Central Bank Digital Currency: Information and Stability

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Introduction

Q: How would a CBDC affect financial stability?

- much discussion of this issue in policy circles
- but little formal analysis

- Common view: CBDC would make runs on banks more likely
  - offers depositors a more attractive safe option

  $\Rightarrow$ makes them more likely to withdraw at first sign of trouble

- We show: there is another side to the story

- CBDC can change the flow of information to regulators
  - leads to a faster policy response to an emerging crisis
  - this faster response *reduces* the incentive for depositors to run

The mechanism (1)

- We construct a model where the common concern arises
  - build on the Diamond-Dybvig framework
  - a "better" safe asset makes withdrawing early more attractive
- And where the timing of the policy response is endogenous
- In the early phases of a crisis:
  - banks and (some) depositors have private information about the quality of their assets
  - banks have an incentive to hide this information for a while (Keister & Mitkov, 2021)
    - continue operating as normal; pushes losses onto public sector
- Policy makers can eventually see where the problems are
  - by observing withdrawal behavior, evaluating assets …

The mechanism (2)

- … but doing so takes time
  - this delay in the policy reaction makes the crisis worse
  - which increases the ex ante incentive to withdraw
- CBDC provides a new source of information
  - during a run, more withdrawals are converted to CBDC
  - these flows into CBDC are observed by the central bank
- We show: with CBCD, the policy reaction comes sooner
  - this quicker response reduces early liquidation, misallocation
  - which <u>decreases</u> the incentive to withdraw early
- Competing effects; CBDC improves stability in some cases

Outline

1) A baseline model
   - the environment
   - equilibrium and fragility
2) Introducing CBDC
3) The information effect
4) Optimal CBDC policy
5) Conclusion

Environment

- $t = 1,2$
- Depositors: $i \in [0,1]$ in each of many locations
  - begin with 1 unit of good deposited in bank in their location
  - desire consumption at $t = 2$
- Investment technology:
  - goods not consumed at $t = 1$ earn return $R > 1$ at $t = 2$
- Government:
  - endowed with resources τ at $t = 1$
  - can be used to provide a public good valued by all depositors

Relocation

- At $t = 1$, a fraction π of depositors will be relocated
  - unable to contact their bank at $t = 2 \rightarrow$ must withdraw at $t = 1$ (as in Champ, Smith, and Williamson, 1997)
- Earn an idiosyncratic return ρ on goods carried to new location
  - $\rho \sim \left[\underline{\rho}, \overline{\rho}\right]$ with continuous distribution F
  - idea: movers are withdrawing for transaction purposes
  - ρ: how well an individual is served by current payment methods
- Relocation status and ρ are private information
  - banks allow depositors to choose when to withdraw ($t = 1$ or $t = 2$)
  - creates the possibility of a run, as in Diamond & Dybvig (1983)

Banking arrangement

- Banks maximize expected utility of depositors
- Choose: how much to pay depositors who withdraw at $t = 1$
  - same for all such depositors, since ρ is private information
- In normal times, a bank solves:

$$\max \pi \int_{\underline{\rho}}^{\overline{\rho}} u(\rho x_1) dF(\rho) + (1-\pi) u(x_2)$$

$$s.t. \qquad \pi x_1 + (1-\pi)\frac{x_2}{R} \leq 1$$

solution: (x_1^*, x_2^*)

- Very similar to a standard DD allocation problem
  - interpretation: (x_1^*, x_2^*) is "face value" of the deposit

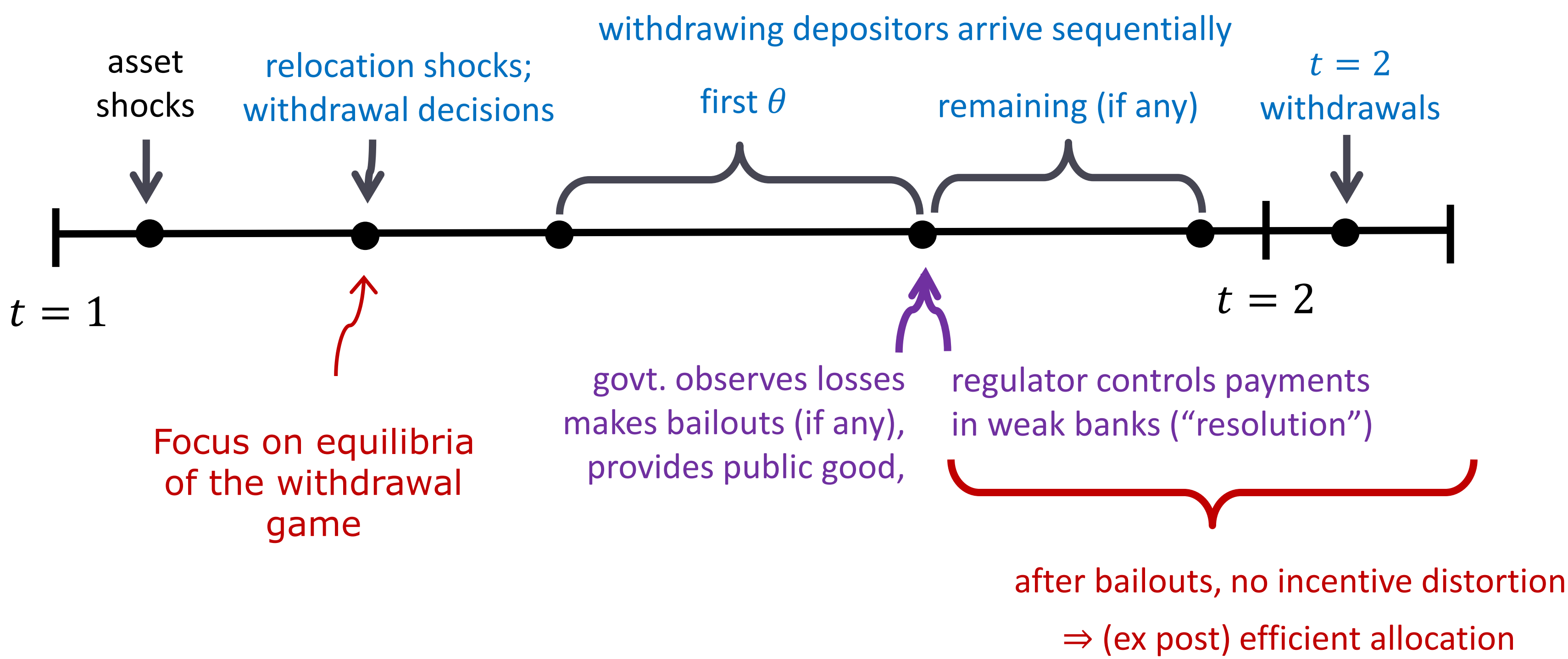
Shocks

- Aggregate state realized at the beginning of $t = 1$
- Two possibilities:
  - normal times: all bank assets are unchanged
  - crisis: a fraction $n > 0$ of banks each lose a fraction σ of assets
- Depositors observe the realized loss of their own bank
  - can condition withdrawal decision on this information
- Baseline case: regulators observe the aggregate state …
- But observe bank-specific information with a delay
  - can make inferences based on equilibrium behavior (withdrawals)

Two roles of govt

- Fiscal authority:
  - endowed with τ units of good at $t = 1$ ("fiscal capacity")
  - divided between public good and bailouts to banks facing losses
  - no commitment: bailouts are chosen to maximize ex post welfare
- Regulator:
  - can restrict the payments made by banks to depositors
    - policy must be measurable w.r.t. the regulator's information set
  - if no run: observe bank's status after π withdrawals
    - observes withdrawals stop; also observes value of assets
  - if a run is detected: bank is placed in resolution (and run ends)
    - with no CBDC, a run is detected … after π withdraals

Timeline



- Note: no decisions are made before shocks are realized
  - ex ante probabilities of the aggregate states do not matter

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No bail-ins

- We assume depositors do not run on sound banks
  - and that sound banks receive no bailouts

  ⇒ optimal for sound banks to follow (x_1^*, x_2^*)
- A weak bank anticipates being bailed out → distorts incentives
  - if it pays more than x_1^*, regulator would intervene
  - could pay $< x_1^*$ ("bail in"); focus on case where this is not optimal

    ⇒ weak banks pay x_1^* until placed in resolution
- Keister & Mitkov focus on the "bail-in game"
  - weak banks best choice of x_1^* depends on choices of others
- Here: assume no bail-in is a dominant strategy
  - focus on the withdrawal game played by depositors

Fragility

Q: Do depositors run on weak banks?

- focus on non-movers (movers always withdraw at $t = 1$)

- A non-mover in a weak bank compares:
  - withdraw at $t = 1$: receive x_1^*, store until $t = 2$ at rate $\rho_N < 1$
  - wait until $t = 2$: receive payment from bank in resolution process
    - depends on the amount of resources remaining in the bank
    - and on the bailout payment the bank receives

- Let $\alpha_i \in [0,1]$ denote prob of withdrawing at $t = 1$ for depositor i
  - $\alpha_i = 0 \Rightarrow$ "not run" and $\alpha_i = 1 \Rightarrow$ "run"
  - we allow for mixed strategies (we'll see why later on)
  - focus on symmetric outcomes across weak banks

Resolution

- A fraction $\alpha = \int_0^1 \alpha_i di$ of non-movers attempt to withdraw early
- After π withdrawals, bank is placed into resolution
  - fraction of *remaining* depositors who are movers:

$$\frac{\pi\alpha}{\pi + \alpha(1-\pi)} \equiv \hat{\pi}(\alpha;\theta)$$

- Resolution authority will solve:

$$\max_{\{x_1,x_2,b\}} n(1-\pi)\left\{\hat{\pi}(\alpha)\int_{\underline{\rho}}^{\overline{\rho}} u(\rho x_1)dF(\rho) + \big(1-\hat{\pi}(\alpha)\big)u(x_2)\right\} + v(\tau - nb)$$

$$s.t. \qquad (1-\pi)\left\{\hat{\pi}(\alpha)x_1 + \big(1-\hat{\pi}(\alpha)\big)\frac{x_2}{R}\right\} \le 1 - \sigma - \pi x_1^* + b$$

- Solution: $\big(\hat{x}_1(\alpha), \hat{x}_2(\alpha)\big)$

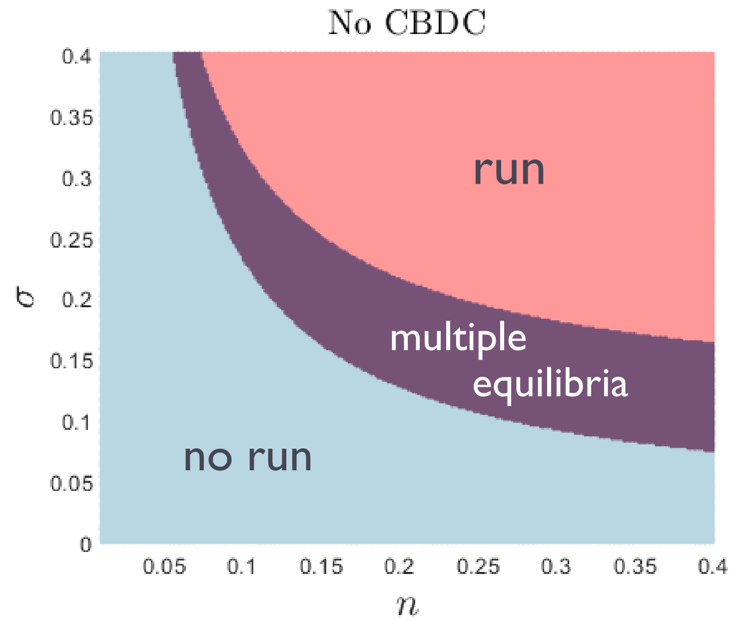
Equilibrium

- An equilibrium is a profile of strategies $\alpha^*: [0,1] \to [0,1]$ such that:

$$\alpha_i^* \begin{Bmatrix} = 0 \\ \in [0,1] \\ = 1 \end{Bmatrix} \quad \text{if} \quad \rho_N x_1^* \begin{Bmatrix} < \\ = \\ > \end{Bmatrix} \hat{x}_2(\alpha^*)$$

  - focus is symmetric across depositors, weak banks

- If (n, σ) are small:
  - $\hat{x}_2$ in resolution is $> x_1^*$
  - unique equilibrium, no bank runs
- If (n, σ) are large:
  - $\hat{x}_2 < x_1^*$ for all $\alpha \to$ running is D.S.
- In between: multiple equilibria



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CBDC

- Central bank has a storage technology between $t = 1$ and $t = 2$
  - earns a return R_{CB}. Baseline case: set $R_{CB} = 1$
- Depositors who withdraw from bank can deposit in CBDC
  - earn an interest rate ρ_{CB} from central bank
  - available to both movers and non-movers
  - baseline case: set $\rho_{CB} = 1$ $(> \underline{\rho})$
- Interpretation:
  - for some people (low ρ), CBDC is a better way of transacting
  - for others (high ρ), CBDC is not useful in normal times
  - but CBDC is available to all agents as a store of value

Normal times

- Availability of CBDC changes the bank's problem

some movers …

$$\max \pi\left(u(\rho_{CB}x_1)F(\rho_{CB}) + \int_{\rho_{CB}}^{\bar{\rho}} u(\rho x_1)dF(\rho)\right) + (1-\pi)u(x_2)$$

… now earn $\rho_{CB} > \rho$

$$s.t. \qquad \pi x_1 + (1-\pi)\frac{x_2}{R} \leq 1$$

solution:
$\left(x_1^*(\rho_{CB}), x_2^*(\rho_{CB})\right)$

- CRRA > 1 implies x_1^* is decreasing in ρ_{CB} (⇒ x_2^* is ↑ in ρ_{CB})
  - but $\rho_{CB}x_1^*(\rho_{CB})$ is increasing in ρ_{CB}

⇒ CBDC leads banks to do less maturity transformation

  - seems like an interesting (new?) point

Resolution and the incentive to run

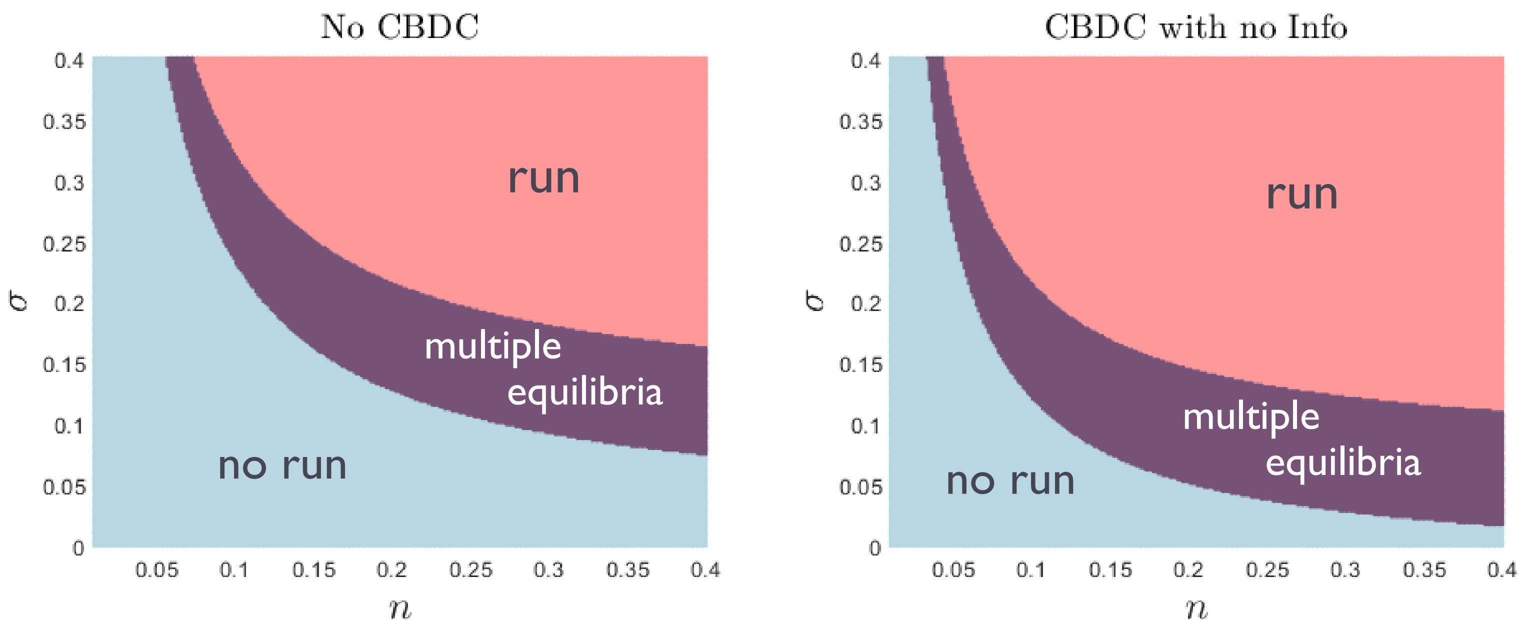
- CBDC changes the resolution problem in a similar way
  - new solution: $\left(\hat{x}_1(\alpha, \rho_{CB}), \hat{x}_2(\alpha, \rho_{CB})\right)$
- More directly, it changes the incentives of non-movers

$$\alpha_i \left\{ \begin{array}{c} = 0 \\ \in [0,1] \\ = 1 \end{array} \right\} \quad \text{if} \quad \rho_{CP} x_1^*(\rho_{CB}) \left\{ \begin{array}{c} < \\ = \\ > \end{array} \right\} \hat{x}_2(\alpha, \rho_{CB})$$

concern in policy discussions

- Model captures the concern that CBDC makes withdrawing early more attractive
  - of course, the payoffs x_1^* and $\hat{x}_2$ adjust as well
  - but these effects appear to be secondary

Example



- Result: When the policy reaction to a run occurs after π withdrawals, CBDC increases the fragile sets
  - both "run" and "run+ME"
- Result holds in this example
  - conjecture: the result holds in general as well

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Information

Q: How might CBDC affect the timing of the policy reaction?

- Assume the CB an observe flows into CBDC *from each bank*
  - plan to relax this assumption later on
- If there is no run on the bank:
  - all withdrawals from the bank are by movers
  - those movers with $\rho < \rho_{CB}$ will use CBDC

$$\pi \int_{\underline{\rho}}^{\rho_{CB}} dF(\rho) = \pi F(\rho_{CB})$$

- If deposits in CBDC go above this level …
  - some non-movers are withdrawing → a run must be underway

- How quickly can the CB detect a run is underway?
- After θ withdrawals, where θ is the solution to:

withdrawals

$$\theta \underbrace{\left\{\frac{\pi F(\rho_{CB})+\alpha(1-\pi)}{\pi+\alpha(1-\pi)}\right\}}_{\text{fraction who convert to CBDC}} = \underbrace{\pi F(\rho_{CB})}_{\text{CBDC use if no run}}$$

  - or:

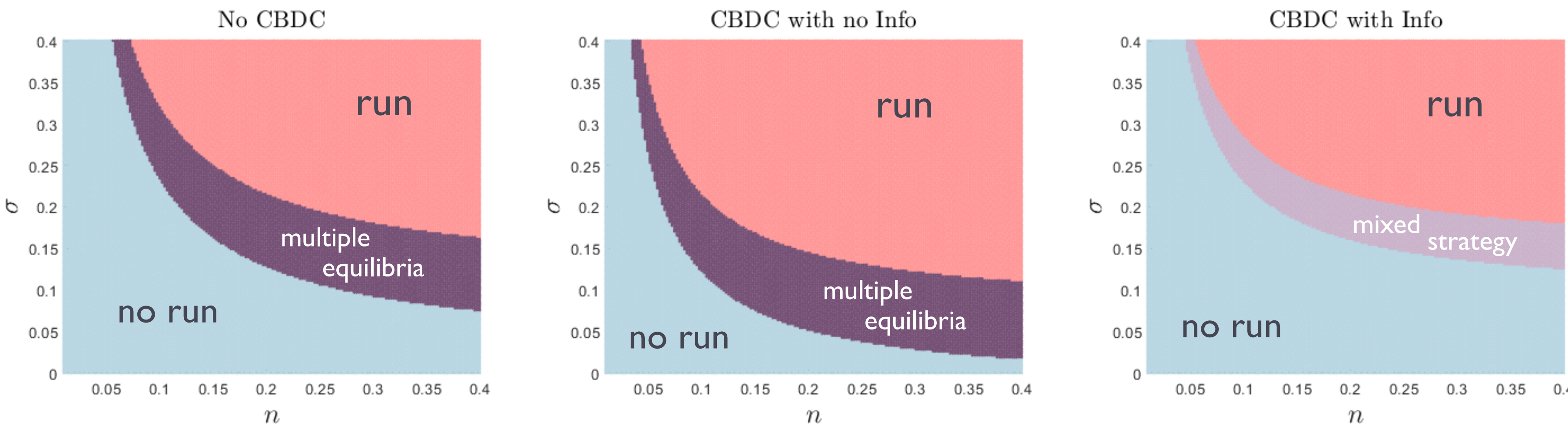
$$\theta(\alpha,\rho_{CB}) = \frac{\big(\pi+\alpha(1-\pi)\big)F(\rho_{CB})}{\pi F(\rho_{CB})+\alpha(1-\pi)}\pi \qquad < \pi \text{ when } \alpha > 0$$

- Can show that $\theta(\alpha,\rho_{CB})$ is:
  - decreasing in α → a larger run will be detected more quickly
  - increasing in ρ_{CB} → more CBDC use in normal times makes a run harder to detect

Comments

- Notice the role of sequential service
  - traditionally: detect a run by counting withdrawals as they occur
  - here: detect a run by counting deposits into CBDC as they occur
    - this second way is always faster $(\theta < \pi)$
    - how much faster depends on how much use the CBDC normally has
- When many other agents are withdrawing (α is large) …
  - the run will be detected more quickly → faster resolution
  - payoff of waiting $\hat{x}_2$ will be larger → <u>less</u> incentive to join the run
- Endogenous θ introduces a strategic substitutability
  - withdrawing early may become <u>less</u> attractive if others do so
  - can eliminate the multiplicity of equilibrium

Fragility



- Information effect reduces fragility (relative to middle case)
  - conjecture: this result is true in general
- Net effect of CBDC can be lower fragility (in examples)
- May be regions with a unique equilibrium in mixed strategies
  - withdrawal decisions are substitutes rather than complements

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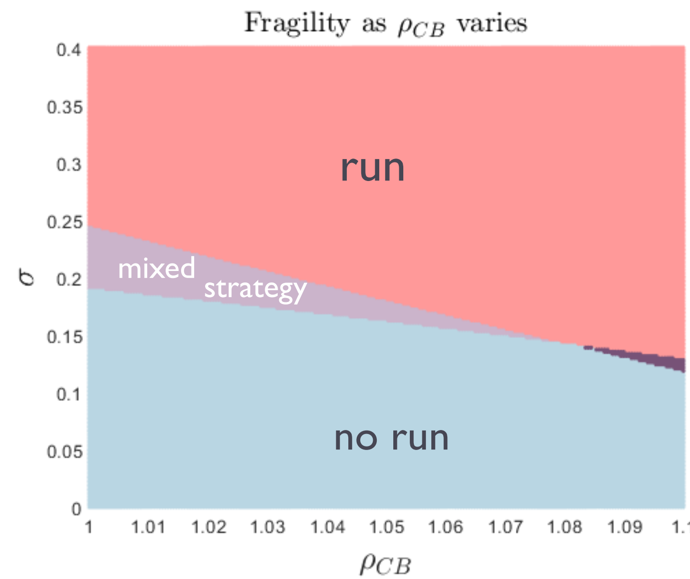
Paying interest

- Now: allow the CB to pay interest on CBDC
  - CB earns a return $R_{CB} > 1$ on goods held from $t = 1$ to $t = 2$
  - chooses an interest rate $\rho_{CB} \in [1, R_{CB}]$ to pay to depositors
    - any seignorage revenue is used for public good/bailouts
- Represents a range of design choices that affect how useful CBDC is to agents
  - methods of access, transaction fees, etc.
- Policy tradeoff arises
  - higher ρ_{CB} encourages agents to use this better technology (good)
  - but implies that runs on weak banks will be detected more slowly
  - and may increase equilibrium fragility

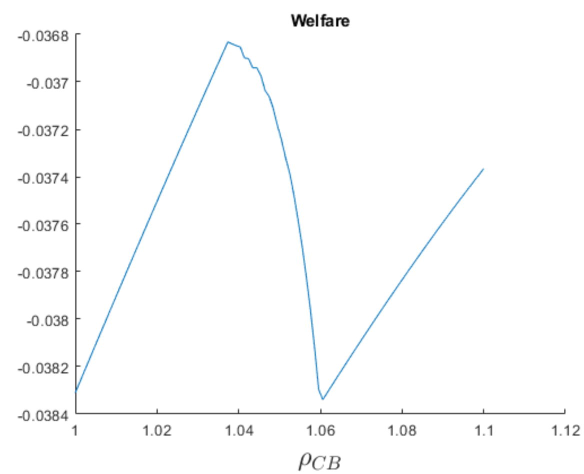
Example

- Higher ρ_{CB} increases fragility
  - non-movers find withdrawing more attractive
  - and higher use in normal times increases θ

    → slower policy response to a run



- Optimal policy balances these concerns
  - in some cases: set ρ_{CB} as high as possible without inducing a run
  - are there any general policy results?



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Conclusion

- Widely understood that CBDC can change withdrawal incentives
- We emphasize: it also changes regulators' information
  - can lead to a quicker policy response to a crisis
  - that quicker response that decrease the incentive to run
- Policy implications:
  - CBDC design should generate detailed information
    - account rather than token based?
  - Might not want heavy CBDC using in normal times
    - because it makes runs more difficult to detect