Optimal Design of Tokenized Markets*

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* The views expressed herein are those of the authors and do not necessarily reflect the views of the Federal Reserve Bank of New York or the Federal Reserve System.

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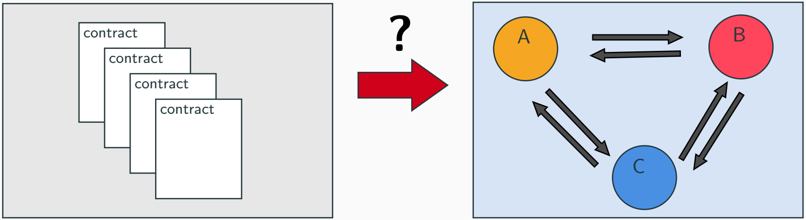
Trade and Settlement

Agree to Trade

Settlement



Age-old problem of **Limited Commitment**

- Third-party mediation (intermediaries and platform)
- Margin requirements and other uses of collateral
- Long-term relationships and reputation

Settlement Fails in Modern Financial Markets

Settlement fails still occur

- At peak of GFC, $400 billion *per day* in settlement fails in Treasury market
- A fails charge introduced to reduce this
- Settlement fails still occur!

Settlement Risk in Legacy System

Persistence of **Settlement Fails**

- Institutional and technological feature of (current) **legacy** system
- Individual traders must submit instructions corresponding to contractual obligations arising from trading activity

$\therefore$ Incentives break down $\rightarrow$ Settlement breaks down

Resolving Settlement Uncertainty in Token System

- DLT-based settlement system as technological solution, **token system**
- Security tokenization on DLT
- Programmability of assets
  - Progammability enables traders to commit to settlement
  - "Collapse" between trade and settlement (often called "atomic settlement")

$\therefore$ **Eradicate** potential for fails

Today's Talk

- Market where traders must enter inter-dependent trades to achieve optimal allocation of a long-lived asset
- **Limited Commitment** – traders tempted to break contracts after trade
- Compare equilibrium trade and settlement under Legacy vs. Token System

Main Question

Does a token system strictly improve upon legacy system?

- **Not** true in a setting with endogenous trading and intermediation
- Eliminates settlement risk, but exacerbates an information problem
- Token system implicitly requires traders to reveal more info about position; provides commitment with “strings attached”

Key Intuition

Suppose A and B agree to trade in token system

- A and B jointly write program that governs (future) ownership of asset
- **Basic requirement:** trader must have ownership rights to asset at the time settlement must take place
- Knowing trader owns asset $\rightarrow$ Info that does not arise in legacy system

This information aggravates **hold-up** problem, can breakdown trade altogether

Literature

- **Blockchain in Financial Markets.** Townsend (2019); Chiu and Koeppl (2017); Chiu and Koeppl (2019); Cong and He (2019); Abadi and Brunnermeier (2018); Easley, O'Hara, and Basu (2019);
- **Settlement and Trading.** Martin and McAndrews (2008); Koeppl, Monnet, and Temzelides (2012); Khapko and Zoican (2020); Lee, Martin, and Townsend (2021); Garratt, Lee, Martin, and Townsend (2021)

Model

Model

- Three risk-neutral traders $i = \{A, B, C\}$
- Single long-lived asset, initially owned by A
- Traders have period-dependent payoffs for holding asset $\{L, M, H\}$

Model Timeline

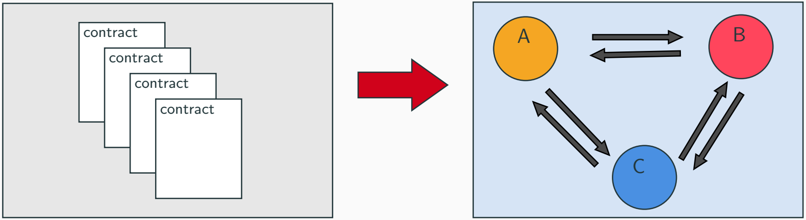
Two stages

- **Trading stage.** $t = m1, m2$
  Two sequential bilateral meetings between traders

- **Settlement stage.** $t = 1, 2, 3$
  Actual transfer of asset between traders

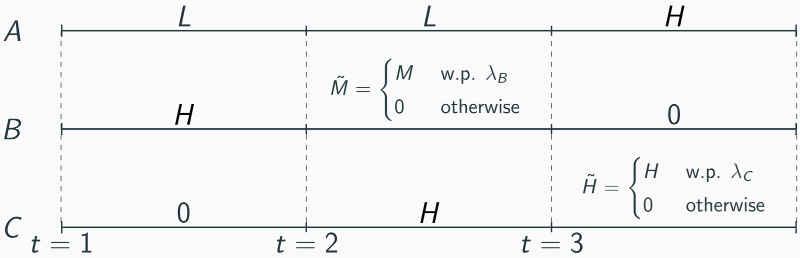
Trading Stage
$t = m1, m2$

Settlement Stage
$t = 1, 2, 3$



Traders' Payoffs

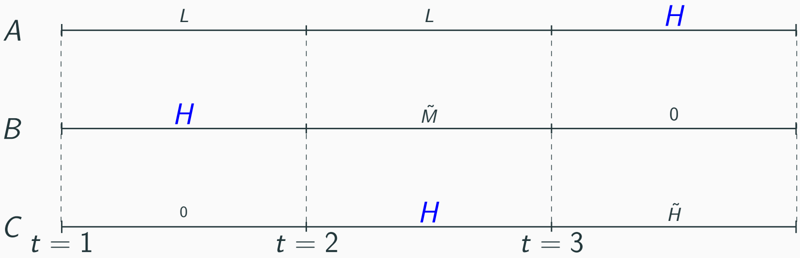
- Payoff from holding asset differ
- $H > M > L > 0$
- B and C privately learn $\tilde{M}$ and $\tilde{H}$ after trading stage



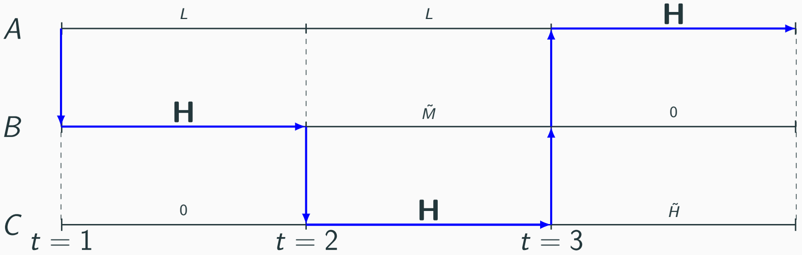
Efficient allocation

- Maximum payoff from holding asset:

$$A \text{ in } t = 3$$
$$B \text{ in } t = 1$$
$$C \text{ in } t = 2$$



Efficient trades



Efficient trades:

- A lends asset to B for $t = 1$ and $t = 2$
- B lends asset to C for $t = 2$

Trading Stage $t = m1, m2$

- Two meetings sequentially occur at $t = m1$ and $t = m2$

[A meets with B] [B meets with C]

- Order of meetings random, **known only to** B
  - A and C **never** meet
  - B acts as intermediary between A and C

Negotiation

- In a meeting, traders negotiate securities lending contract for settlement at $t = 1, 2, 3$

A lends asset to B in period $t = 1$ *at price* P

- Up to two trades successfully occur in trading stage

Settlement Stage $t = 1, 2, 3$

- Trades specify "transfer" of asset between A, B, and C over $t = 1, 2, 3$

Asset is lent to B from A in period $t = 1$ at price P

  - A transfers asset to B at the beginning of $t = 1$
  - B transfers asset to A at the end of $t = 1$

- In the settlement stage, settlement actions take place

Settlement Technologies

Study trade and settlement under two settlement technologies

- Legacy system
- Token system

Settlement in Legacy System

- Asset moves *only if* owner initiates transfer
- Trader that fails to settle suffers cost Δ
  - Reputational cost or penalty
  - Focus on intermediate values of $\Delta \in (2L, \frac{1}{2}H)$
    - Δ not high enough to prevent all fails
    - Δ not too low such that fails happen all the time

Settlement in Token System

Bargaining and programming occurs simultaneously, as if “immediately settled”

- Asset “programmed” during meetings in trading stage
- Transfer instructions are self-executing
  - Assets are transferred without any further trader action
  - No trader able to prevent programmed transfer from occurring
- **Requires** trader to be current holder of asset at the time contract specifies it to be transferred

Implication: Both parties know that conditions of the trade are satisfied, e.g. A must own the asset to lend the asset, **and B knows**

Legacy System

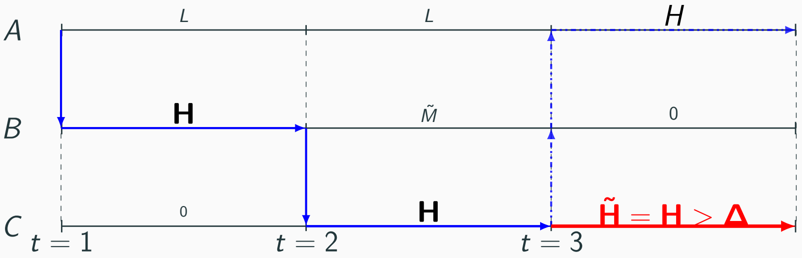
Two Frictions

- Limited Commitment Problem
- Hold-up Problem

- C's value the asset at $t = 3$ is $\tilde{H}$

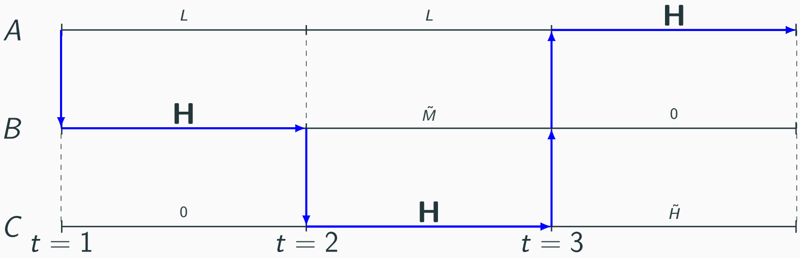
$$\tilde{H} = \begin{cases} H & \text{with prob. } \lambda_C \\ 0 & \text{otherwise} \end{cases}$$

- C privately learns $\tilde{H}$ *after* trade
- $H > \Delta \rightarrow C$ doesn't wants to gives asset back to B if $\tilde{H} = H$



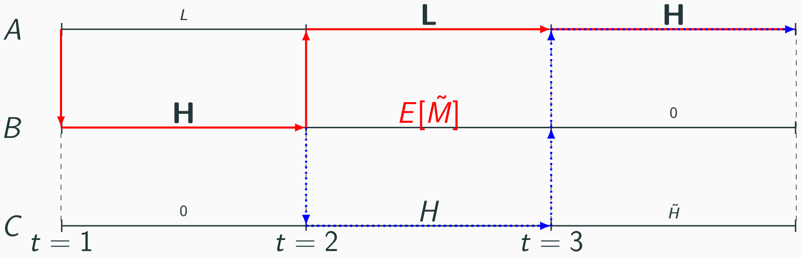
Hold-up Problem

- B is the only trader who is matched with both lender A, borrower C
- For C to acquire ownership of the asset in $t = 2$, B must successfully negotiate two sides of intermediation chain
- Trades occur asynchronously $\rightarrow$ B "makes markets" by completing one side of the chain in advance of other, anticipating future trade



Hold-up Problem

- B needs to pay a price that may be in excess of her own valuation in order to acquire the asset on behalf of C
- Potential for C to make "low-ball" offer to B, who might have already acquired the asset from A



Trader C's Temptation

- Both A and B know C might not send the asset back
- Reservation price at which B *always* intermediates on behalf of C:

$$\underbrace{L}_{A\text{'s } t=2 \text{ value}} + \underbrace{\color{red}{\lambda_C} H}_{\text{settlement risk premium}} + \underbrace{\color{red}{\lambda_C} \Delta}_{\text{daisy chain premium}}$$

  - **Settlement risk premium.** A fails to receive asset back with prob. λ_C
  - **Daisy chain premium.** B fails on A if C fails on B

- As λ_C $\color{red}{\uparrow}$, Price to borrow asset for $t = 2$ $\color{red}{\uparrow}$

Trader C's Temptation

What if B already traded with A?

- If B already traded with A, trade is *sunk*
- C simply needs to offer $E[\tilde{M}] + \lambda_C \Delta \ll L + \lambda_C H + \lambda_C \Delta$

BUT

1. C does not know if B met with A prior
2. C does not know if B has obtained the asset from A

Equilibrium Trade in Legacy System

Result.

- If C's limited commitment problem is not too severe ($\lambda_C < \bar{\lambda}$), optimal trades are achieved with certainty
- If severe ($\lambda_C > \bar{\lambda}$), C obtains the asset with probability $\frac{1+\mu^*}{2} < 1$, where $\mu^* \in [0, 1)$ decreases in λ_C

Strong Feature of Legacy System

- Complete decoupling between trade and settlement
  - Traders can enter any contract without explicit proof that they can fulfill it
  - B can hide from C whether she has met with A before
- Interplay between the trading system and the settlement system
  - Trading occurs asynchronously, no transparency over the history of trades
  - Taken in isolation, opaque trading and incentive-dependent settlement appear sub-optimal from a market design standpoint
- In fact, decoupling is fundamental to facilitating the efficient transfer of ownership between multiple traders

Token System

Settlement in Token System

Revisit the limited commitment problem

- C may want to hold onto the asset at $t = 3$
- If B and C agree for C to borrow asset for $t = 2$, asset programmed to transfer back to B automatically
- Settlement occurs irrespective of realization of $\tilde{H}$

Two New Issues

- Hold-Up Problem Worsens
- Trade Asynchronicity

Hold-Up Problem Worsens

Issue 1. Hold-Up

- When B meets C, B de-facto reveals to C whether she has ownership of asset at $t = 2$
- Whenever B obtains the asset from A on behalf of C, C knows!
- C's temptation to low-ball remain, but now C has additional information
- C's **optimal** offer strategy:

$$B\text{'s private value of } t = 2 \text{ ownership, } E[\tilde{M}]$$

Order of Trades Matter in Token System

Issue 2. Trade Asynchronicity

- Trade asynchronicity was desirable in Legacy system to reduce the hold-up problem
- In Token system, B needs to meet with A *before* C, otherwise B cannot enter trade (and program asset) with C
- With probability $\frac{1}{2}$, when B matches with C first, **no trade**

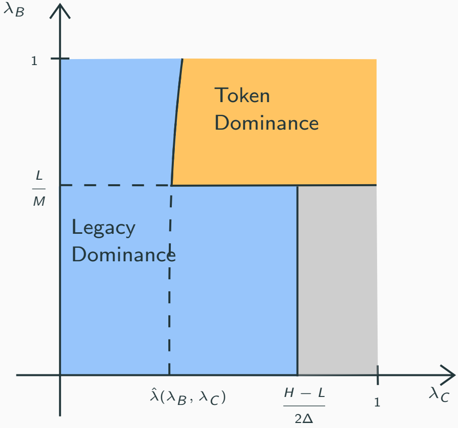
Trade Breaks Down in Token System

Result.

- Suppose the hold-up problem binds ($E[\tilde{M}] < L$), then C never gets the asset
- Otherwise, C obtains $t = 2$ ownership of asset with probability $\frac{1}{2}$

Relative Efficiency

Result. Token system improves efficiency over legacy system only if hold-up problem does not bind ($E[\tilde{M}] \geq L$), and limited commitment problem is sufficiently high



Conclusion

- Tokenization has clear advantages, eliminates limited commitment problem
- Collapsing trade and settlement, however, comes at a cost
- Some features are not amenable to certain market structures
  - Tokenization affects equilibrium trade in an decentralized market
  - May not work well in markets that depend on intermediaries to facilitate trades
- Efficiency of settlement protocol intricately tied to the whether it is paired with a harmonious trading mechanism