Money Creation in Decentralized Finance: A Dynamic Model of Stablecoins and Crypto Shadow Banking

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Cryptocurrencies and Decentralized Finance (DeFi)

- 2008: Bitcoin heralded new era of digital payments

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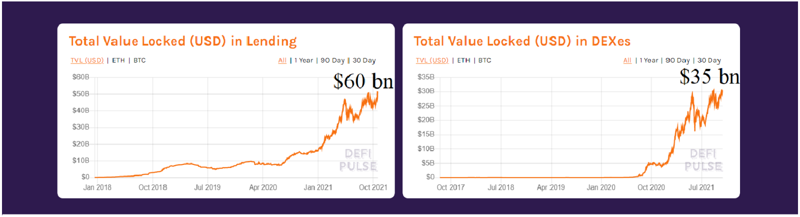
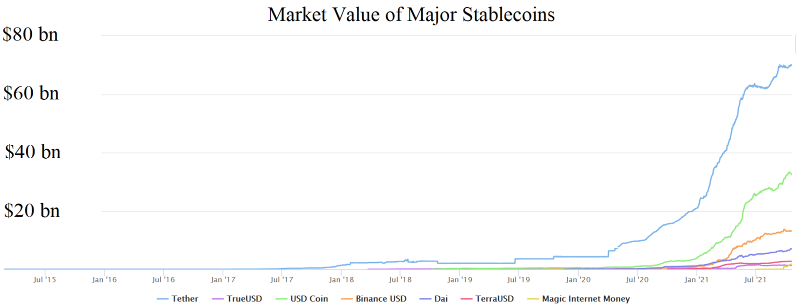
- Most recent phenomenon: Decentralized Finance (DeFi)
  - Blockchain-based alternatives to banking, brokerage, and exchanges
  - E.g: Collateralized Borrowing, Decentralized Exchange, P2P Lending

$\Longrightarrow$ Demand for blockchain-based safe assets (= Stablecoins)

  - Many DeFi activities require stable blockchain-based asset
  - Portfolio rebalancing
  - Safe asset as a store of value and means of payment

Stablecoins and Decentralized Finance (DeFi)





Stablecoins (Today's Market Cap: $ 180 bn)

- Cryptocurrency pegged to reference unit (e.g., USD)
  - Specialized stablecoin service providers: MakerDAO, Tether, ...
  - Established networks/payment providers: JPM Coin, PayPal

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  - Established networks/payment providers: JPM Coin, PayPal
- Reserve/collateral-based stability mechanisms:
  - Stablecoin backed by risky reserves (e.g., Tether)
  - Open Market Operations (OMO)
- Algorithmic stability mechanisms
  - Typically means less or riskier reserves
  - Example of drastic failure: Iron Finance run

This Paper

- Develop a realistic model to analyze the stability of stablecoins
- Rationalize the strategies in practice and optimal implementation
  - Open market operations, dynamic requirement of users' collateral, transaction fees, price bands, issuances of governance tokens
- Valuation of "governance tokens" behind stablecoins initiatives

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  - Open market operations, dynamic requirement of users' collateral, transaction fees, price bands, issuances of governance tokens
- Valuation of "governance tokens" behind stablecoins initiatives
- Large platforms' stablecoins, transaction data (e.g., PayPal), and privacy requirements
- Implications for regulation of stablecoins

This Paper — Setup

- A dynamic model of stablecoins issued by financially constrained **platform** (i.e., equity issuance is costly)
- Stablecoins offer convenience yield and held by risk-averse users
- To maximize equity value, platform dynamically manages:
  1. Reserve assets
  2. Transaction or usage fees
  3. Stablecoin supply (e.g., via issuing/buying stablecoins)

Results — Instability Trap

Excess reserves $C =$ Reserve assets $-$ Value of outstanding stablecoins

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- When C is large (virtuous cycle):
  1. Low transaction fees and stable price
  2. Price is at peg
  3. High stablecoin demand and revenues $\Longrightarrow C \uparrow \Longrightarrow$ Stability $\uparrow$, ...
- When C is low (vicious cycle):
  1. High fees and volatile price
  2. Price falls below peg
  3. Low stablecoin demand and revenues $\Longrightarrow C \downarrow \Longrightarrow$ Stability $\downarrow$, ...
  4. Possible liquidation (e.g., due to a run)

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$\implies$ **Instability Trap**

Results — Stablecoin Regulation

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- Our model recommends:

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1. Reserve (capital) requirements for issuer are beneficial
2. Volatility Paradox: Restricting riskiness of reserves can reduce stability
3. Privacy requirements improve stability

Model — Token Price

- Continuous time and infinite horizon
- Users $i \in [0, 1]$) with discount rate (=interest rate) $r > 0$
- Token (= stablecoin) price P_t in dollars:

$$\frac{dP_t}{P_t} = \mu_t^P dt + \sigma_t^P dZ_t \qquad (1)$$

- dZ_t: Brownian reserve shock
- Users can trade tokens at price P_t
- Token supply S_t:
  - $dS_t > 0$: Platform issues (mints) tokens
  - $dS_t < 0$: Platform buys back (burns) tokens

Model — Stablecoin Demand and User Problem

- $u_{i,t}$: Dollar value of user i's token holdings
- User i's instantaneous payoff from holding $u_{i,t}$ dollars in tokens is

$$dR_{i,t} \equiv \underbrace{\frac{1}{\beta} u_{i,t}^{\xi} A^{1-\xi} dt}_{\text{Convenience yield}} + u_{i,t} \left(\underbrace{\frac{dP_t}{P_t}}_{\substack{\text{Token}\\\text{returns}}} - \underbrace{rdt}_{\substack{\text{Opportunity}\\\text{cost}}} - \underbrace{f_t dt}_{\text{Fee}} - \underbrace{\eta |\sigma_t^P| dt}_{\substack{\text{Stability}\\\text{Preference}}} \right) \tag{2}$$

- Preference for token price stability ($\eta > 0$)
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- Preference for token price stability ($\eta > 0$)
- Platform sets fees f_t
- Stablecoin demand ("transaction volume"):

$$N_t = \frac{A}{\left(r + f_t - \mu_t^P + \eta |\sigma_t^P|\right)^{\frac{1}{1-\xi}}} \quad \wedge \quad \overline{N}, \tag{3}$$

Model — The Platform's Problem

- Platform reserves evolve according to

$$dM_t = \underbrace{rM_t dt}_{\text{Interest earnings}} + \underbrace{(P_t + dP_t)dS_t}_{\text{Issuance proceeds}} + \underbrace{N_t f_t dt}_{\text{Fee revenues}} + \underbrace{N_t \sigma dZ_t}_{\text{Shock}} - \underbrace{dDiv_t}_{\text{Dividend}} . \quad (4)$$

  - $(P_t + dP_t)dS_t$: Proceeds from token issuance over $[t, t + dt)$
  - dZ_t: Brownian reserve shock
  - Dividend payouts: $dDiv_t \geq 0$

- Platform maximizes

$$V_0 \equiv \max_{\{f_t, dS_t, dDiv_t\}} \mathbb{E}\left[\int_0^\infty e^{-\rho t} dDiv_t\right] \quad \text{subject to} \quad dDiv_t \geq 0, \quad (5)$$

with discount rate $\rho > r$

Model Solution and Equilibrium

- Market clearing condition:

$$\underbrace{N_t}_{\text{User token holdings}} = \underbrace{S_t P_t}_{\text{Value of Outstanding Tokens}} \tag{6}$$

- Platform assets: M_t
- Platform liabilities: $S_t P_t$
- Platform excess reserves:

$$C_t = M_t - S_t P_t$$

Runs and Liquidation

- C_t only state variable in Markov Equilibrium
- Over-collateralization: $C_t > 0$
  - Platform can "defend" exchange rate
- Under-collateralization: $C_t < 0$
  - Platform cannot always "defend" exchange rate
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  - Possibility of run causing failure (e.g., Iron Finance)
- Liquidation (e.g., due to run) at $C = \underline{C} = 0$
  - Threshold strategy (Goldstein and Pauzner, 2005): Run when $C \leq \underline{C}$
- $\underline{C} = 0$ is the only possible run threshold:
  - A run at $C = M - SP < 0$ implies loss for users
  - Anticipating run at $\underline{C} < 0$, user would optimally run at $\underline{C} + \varepsilon$

Model Solution — Details

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1. **Stability Region**: $C \in [\tilde{C}, \overline{C}]$ and

$$N(C) = \min\left\{\left(\frac{\xi A^{1-\xi}}{\gamma(C)\sigma^2}\right)^{\frac{1}{2-\xi}}, \overline{N}\right\} \quad \text{and} \quad \sigma^P(C) = 0.$$

2. **Instability Region**: $C \in (0, \tilde{C})$ and

$$N(C) = \underline{N} = A\left(\frac{\xi}{\eta\sigma}\right)^{\frac{1}{1-\xi}} \quad \text{and} \quad \sigma^P(C) = \sigma - \frac{\eta}{\gamma(C)\underline{N}} \in (0, \sigma)$$

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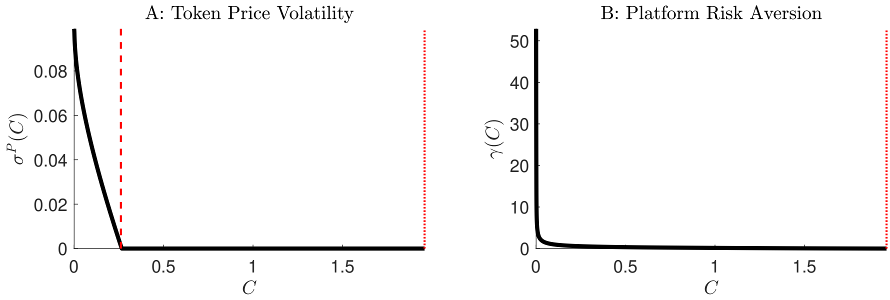
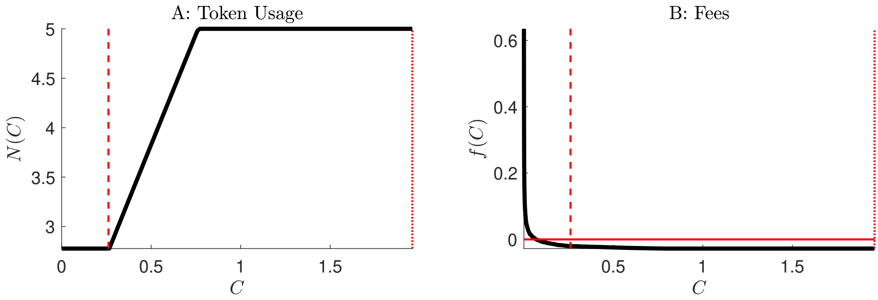
$\Longrightarrow$ As $C \to 0$, $\gamma(C) \to \infty$ and $\sigma^P(C) \to \sigma$

Model Results



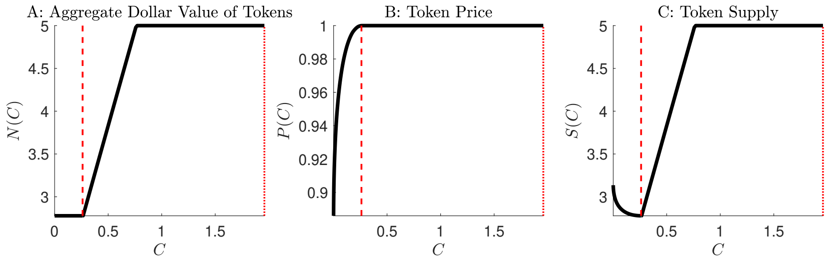
- When C is low: Risk-sharing via debasement ($\sigma^P > 0$)
- When C is high: Stable token price ($\sigma^P = 0$)

Results — Stablecoin Usage



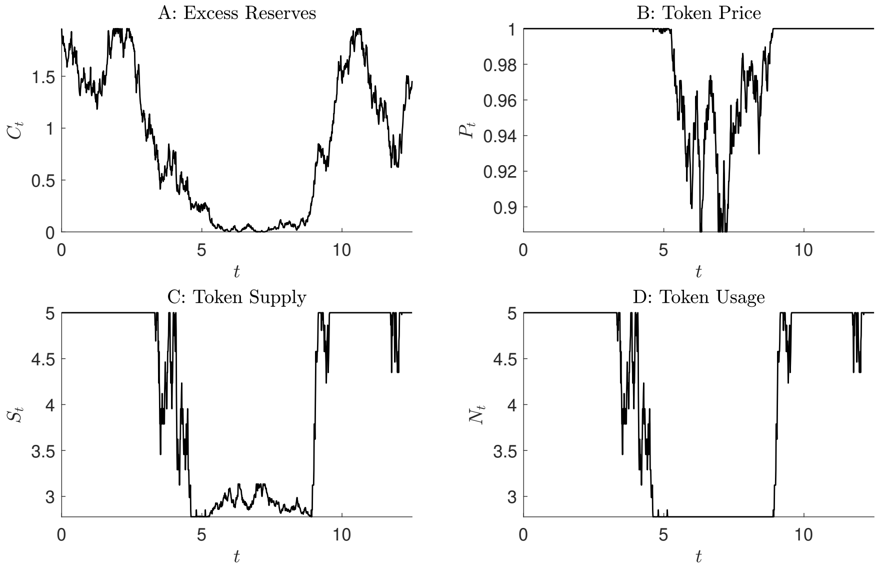
- When C is low: Low stablecoin usage and high transaction fees
- When C is high: High stablecoin usage and **subsidies** ($f < 0$)

Results — Token Price



- Targeted price band and debasement
- Optimal open market operations:
  1. High C: No open market operations
  2. Intermediate C: Buybacks in response to negative shocks ($dZ < 0$)
  3. Low C: Issuance in response to negative shocks ($dZ < 0$)

Model Results — Instability Trap



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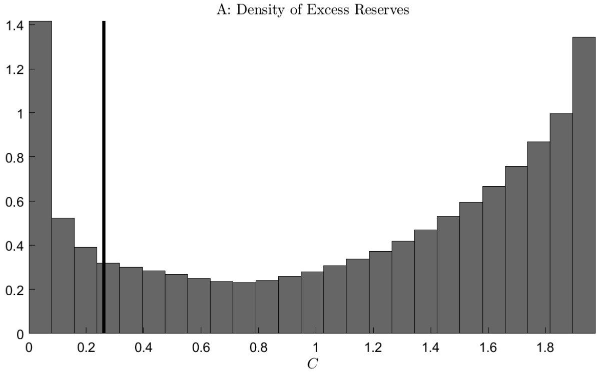
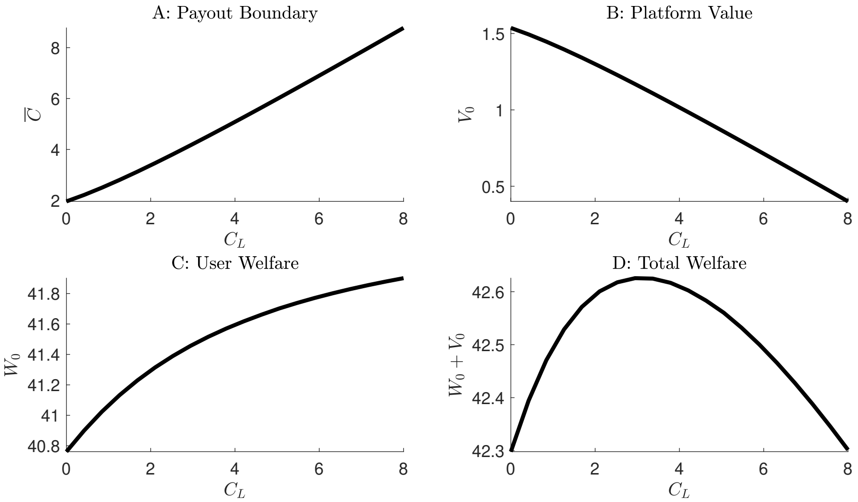


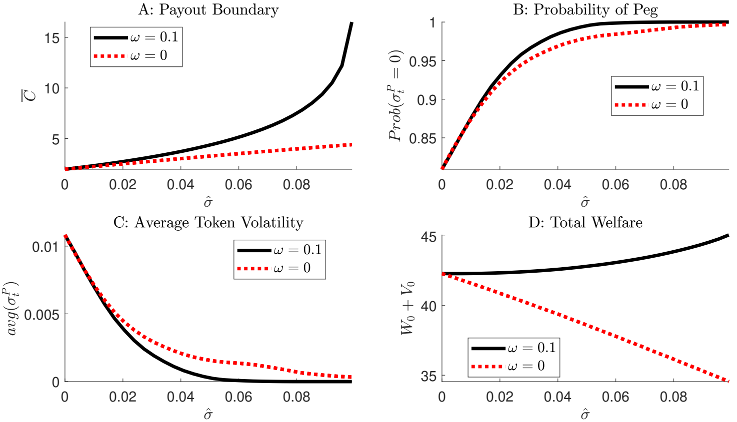
- Distribution of states bi-modal
- Stability persists for most of the time
- **But**: Once volatility rises, recovery back to stability regime is slow

Regulation — Capital Requirements



Capital requirement: C_t must exceed C_L

Regulation — Reserve Risk and Volatility Paradox

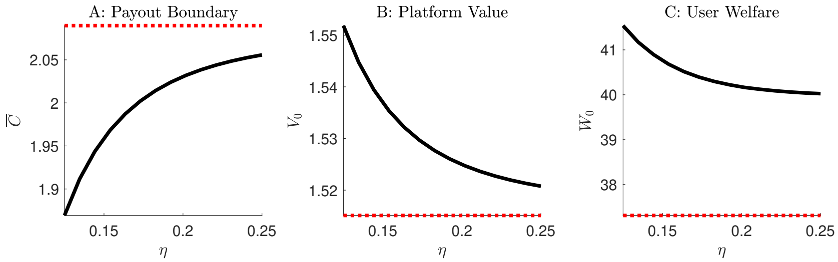


- Reduction in reserve risk, $\hat{\sigma}$, can reduce price stability

$$dM_t = rM_t dt + (P_t + dP_t)dS_t + N_t f_t dt + N_t \sigma dZ_t - dDiv_t + M_t(\hat{\mu} dt + \hat{\sigma} dZ_t)$$

$$\hat{\mu} = \omega\sigma \implies \text{constant "Sharpe Ratio"} \quad \omega = \frac{\hat{\mu}}{\hat{\sigma}}$$

Regulation — Requirement to Price Stability



- Stability regulation (dotted red line): Impose stable price ($\sigma^P = 0$)
- Commitment to price stability reduces price volatility in "good times" but raises risk of run

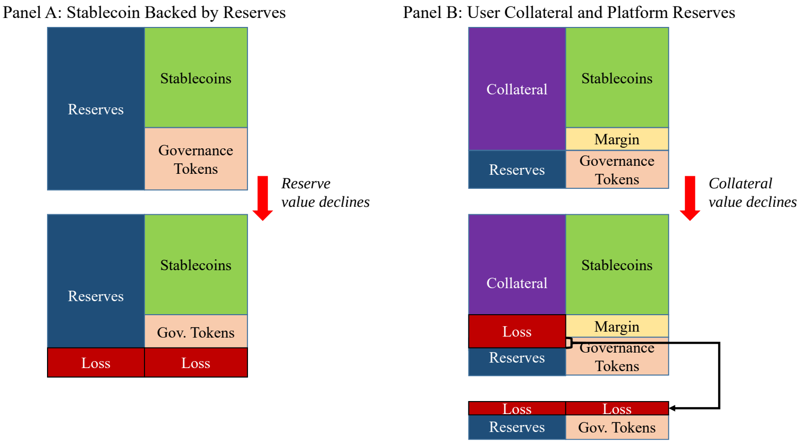
Decentralized Stablecoins and Double Collaterization

1. Stablecoin backed by platform reserves
   - Example: Tether
2. Stablecoin backed by platform reserves and user collateral
   - Users deposit risky crypto collateral in vault
   - User borrow stablecoin against collateral subject to margin requirement
   - Platform reserves as second layer of defense
   - Example: DAI

Optimal Issuance of Governance Tokens (Equity)

- Costly equity issuance, $dDiv_t < 0$
- Three lines of defense:
  1. Reserves
  2. Debasement
  3. Equity issuance at $C = 0$
- At issuance, the jump $\uparrow$ in C implies a jump $\uparrow$ in token demand
  - To rule out predictable price movement (arbitrage), the platform must simultaneously expand stablecoin supply
  - Token price is re-pegged at the pre-issuance level
  - Downward re-pegging after every issuance of governance tokens

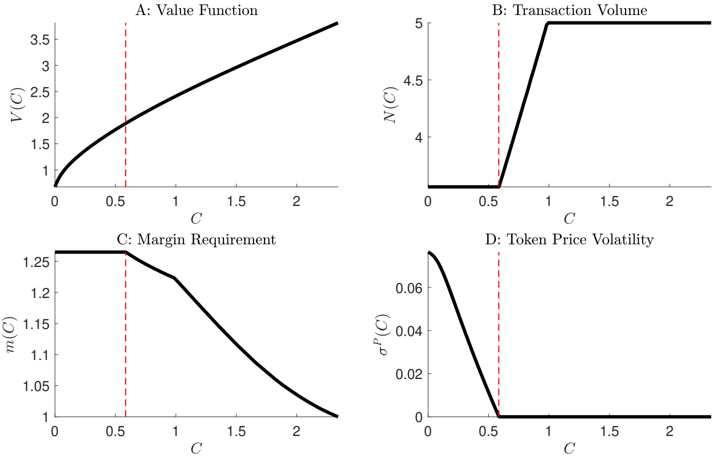
Double Collateralization — Structure



Example: Tether

Example: DAI

Double Collateralization — Results



- For one dollar of stablecoin, $m > 1$ dollars of user collateral required
- **Possibility for Regulation:** Dynamic margin requirements that decrease with platform reserves

Big Tech Stablecoins and Transaction Data

- 2019: Heated debate about Facebook's Libra ("Diem")
  - More recently: PayPal plans to launch stablecoin

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1. Well-established networks have strong network effects
   - Interoperability: Broad usability implies strong network effects
2. Big tech companies possess huge quantities of user data and continue to collect more
   - Privacy concerns
   - Concerns over data monopoly

Transaction Data as Productive Capital

- Transaction data generates incentives for well-established digital platforms (e.g., PayPal) to venture into payment/stablecoins
- Recall: Convenience yield

$$\frac{1}{\beta} N_t^{\alpha} u_{i,t}^{\beta} A_t^{(1-\alpha-\beta)} dt - \eta u_{i,t} |\sigma_t^P| , \tag{7}$$

- We endogenize platform productivity $A_t = A$
- A_t improves as transaction data accumulates:

$$dA_t = \kappa A_t^{1-\xi} N_t^{\xi} dt$$

Transaction Data as Productive Capital

- Model solution scales with "data units" $A_t \implies$ state variable:

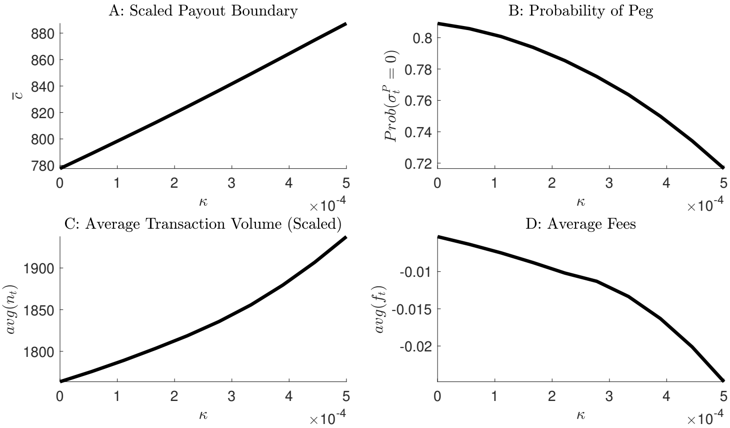
$$c = \frac{C}{A}$$

- Value function $V(C, A) = Av(c)$ and token price $p(c)$.
- Data q analogous to Tobin's q:

$$q(c) = \frac{\partial V(C, A)}{\partial A} = v(c) - v'(c)c \,. \quad (8)$$

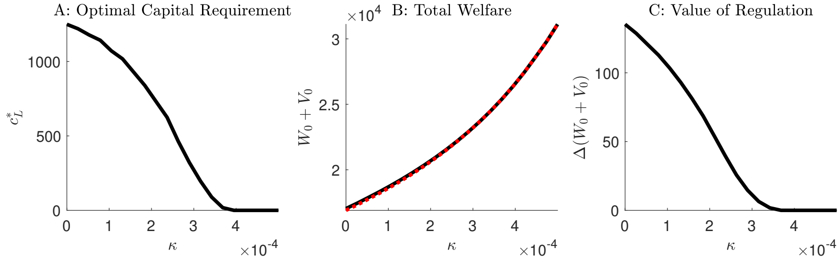
- Data q shapes platform strategy

Data Technology Progress and Platform Operations



- Stablecoins built for collection of transaction data less stable
- **Regulation:** Restricting data accumulation and privacy requirements improves stability

Data Accumulation and Capital Requirements



- Optimal capital requirement for stablecoins accumulating data
- Intuition: Capital requirement induces high fees, reduces transactions, and data collection

Conclusions

- Dynamic model of stablecoins and crypto shadow banking
- Despite over-collateralization: Fragility and instability trap
- Stability mechanisms:
  1. User collateral
  2. Platform reserves
  3. Dynamic fees
  4. Governance token issuance
- Optimal regulation:
  1. Capital requirements
  2. Volatility paradox: Restricting risk of reserves can reduce stability
  3. Privacy requirement improves stability