Are decentralized finance really decentralized? — A social network analysis of Aave protocol on Ethereum Blockchain

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Session C2 Blockchain and Cryptocurrencies
29th Annual Global Finance Conference
Braga, Portugal
Date: 6/21/2022

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The Interdisciplinary Team

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- **Interdisciplinary Team**
- **Cultivate Undergraduate Research**
- **Remote Collaborations during Covid-19**

The Backgrounds

- The actual realization of peer-to-peer transactions and the **levels of decentralization is largely unknown**.
- How the levels of decentralization would affect the economic performance of the blockchain platform is largely unexploited.
- Before blockchain technology exists, market decentralization tended to have worse performance.
- The network features, the proxy for market structure in decentralized markets affect important market outcomes (e.g., liquidity and volatility), and individual traders.

Research Questions:

1. **The realization of decentralization:** Are transactions in decentralized banks on blockchain indeed decentralized?
2. **Blockchain network dynamics:** How do different network features of blockchain transactions correlate and change across time?
3. **Counterfactual impact evaluation:** How do network features predict and interact with the economic performance of the blockchain applications under different time momentum?

The Main Results

We apply social network analysis to measure the **level, dynamics, and impacts of decentralization** in DeFi token transactions on the Ethereum blockchain.

We present the research pipeline in application to the transaction network of AAVE, the native utility token of a top-ranked decentralization finance application on Ethereum.

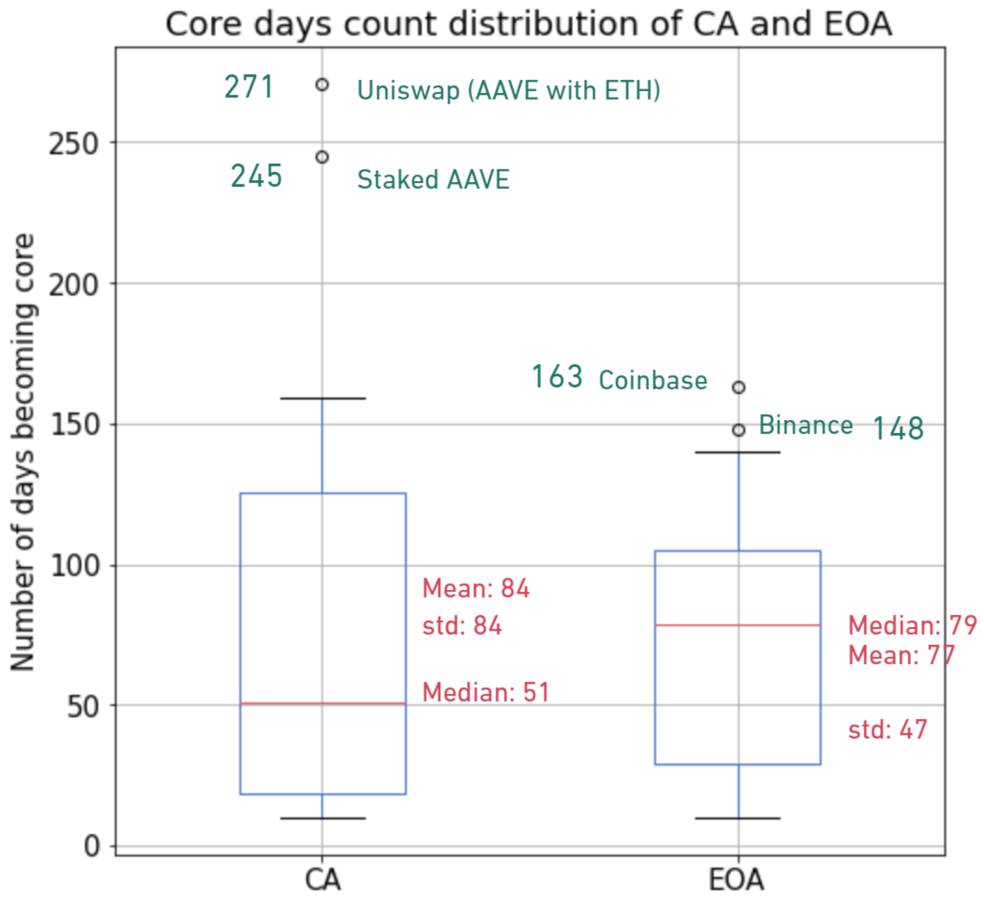
We find that:

1. There exists **a significant core-periphery structur**e in the AAVE token transaction network and the addresses that are cores mostly often are two largest centralized crypto exchanges.
2. Multiple network features including the number of components, relative size of giant components, modularity and standard deviation of degree centrality **consistently characterize decentralization dynamics**.
3. Representing by the network measure, a more decentralized network significantly predicts **a higher return** and **lower volatilities** of the DeFi tokens.

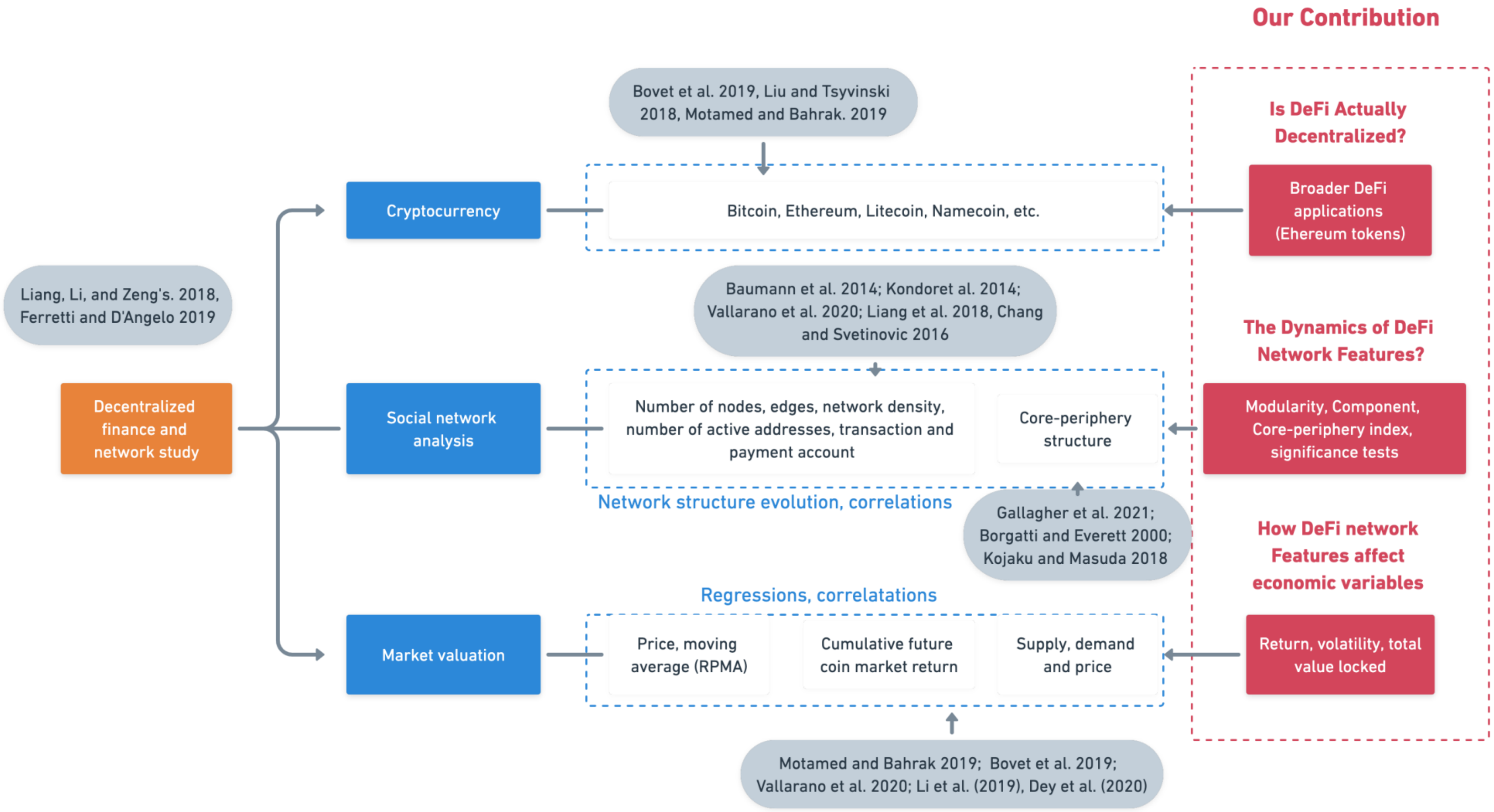
Is DeFi Really Decentralized?

The promises

The perils



The Contribution Map



- Extends the network studies on Bitcoin and Ethereum to **DeFi tokens.**
- Comprehensive **network features** and core-periphery structure tests.
- Evaluate **economic performance** (Return, volatility, and total value locked)

Data Source

Coin Metrics

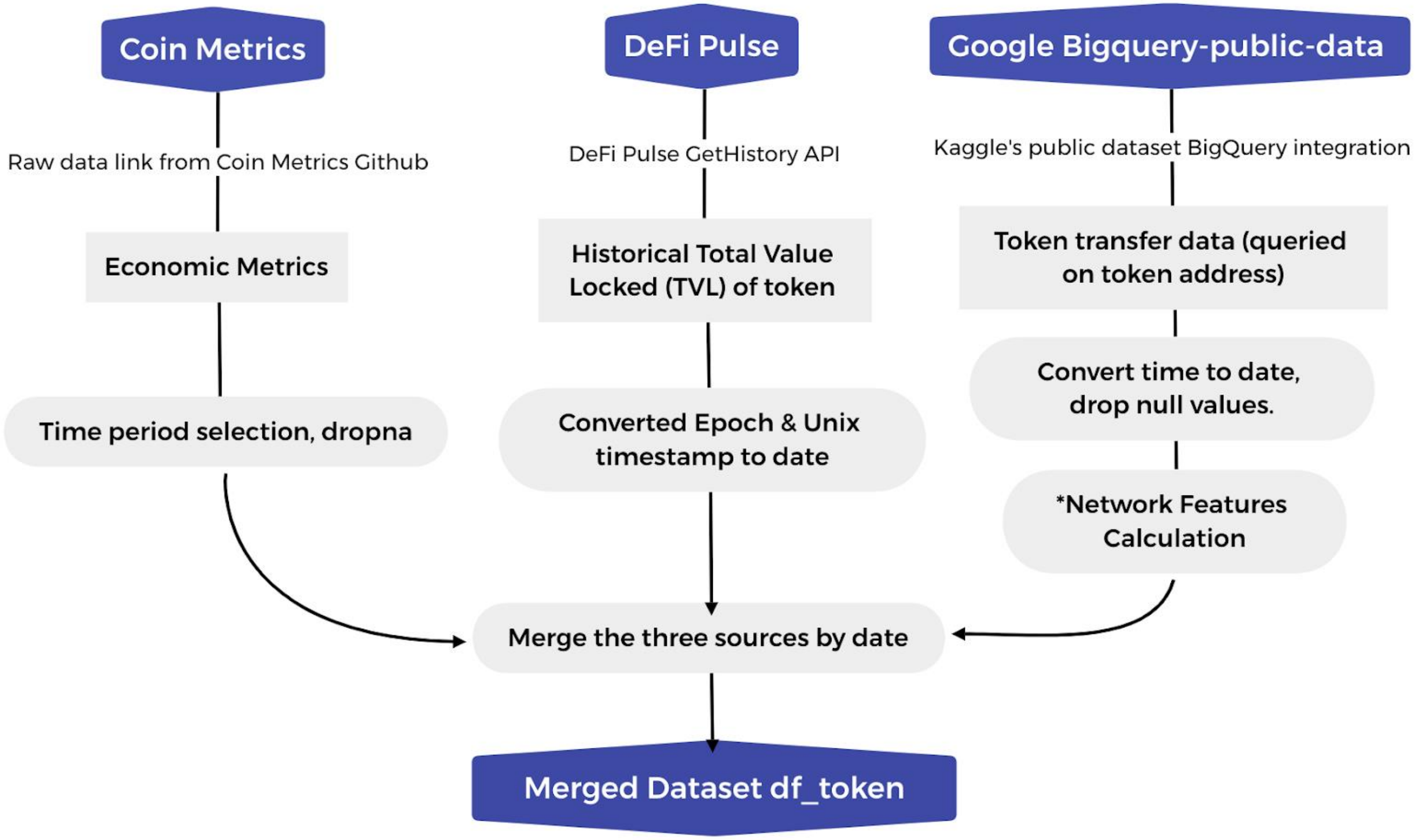
Provides access to historical and real time economic features of DeFi tokens.

DeFi Pulse

Query historical Total Value Locked (TVL) for DeFi tokens.

Google Bigquery-public-data

Offers token transfer data in table *ethereum_blockchain.token_transfer* including from_address, to_address, value and block_timestamp.



Methodology

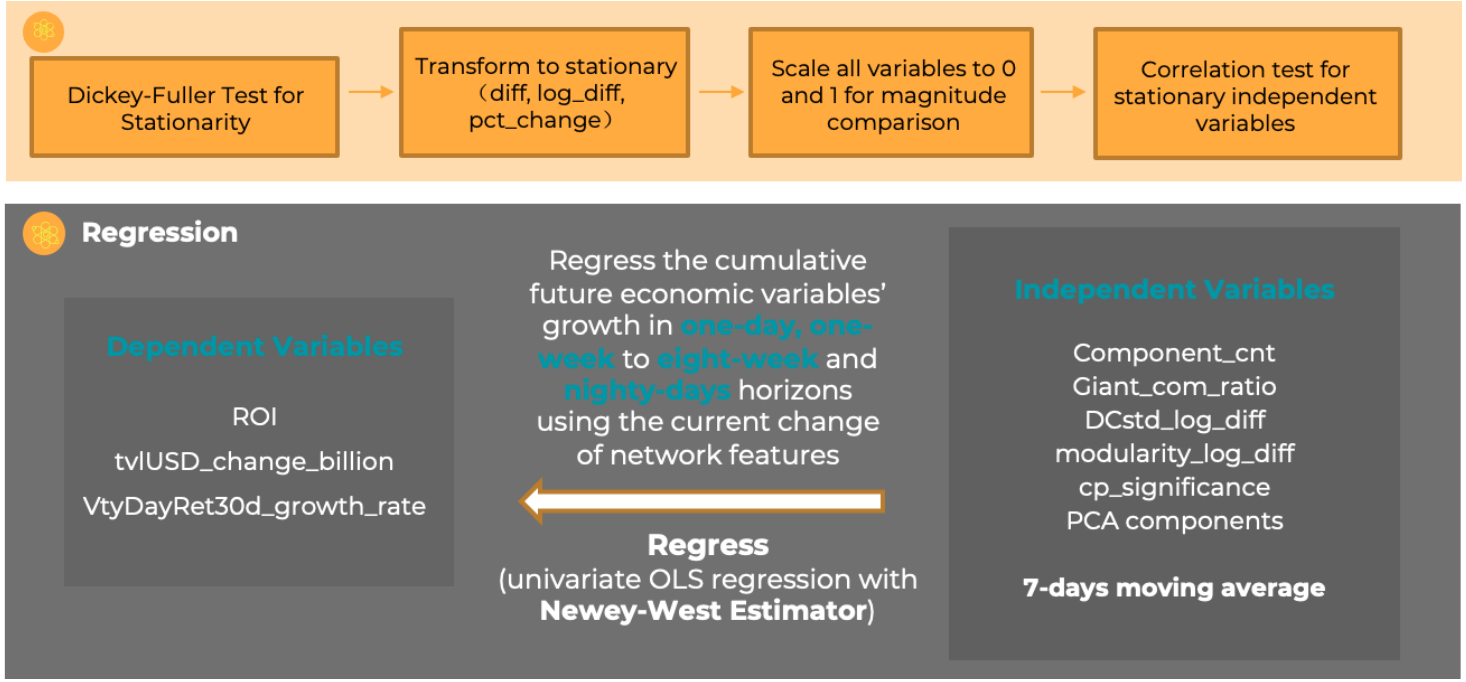
1 Network feature calculation

- Python NetworkX package
- Daily undirected weighted transaction network
- Type of network: Graph (graph with undirected edges. Self-loops are allowed but multiple edges are not)

2 Core-periphery structure analysis

- Python *cpnet* package (BE structure)
- Significant tests on core-periphery structures (0.05 as the significance level)

3 Regression Workflow



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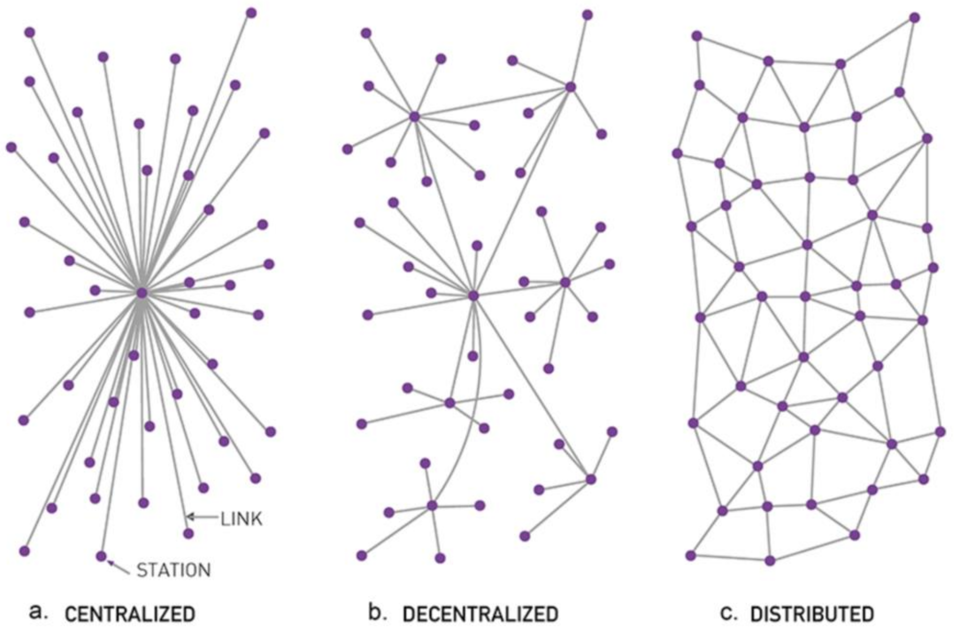
Result 1: Defining decentralization via network measures

- Time-series Plots
- Correlation Heatmap

Conceptual Framework



Different types of network structures

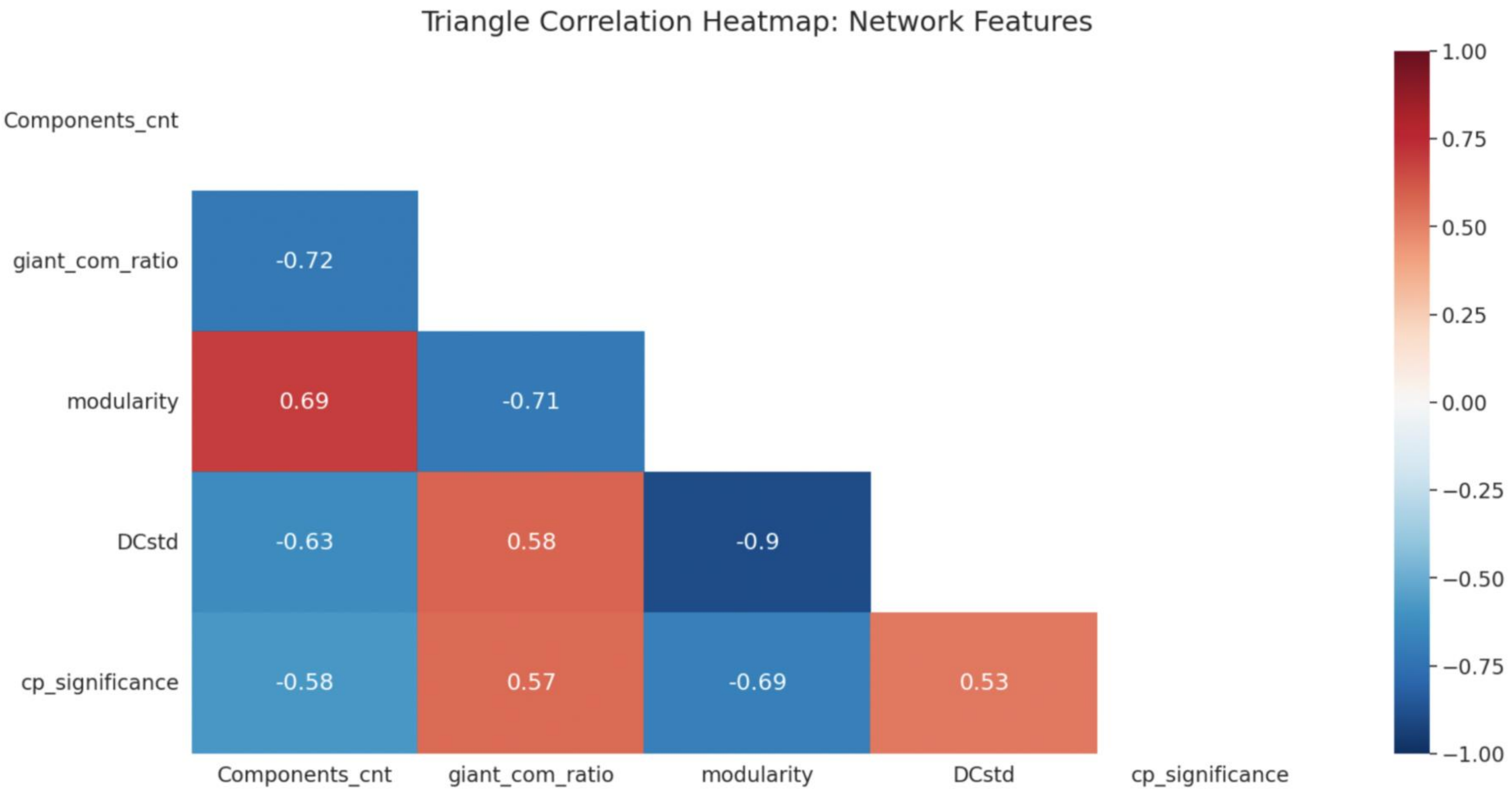
Note: This figure illustrates three types of communication networks (borrowed from [Barabási 2016]).

Network features as decentralization indexes

Name	Definition
num_nodes	Number of unique addresses in the daily transaction network.
num_edges	Number of transactions in the daily transaction network.
Components_cnt	The various disconnected parts of the network, where there is no path that can connect from a node in one component to a node in another component. Components_cnt here refers to the number of components in the daily transaction network
giant_com_ratio	Size of the giant component divided by the total number of nodes in the daily transaction network.
DCstd	Standard deviation of degree centality. Degree centrality measures the number of neighbors one node has: the higher the number, the more central the node is.
Modularity	Measure of the strength of a network divided into modules. A network with a high degree of modularity has dense connections between nodes within a module but sparse connections between nodes in different modules.
cp_test_pvalue	P value of the significance test of the core-periphery structure.
cp_significance	1 if cp_test_pvalue is less than 0.05 and, else 0 otherwise.
core_cnt	Number of nodes in the core based on the BE core-periphery structure algorithm in daily transaction network.
avg_core_neighbor	Average number of neighbors (degree) of the core nodes detected by the core-periphery structure algorithm in the daily transaction network.

Note: This table gives the general definitions of the network features included in our study with an explanation and equation.

Correlation Heatmap

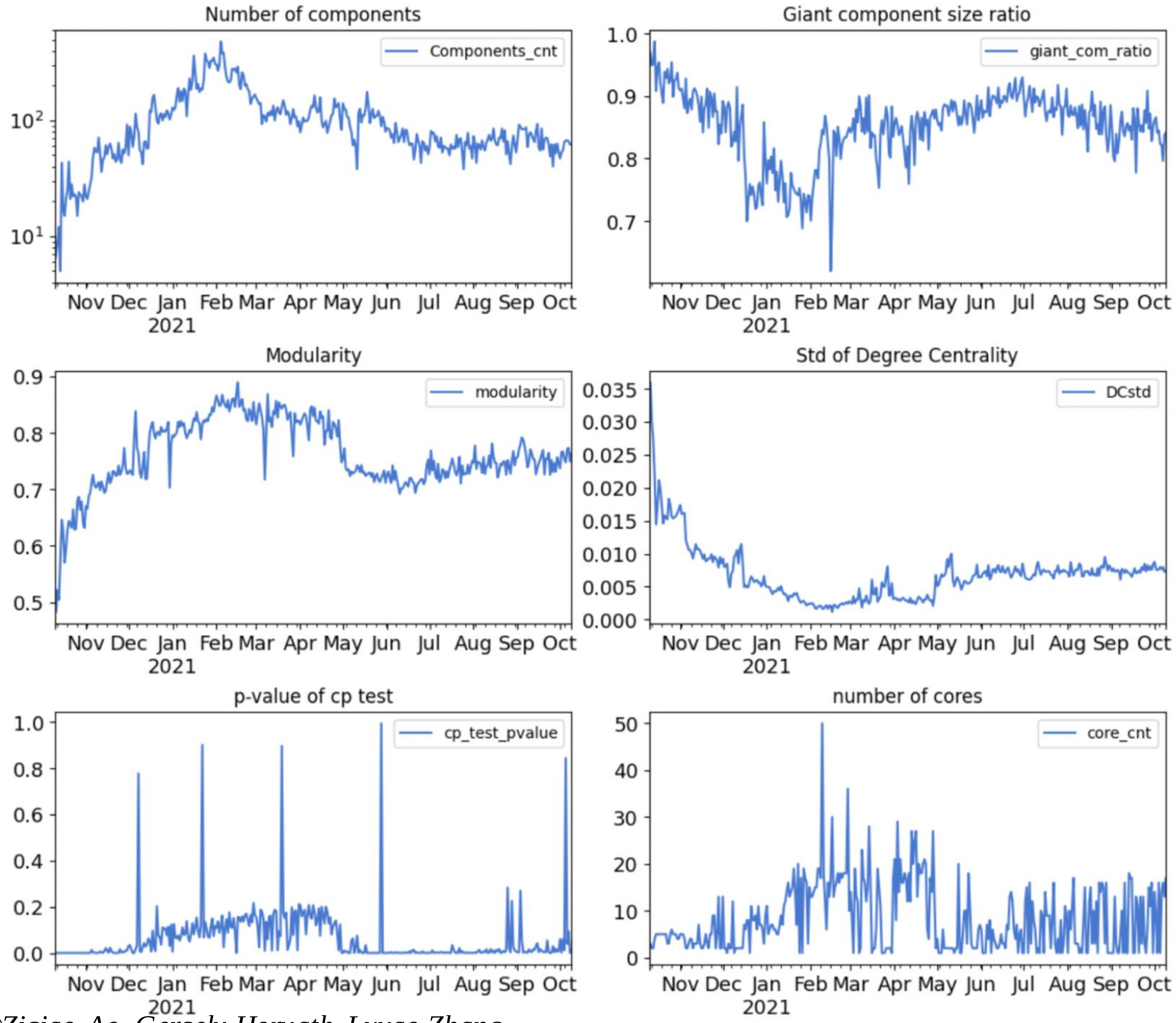


Centralization implies:

- low p-value: CP-structure
- low number of components
- low modularity score
- large size of the giant component
- high standard deviation of degree centrality

The signs of the correlations are as expected based on our network-based measures of centralization.

Time-series Plots



- **Numbers of components:** more centralized, we expect to have fewer components in the network.
- **Giant component size ratio:** A related network property is the relative size of the giant component.
- **The modularity score:** small when the market is centralized, meaning there are no separate communities in the network.
- **The standard deviation of degree centrality:** large (small) when the market is centralized (decentralized)
- **Core-periphery structure significance test p-value:** The transaction network is more centralized if the core-periphery test gives a significant result ($p<0.05$)

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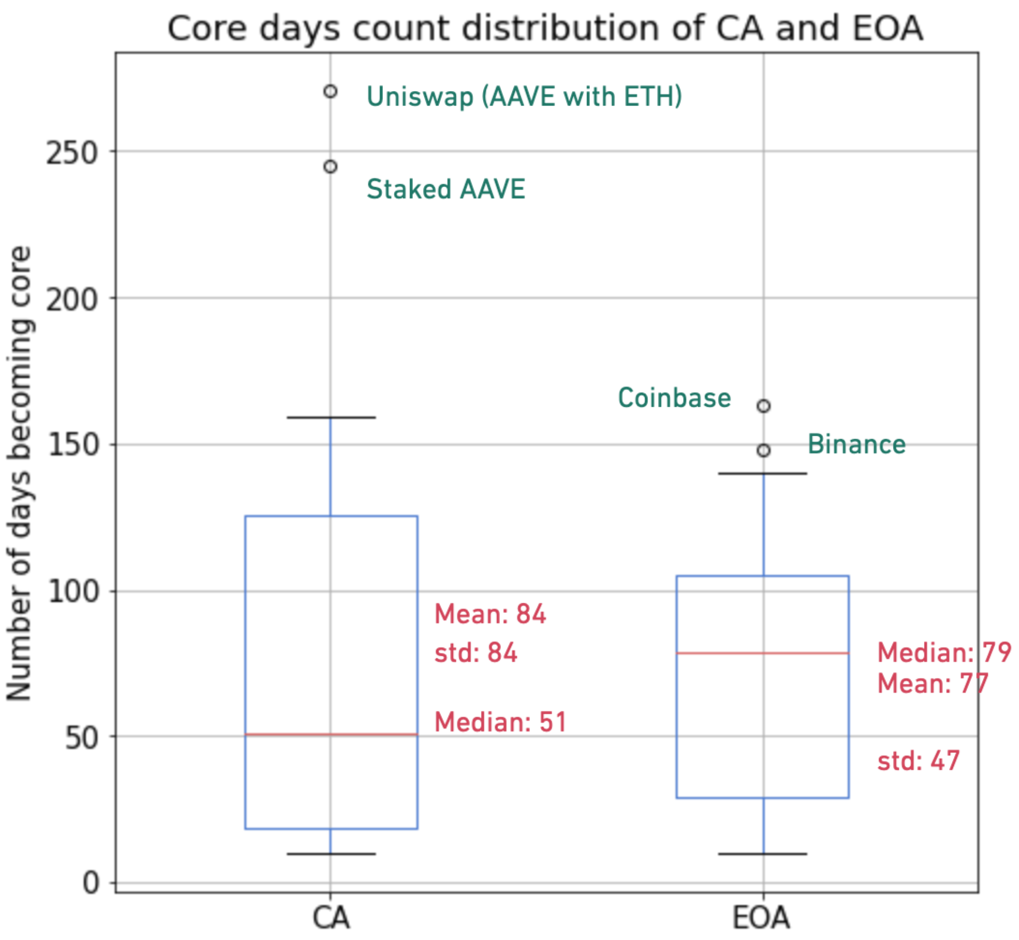
Result 2: A closer look at core-periphery structure

- Construct core-periphery structures
- Compare the core-periphery structure for externally owned and contract account

Compare the core-periphery structure for externally owned and contract account



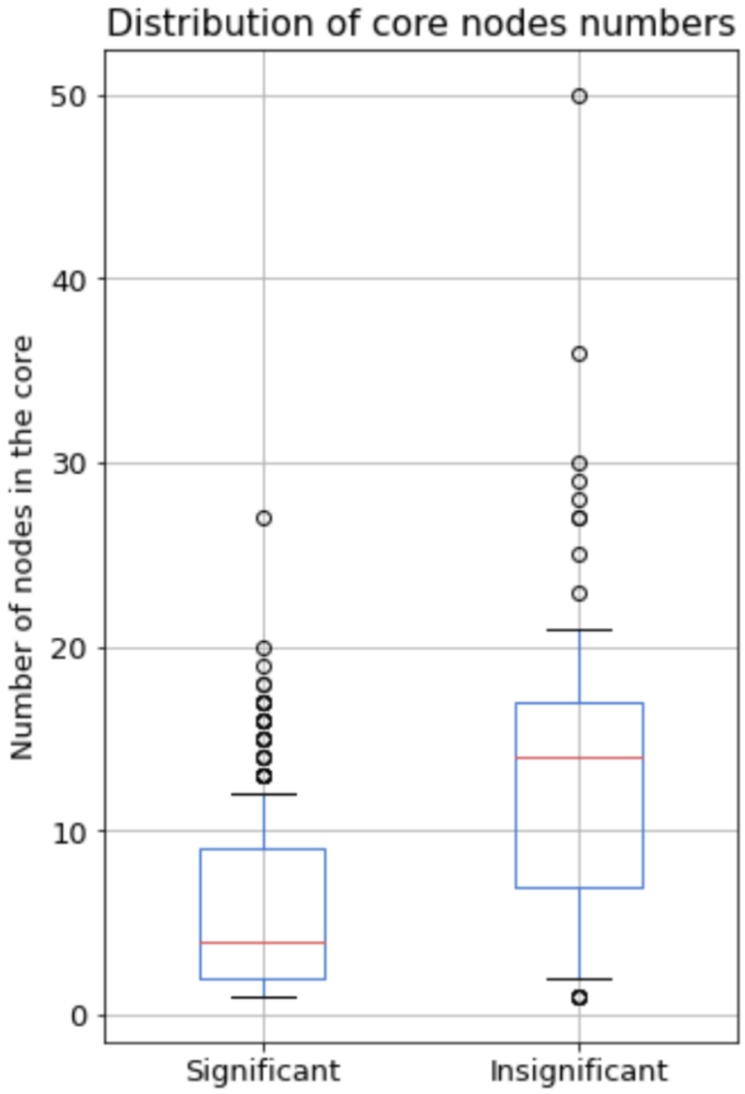
- Connect the properties of core-periphery structure with the real functions and types of the specific addresses.

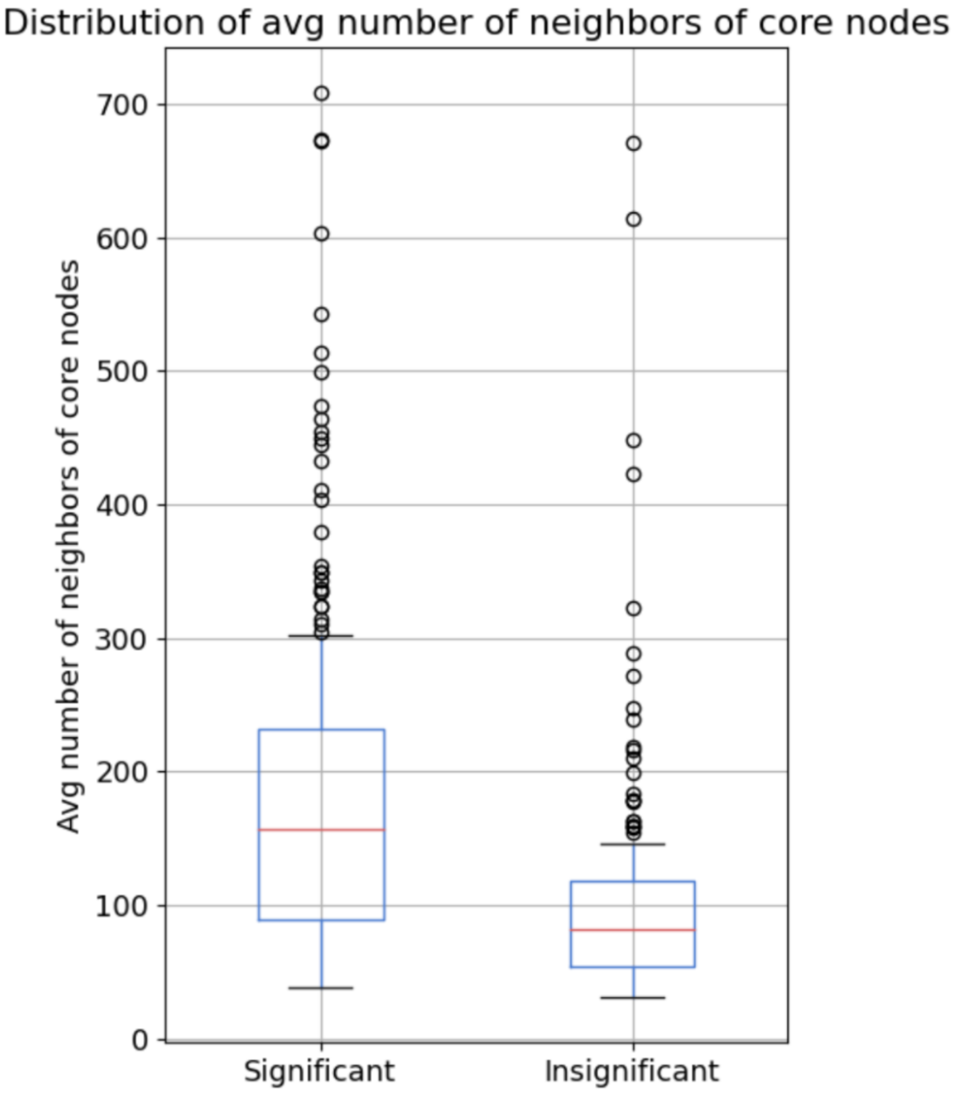
- **Outliers of EOA**: Centralized Exchanges —— Binance and Coinbase
  - Put the promise of blockchain decentralization in doubt

- **Outliers of CA**: Decentralized Exchanges —— Uniswap and Staked Aave
  - Evidence that blockchain can mitigate the dependence on trusted centralized entities.

Construct core-periphery structures

- 232 significant (64%) and 133 insignificant (36%) days.
- When significant structure, it can be **divided into small groups** of denser and looser connections.
- The degree of centralization is greater, a few addresses are likely to dominate most transactions.





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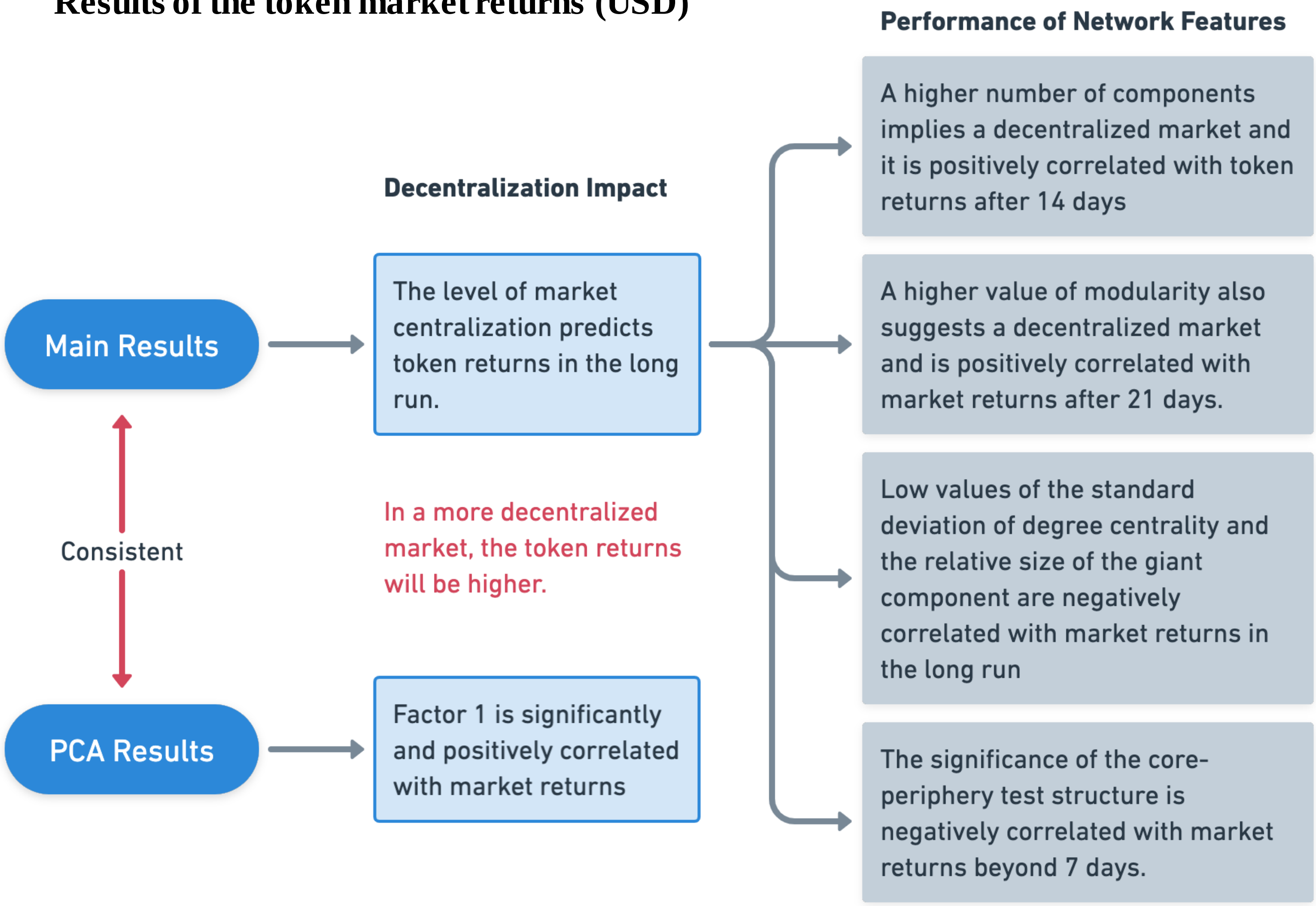
Result 3: Counterfactual impact evaluation

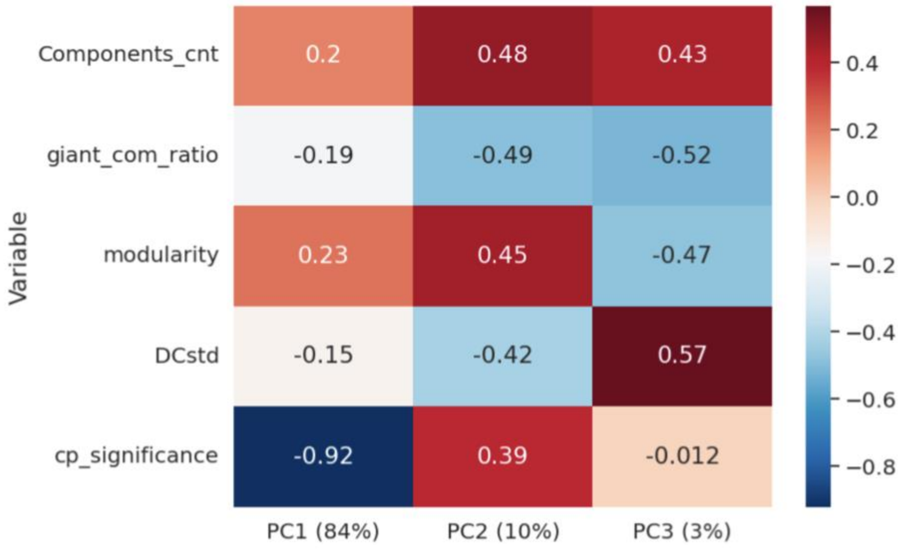
- Results on market returns
- Results on volatility

Results on market returns

Results of the token market returns (USD)



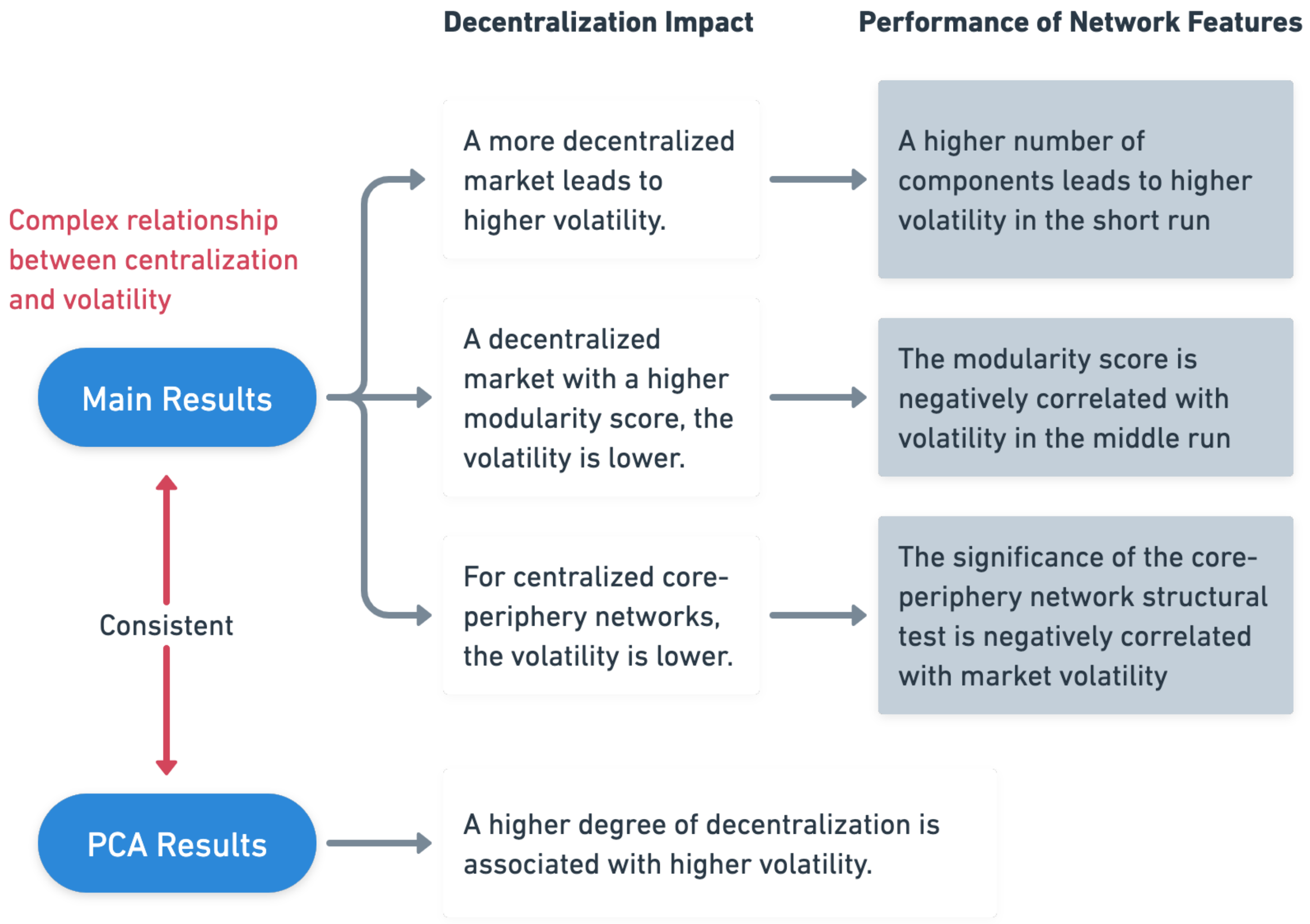
- The level of market centralization predicts token returns **in the long run**; namely, in a more decentralized market, the token returns will be higher.
- PCA: Focusing on Factor 1, which measures decentralization, we find that it is significantly and positively correlated with market returns.



Interpretation of PCA

Results on 30-day volatility

Results of the 30-day volatility growth rate



- A higher number of components is significantly and positively correlated with future market volatility in the short run (7-28 days).
- In a decentralized market with a higher modularity score, the volatility is lower.
- For centralized core-periphery networks, the volatility is lower.
- **PCA:** Considering Factor 1, which is measures the degree of decentralization, we find that a higher degree of decentralization is associated with higher volatility.

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Takeaways

- Conclusions
- Future Research

Conclusions

(1) Application Scenarios

Our methods can be generally applied to transaction tokens issued by other DeFi protocols, such as decentralized payment, exchange, assets, derivatives and even non-financial applications on blockchains.

(2) Research Questions

We can extend our analysis to study the interplay of other network features and economic variables.

For example, one straightforward follow-up research is to extend the analysis to include other network features for which we have provided open-source data as defined in Appendix A of the paper.

(3) Methodology

We can further explore the interplay of network dynamics and token economics by causal inference in advanced econometrics and prediction algorithms in machine learning [Athey, 2015].

Future Research

(1) How incentives affect agents' behavior in transaction network formations?

(2) How incentives affect the final realizations of network decentralization?

- The actually realized decentralization of blockchain transaction network depends on the behavior of stakeholders, which are affected by incentives.
- Design the incentives schemes toward the desired levels of decentralization
- Network game theory [Azouvi and Hicks, 2020]
- Agent-based modeling [Iori and Porter, 2012] to simulate the transaction networks

Working paper:

https://arxiv.org/abs/2206.08401

Data and Code:

https://github.com/Blockchain-Network-Studies/BNS

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Thanks!