

6 October 2026

Is Decentralized Finance Actually Decentralized?

An Interdisciplinary Framework Integrating Network Theory, Agent-Based Simulation, and Longitudinal Evidence from Aave, GHO Issuance, and Cross-Chain Expansion

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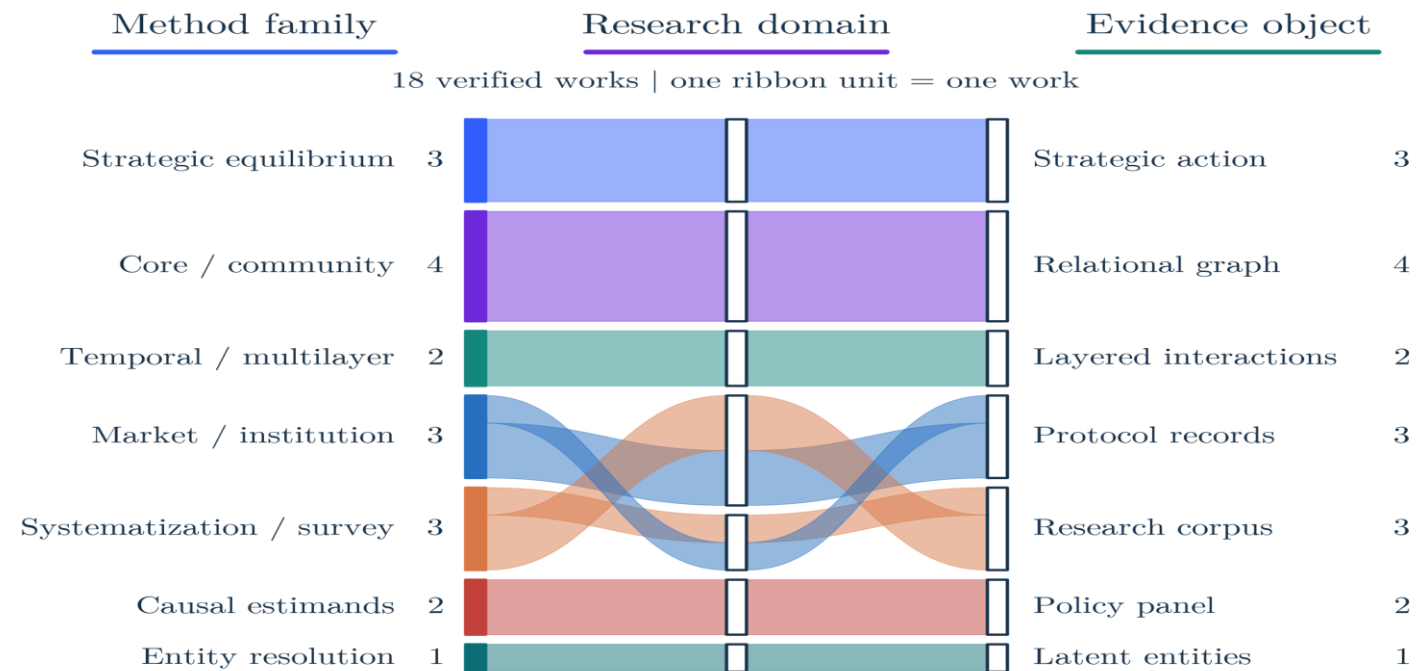
Decentralisation, theory and practice

Three contributions link economics / finance, network science, and blockchain systems.

01 Decentralisation
Four facets with distinct measures and interpretations

02 Theory
Network economics and validated agent-based simulation

03 Practice
Protocol semantics and longitudinal Aave evidence



Middle column = research domain; read its nodes from top to bottom:

1 Network economics · 2 Network structure · 3 Temporal networks

4 DeFi institutions · 5 Stablecoins / interoperability · 6 Policy evaluation · 7 Record linkage

18 selected works; ribbon width counts works. Links show coded scope, not citations.

Four facets can move in different directions

Economics / finance: distribution · network science: structure · systems / law: dependencies and control



Participation

How many addresses take part?

ETH +91.0% ARB +1.7%



Activity distribution

How evenly is observed activity shared?

ETH -31.5% ARB +58.1%



Structural position

Which addresses occupy central roles?

role- and scale-aware evidence



Infrastructure dependence

How much relies on common routes?

additional route data needed

Address-level decentralisation: observed

Participation N_t = distinct active position-holder addresses.

Activity $H_t = \sum_i (n_{it} / \sum_j n_{jt})^2$; n_{it} = holder i 's event count.

Structure = centrality / coreness of the typed address graph.

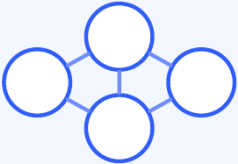
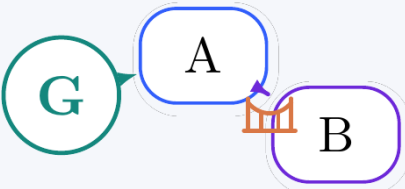
Economic-actor decentralisation

Actor HHI needs verified control links across wallets. Route resilience needs verified activity-to-component links.

Lower event HHI = more even activity; broader address participation does not identify independent decision makers.

An interdisciplinary theoretical integration

Established network-game foundations connect to DeFi benefits, concentration and route dependence

Established foundation	 fixed network G $x^* = (I - \beta G)^{-1}b$	Best responses, stability, path amplification, and centrality follow the classic fixed-network model.
DeFi setting	 $b_i(p)$ varies across actors	Stablecoin access, chain availability, cost, risk, and route dependence enter actors' direct benefits.
New results	 $X \uparrow$ while $H_x \uparrow$ or $\downarrow$  $H_c \downarrow$ while $\max r_k$ varies	The analysis separates aggregate growth from concentration, and chain location from route exposure.
Empirical scope	 Measured breadth; HHI  Needed route data	Address-level breadth and concentration are measured; route resilience requires route-event observations.

What the theory adds to empirical measurement

Inherited equilibrium foundation → context-specific mechanisms → separately testable questions

Inherited result

Unique equilibrium and network multiplier on a fixed influence network.
Ballester et al. (2006); Bramoullé et al. (2014); Jackson et al. (2015).

Our DeFi adaptation

Map stablecoin access, fees and venue availability to direct benefits.
Derive the growth–HHI criterion and chain / route counterexample.

Growth ≠ evenness

Who receives amplified gains?
Activity may rise while HHI falls, stays fixed or rises.

Location ≠ resilience

What do separate venues share?
The same chain shares can hide different component losses.

Theory + evidence

Simulation checks mechanisms.
Measured roles classify patterns.
Causal attribution stays open.

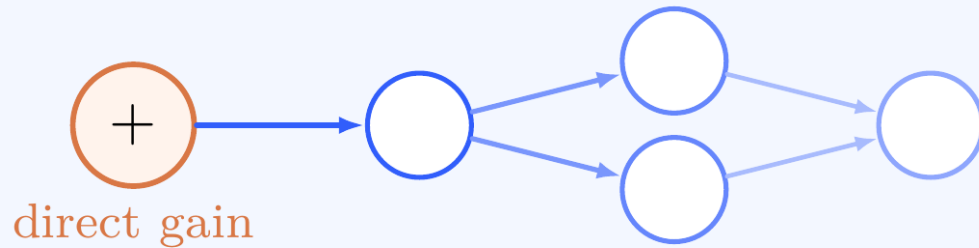
Contribution: joint interpretation across dimensions, matched simulations, and role-aware longitudinal evidence.

Model assumptions and analytical intuition

Fixed $G \geq 0$; positive direct benefits; fixed active set; $\kappa = \beta \rho(G) < 1$ keeps feedback stable.

A. Network effects spread a direct gain

Theorem 1



$$I + \beta G + \beta^2 G^2 + \dots$$

Each term carries the initial gain through a longer path. Stability keeps the sum finite.

I = direct effect; βG = one-step feedback; $\beta^2 G^2$ = two-step feedback; I is the identity matrix.

$$u_i = b_i x_i - \frac{1}{2} x_i^2 + \beta x_i \sum_j g_{ij} x_j$$

$$x_i = \max\{0, b_i + \beta \sum_j g_{ij} x_j\}$$

$x_i \geq 0$: activity; u_i : payoff
 b_i : direct net benefit; β : feedback
 g_{ij} : influence of j on i ; $\sum_j$: sum
 G : influence matrix; $\rho(G)$: spectral radius

Payoff = direct benefit – quadratic activity cost + peer feedback. Entry, exit and rewiring are outside this benchmark.

Network feedback amplifies a local gain

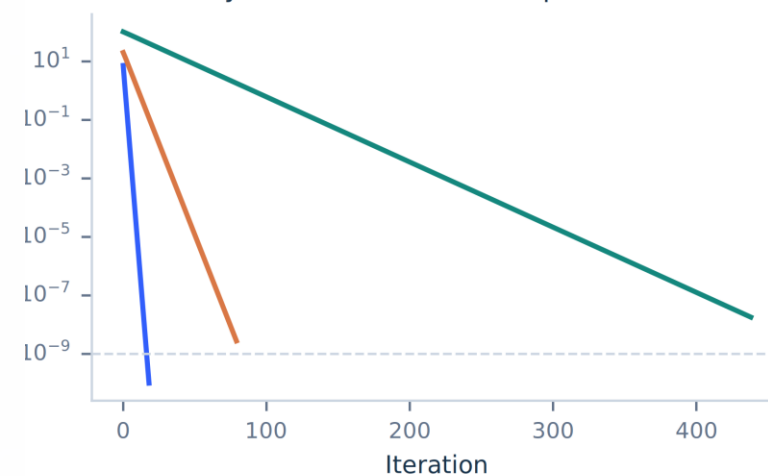
40 synthetic agents repeatedly update activity. The plot measures distance $\|x(t) - x^*\|_2$ from equilibrium.

Trigger: matched targeted benefit



Stronger feedback $\rightarrow$ larger spillovers; slower convergence.
Synthetic influence network $\neq$ observed address-role graph.

Dynamics: distance to equilibrium



$\kappa = 0.25$

$\kappa = 0.75$

$\kappa = 0.95$

$$x^* = (I - \beta G)^{-1}b$$

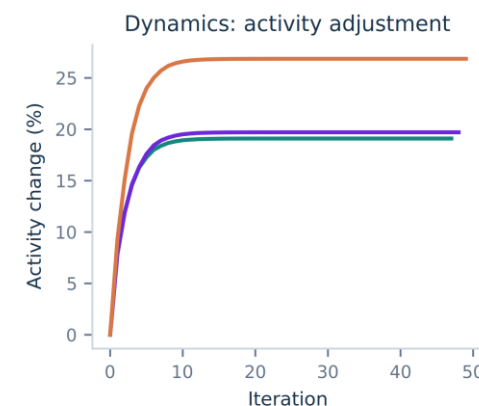
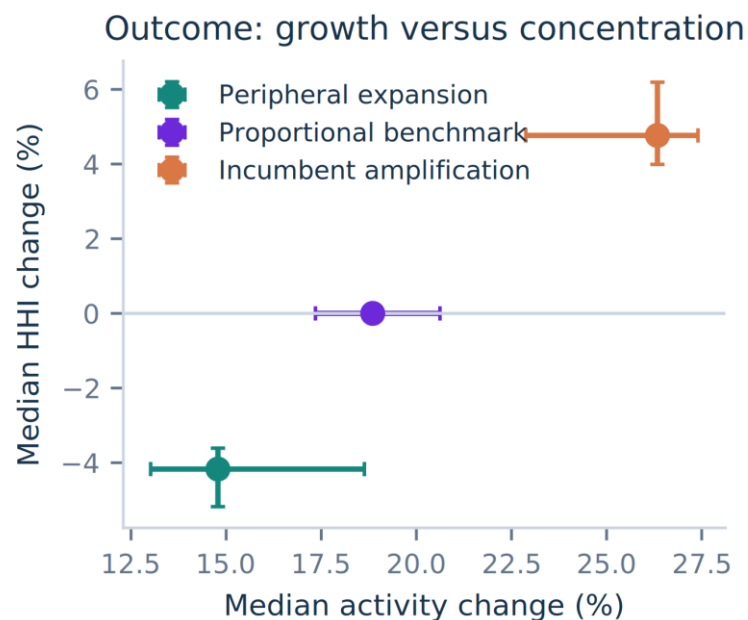
$\kappa = \beta \rho(G) < 1$; $\rho(G) = 1$ here

x^* : equilibrium; b : benefits

I : identity matrix

Growth and concentration can diverge

40 agents; fixed network and active set; $\kappa = 0.75$; equal benefit mass $\sum_i \Delta b_i = 6$; 10 seeds.



$$X = \sum_i x_i; q_i = x_i/X; H_x = \sum_i q_i^2$$

$$dH_x/d\theta = (2/X)\sum_i (q_i - H_x)m_i; m_i = dx_i/d\theta$$

θ = shock size. Weighted sum < 0 / $= 0$ / > 0 :

HHI falls / stays unchanged / rises.

Peripheral: lowest 13 baseline x^* (of 40).

Incumbent: highest 13 baseline x^* .

Proportional: $\Delta b \propto b$; activity shares unchanged.

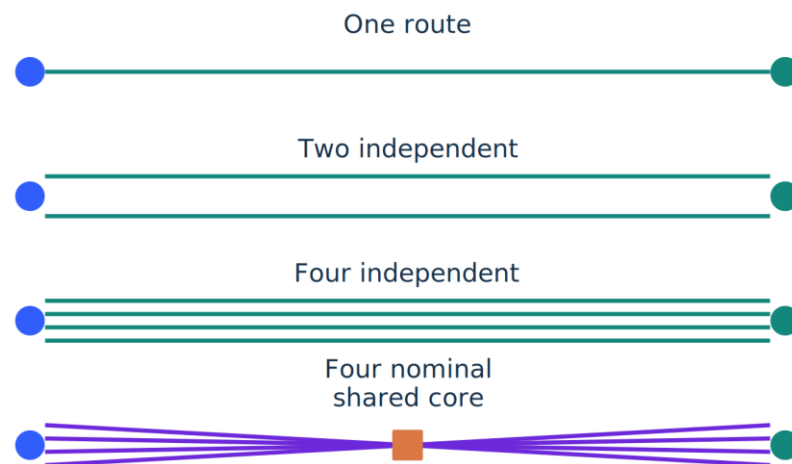
Peripheral: +14.78% activity
-4.17% HHI

Incumbent: +26.34% activity
+4.77% HHI

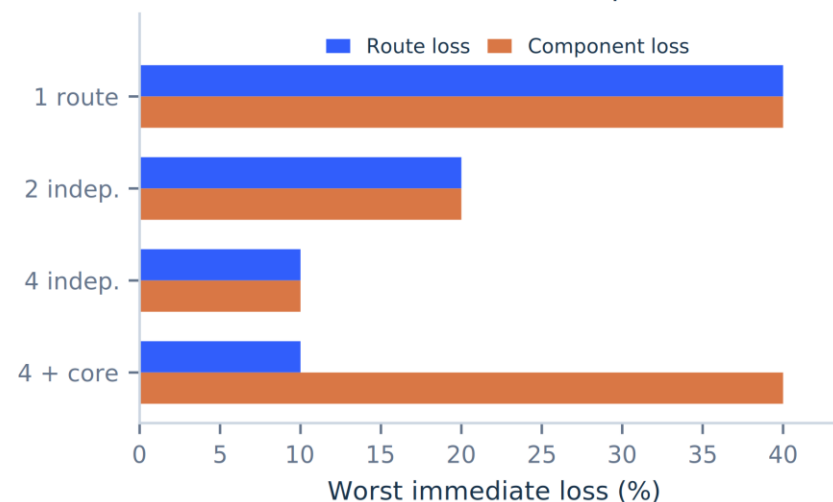
Common components preserve fragility

Synthetic stress test: 60/40 chain shares give $H_c = 0.6^2 + 0.4^2 = 0.52$; component independence varies.

Structures: routes and shared components



Outcome: route versus component loss



100 activity units: 60 stay; 40 use the destination.

4 equal routes $\Rightarrow 40/4 = 10$ units each; no rerouting.

$L = (X - X^f)/X$; X^f = feasible activity after failure.

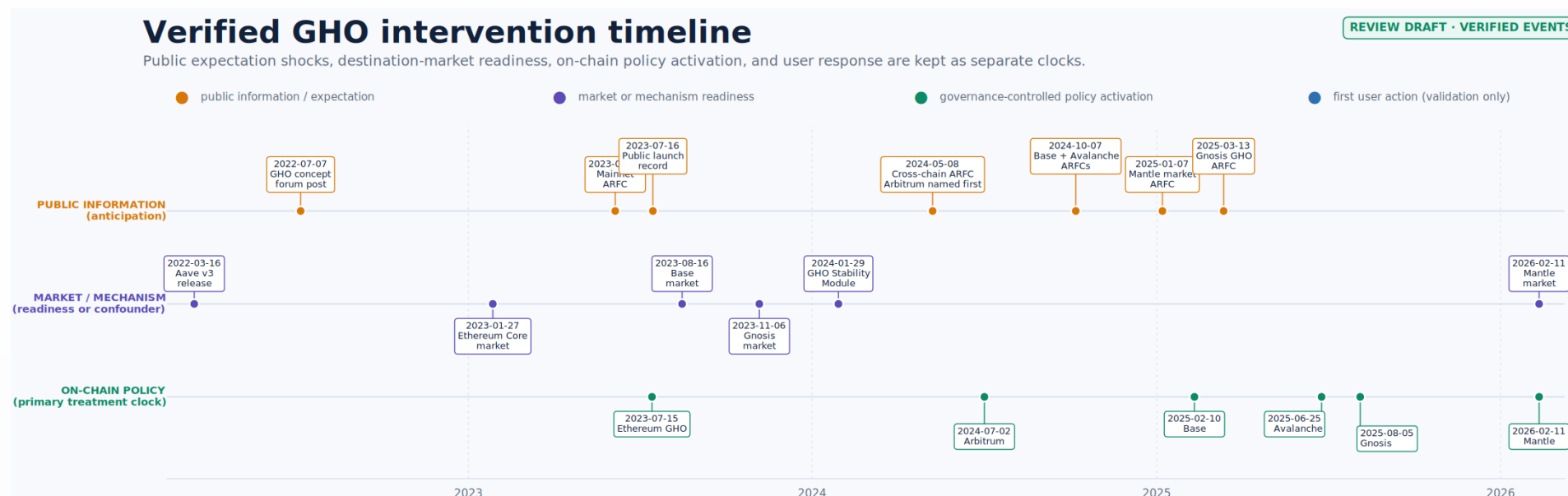
Four routes share one component

One route: $(100-90)/100 = 10\%$

Shared: $(100-60)/100 = 40\%$

Two protocol events, two empirical windows

1,956,216 Aave V3 Pool events across Ethereum and Arbitrum



Market / mechanism = venues, assets, facilitators and route design.

On-chain policy = governance decisions executed to activate or configure those mechanisms.

15 July 2023

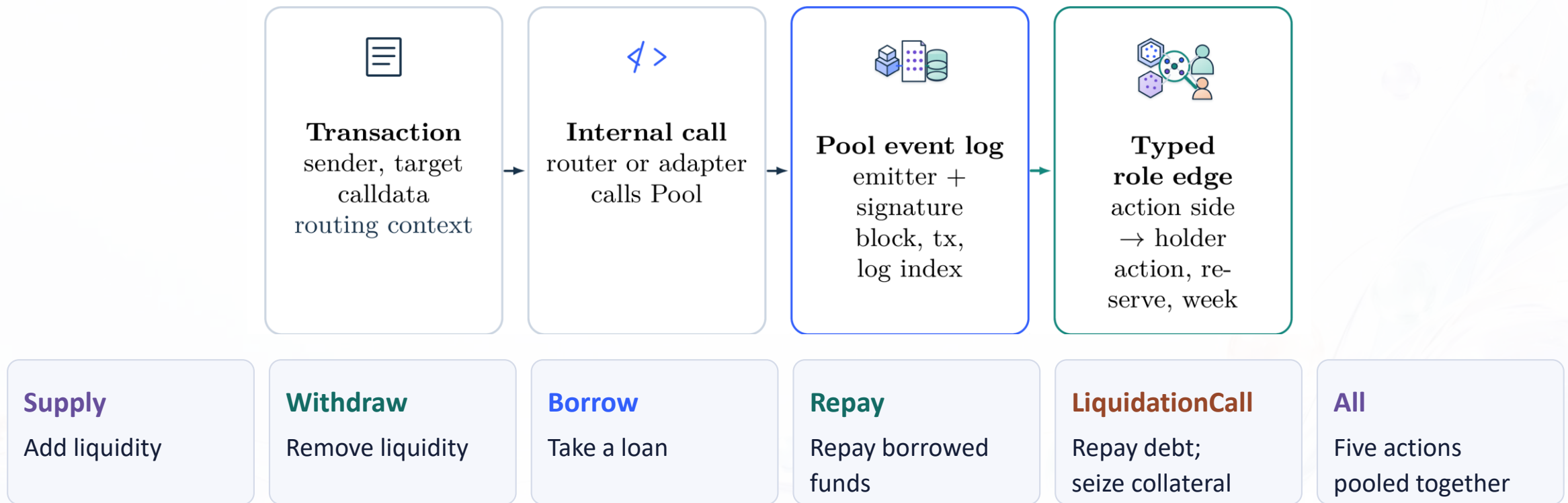
GHO issuance on Ethereum

2 July 2024

GHO in the existing Arbitrum market

Five event types, six analysis views

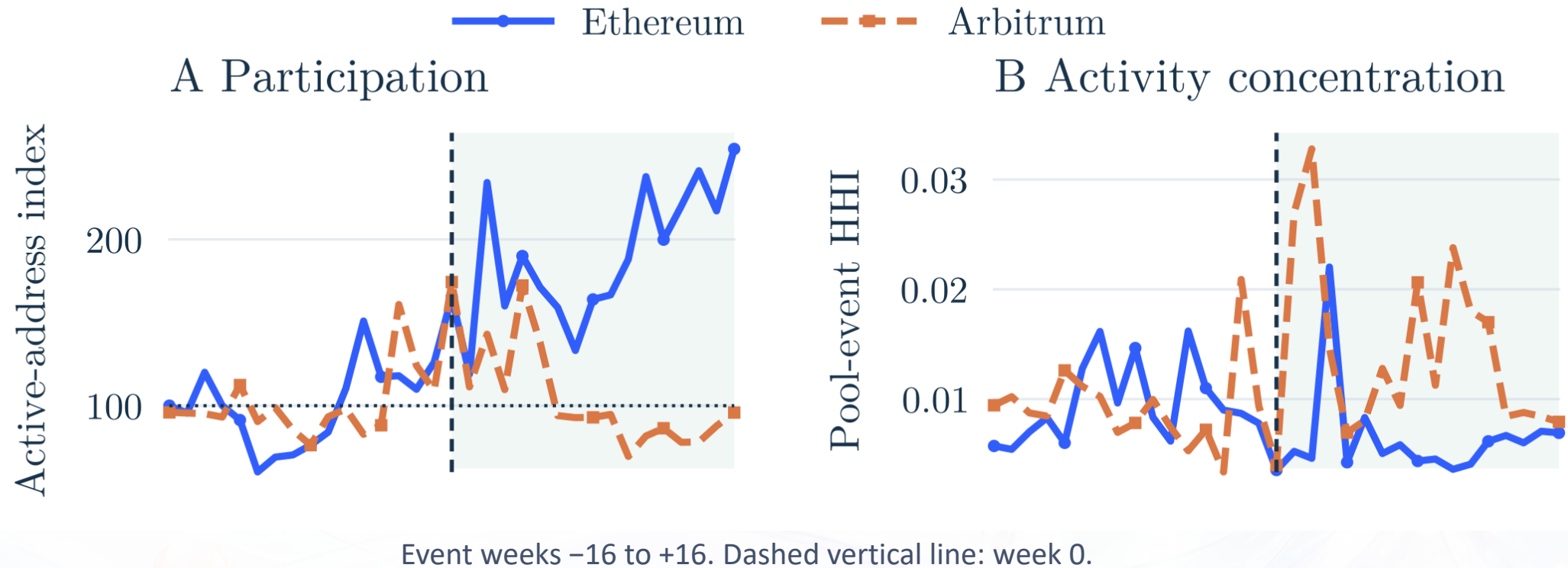
Decoded Pool logs identify the action-side address and position holder; those roles define the network edge.



Takeaway: action-side → holder edges represent protocol roles; transaction senders can differ.

The event windows show different patterns

Original paper participation and HHI trajectories. Different calendar clocks. Descriptive address-level evidence.

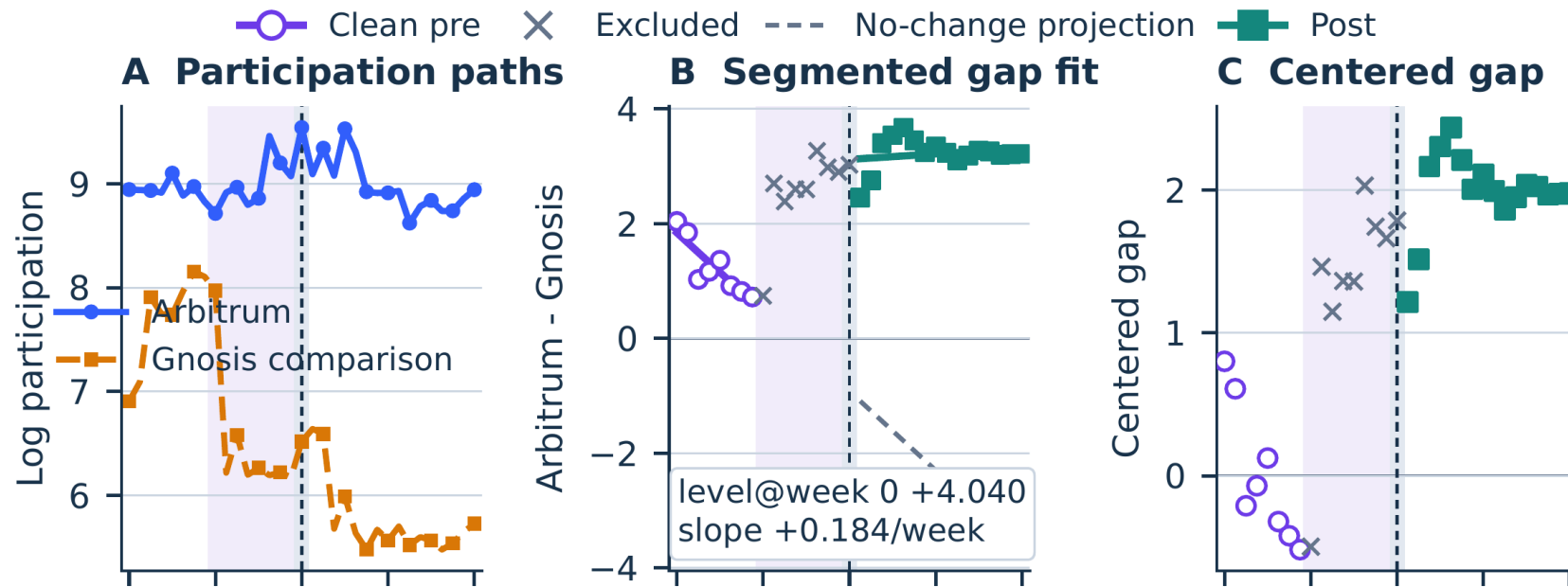


ETH Participation +91.0%
Event-frequency HHI -31.5%

ARB Participation +1.7%
Event-frequency HHI +58.1%

Arbitrum and Gnosis provide a comparative check

Common 2024 calendar. Clean pre-window. Anticipation weeks excluded.



Pre/post mean gaps

Log participation
+1.9833

Activity HHI
-0.01842

HHI rises in both chains

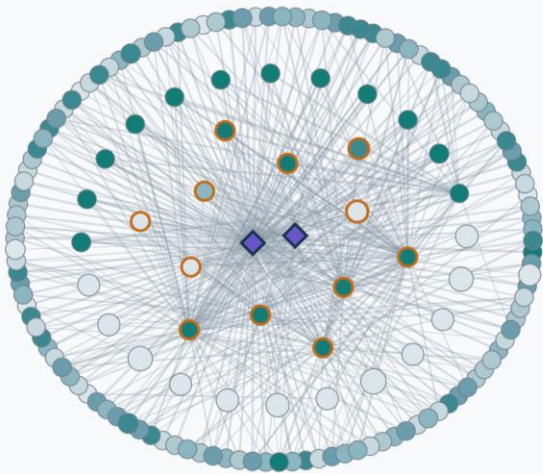
Event weeks -16 to +16. Differential pretrends and anticipation sensitivity limit causal interpretation.

Core position depends on the network definition

Cohesion, directed importance and fitted coreness are distinct; none establishes governing authority.

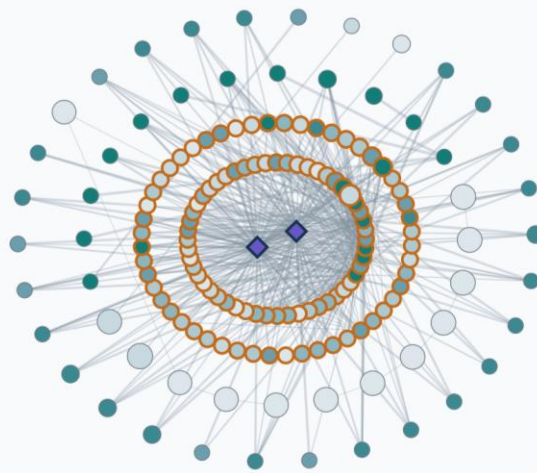
A. Ethereum address-role network

Full graph: 8,891 nodes; max k-core k=6 (14 nodes); BE core: 2
BE-k-core Jaccard 0.143; Rombach-k-core Spearman 0.521



B. Arbitrum address-role network

Full graph: 50,693 nodes; max k-core k=8 (106 nodes); BE core: 2
BE-k-core Jaccard 0.019; Rombach-k-core Spearman 0.578



Rings · k-core (undirected)

$\geq k$ neighbours inside the subgraph.
ETH k=6 (14); ARB k=8 (106).

Diamonds · BE binary core

Borgatti–Everett fits a dense core.
Sparse peripheral ties; 2 nodes/chain.

Size · weighted PageRank

Importance from directed in-links;
important neighbours weigh more.

Fill · Rombach coreness

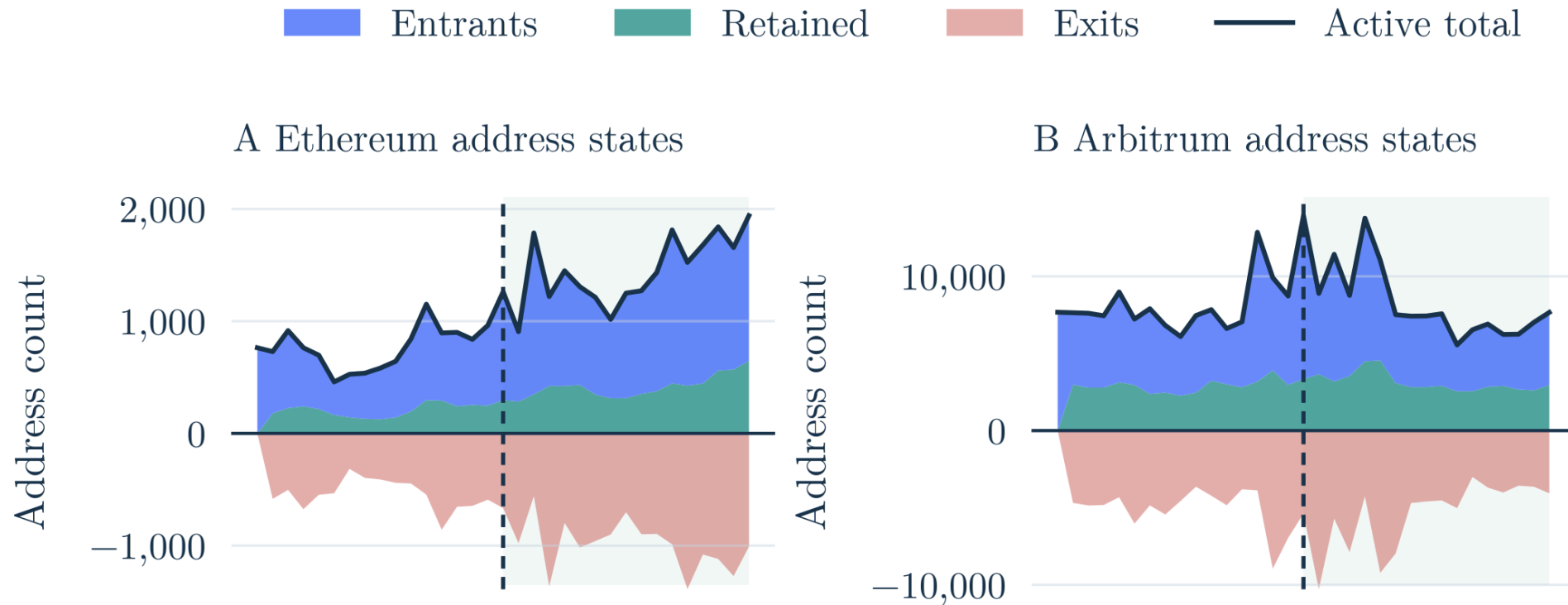
Continuous core–periphery fit;
higher = stronger core position.

160 nodes shown per panel; metrics use full graphs:
ETH 8,891 nodes; ARB 50,693 nodes.

Takeaway: the core depends on the definition. Structural position alone does not establish control.

Participation includes entry, retention and exit

Original paper address-state panels distinguish address-set changes around each event



Event weeks -16 to +16. These are address-set changes, not asset or actor flows.

What evidence should we collect next?

A prospective agenda for economics, blockchain systems, network science and governance

Economics / finance

EVIDENCE

Repeated rollouts + entity panels

METHODS

Cohort comparisons; formation and welfare models

TEST

Does peripheral entry slow concentration growth?

Systems / computation

EVIDENCE

Route + authorization traces

METHODS

Component stress tests; validated agent experiments

TEST

Do independent paths recover, or shared providers spread loss?

Network science

EVIDENCE

Typed temporal + multilayer events

METHODS

Persistent roles; dynamic communities and cascades

TEST

Do cores disperse, persist, or relocate across layers?

AI delegation: many wallets may share one principal, model, strategy or provider.
Measure decision-making concentration only after verifying control and authorization.

All paths are proposed research steps, not completed analyses or observed causal links.

Three mechanisms in an animated walkthrough

A guided tutorial of network feedback, benefit allocation and infrastructure stress

3 COMPARE GROWTH WITH CONCENTRATION

Equal benefit mass • different allocation • median over 10 seeds



Network feedback

Benefit allocation

Shared components

Synthetic mechanisms
25-second tutorial

An interactive empirical network observatory

Explore the evidence, inspect its definitions and trace each result to its provenance



ABSTRACT DISPLAY BACKBONE · RECORDED ORBIT · FIXED GEOMETRY

Ask a question

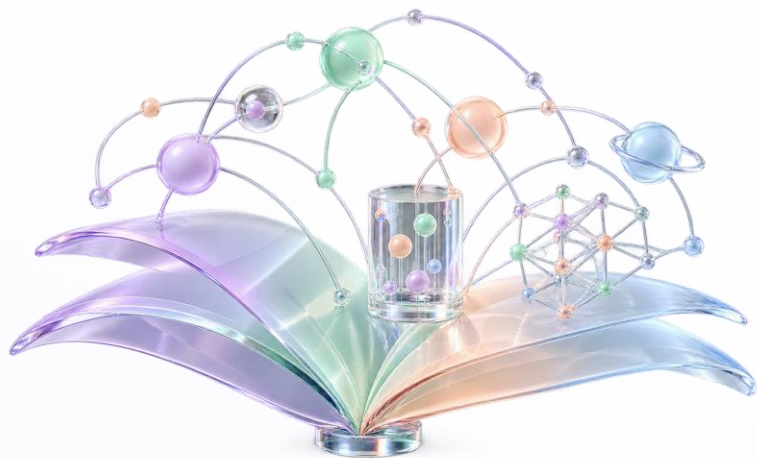
Choose a chain

Inspect the evidence

Trace provenance

Open science for research and teaching

Versioned evidence and interactive learning, open to everyone



Research and education

Potential alignment with the SDGs



Education



Research



Knowledge sharing

un.org/sustainabledevelopment

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Authoritative releases

Research dataset



CC BY 4.0

Reproducible code



MIT

Metadata, provenance, dictionary, checksums
and Responsible AI documentation

Explore and teach

Theory tutorial



Mechanisms +
simulations

Practice tutorial

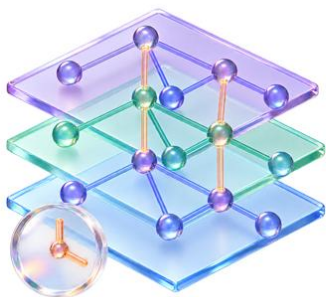


Protocol-network
evidence

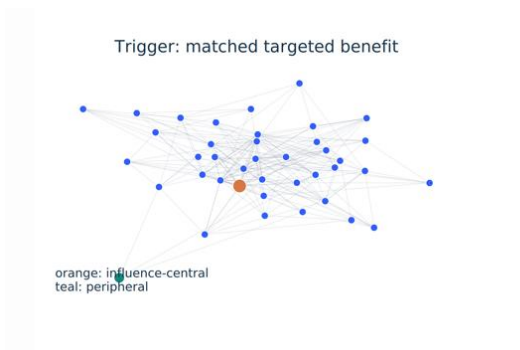
Decentralisation has several dimensions

Network theory, agent-based simulation and longitudinal evidence from Aave

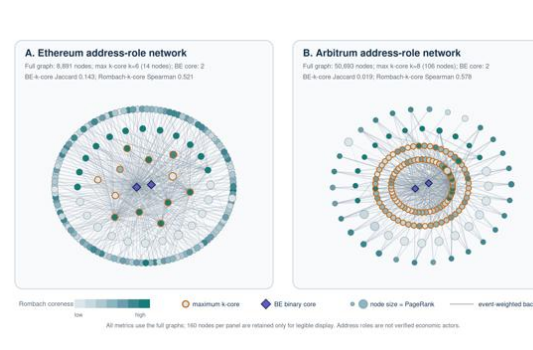
Decentralisation



Theory



Practice



Open science



Four facets

Participation
Activity distribution
Structural position
Infrastructure dependence

Three mechanisms

Inherited multiplier
Recipient-sensitive HHI
Shared-component exposure

1.96M events

Activity HHI: ETH -31.5%
Activity HHI: ARB +58.1%
Descriptive address-level evidence

Research + teaching

Versioned data and code
Two interactive tutorials
Reusable educational resources

Thank you

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