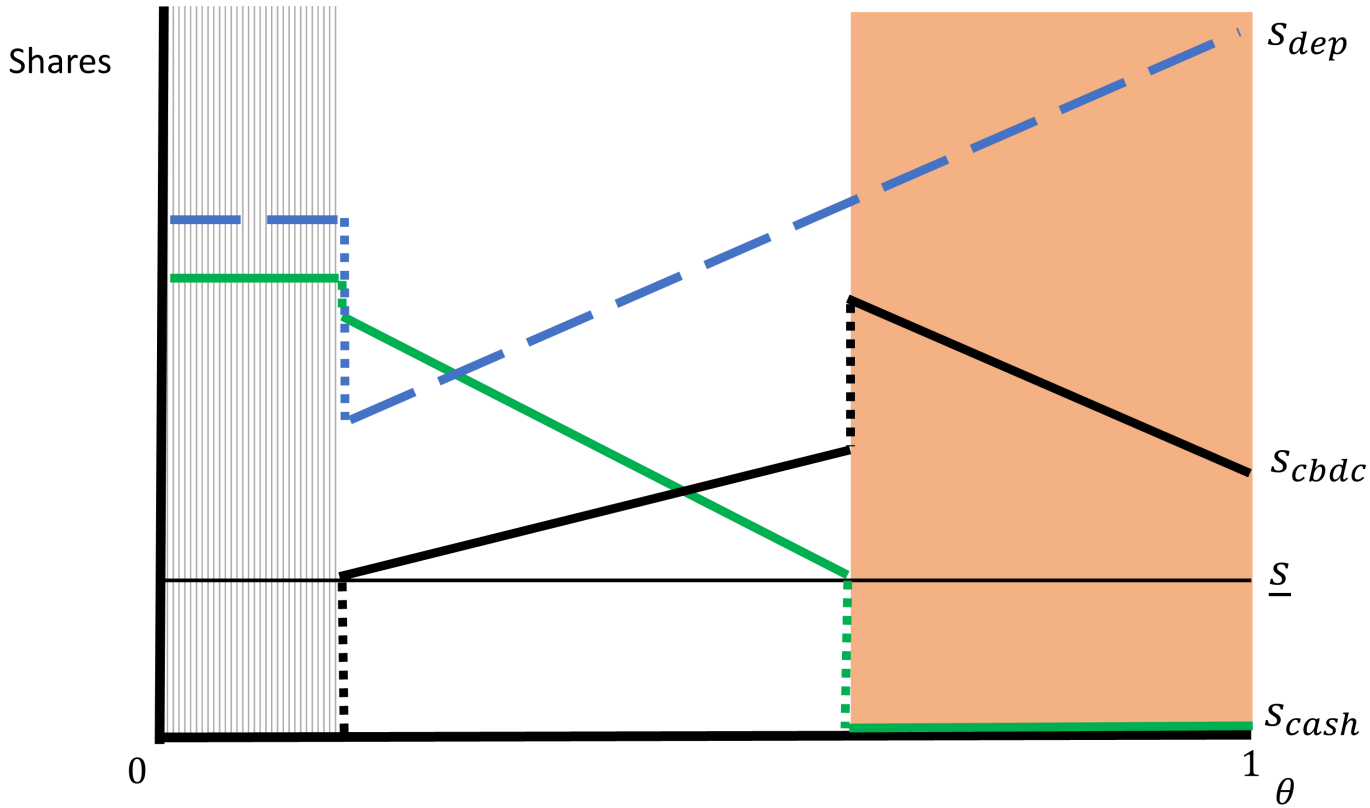
$$\text{Cash over CBDC: } 1 - i + \eta_c < |\theta - i| - \rho r_{cbdc} + \eta_{cbdc}$$
$$\text{Cash over deposits: } 1 - i + \eta_c < i - \rho r_d + \eta_d$$
$$\text{CBDC over deposits: } |\theta - i| - \rho r_{cbdc} + \eta_{cbdc} < i - \rho r_d + \eta_d$$

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

Network effects

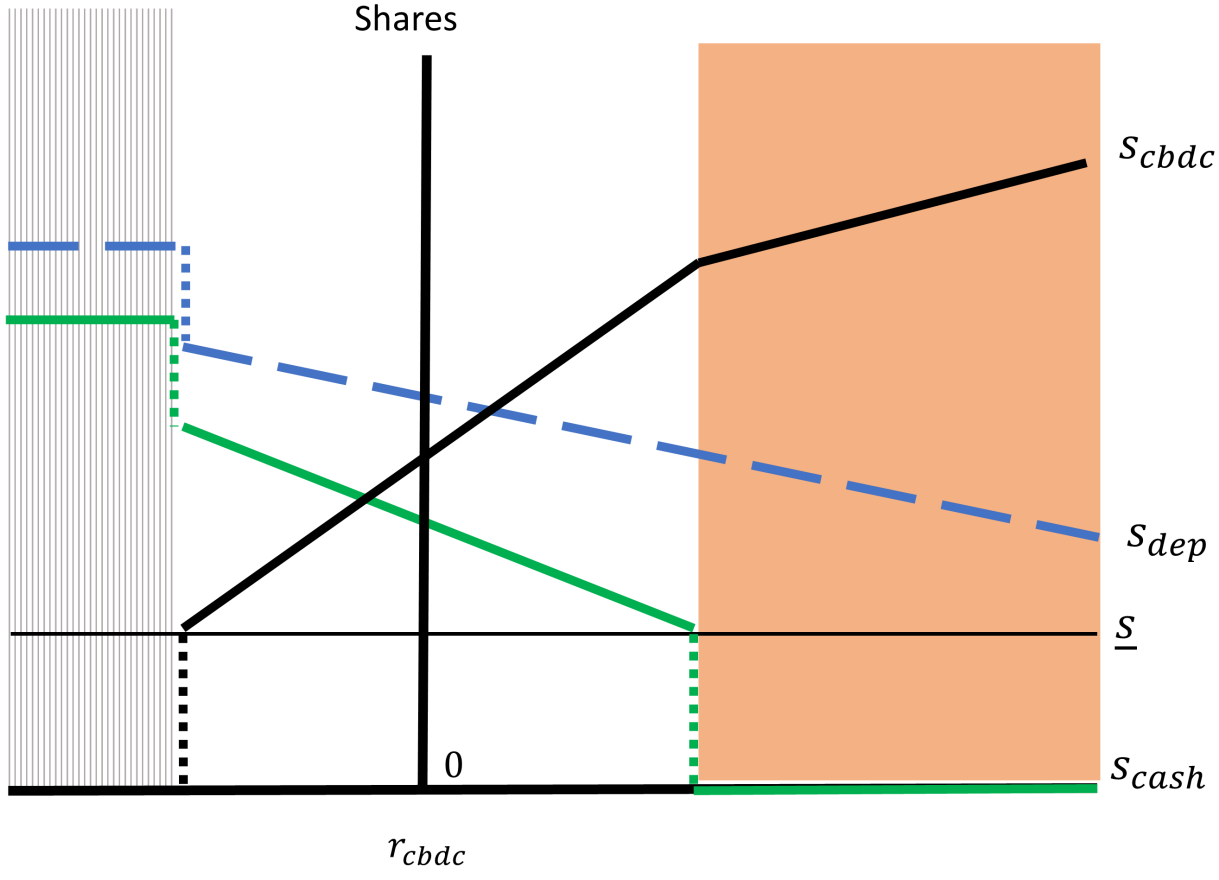
Equilibrium: Money shares across θ

- 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



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Welfare analysis

- Welfare is given by

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

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

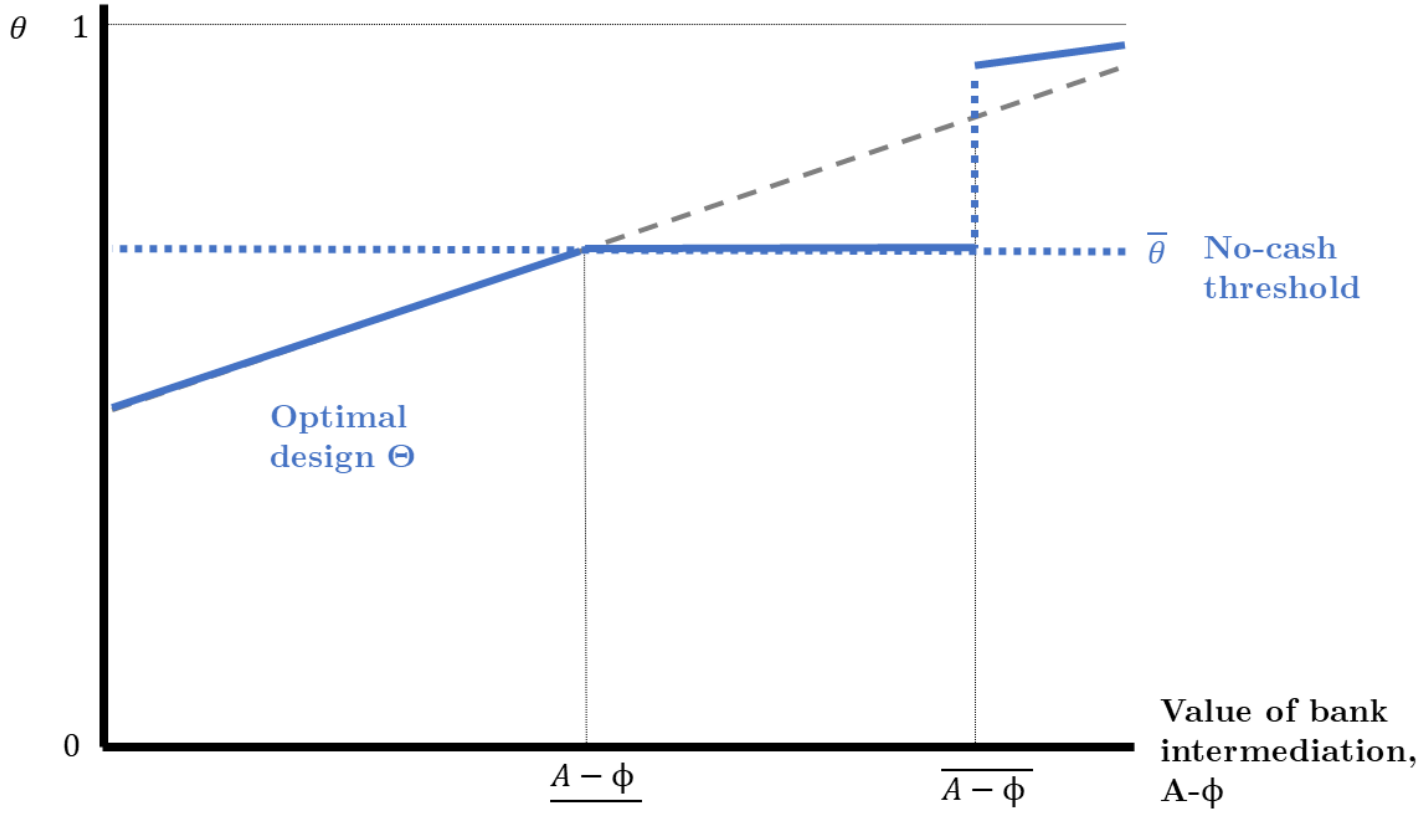
- Trade-off: bank intermediation vs. variety in payment instruments
- Safeguarding bank intermediation favors cash-like design, while variety is best served by intermediate design

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

- Closed form expression for welfare in a given equilibrium:

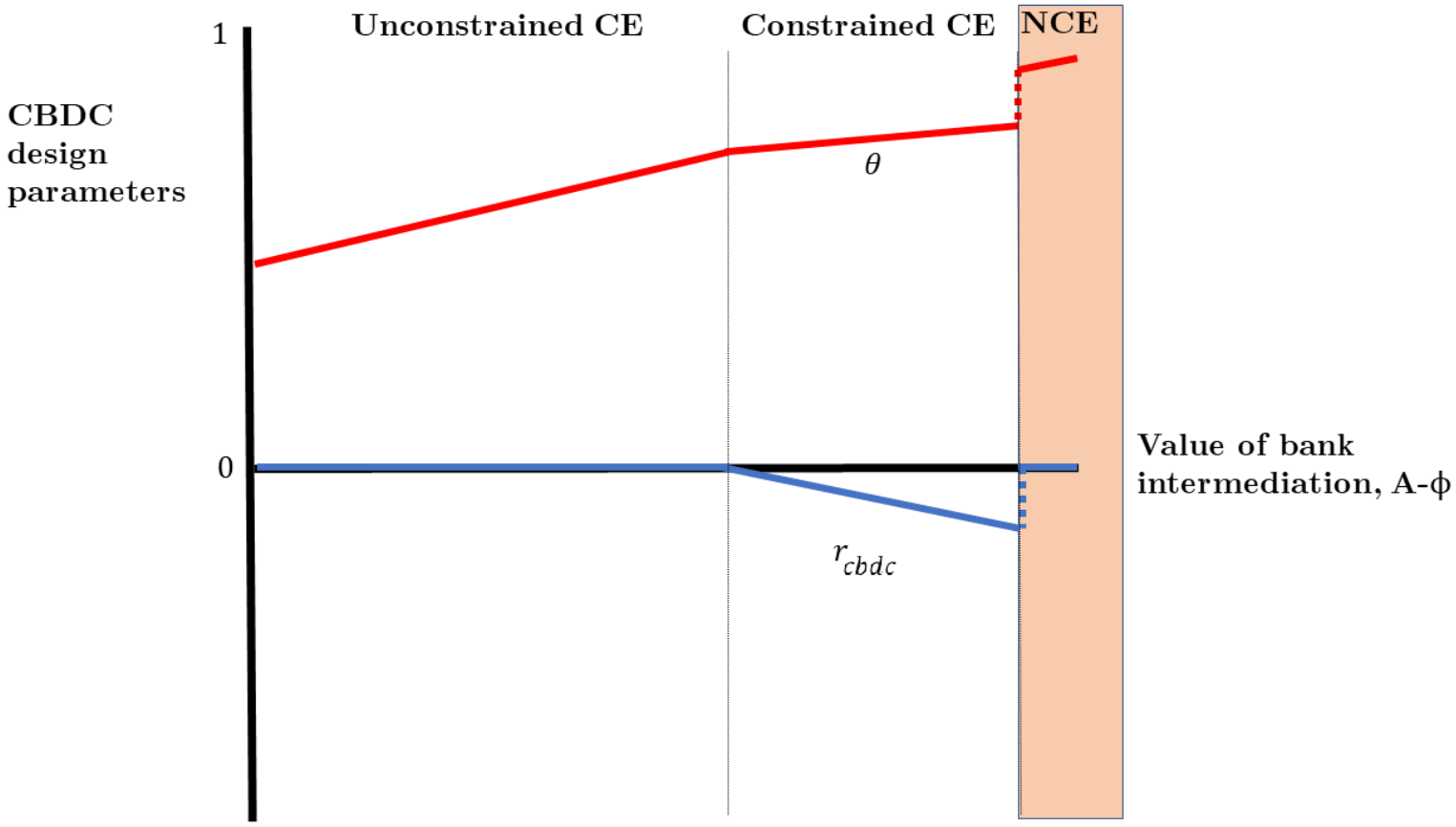
$$\frac{1}{8+4\rho}\left[\underbrace{4\rho\left(A-\phi-\frac{1}{2}\right)\theta}_{\textit{bank intermediation}}+\underbrace{4(1-\theta)\theta-3\rho\theta^2}_{\textit{variety}}-\underbrace{(4+\rho)\rho^2 r_{cbdc}^2}_{\textbf{\textit{CBDC interest rate}}}\right]$$
$$+\ \textit{constants}$$

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

- Select θ 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}

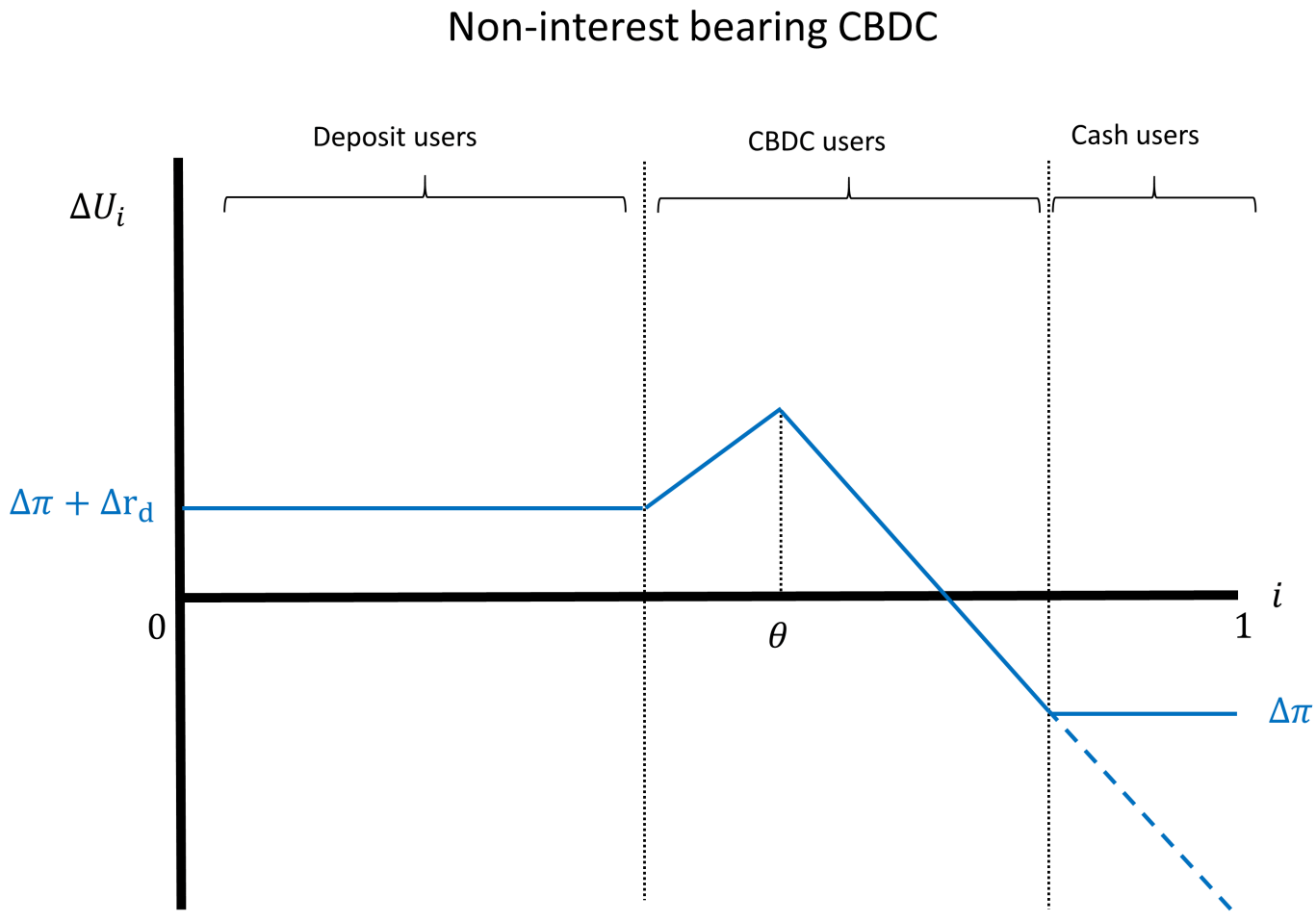
Optimal design: interest-bearing CBDC

- 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

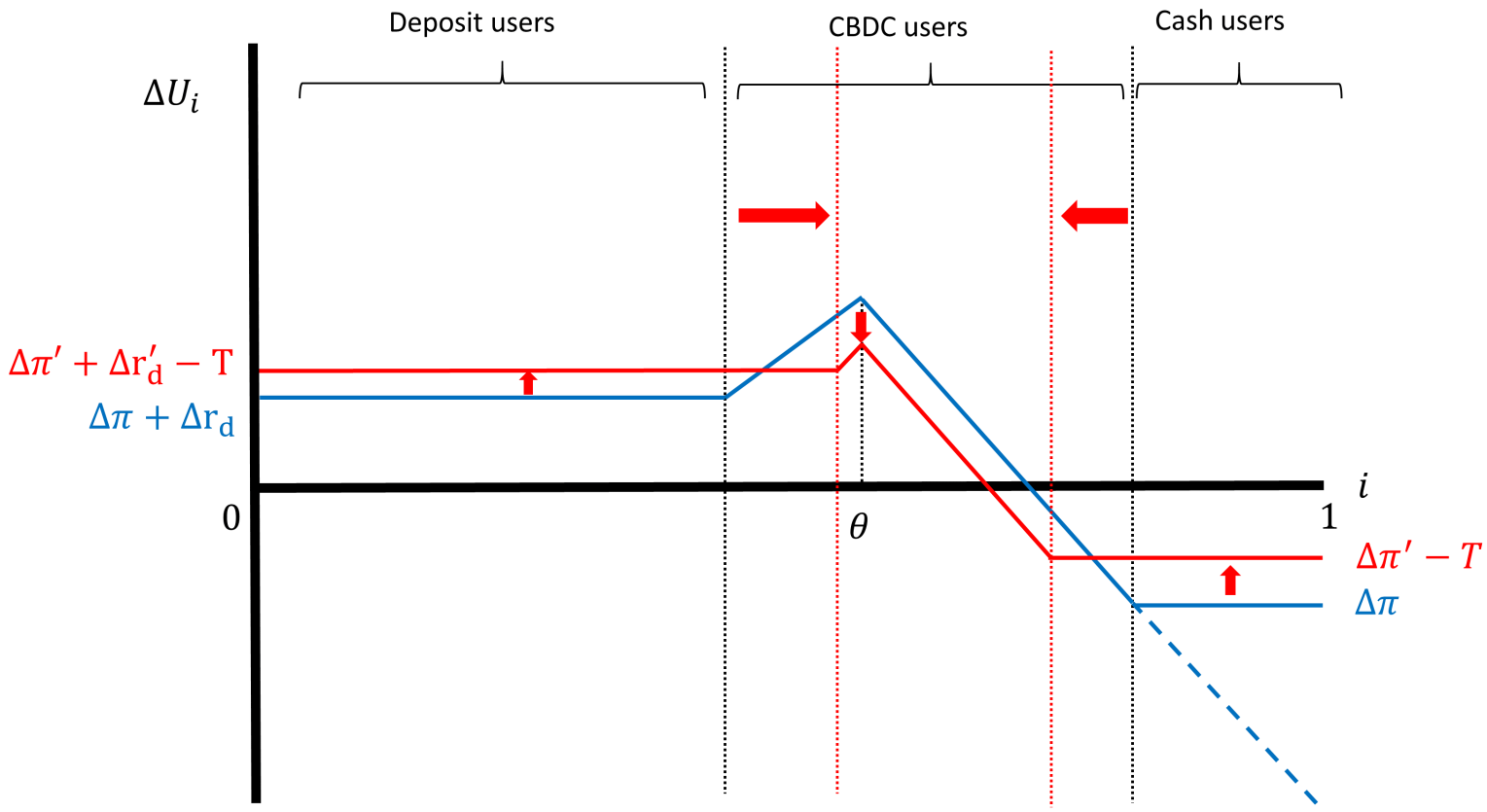
- Optimally designed CBDC raises aggregate welfare, but not all gain
- Cash holders lose, especially if cash is eliminated



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

Comparative statics of reduction in CBDC rate



More

Design mistakes

- If CBDC design is sub-optimal, perverse outcomes posssible:
  - 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?

$\Rightarrow$ 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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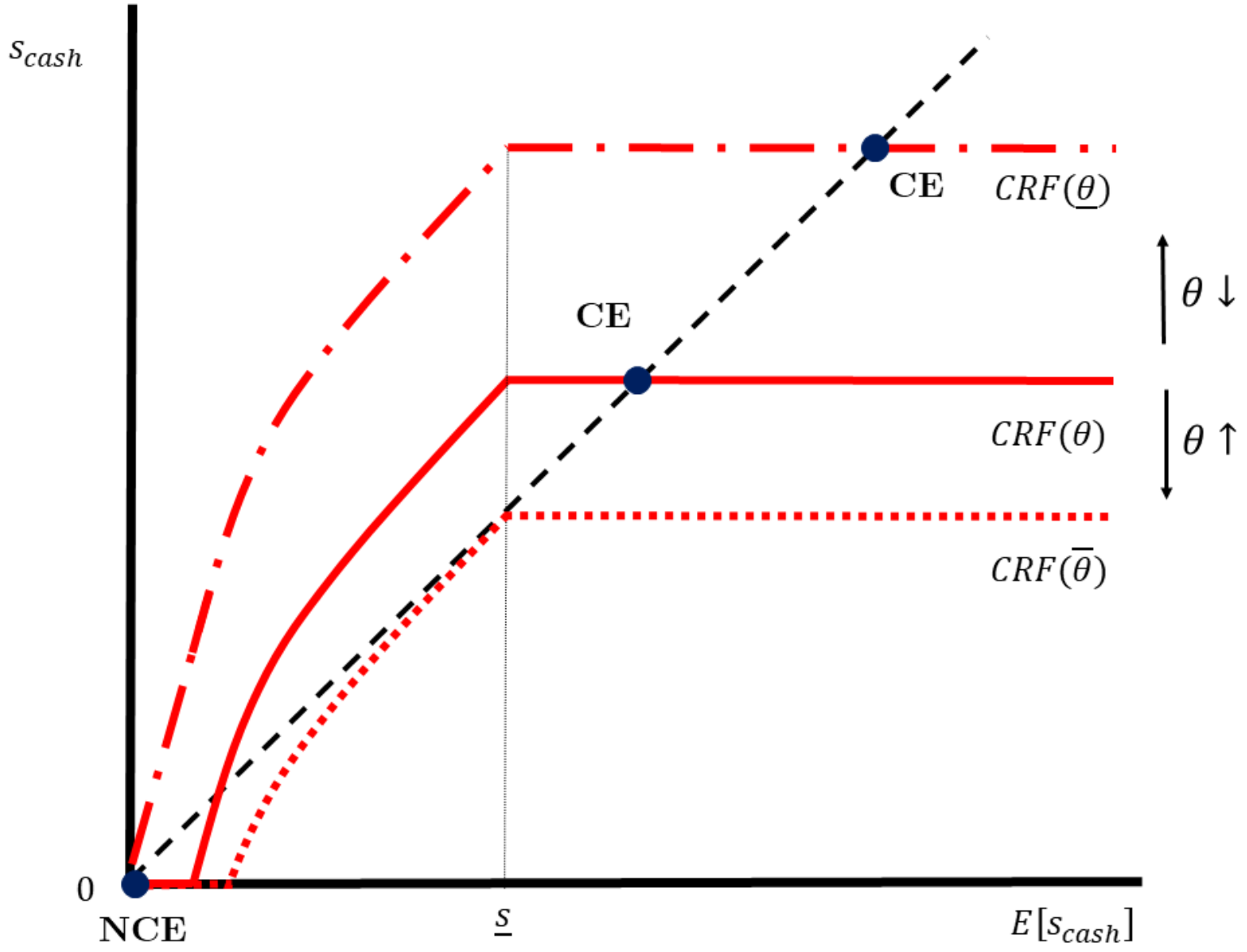
Conclusion

- 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



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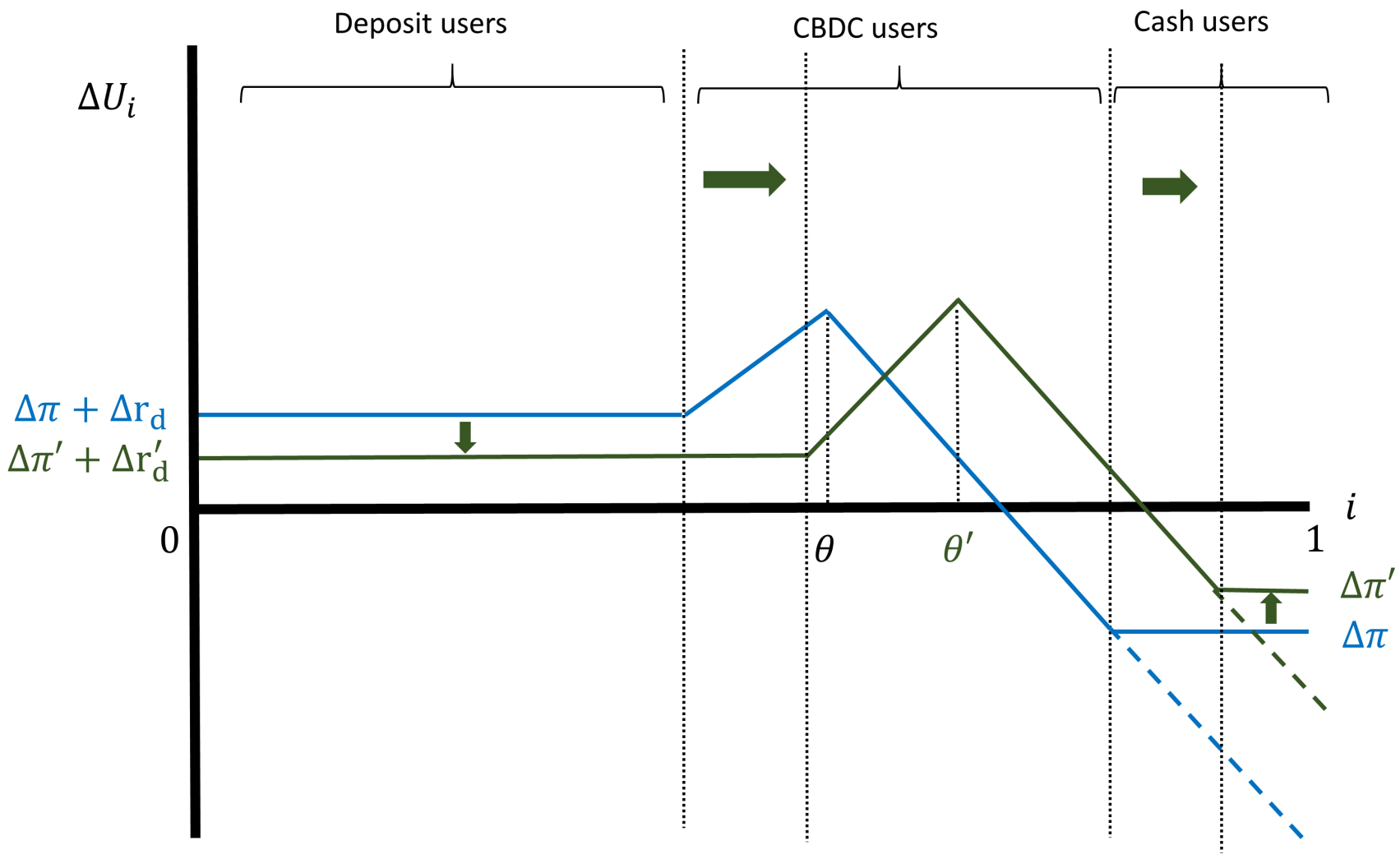
Comparative statics of rise in θ



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