The Evolution of DeFi: Achievements, Challenges, and the Road Ahead

Agostino Capponi

Columbia University

Director of the Center for Digital Finance and Technologies

WBS Gillmore Centre Academic Conference: DeFi & Digital Currencies

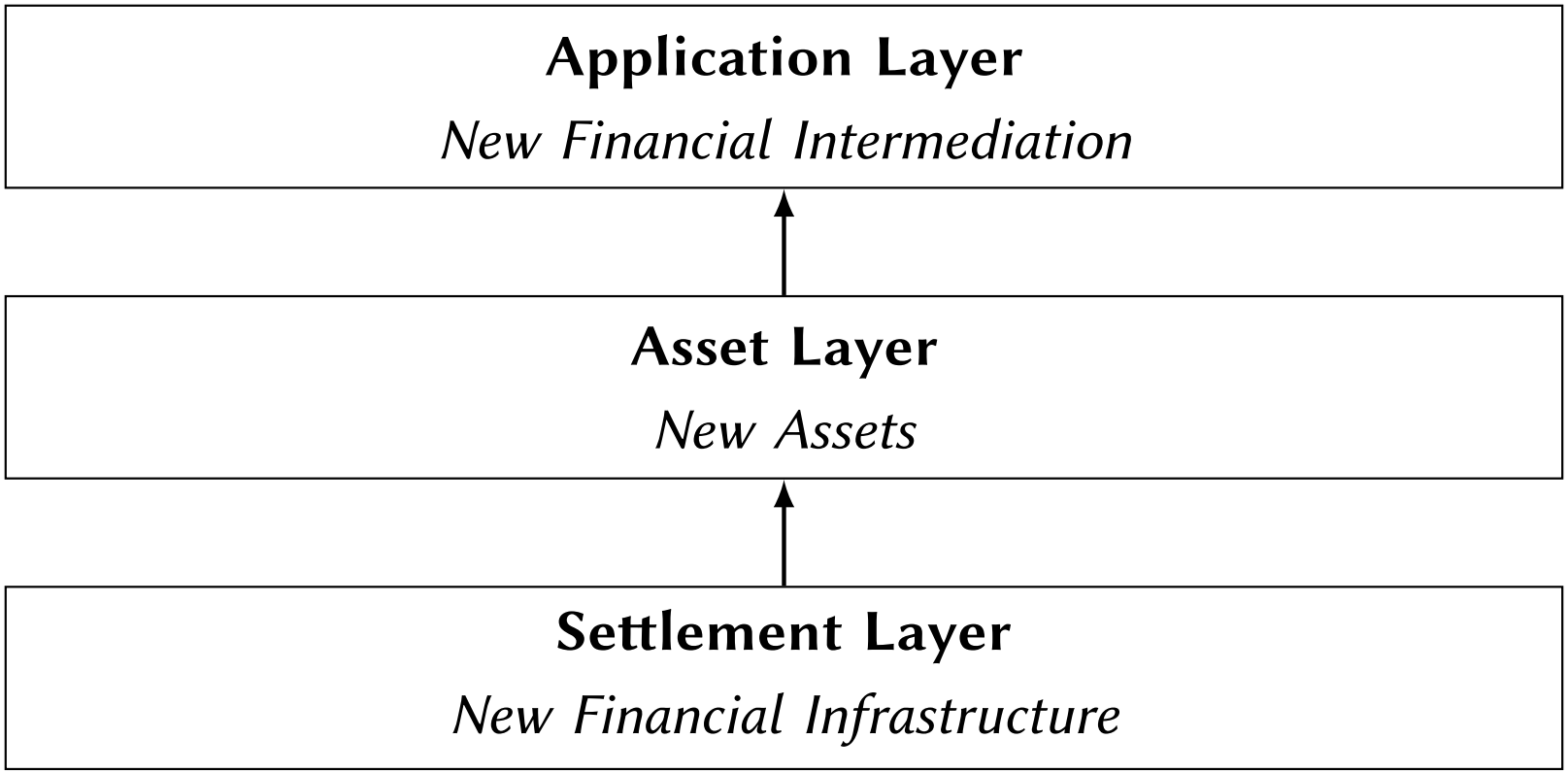
The Shard

London

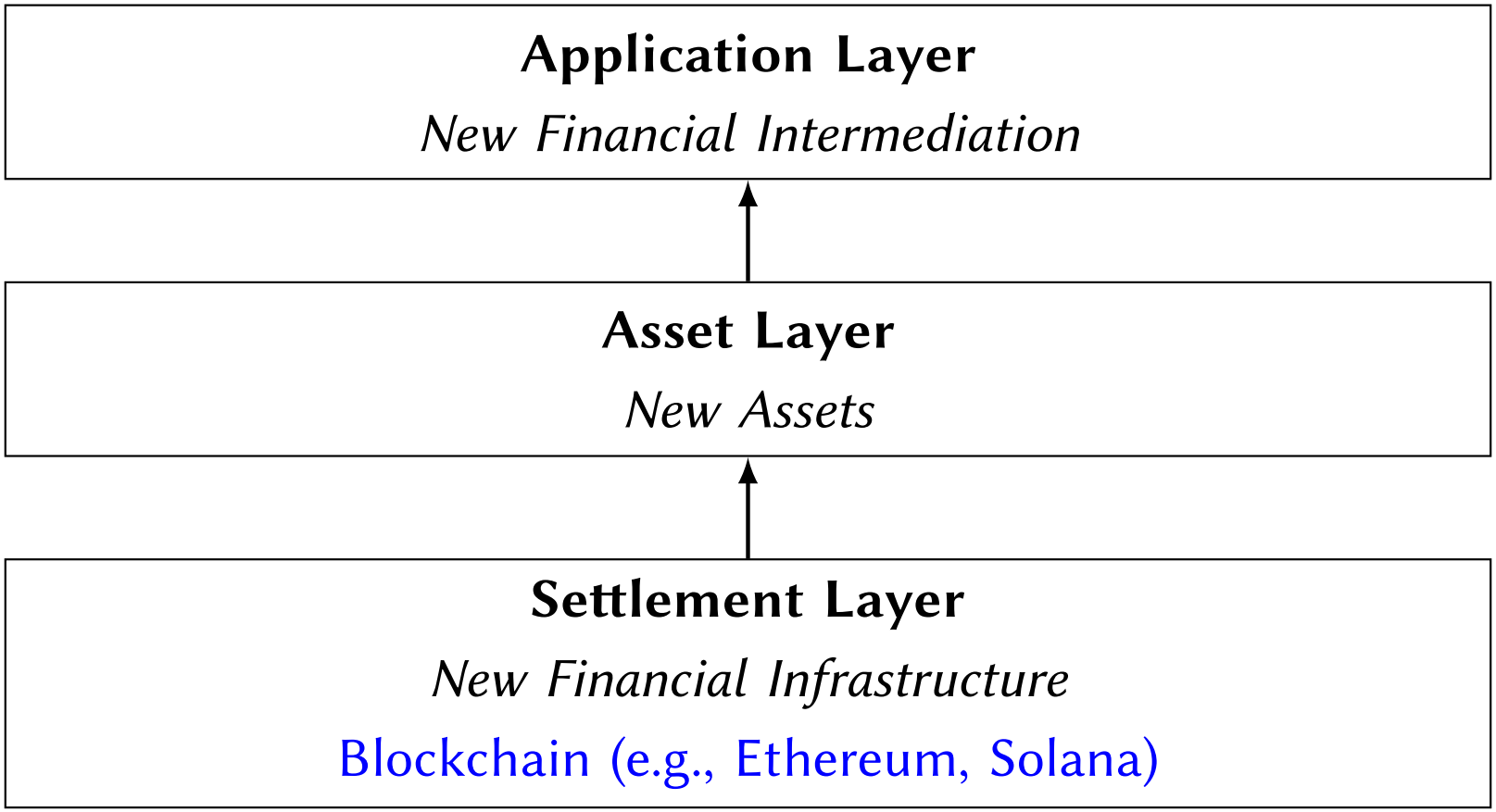
Outline

Outline

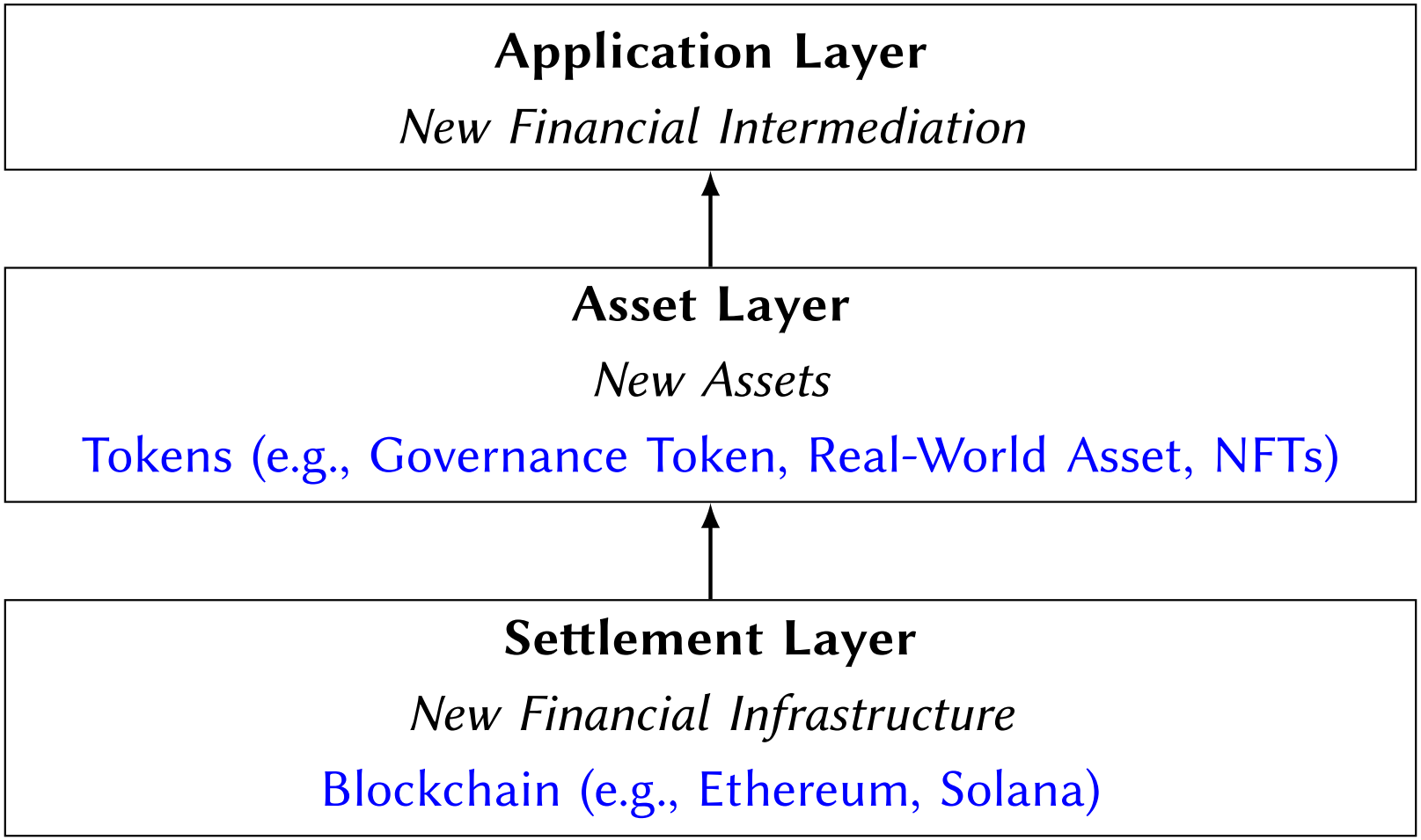
DeFi: New Financial Infrastructure, Assets, and Intermediation



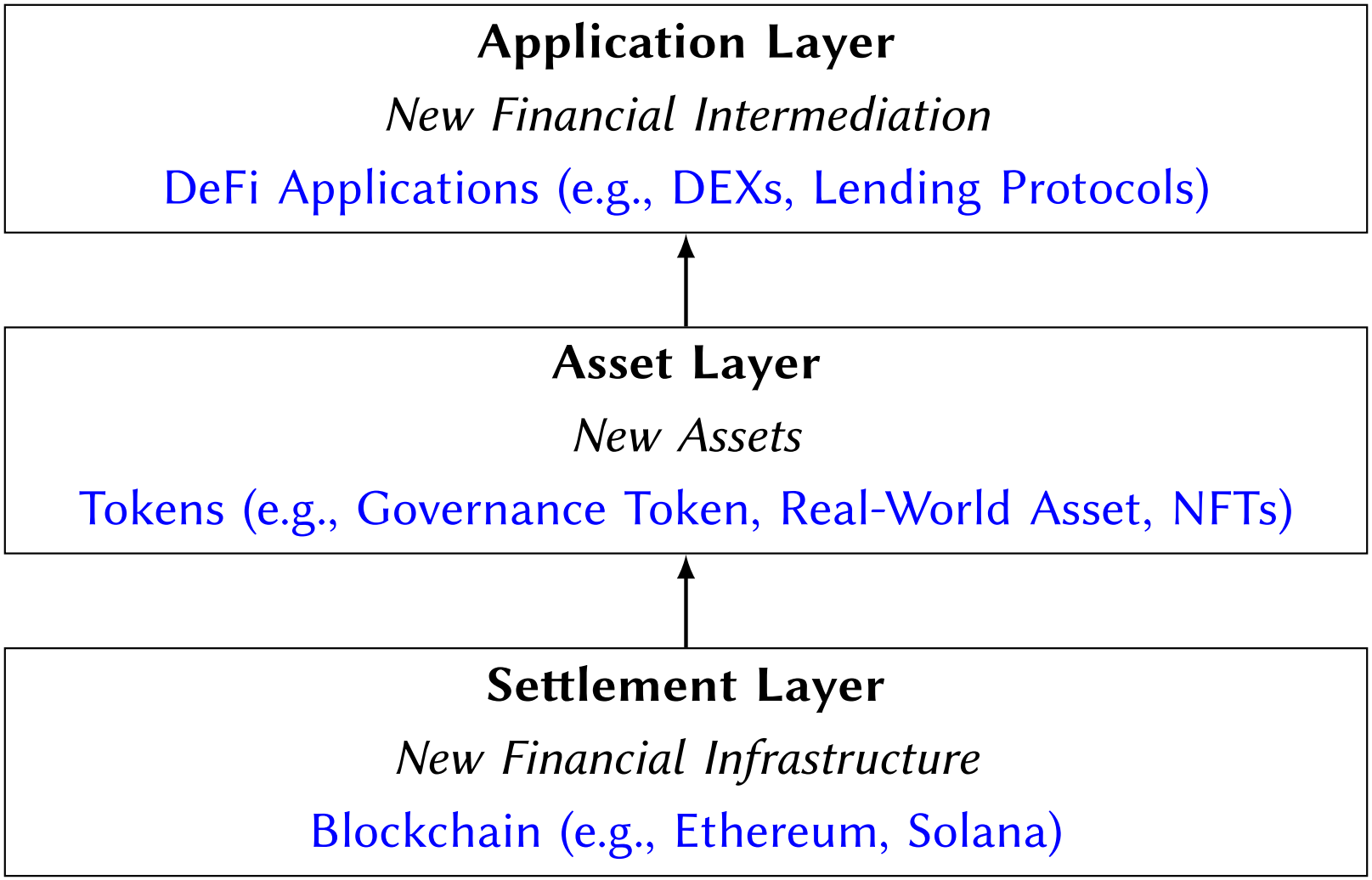
DeFi: New Financial Infrastructure, Assets, and Intermediation



DeFi: New Financial Infrastructure, Assets, and Intermediation



DeFi: New Financial Infrastructure, Assets, and Intermediation



Outline

DeFi's Three Layers: Promises

1. **New Infrastructure**
   - **Blockchain:**
     - Enables quick payment, efficient settlement, and transparent book keeping
   - **Smart Contracts:**
     - Facilitate **credible commitment** without centralized enforcement (John, Kogan, & Saleh (2023))
     - Automated execution of financial agreements when conditions are met

DeFi's Three Layers: Promises

2. New Assets: Tokens

- **Alignment of Incentives:**
  - Enable innovative fundraising (e.g., ICOs) and governance models. (Cong, Li, & Wang (2022); Goldstein, Gupta, & Sverchkov (2022); Sockin & Xiong (2022))
- **Enhanced Market Completeness:**
  - Tokenize previously illiquid assets (e.g., real estate, art)
  - Facilitate efficient risk-sharing and capital allocation
  - Fractionalization of loans, bonds, deposits.

DeFi's Three Layers: Promises

3. New Financial Intermediation: DeFi Applications

- **Innovative Platforms and Trusted Intermediation**
  - Offer lower-costs and trust-worthy financial intermediation through smart contracts, and without relying on centralized entities
  - DeFi reduces friction and operational burdens through automation
- **Solving Traditional Finance Problems**
  - Addresses issues of centralized control, limited access, inefficiency, and opacity (Harvey et al. (2021))
  - Provides access to financial services in underdeveloped regions lacking traditional infrastructure
- **Interoperability**
  - DeFi applications are highly interoperable, allowing for integration of financial services

Today's Roadmap: DeFi's Evolution, Challenges, and Potential

1. **DeFi's Journey Since the 'DeFi Summer'**
   - Major achievements
2. **Economics of DeFi Stack**
   - Economic incentives and disincentives
   - Technical constraints impacting economic designs
   - What is improved? What persistent challenges require attention?
3. **Barriers to Growth: What is Slowing DeFi's Progress?**
   - Worsening incentive structures for innovations
   - Critical areas of attention for financial economists
4. **Opportunities for Expansion in DeFi**
   - Microfinance, real-world assets tokenization

Outline

Protocols Innovation

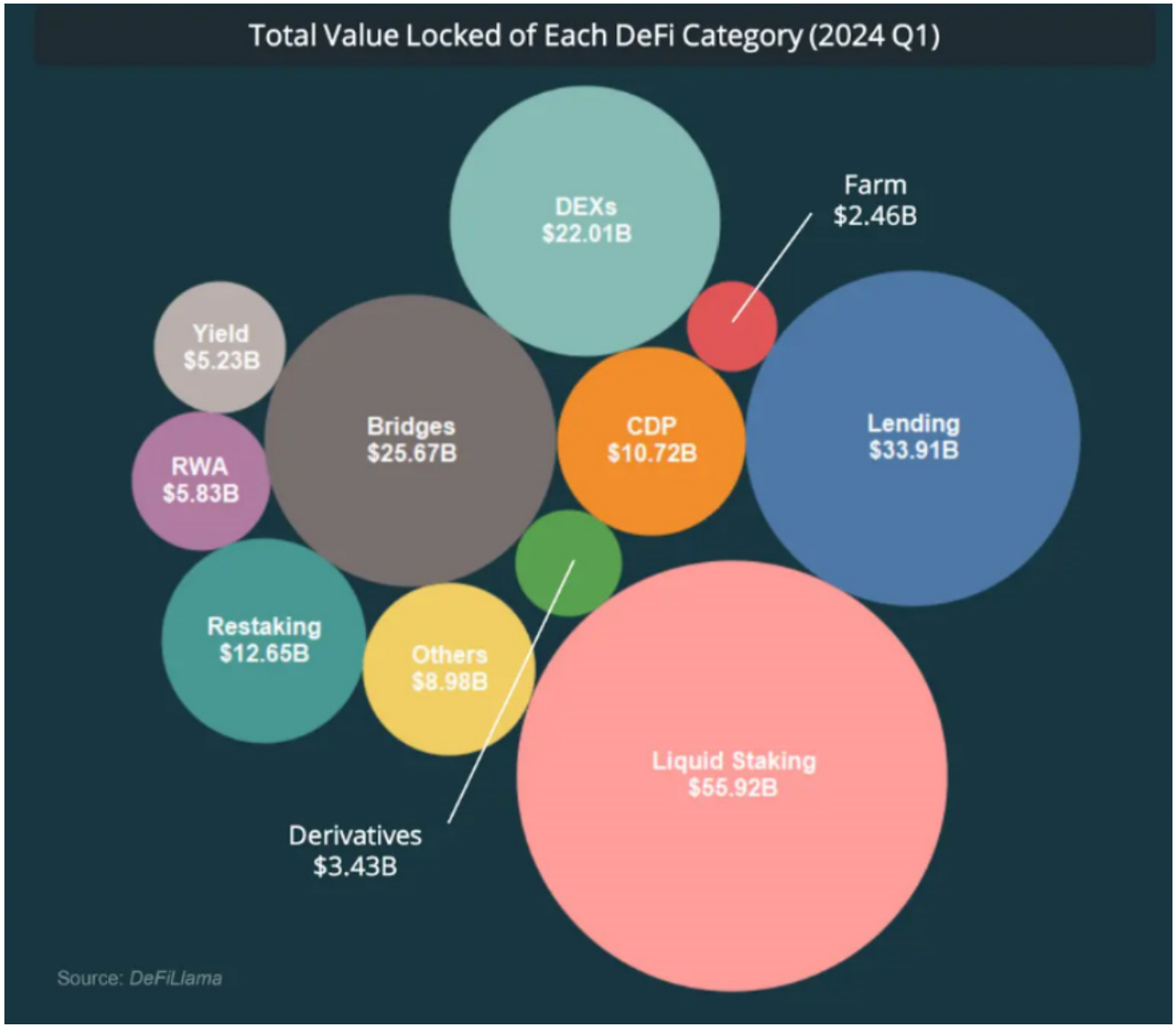
- DeFi roots trace back to 2014 with MakerDAO, which introduced decentralized borrowing, lending, and stablecoins.
- Ethereum's 2015 launch enabled the growth of DeFi through smart contracts and DApps.
- EtherDelta, in 2017, was a pioneer in decentralized token trading without centralized control.
- Compound's 2018 launch revolutionized governance and incentivization in DeFi (42% of governance tokens distributed to users).
- Uniswap, also in 2018, popularized liquidity pools and automated market makers for decentralized exchanges (DEXs).

DeFi's Summer Boom and Continued Growth

- **DeFi Summer 2020**: Marked by a massive growth in DeFi lending platforms and exchanges (e.g. MakerDAO, Uniswap, and Compound).
- **Total Value Locked (TVL) Growth**:
  - TVL across all chains surpassed $80 billion by 2024 summer, and more than half of the TVL is on Ethereum.
  - **Observation**: Most leading DeFi protocols were founded before the DeFi Summer. Where are the new innovations?

DeFi Protocol	TVL (in billions)
Aave	$11.10
MakerDAO	$5.04
Uniswap	$4.31
Compound	$1.88
Curve	$1.84

DeFi's Summer Boom and Continued Growth



Survival of the Fittest in DeFi

- **Decentralized Exchanges (DEXs)**
  - **AMMs:** Automated quoting and liquidity pools (Capponi and Jia (2021), Lehar and Parlour (2023), Park (2023), Hasbrouck, Rivera, & Saleh (2023))
  - **Liquidity:** 10%–15% of spot volume, resilient during CEX failures
  - **Price Discovery:** Facilitate cryptocurrency price discovery (Capponi, Jia, & Yu (2022); Klein et al. (2023))
- **Lending Protocols: Two-Sided Capital Platforms**
  - **Collateralized loans:** High capital efficiency
  - **Flash loans:** enhance market efficiency through financing CEX-DEX arbitrage strategies
- **Operational Protocols: Bridges, Staking, and re-staking**
  - Bridges: Cross-chain asset transfers
  - Staking and Re-staking: support for proof of stake, reuse of the capital locked.

All aboard of the DeFi train?

- **DeFi's Promise:** bold vision is to transform finance through decentralization, transparency, and democratization.
- **Current Reality:**
  - Steady progress, but development in the past 2-3 years has stagnated with similar use cases and limited financial innovation.
  - Limited integration with the real world assets.
- **Key Questions:**
  - What barriers are preventing DeFi from realizing its full potential?
  - How can we overcome these challenges?

Challenges Hindering DeFi's Growth

1. Application Layer

- Improved: Technical vulnerabilities
  - Reduction in hacks and exploitation.
- Unsolved:
  - Mechanism design problems due to constraints from the settlement layer.
  - Phantom TVL and poor user retention (Park and Stinner (2024)).
  - Route DeFi flow to centralized parties, which leads to cream-skimming

Challenges Hindering DeFi's Growth

2. Settlement Layer

- Unsolved: Maximal Extractable Value (MEV) and systematic frontrunning
- Currently proposed solutions have limits: resort to centralization, treating the symptoms but failing to address the root causes.

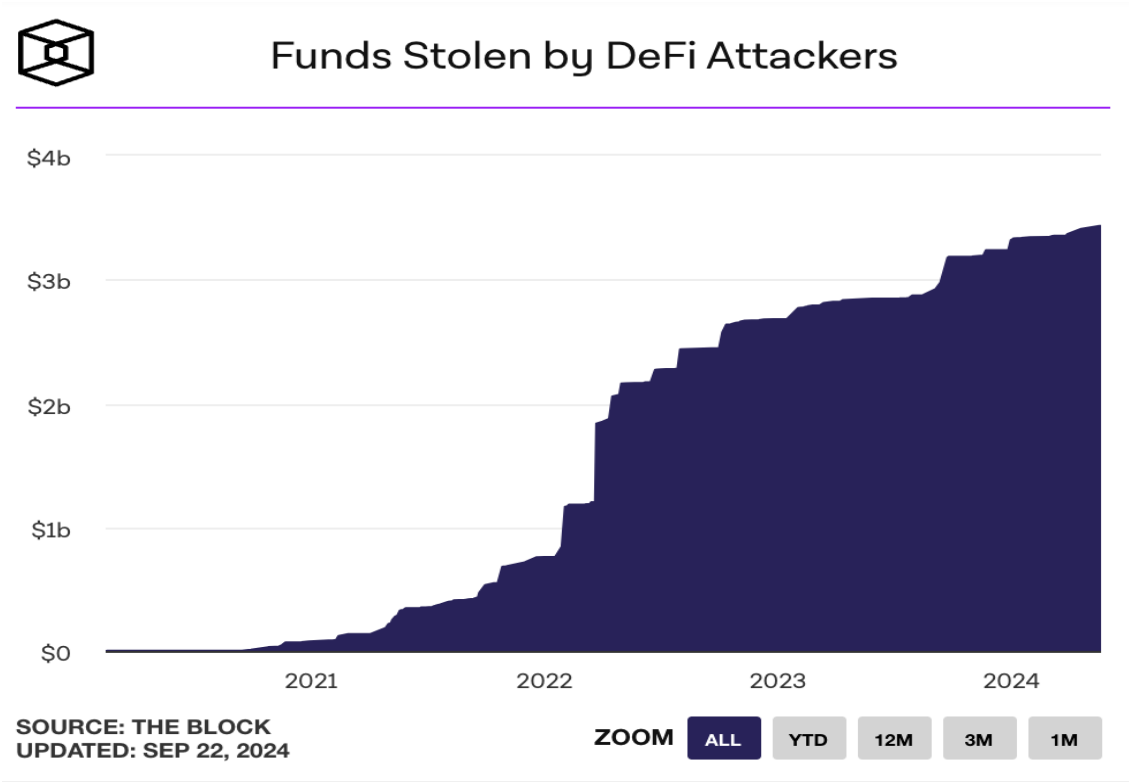
Challenges Hindering DeFi's Growth

3. Asset Layer

- Getting Better: Design Flaws Exposed
  - Failures like Terra-Luna highlight vulnerabilities (e.g. non-instant conversion of UST into dollars, high volatility of the backing token Luna)
- Key Challenges:
  - Current tokenomics impede innovation and misalignment of incentives
  - Power imbalances within exchanges impact market dynamics.

Application Layer: What is getting better

- **Reduction in Technical Vulnerabilities**
  - Significant decrease in smart contract hacks.
- **Improved Smart Contract Design**
  - Fewer DeFi exploits due to naive mechanism designs.



Application Layer: Settlement Layer Constraints

- **Infrastructure:** DeFi applications are built on blockchain, and thus need to comply with the rules of the blockchain settlement layer
- **Settlement Rules Rules:** Validators prioritize execution of transactions offering them highest fees.

Application Layer: Settlement Layer Constraints

- **Case Study**: Liquidity Provision in DEXs (Capponi and Jia (2021))
  - **Arbitrageur rent extraction:** Arbitrageurs snipe the entire pool and bid a fee in the amount equal to the arbitrage value
  - **Tragedy of the Commons:** Liquidity providers do not find it cost effective to outbid arbitrageurs, and withdraw liquidity

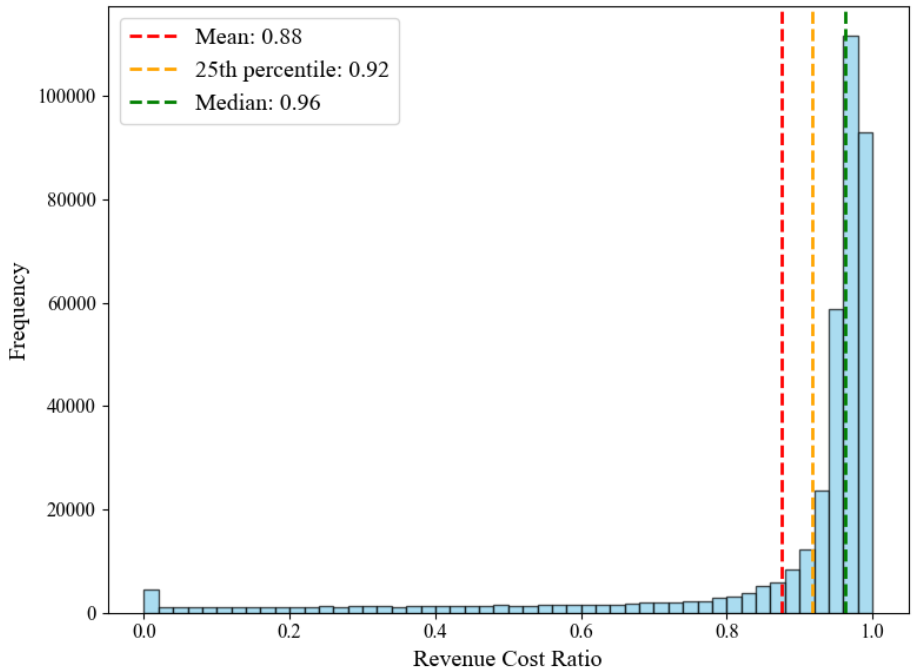


Figure 1: Capponi and Jia (2021): Distribution of the Revenue Cost Ratio.

Application Layer: Challenges in Resolution

Challenges in Resolution:

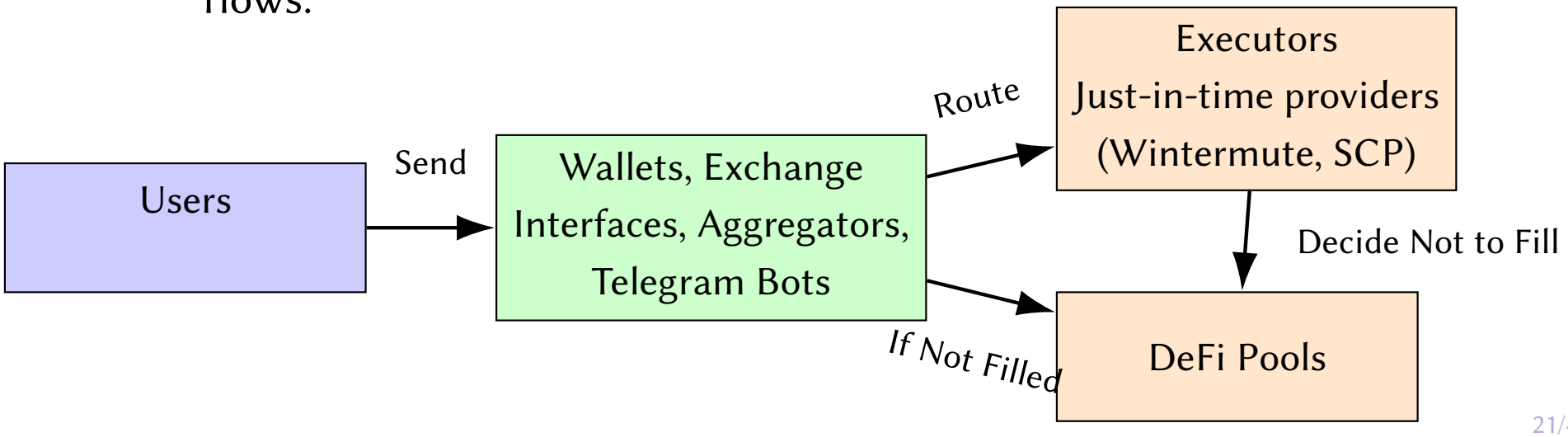
- **Infrastructure Rents:** Validators benefit from high fees, and do not find it incentive compatible to reduce their rents voluntarily.
- **Ineffectiveness of Traditional Solutions:**
  - Capponi and Jia (2021) show that speed priority, modified order sequencing have minimal impact
  - Flexible pricing curves can reduce arbitrage rents, but also result in reduced trading volume and fees earned by liquidity providers

Infrastructure Rents: DEXs vs. CEXs

Category	Decentralized Exchanges (DEXs)	Centralized Exchanges (CEXs)
Rent Extraction	Validators capture up to 100% of arbitrage profits via gas fees.	Exchanges capture about 30% of arbitrage profits through co-location fees[1].
Execution Mechanism	Block-by-block; first-price auctions favor high-fee transactions.	Continuous-time; equal priority for orders at the same speed.
Market Structure	Validators control block space allocation.	Market makers can redirect liquidity to negotiate fees.
Arbitrage Impact	Liquidity providers can't outbid arbitrageurs; incur losses.	Fast traders can cancel orders to avoid being sniped; slow traders are vulnerable.
Market Impact	High arbitrage rents reduce liquidity; risk of liquidity freeze.	Leads to wider spreads and lower order book depth.

Application Layer: Cream-Skimming

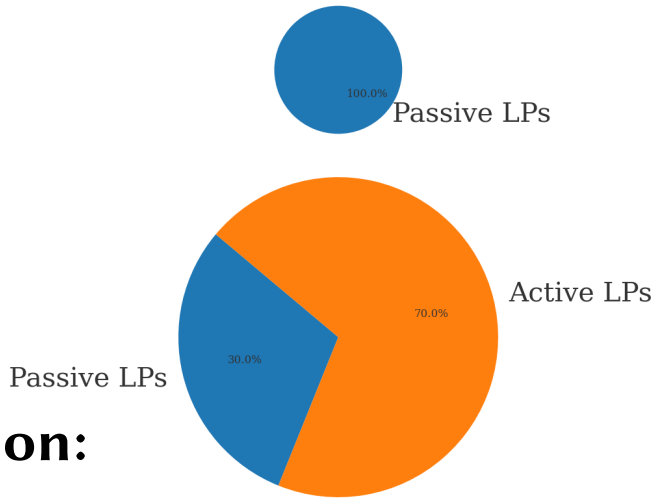
- **Routing DeFi Orders to Centralized Parties:**
  - Users send orders through wallets, exchange interfaces, aggregators,...
  - Orders are routed or sent as Request for Quotes (RFQs) to centralized executors (e.g., Wintermute)
  - If executors decide not to fill the orders, they are sent to DeFi pools.
  - This process is akin to payment for order flow in traditional finance.
- **Increased Toxic Flow:**
  - DeFi applications may suffer from selection bias and accept more toxic flows.



Application Layer: Cream-Skimming

Case Study: Just-in-Time Liquidity (Capponi, Jia, & Zhu, 2023)

- **Key Finding:** More liquidity providers can lead to less overall liquidity.
- **However,** if the order flow is not routed off-pool, cream-skimming may not happen, as more non-toxic flow may appear in equilibrium. (akin to PFOF in option vs equity)



Challenges in Resolution:

- **Interface Centralization:** Centralized interfaces may have misaligned incentives and lack regulation.

Application Layer Challenge 3: Phantom TVL

- **Artificial Inflation of TVL:**
  - Projects seek to appear more successful to attract listings on exchanges.
  - They engage centralized parties to provide short-term liquidity in exchange for token rewards.
- **Why not incentivizing decentralized users?**
  - Centralized parties can contribute significant TVL quickly.
- **Temporary Boosts:**
  - After the fixed term, the artificially added TVL often evaporates.
  - User engagement and liquidity decline once incentives end.

Parallels to Traditional Finance:

- Comparable to fraudulent practices aimed at misleading investors.

Application Layer Challenge 3: Phantom TVL

- **Artificial Inflation of TVL:**
  - Projects seek to appear more successful to attract listings on exchanges.
  - They engage centralized parties to provide short-term liquidity in exchange for token rewards.
- **Why not incentivizing decentralized users?**
  - Centralized parties can contribute significant TVL quickly.
- **Temporary Boosts:**
  - After the fixed term, the artificially added TVL often evaporates.
  - User engagement and liquidity decline once incentives end.

Parallels to Traditional Finance:

- Comparable to fraudulent practices aimed at misleading investors.

Settlement Layer Challenge: Maximal Extractable Value

Execution Layer Limitations:

- An efficient settlement layer should be
  - Safe: protect users' pre-settlement transaction details
  - Low cost: prevent excessive rent extraction by infrastructure providers.
- **Key Issue:** Validators extract rents from users of the blockchain.

Settlement Layer Challenge: Maximal Extractable Value

Root Causes of MEV:

- **Temporary Monopoly of Validators:**
  - Once randomly selected, a validator has monopoly control over block contents: transaction inclusion and ordering.
  - Incentivized to extract rents or delegate to agents who can do so (e.g., Proposer-Builder Separation).
- **Information Leakage:**
  - Users must broadcast signed, unsettled transactions to the network.
  - Transaction details are exposed before settlement
- **Lack of Oversight:** DeFi protocols are open and usable by anyone with no restriction

Settlement Layer Challenge: Systematic Frontrunning

- Systematic frontrunning has been present since the inception of DeFi.
- Goes beyond simple "sandwich attacks" and affects quality of market functions.

Impact on Critical Market Functions:

- **Trading:**
  - Traders may experience high slippage due to frontrunning
  - In extreme cases, slippage can exceed 90%
- **Market Making:**
  - Liquidity providers quoting near the mid-price may be exploited.
  - Frontrunners manipulate prices, forcing unfavorable quotes.
- **Price Discovery:**
  - Arbitrageurs attempting to align prices can have transactions preempted.
  - Frontrunners nullify arbitrage opportunities, hampering market efficiency.

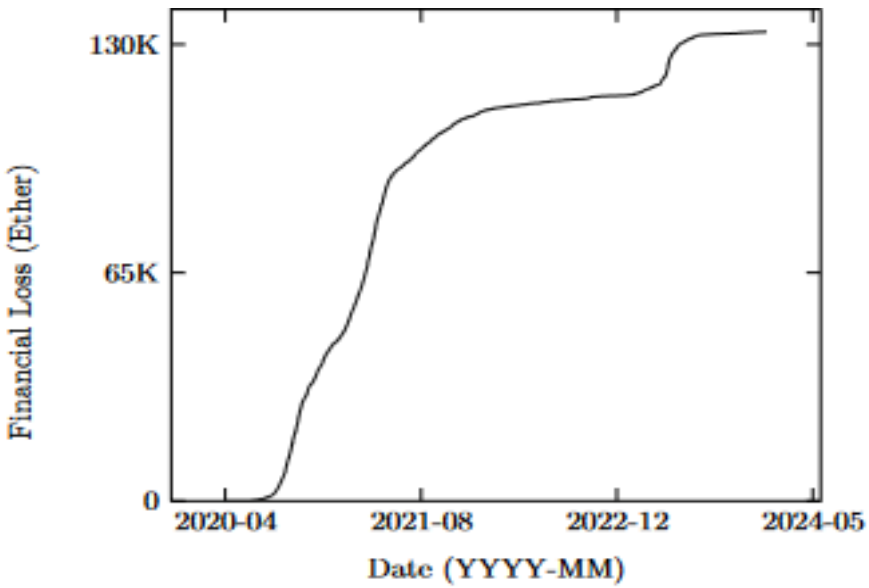
Settlement Layer Challenge: Systematic Frontrunning

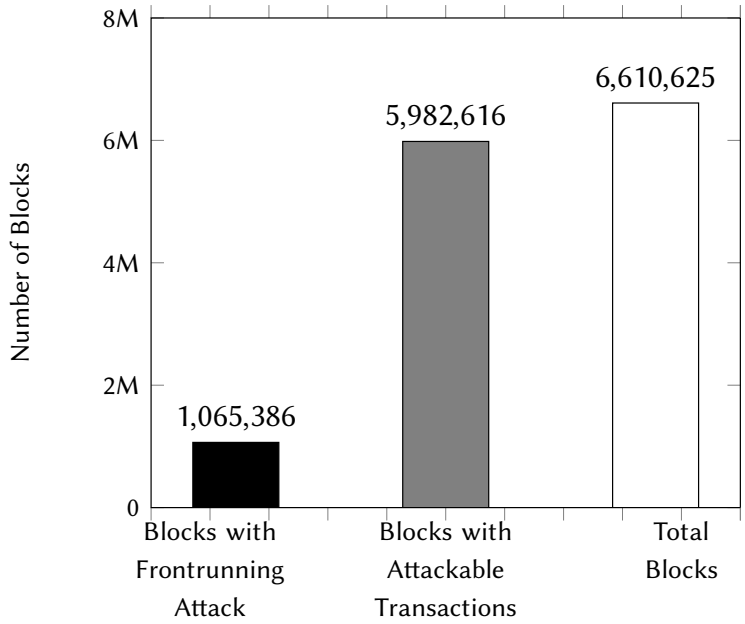
- Systematic frontrunning has been present since the inception of DeFi.
- Goes beyond simple "sandwich attacks" and affects quality of market functions.

Impact on Critical Market Functions:

- **Trading:**
  - Traders may experience high slippage due to frontrunning
  - In extreme cases, slippage can exceed 90%
- **Market Making:**
  - Liquidity providers quoting near the mid-price may be exploited.
  - Frontrunners manipulate prices, forcing unfavorable quotes.
- **Price Discovery:**
  - Arbitrageurs attempting to align prices can have transactions preempted.
  - Frontrunners nullify arbitrage opportunities, hampering market efficiency.

Systematic Frontrunning: Losses and Inefficiencies





Source: Capponi, Jia, and Wang (2024)

MEV: Are There Reasonable Solutions?

Private Submission Channels:

- Transactions are privately sent to block builders (PBS) or private pools (e.g., Flashbots Protect, Jito on Solana).
- Relies on trusting centralized parties to not exploit transaction details.
- Creates a marketplace between searchers and validators to compete for MEV and blockspace.

Private Pools and Frontrunning

- Capponi, Jia, and Wang (2022) show that private pools do not eliminate frontrunning.
- Validators lack incentive to forgo infrastructure rent by solely monitoring private pools
- **Even worse**, the private pool leads to increased priority fees, and thus higher MEV

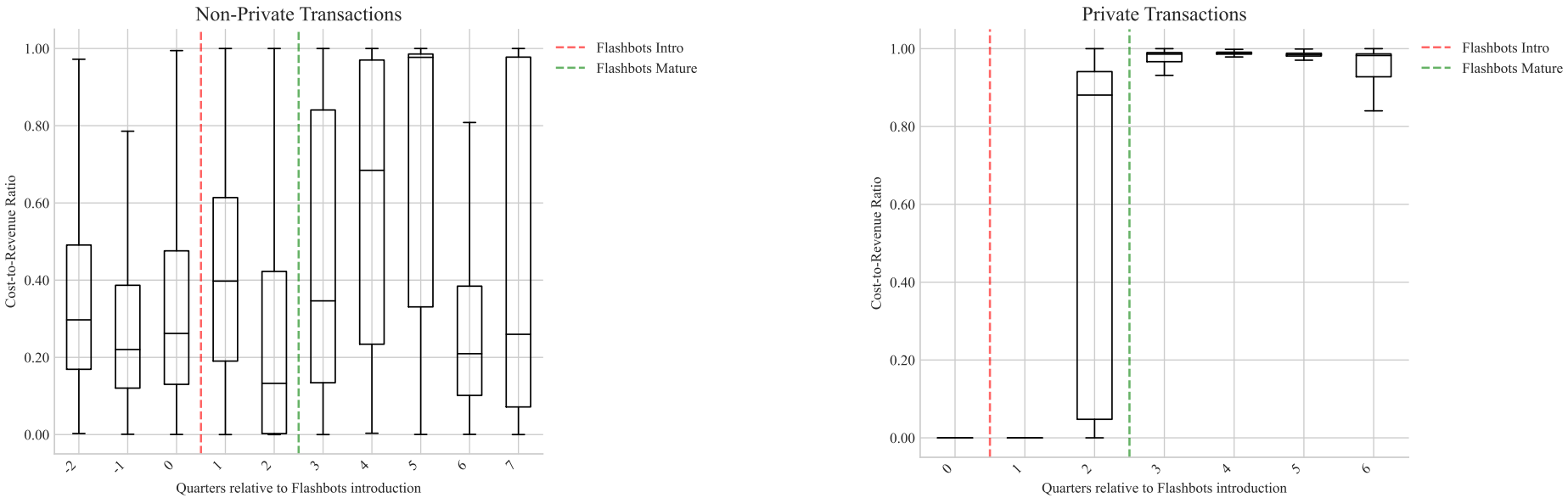


Figure 3: Source: Capponi, Jia, and Wang (2023)

MEV: Are There Reasonable Solutions?

- **Redistribution vs. Elimination:**
  - Most existing solutions aim to redistribute MEV among searchers, validators, and potentially users.
  - They do not address the root causes necessary to eliminate MEV.
- **Order Flow Auctions (OFAs).**
  - OFAs aggregate multiple users' transactions into batches optimized and settled by third parties.
  - Designed to to be a solution to the problem of MEV distribution, and allow users to recapture the value they are responsible for.
  - The auctioneer is a centralized party whose incentives may not align with the user's best interests

MEV: Open Questions

- Is it possible to achieve decentralized settlement with no MEV?
- Can we combine efficiency and security without sacrificing decentralization?
- Are privacy-preserving solutions, like zero-knowledge proofs, the way forward?
- What is the theoretical best we can achieve?

Outline

What drives TVL inflows and outflows for major blockchains?

- Capponi and Ramesh (2024) find that investment in newer DeFi blockchains is up to 8 times more sensitive to changes in Bitcoin's expected returns compared to older blockchains

	Total	Ethereum	Polygon	BSC	Terra	Solana
expectedDailyReturn	**6.64****	**5.66****	**41.60****	**26.39*****	**18.21*****	**32.85*****
	(2.66)	(2.62)	(17.72)	(7.21)	(5.62)	(10.84)
lag(TVLPercChange)	0.18***	0.12***	0.26***	0.13*	0.25	-0.20**
	(0.06)	(0.04)	(0.05)	(0.07)	(0.17)	(0.10)
btcLaggedOneDay	-0.06	-0.03	-0.19	-0.02	0.01	0.13
	(0.04)	(0.03)	(0.12)	(0.05)	(0.10)	(0.15)
Constant	0.15*	0.16*	-0.05	0.11	0.14	0.42
	(0.09)	(0.09)	(0.19)	(0.15)	(0.60)	(0.31)
Observations	1,400	1,400	1,299	1,309	539	1,171
R^2	0.03	0.02	0.11	0.06	0.07	0.04

Note: *p<0.1; **p<0.05; ***p<0.01

What drives TVL inflows and outflows for major protocol types?

- Investment in newer DeFi protocols is twice more sensitive to changes in Bitcoin's expected returns compared to older protocols

	Lending	LST	CDP	DEX
expectedDailyReturn	**0.90****	**2.14*****	**1.05***	**1.58*****
	(0.38)	(0.80)	(0.57)	(0.48)
lag(TVLPercChange)	0.11	-0.02	-0.22***	0.02
	(0.08)	(0.05)	(0.06)	(0.09)
btcLaggedOneDay	-0.01	0.16**	0.21***	-0.01
	(0.05)	(0.07)	(0.04)	(0.04)
Constant	0.16	0.60***	0.10	0.14
	(0.10)	(0.16)	(0.10)	(0.12)
Observations	1,399	1,293	1,399	1,399
R^2	0.02	0.02	0.04	0.01

Why Does Innovation Seem to Slow Down in DeFi?

Observations:

- **Stagnation in Development:**
  - DeFi development appears to be stagnating.
  - Few exciting new protocols; similar projects on different chains.
- **Focus on Narratives Over Innovation:**
  - Developers and investors prioritize popular narratives or buzzwords (e.g. restaking, real world asset tokenization, AI).
  - There is a tendency to work on similar ideas rather than pioneering new ones.

Key Question:

- Do we have the right incentives for innovation in DeFi?
- Shouldn't we incentivize the development of valuable projects?

Why Does Innovation Seem to Slow Down in DeFi?

Hypothesis:

- Current tokenomics may fail to provide correct incentives.
- Tokens offer liquidity but may lead to fewer positive Net Present Value (NPV) projects
- There is a tendency for participants to game the system rather than focus on true innovation.

The Impact of Tokenomics on Innovation

Observations from preliminary findings in Jia (2024):

- **Exit Liquidity Dynamics:**
  - Traditional finance: Exit liquidity comes from IPOs; most projects fail, so investors exert effort to screen for good projects.
  - DeFi: Tokens listed on exchanges (spots & futures) early, providing quick exit liquidity.
  - **Economics:** Investors may prioritize negotiating token allocations over thoroughly screening DeFi projects, resulting in fewer positive NPV projects in equilibrium.

The Impact of Tokenomics on Innovation

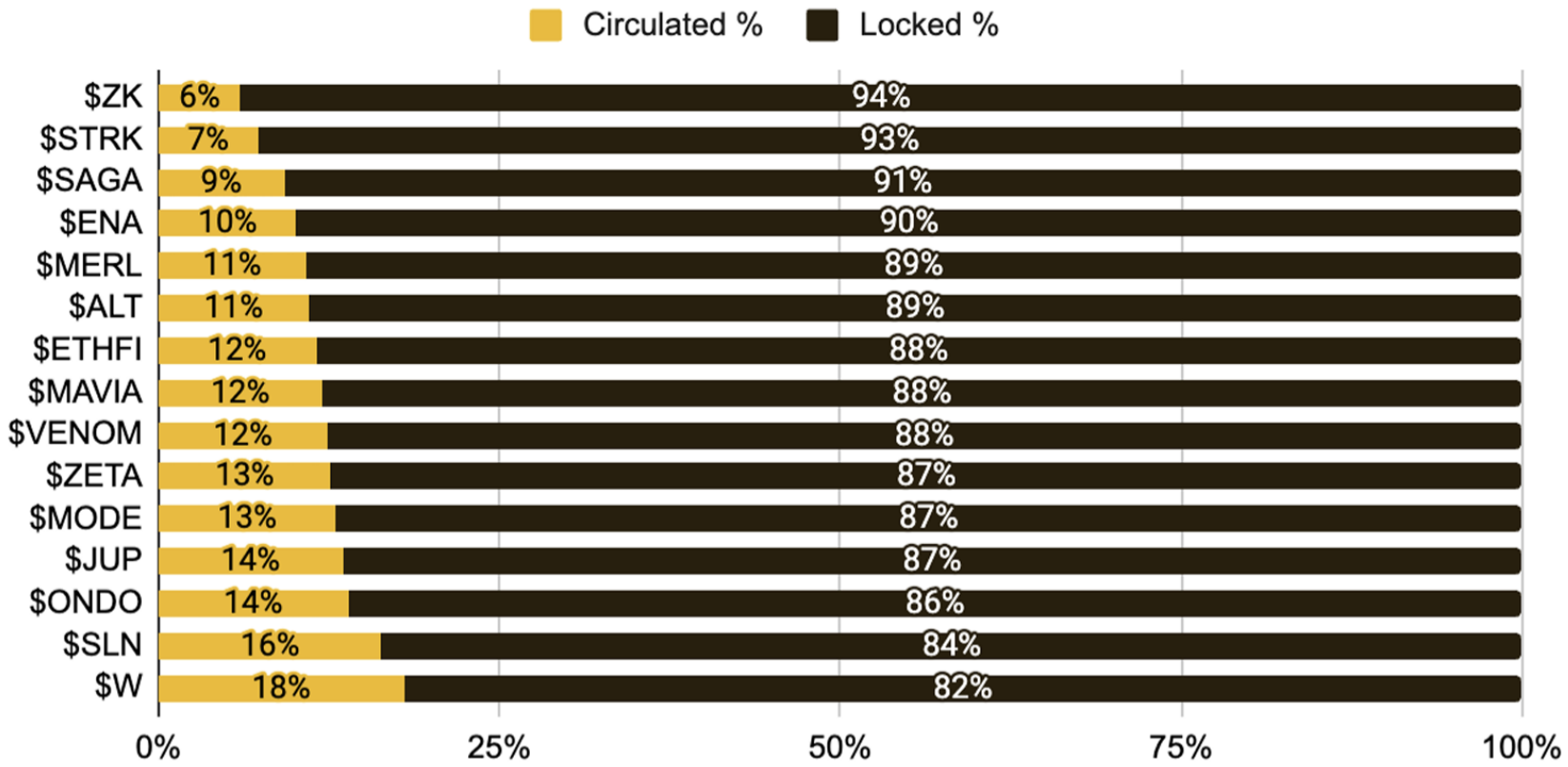
Observations from preliminary findings in Jia (2024):

- **Consequences:**
  - Projects are evaluated based on potential for short-term exchange listing rather than long-term viability.
  - Emphasis on network effects and narratives, which can be artificially inflated (e.g., fake TVL).
  - Investors and entrepreneurs concentrate on a few projects with popular narratives.
  - Subsidizing TVL to achieve listings may lead to an equilibrium with fewer positive NPV projects.

Key Assumption:

- Retail investors often serve as the exit liquidity for early investors.

The Emergence of "VC Coins": Massive Supply Reserved for VCs and Insiders



Source: CoinMarketCap, Binance Research, as of May 14, 2024

Figure 4: Token Supply Distribution

The Emergence of "VC Coins": Massive Supply Reserved for VCs and Insiders

Concentration of Token Supply

- **Large Allocations to VCs and Insiders:**
  - Significant portions of new tokens are reserved for venture capitalists and project insiders.
  - Creates a low circulating supply ("low float") in the market.
- **Potential Market Implications:**
  - Low float can lead to increased price volatility.
  - Easier to influence and inflate initial token prices.
  - Retail investors may face disadvantages due to information asymmetry. (Do retails know that VC acquire the same tokens with huge discount?)

The Emergence of "VC Coins": Massive Supply Reserved for VCs and Insiders

Concentration of Token Supply

- **Large Allocations to VCs and Insiders:**
  - Significant portions of new tokens are reserved for venture capitalists and project insiders.
  - Creates a low circulating supply ("low float") in the market.
- **Potential Market Implications:**
  - Low float can lead to increased price volatility.
  - Easier to influence and inflate initial token prices.
  - Retail investors may face disadvantages due to information asymmetry. (Do retails know that VC acquire the same tokens with huge discount?)

Rethinking and Redesigning Tokenomics

- **Current Challenges:**
  - **Perverse Incentives.** Exploitation over long-term innovation.
  - **Misalignment with Project Success:** Token value does not reflect the underlying project's performance or viability.
- **Consequences:**
  - **Investor Exploitation Risks:** Early insiders benefit disproportionately at the expense of retail investors.
- **Call to Action:**
  - **Redesigning Tokenomics:** Develop mechanisms that align incentives of developers, investors, and users.
  - **Enhancing Incentive Compatibility:** Ensure that all stakeholders benefit from long-term project success.
  - **Education and Regulation:** Regulatory frameworks to protect market participants.

Rethinking and Redesigning Tokenomics

- **Current Challenges:**
  - **Perverse Incentives.** Exploitation over long-term innovation.
  - **Misalignment with Project Success:** Token value does not reflect the underlying project's performance or viability.
- **Consequences:**
  - **Investor Exploitation Risks:** Early insiders benefit disproportionately at the expense of retail investors.
- **Call to Action:**
  - **Redesigning Tokenomics:** Develop mechanisms that align incentives of developers, investors, and users.
  - **Enhancing Incentive Compatibility:** Ensure that all stakeholders benefit from long-term project success.
  - **Education and Regulation:** Regulatory frameworks to protect market participants.

Rethinking and Redesigning Tokenomics

- **Current Challenges:**
  - **Perverse Incentives.** Exploitation over long-term innovation.
  - **Misalignment with Project Success:** Token value does not reflect the underlying project's performance or viability.
- **Consequences:**
  - **Investor Exploitation Risks:** Early insiders benefit disproportionately at the expense of retail investors.
- **Call to Action:**
  - **Redesigning Tokenomics:** Develop mechanisms that align incentives of developers, investors, and users.
  - **Enhancing Incentive Compatibility:** Ensure that all stakeholders benefit from long-term project success.
  - **Education and Regulation:** Regulatory frameworks to protect market participants.

Outline

Under-explored opportunities: DeFi in Microfinance

Who Needs DeFi the Most?

- **Emerging Economies:**
  - Countries lacking robust financial infrastructure and technology.
  - Limited access to financial services due to untrustworthy centralized institutions
  - High barriers to financial inclusion for individuals and small businesses.
- **Examples: Laos**
  - **Challenges:**
    - Limited expertise in financial technology.
    - Low investor trust in financial intermediaries and local currency.
    - Absence of markets leading to mispricing of commodities (e.g., rare-earth minerals).
  - **Government Initiation:**
    - Utilizing DeFi solutions to improve price discovery
    - Projected to demonstrate an annual growth rate of 9.56% in 2024-2028, resulting in a projected total amount of US$187.00k by 2028.

Under-explored opportunities: DeFi in Microfinance

- **Promising Initiatives:**
  - Projects like **Ejara** and **Kotani Pay** are making strides in this space.
  - They demonstrate the potential of DeFi to promote financial inclusion.
- **Challenges to Address:**
  - **Misaligned Tokenomics:** Current DeFi models do not incentivize projects focusing on underserved markets.
  - **Narrative Misalignment:** The long-term social welfare aimed by these alternatives may not align with prevailing investment narratives, affecting funding and exchange listings.
  - **Capital Allocation:** Large investors tends to favor projects with quick returns and quicker exit options over those with significant social impact.

How to integrate DeFi into real world

- Can AMMs enhance traditional financial markets? Would they reduce trading costs and improve market quality (see also Malinova and Park (2023))?
- What real-world assets should be tokenized (real estate, commodities, and traditional securities)?
- How to bridge on-chain and off-chain assets? How to sync ownership on-chain and off chain? Should we introduce government and trusted parties as nodes on blockchain?

Conclusion

- Significant progress has been made on DeFi from 2020 till today
- Some DeFi projects have succeeded, establishing themselves as complementary to CeFi. Still a long way to go:
  - Persistent issues such as MEV require market innovations at the settlement layer.
  - DeFi adoption requires market design changes to strengthen liquidity provision and trading incentives
- Change the incentives of venture capitalists from token value to monitor the success of DeFi projects
- Microfinance and real-world asset tokenization are promising avenues for future research in DeFi

Outline

References

- **Agostino Capponi** and Ruizhe Jia. Liquidity Provision in Blockchain Based Decentralized Exchanges. *Review of Financial Studies*, Revise and Resubmit
- **Agostino Capponi**, Ruizhe Jia, and Shihao Yu. Price Discovery on Decentralized Exchanges. *Review of Financial Studies*, Revise and Resubmit
- **Agostino Capponi**, Ruizhe Jia, and Brian Zhu. The Paradox of Just-in-Time Liquidity in Decentralized Exchanges: More Providers Can Lead to Less Liquidity. *Working Paper*. Working paper, Columbia University
- **Agostino Capponi**, Ruizhe Jia, and Ye Wang. Maximal Extractable Value and Allocative Inefficiencies in Public Blockchains. *Journal of Financial Economics*, Revise and Resubmit
- **Agostino Capponi**, Ruizhe Jia, and Sveinn Olafsson. Proposer-Builder Separation, Exclusive Order Flow, and Centralization in Blockchain. Working paper, Columbia University
- **Agostino Capponi** and Sathya Ramesh. Return Extrapolation and Financial Innovation: Evidence from Cryptocurrency Markets. Working Paper, 2024.
- Ruizhe Jia. The Impact of Tokenomics on Innovation. Working Paper, 2024.