(In)Stability for the Blockchain: Deleveraging Spirals and Stablecoin Attacks

Ariah Klages-Mundt, Andreea Minca

July 26, 2019
P2P Financial Systems, European Central Bank
Problem: No models to understand stablecoin design
- Complex feedback effects
- No truly stable asset easily accessible

This paper: Develop a first model of noncustodial stablecoins
- Dynamic model with feedback effects, yet remains tractable
- Characterize dynamics and liquidity $\implies$ deleveraging spirals
- Analytically show ‘stable’ and ‘unstable’ regions
- Explains actual stablecoin movements
- Suggests attacks from speculators and miners
- A foundation for future design study
Focus of the talk:

1. Introduction to stablecoins
2. Motivate how stablecoins are distinct from traditional currency literature

Briefly:

3. Our model
4. Analytical results on dynamics & liquidity
5. Simulation results
6. Motivations for follow-up work

So please refer to the paper (on arXiv) for more in-depth discussion!
Cryptocurrencies

- **Blockchain**: a new way for mistrusting agents to cooperate without trusted third parties
- **Ethereum**: generalized scripting functionality, allowing ‘smart contracts’ that execute algorithmically in a verifiable and somewhat trustless manner
- **The promise**: cryptographic security, privacy, incentive alignment, reduced counterparty risk
- **A tradeoff**: their price is highly volatile
  - Price tied to network effects, adoption, further technical progress, regulatory hurdles
Introduction to Stablecoins

Aim of stablecoins
- Protocol that stabilizes market price
- More usable/adoptable cryptocurrency

Types of stablecoins
- **Custodial**: reserve assets held off-chain. E.g., Libra
  - Introduces counterparty risk that cryptocurrencies otherwise solve
- **Noncustodial**: on-chain contracts collateralized in cryptoassets, e.g., MakerDAO’s Dai
  - Operate in public/permissionless blockchain setting, in which any agent can pseudonymously participate. Malicious agents can participate, which can introduce new economic attacks
Stablecoin Volatility

Current stablecoins not robust
- Designs all similar and ad hoc
- Markets can break down during extreme events

NuBits Charts

bitUSD Charts
Noncustodial Contract for Difference

$t = 0$

Stablecoin Holder

1 ETH = $100

Contract

Speculator

1 ETH = $100

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Noncustodial Contract for Difference

$t = 0$

Stablecoin Holder

Contract

2 ETH = $200

Speculator
Noncustodial Contract for Difference

$t = 1$

Stablecoin Holder

Contract

Speculator

2 ETH = $160

Price Oracle

1 ETH = $80

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Noncustodial Contract for Difference

\[ t = 1 \]

Stablecoin Holder

\[ 1.25 \text{ ETH} = \$100 \]

Contract

Speculator

\[ 0.75 \text{ ETH} = \$60 \]
Noncustodial Contract for Difference

$t = 1$

Stablecoin Holder

1.25 ETH = $100

Contract

Speculator

0.75 ETH = $60

Similar to a forward contract except:

- Price is only fixed in fiat terms while payout in units of risky collateral
- In these markets: heavy frictions to convert to fiat
DStablecoins - no set expiration

Variants on contracts for difference:

- Tranche-like risk transfer structure
  - Losses/gains borne by speculators, stablecoin holders hold instrument like senior debt
- Oracle provides information from off-chain markets
- Dynamic deleveraging process balances positions according to protocol rules
  - Important difference from CDOs! Critical to understand deleveraging effects
- Agents can change positions through pre-defined process
  - Settlement times are random and dependent on the protocol and agent decisions

Noncustodial risks

- Risk of market collapse (this paper)
- Oracle/governance manipulation
DStablecoins - no set expiration

Collateral Contract

Speculators
Locks 1 ETH = $100
Creates 50 STBL
DStablecoins - no set expiration

Speculator Balance Sheet

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETH (pledged) $100</td>
<td>Equity $100</td>
</tr>
<tr>
<td>DStablecoin $50</td>
<td>Smart contract $50</td>
</tr>
</tbody>
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Collateral Contract

Speculators
Locks 1 ETH = $100
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DStablecoins - no set expiration

Speculators
Locks 1 ETH = $100
Creates 50 STBL

Collateral Contract

STBL Market
‘Arbitrage’ maintains price target

50 STBL → ~0.5 ETH
DStablecoins - no set expiration

Speculators
Locks 1 ETH = $100
Creates 50 STBL

Collateral Contract

STBL Market

50 STBL → ~0.5 ETH

‘Arbitrage’ maintains price target

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DStablecoins - no set expiration

Speculators
Locks 1 ETH = $100
Creates 50 STBL

Collateral Contract

Can repurchase 50 STBL to unlock ETH

STBL Market

‘Arbitrage’ maintains price target

DStablecoins - no set expiration

Speculators
Locks 1 ETH = $100
Creates 50 STBL

Collateral
Contract

STBL Market

'SArbitrage' maintains
price target

Stablecoin Holders
Buys STBL

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DStablecoins - no set expiration

Speculators
Locks 1 ETH = $100
Creates 50 STBL

Collateral Contract

STBL Market

Price Oracle

If Collateral ↓ < β, partially liquidated on STBL market

Stablecoin Holders
Buys STBL
DStablecoins - no set expiration

Speculators Receive excess collateral

Collateral Contract

Price Oracle

System can be globally settled

Stablecoin Holders Exchange STBL for ETH at last oracle price
Academic Literature

Work on custodial stablecoins [Lipton et al., 2018], [Griffin et al., 2018]

[Chao et al., 2017] presents a tweaked DStablecoin design that restricts leverage to pre-defined bounds using automated resets

- Stablecoin holders are liquidated from positions during these resets
- Maintaining stablecoin position involves re-buying in at possibly inflated prices at resets

They develop a PDE method to value their proposed stablecoin

- Stability results rely on assumption that payouts are exogenously stable
- Payouts actually made in ETH, not efficiently convertible
- Ignores endogenous price effects from re-buying into stablecoins

Of the many designs, it is unclear which deleveraging method would lead to a system that survives longer
Can we use the existing literature on currency peg models? Unfortunately, no

In traditional currency peg models, e.g., [Morris & Shin, 1998]:
- Gov. issuer mechanically committed to stability, not a player in the game

In contrast, in stablecoin systems:
- Issuer role is replaced by decentralized speculators, who issue and withdraw stablecoins to optimize profits. **They are not committed to maintaining a peg.**
- Best we can hope: protocol well-designed and peg maintained whp through incentives
- Agents’ decisions affect price of the ‘stable’ asset and future incentives
Model

Simple model, but versatile, inspired by [Aymanns & Farmer, 2015]

- Dynamic model complex enough to take into account feedback effects
- Agents solve optimization problems consistent with a wide array of documented market behaviors and well-defined financial objectives
- Tractable and modular foundation to build on (can add more features later)
- Provides core of more general simulation environment

Assumption: In this first model, there is no movement out of the blockchain system to fiat

- This actually applies to some agents
- In reality, there is going to be some movement, but it is by nature limited and costly

If relaxed (working on this), the effects in this model might be damped, but probably still exist (and indeed we see evidence in data)
Model

Agents

- **Stablecoin holder** chooses portfolio weights to seek stability
  - Leave generic where possible; assume specific form for some results
- **Speculator** chooses leverage in speculative position behind stablecoin

Assets

- **Ether**: risky asset with exogenous price $p_t^E$
- **DStablecoin** with endogenous price $p_t^D$

**DStablecoin market** clears by setting demand = supply in USD (blackbox stable) terms

- Similar to clearing in Uniswap DEX
- Related to quantity theory of money
Model Outline

$t = 0$: agents have endowment, prior beliefs

In each period $t$:

1. New Ether price revealed
2. Update Ether expectations
3. Stablecoin holder decides portfolio weights
4. Speculator, seeing demand, decides leverage
5. DStablecoin market is cleared

Rationale

- Sophisticated agents able to front-run DEXs [Daian et al., 2019]
- Evidence demand may not decrease tremendously with price (SBD)
Model: Speculator

Choose $\Delta_t$ to maximize next period expected returns s.t. constraints

**Liquidation constraint (protocol):** $\lambda_t := \frac{\beta \cdot \text{liabilities}}{\text{assets}} \leq 1$

**Risk constraint (self-imposed):** $\ln \lambda_t = \mu_t - \alpha \sigma^b_t$

VaR example: $\lambda_t \leq \exp(\mu_t - \alpha \sigma_t)$. Consistent with a margin of safety

| $\Delta_t$ | Change to DStablecoin supply |
| $\mu_t$   | Expected Ether return        |
| $\sigma^2_t$ | Expected Ether variance |
| $\beta$  | Collateral threshold        |
| $\alpha$ | Inverse measure of riskiness |
| $b$      | Cyclicality parameter        |
Analytical Results about Dynamics & Liquidity

**Proposition**

There is a bound to the speculator’s ability to maintain the market

\[
(A \text{ lower bound on collateral}) - (\text{capital available to enter market})
\]

must be sufficiently high

**Proposition**

Speculators face limits to speed of leverage reduction, even w/ new capital.

*Deleveraging spiral:* speculators repurchase DStablecoins at increasing prices as liquidity dries up in the market.
‘Stable’ and ‘Unstable’ Regions

Proposition

Assume
- \( D_{\text{stablecoin demand constant}} \)
- \( \text{Expected Ether return constant} \)

Then if the leverage constraint remains inactive, the system converges exponentially to a steady state with stable price and zero variance.

Observation: Steady state may have price < $1.

Conjecture: Outside of ‘stable’ domain, volatility bounded > 0 whp.
- Once outside, more likely to remain outside due to feedback loop
- ‘Kink’ in probability distribution at boundary
These Effects Explain Data from Dai Market

(a) Dai leverage reduction feedback

(b) Dai normally trades below target

Source: Kenny Rowe, Tweet
Simulation: ‘Stable’ and ‘Unstable’ Regions

Figure: Constant expected ETH return.
Simulation: Different Speculator Behaviors

![Heatmaps of DStablecoin volatility for different speculator risk management methods.](image)

(a) $t\text{-distr}(\text{df} = 3, \mu = 0)$  
(b) $t\text{-distr}(\text{df} = 3, \mu = r_0)$  
(c) normal($\mu = 0$)

Figure: Heatmaps of DStablecoin volatility for different speculator risk management methods.
Simulation: DStablecoin Failures

DStablecoin failure/stopping time when

1. Speculator’s liquidation constraint unachievable, or
2. DStablecoin price remains below $0.5 USD

(a) t-distr (df = 3, µ = 0)

(b) normal (µ = 0)
Discussion: A Profitable Economic Attack

Attacking a stablecoin is different than a traditional currency attack

- Focus not on breaking willingness of central bank to maintain peg
- Instead, involves manipulating interaction of speculators

The attack: Attacking speculator manipulates the market to trigger and profit from spiraling liquidations

This can cause perverse incentives for blockchain miners

- Attack rewards can be > mining rewards
- Miners can censor or reorder transactions to extract value
- Incentive to re-write blockchain to trigger liquidations in present
Discussion: Design Insights

**Design focus:** widen ‘stable’ region, limit severity of ‘unstable’ region

**Design considerations in Dai**

- Fees amplify deleveraging spirals. Can instead make counter-cyclic fees
- Good fee mechanism could reduce speculator herd behavior
- Better ‘last resort’ use of MKR to quell deleveraging spirals
Summary

This paper: Develop a first model of noncustodial stablecoins

1 Dynamic model with feedback effects, yet remains tractable
2 Analytical results
   ▶ Characterize dynamics, liquidity, deleveraging spirals
   ▶ Show ‘stable’ and ‘unstable’ regions
   ▶ Explains actual stablecoin movements
3 Simulation results
   1 Support for ‘stable’ vs. ‘unstable’ regions
   2 Speculator behavior affects volatility
   3 Failure dominated by collateral returns
4 Discussion
   1 Suggests attacks from speculators and miners
   2 A foundation for future design study