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EDITED BY
Andrea Pinna,
University of Cagliari, Italy

REVIEWED BY
Vangelis Papadimitropoulos,
Panteion University, Greece
Azmat Ullah,
University of Camerino, Italy

*CORRESPONDENCE
Vladimir Kovšca,
vladimir.kovsca@foi.unizg.hr

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Ethereum value formation as a feedback system: an integrative causal-loop framework

Vladimir Kovšca*, Zrinka Lacković Vincek and Suzana Keglević Kozjak

Department of Economics, University of Zagreb Faculty of Organization and Informatics, Varaždin, Croatia

The valuation of decentralized blockchain platforms remains challenging because their native tokens do not represent conventional residual claims and may derive value from several interacting economic mechanisms. This study develops an integrative framework of Ethereum value formation through a mechanism-based conceptual synthesis of the relevant literature. The literature is organized into six principal valuation perspectives: fundamental and on-chain, network-based, monetary and tokenomics, scarcity-oriented, security and staking-based, and behavioral and reflexive approaches. The synthesis indicates that the six perspectives emphasize different but partly overlapping mechanisms of value formation and that none independently explains the interaction among productive activity, adoption, monetary demand, token scarcity, network security, and market expectations. These mechanisms are integrated into a causal-loop framework comprising five reinforcing feedback loops, three balancing feedback loops, and additional productive value-creation pathways that do not form a closed feedback loop. The framework analytically distinguishes ecosystem value creation, ETH-related value capture, and market-price formation while conceptualizing Ethereum as a complex adaptive socio-economic system rather than solely as a conventional productive asset or monetary instrument. The resulting framework provides a theory-building foundation for subsequent stock-and-flow model development, empirical calibration, and comparative application to other blockchain platforms.

KEYWORDS
blockchain valuation, causal loop diagrams, complex adaptive systems, decentralized finance, ethereum, system dynamics, token economics

1 Introduction

1.1 Background and problem context

The rapid expansion of decentralized blockchain platforms has created significant challenges for traditional financial valuation approaches. Unlike conventional corporations, blockchain platforms such as Ethereum do not represent legally incorporated business entities with clearly identifiable shareholders or residual claims on future cash flows. Nevertheless, these networks generate substantial economic activity and attract significant capital inflows, creating a significant theoretical and practical challenge: their economic relevance is evident, but the mechanisms through which this activity contributes to token value cannot be adequately represented by conventional valuation frameworks alone. Existing valuation guidance consequently treats cryptoasset valuation as a

plural field encompassing market, fundamental, network, and cost-based approaches rather than a single settled method (Marin et al., 2023; Soni and Preece, 2023).

However, decentralized blockchain ecosystems fundamentally challenge this distinction. Ethereum participants may simultaneously act as users, validators, speculators, liquidity providers, collateral holders, or long-term investors (John et al., 2024).

Consequently, the economic role of token holders differs substantially from that of traditional shareholders within conventional financial theory (Abadi and Brunnermeier, 2024).

1.2 Existing approaches and research gap

Traditional valuation frameworks face substantial challenges when applied to decentralized blockchain ecosystems (Soni and Preece, 2023). Unlike conventional firms, blockchain platforms generate value through multiple interacting mechanisms that do not fit neatly into standard financial categories. Transaction fees, staking rewards, issuance dynamics, network growth, liquidity demand, collateral usage, and token scarcity may all contribute to value formation, yet each reflects a different underlying economic process (Marin et al., 2023).

As a result, existing blockchain valuation approaches tend to emphasize particular dimensions of ecosystem activity.

Network-based models focus on adoption and network externalities; fundamental and on-chain approaches emphasize transaction activity and protocol-generated revenues; tokenomics models examine transactional demand and velocity dynamics; and scarcity-oriented perspectives highlight supply constraints and token-burning mechanisms (Cong et al., 2021; Eick, 2018; Marin et al., 2023; Papadogiannis, 2025). More recent studies also consider security provisioning and staking participation (Kogan et al., 2021), while behavioral research emphasizes investor attention, expectations, and speculative dynamics (Kukačka and Krištoufek, 2023; Liu and Tsyvinski, 2021). Systems-oriented research has also examined selected relationships within cryptocurrency ecosystems. Zornić et al. (2019) apply System Dynamics to model the cryptocurrency space and the factors influencing cryptocurrency popularity and value. Zhang et al. (2020) develop a formal stochastic-dynamical framework for a generalized token economy involving users, service provision, token value, and block-reward design. Lasi and Saul (2020) focus more narrowly on the feedback between Bitcoin mining incentives and network hash rate, whereas Roozkhosh and Pooya (2024) use System Dynamics to simulate Bitcoin price behavior under news, market sentiment, and government-support scenarios. These studies demonstrate the usefulness of systems-oriented modeling, but their scope is generic, Bitcoin-specific, or restricted to selected cryptoeconomic relationships rather than integrating the principal mechanisms of Ethereum value formation identified across distinct streams of valuation literature. Against this background, the unresolved problem is not the absence of valuation approaches or systems-oriented models, but the limited understanding of how the mechanisms emphasized by these perspectives interact within Ethereum. Productive activity, network adoption, transactional demand, token scarcity, staking participation, and investor expectations are generally examined separately or in partial combinations, even though changes in one mechanism may reinforce or constrain several others. Accordingly, the targeted literature reviewed here did not identify an Ethereum-specific causal-loop representation that integrates these mechanisms within a single value-formation framework.

1.3 Research objective and questions

The objective of this paper is to develop a theory-driven classification of the principal mechanisms of Ethereum value formation and to map the causal relationships among these mechanisms within an integrated causal-loop framework. Specifically, the paper compares six valuation perspectives according to the primary mechanism they emphasize, their representative indicators, value-capture logic, and principal limitations. These perspectives inform six partly overlapping analytical domains—productive activity, adoption and utility, monetary use and liquidity, scarcity and monetary-premium dynamics, staking and network security, and speculative and reflexive dynamics—whose causal relationships are represented through reinforcing and balancing feedback structures.

Consistent with this objective, the paper addresses the following research questions:

RQ1: Which mechanisms of Ethereum value formation are emphasized by existing fundamental and on-chain, network-based, monetary and tokenomics, scarcity-oriented, security and staking-based, and behavioral and reflexive valuation approaches, how do these mechanisms overlap, and what are the principal limitations of each perspective?
RQ2: How can these mechanisms and their interdependencies be represented within an integrated causal loop framework of Ethereum value formation?

1.4 Contribution of the study

The contribution of the paper is therefore not another standalone Ethereum valuation model or a method for estimating a specific token price. Instead, it provides a higher-level conceptual framework that organizes existing valuation approaches according to the mechanisms they explain and makes their interdependencies explicit. Unlike models that isolate individual drivers of value, the proposed framework treats the interaction among mechanisms as the primary unit of analysis. In this way, System Dynamics and causal loop thinking are used to explain how otherwise separate valuation perspectives may operate simultaneously within a complex adaptive blockchain ecosystem.

2 Conceptual approach and framework development

2.1 Research design

This study adopts a theory-building conceptual research design aimed at integrating currently fragmented explanations of Ethereum value formation. The objective is not to conduct a systematic or bibliometric review, rank existing valuation models, or estimate a

specific token price. Instead, the study applies a mechanism-based conceptual synthesis in which the primary unit of analysis is the value-formation mechanism represented by each valuation perspective. The identified mechanisms are subsequently translated into system variables and interconnected through causal-loop modelling. The choice of System Dynamics follows directly from the research question, which concerns the interdependence of value-formation mechanisms and the feedback structures produced by their interaction rather than the isolated effect of individual variables. At this theory-building stage, a causal-loop diagram provides an appropriate qualitative representation because it makes the direction, polarity, and closure of hypothesized causal relationships explicit before numerical functional forms and parameter values are specified (Sterman, 2000). The CLD is therefore not used as an all-inclusive method for measuring Ethereum's overall value, estimating causal effect sizes, or predicting token prices. Its purpose is to formulate a coherent structural hypothesis that can subsequently be examined and extended through complementary stock-and-flow simulation, econometric analysis, agent-based modeling (Wang and Kampakis, 2024), and qualitative inquiry into governance and participant behavior.

2.2 Literature identification and conceptual scope

Relevant literature was identified through targeted searches of the Scopus and Web of Science Core Collection databases conducted on 23 July 2026 and covering publications from 2015 to 2026. Two complementary Scopus TITLE-ABS-KEY searches were used. The first combined platform-related and valuation-related terms: TITLE-ABS-KEY((ethereum OR "blockchain platform*" OR cryptoasset* OR "crypto asset*" OR "utility token*") AND (valuation OR "value formation" OR pricing OR tokenomics OR "fundamental value")). This search returned 411 records. After limiting the results to English-language articles and reviews in Economics, Econometrics and Finance; Business, Management and Accounting; and Decision Sciences, 145 records remained. The second search targeted specific value-formation mechanisms: TITLE-ABS-KEY((ethereum OR "blockchain platform*") AND (staking OR "proof of stake" OR scarcity OR "network effect*" OR velocity OR "on-chain" OR reflexiv* OR "investor attention") AND (value OR valuation OR pricing)). It returned 102 records and 36 after applying the same limits, with Computer Science additionally retained.

In the Web of Science Core Collection, an initial Topic search using (ethereum OR "blockchain platform*" OR cryptoasset* OR "crypto asset*" OR "utility token*") AND (valuation OR "value formation" OR pricing OR tokenomics OR "fundamental value") returned 1,291 records and 380 after limiting the results to English-language articles and reviews published between 2015 and 2026 in the relevant economics, business, finance, management, and operations-research categories. Because this search remained broader than required for the mechanism-oriented synthesis, it was refined to TS=((Ethereum OR "blockchain platform" OR "blockchain platforms") AND (valuation OR "value formation" OR tokenomics OR "fundamental value" OR "intrinsic value")), which produced 57 records after filtering. Because substantial overlap was expected across databases and complementary queries, these query-level counts are not additive. Duplicate records and multiple versions of the same study were consolidated, with the published version preferred where available.

Records were provisionally retained when they directly examined blockchain-platform valuation or addressed a mechanism applicable to Ethereum value formation, including platform adoption, productive network use, monetary demand, token scarcity, protocol security, staking incentives, or market reflexivity. Publications focused exclusively on accounting or taxation, NFT valuation, unrelated blockchain applications, technical price prediction, derivatives, portfolio diversification, short-term volatility, or technical implementation without a direct value-formation link were excluded. The database searches were supplemented by backward and forward citation searching and by targeted consultation of Ethereum Improvement Proposals, working papers, and professional reports when these sources documented protocol mechanisms or recent protocol changes not yet adequately represented in peer-reviewed literature. The objective was to obtain sufficient conceptual coverage of the relevant mechanisms rather than to claim exhaustive coverage of cryptocurrency research.

2.3 Mechanism-based synthesis and CLD development

The identified literature was analyzed according to the primary mechanism through which each approach explains token value, its representative variables, implied value-capture logic, and principal limitations. Conceptually related mechanisms were organized into six perspectives: fundamental and on-chain, network-based, monetary and tokenomics, scarcity-oriented, security and staking-based, and behavioral and reflexive approaches. The classification was therefore based on explanatory logic rather than publication type, statistical method, or model accuracy.

In the second stage, the mechanisms identified in the literature were translated into system variables and directional causal relationships. The directional links were organized into reinforcing and balancing feedback loops where causal closure was theoretically justified. Relationships for which the reviewed literature did not support a sufficiently grounded causal return were retained as open causal pathways, resulting in an integrated causal-loop diagram of Ethereum value formation. The CLD is not presented as an empirically validated pricing model. It constitutes an initial theory-building representation intended to support the subsequent development, calibration, and simulation of a formal System Dynamics stock-and-flow model.

The analytical procedure was interpretive and mechanism-oriented rather than bibliometric. Each source was examined to identify: (1) the principal mechanism through which Ethereum value was explained, (2) the main variables associated with that mechanism, (3) the assumed direction of relationships among those variables, and (4) the explanatory limitations of the respective approach. A candidate mechanism was retained when it provided a conceptually distinct explanation of Ethereum value formation, was recurrent or theoretically central in the reviewed literature, was relevant to Ethereum's institutional or protocol characteristics, and could be connected endogenously to at least one other mechanism.

Variables were retained when they represented a central construct within the respective mechanism, were explicitly identified or theoretically supported by the cited literature, and permitted a directional relationship with another system variable to be specified. Overlapping labels and empirical proxies referring to the same underlying construct were consolidated to preserve conceptual parsimony. Sources addressing conceptually similar mechanisms were grouped into six valuation perspectives. These perspectives informed six partly overlapping analytical domains rather than being mapped one-to-one onto separate subsystems. Relationships reported or theoretically supported in the literature provided the basis for the directional links, whereas their integration into reinforcing loops, balancing loops, and open causal pathways represents the authors' conceptual synthesis. The resulting classification and causal structure were iteratively reviewed for consistency across the valuation typology, analytical domains, causal-link polarity, and feedback-loop interpretation.

2.4 Conceptual distinctions: value, value capture, price, valuation, and demand

To avoid conflating related concepts, this study distinguishes ecosystem value, ETH-related value capture, market price, valuation, and demand for ETH. Ethereum ecosystem value refers to the economic utility generated by the services provided or enabled by the network, including computation, settlement, data availability, collateral infrastructure, and consensus security. ETH-related value capture refers more narrowly to the mechanisms through which ecosystem activity and protocol design affect demand for ETH or the supply of ETH available to market participants, including transaction settlement, staking demand, collateral use, fee burning, and monetary holding. Value capture in this sense does not imply that ETH holders possess a legal residual claim on network revenues.

ETH market price denotes the observable exchange rate at which ETH is traded and may reflect both expectations concerning ecosystem activity and token-specific value-capture mechanisms and speculative or reflexive market forces. Valuation denotes the analytical process of assessing the mechanisms and information relevant to ETH's economic value or market price. Demand for ETH denotes the quantity of ETH that users, validators, investors, and other participants are willing to hold at a given price for transactional, staking, collateral, liquidity, store-of-value, or speculative purposes. It is therefore conceptually distinct from transaction activity, which represents a flow of network use. Accordingly, value formation in this study denotes the interaction among ecosystem value creation, ETH-related value capture, and market-price formation rather than treating these concepts as equivalent.

3 Existing perspectives on blockchain value formation

3.1 Fundamental and on-chain valuation

Fundamental and on-chain valuation models attempt to link blockchain token value to observable economic activity generated within the protocol ecosystem. Similar to traditional fundamental analysis, these approaches assume that network utilization, transaction activity, fee generation, and value-capture mechanisms provide information about the platform's underlying economic significance. Proposed indicators include transaction fees, gas usage, active addresses, transaction volume, validator revenues, staking participation, and other on-chain metrics (Eick, 2018; Nadler and Guo, 2020; Soni and Preece, 2023).

One important branch of this literature adapts traditional discounted cash flow (DCF) logic to blockchain ecosystems. DCF valuation remains one of the most widely used approaches in corporate finance (Tang, 2022). The fundamental principle of DCF is that an asset's value equals the present value of its expected future cash flows discounted at an appropriate rate of return (Gulabyan, 2021). Within traditional firms, these cash flows are ultimately linked to shareholders and creditors possessing legally defined claims on company earnings and assets (Porta et al., 2000).

Applying this logic to decentralized blockchain platforms such as Ethereum raises important conceptual challenges. Ethereum is not a traditional corporation with identifiable equity holders or formal ownership rights over network infrastructure and future revenues (Extance, 2015; Lo and Medda, 2020). Holding ETH does not provide legal entitlement to profits or residual earnings comparable to equity ownership, making the relationship between token ownership and economic value fundamentally different from conventional corporate valuation.

Beyond DCF-based approaches, a growing body of literature employs blockchain-specific indicators as measures of underlying economic activity. Transaction fees, gas consumption, active addresses, transaction volume, total value locked (TVL), token dormancy, and staking participation have been proposed as proxies for protocol utilization and ecosystem development (Eick, 2018; Nadler and Guo, 2020; Pantelidis, 2025). Under this perspective, blockchain-generated data are treated analogously to operating metrics used in traditional firm analysis, providing insight into the intensity of network usage and value-creation processes.

Recent empirical evidence offers only limited and exploratory support for the relevance of these indicators. Using 108 bi-weekly observations for Ethereum between August 2021 and September 2025, Mohammad et al. (2026) report a long-run statistical association between ETH price and several tokenomic variables. In their estimates, total value locked shows the strongest positive association with ETH price, while token unlocks show a negative association; transaction fees and token burning also carry positive coefficients. However, the limited sample size and severe multicollinearity, particularly between transaction fees and token burning, restrict the extent to which individual effects or causal mechanisms can be inferred. Governance concentration, proxied by the Gini coefficient, is not statistically significant. The study therefore provides suggestive rather than conclusive evidence that productive activity, scarcity, and ecosystem participation are associated with ETH price.

Although fundamental and on-chain approaches establish a closer connection between token valuation and observable economic activity, they face an important challenge. The relationship between protocol-level activity and token-holder value capture is often indirect and institutionally ambiguous.

Consequently, these models provide valuable insight into productive dimensions of blockchain ecosystems but may capture only one component of a broader value formation process that also involves monetary utility, network effects, security participation, scarcity mechanisms, and behavioral expectations.

3.2 Network-based valuation approaches

Network-effects models represent one of the most influential streams of blockchain valuation literature. Unlike fundamental approaches that emphasize protocol-generated economic activity, network-based models view value as emerging from the growth and connectivity of ecosystem participants. The underlying premise is that the utility and economic significance of a blockchain network increase as more users, developers, validators, and applications join the ecosystem, creating positive network externalities (Cong et al., 2021; Scala and Delmastro, 2023).

The theoretical foundation of many network-based valuation models can be traced to Metcalfe's Law, which proposes that the value of a network is related to the number of connected users. Cryptocurrency studies commonly operationalize network size through active addresses, transaction participants, or user-adoption measures, although the exact functional form need not follow the simple squared-user formulation (Scala and Delmastro, 2023; Wang et al., 2023). In token markets, dynamic models further show that user network externalities can generate S-shaped adoption and feedback between adoption and token prices (Cong et al., 2021).

Subsequent research extended these models by incorporating additional indicators of ecosystem growth, including transaction volume, developer activity, smart contract deployment, decentralized application usage, and Layer-2 adoption. Under this perspective, network expansion itself becomes a primary driver of value creation, independent of short-term revenue generation or token scarcity mechanisms.

Despite their explanatory power, network-based models primarily capture adoption and ecosystem growth while providing limited insight into how network participation is translated into token-holder value. Adoption indicators alone do not fully account for monetary utility, staking incentives, security provision, scarcity dynamics, or speculative expectations. Network effects should therefore be interpreted as one mechanism of Ethereum value formation rather than as a self-contained valuation explanation. This limitation motivates the consideration of monetary and tokenomics models, which focus more directly on transactional demand, token utility, and monetary circulation.

3.3 Monetary and tokenomics models

Monetary and tokenomics models explain blockchain value through the economic functions performed by native tokens within decentralized ecosystems. Unlike fundamental approaches that focus on protocol-generated activity or network models that emphasize adoption and connectivity, these frameworks view token value as emerging from transactional demand, liquidity provision, monetary utility, and participation in platform-specific economic processes. Token demand may arise when users, applications, or intermediaries acquire or hold native tokens for fees, settlement, collateral, liquidity provision, or other platform-specific functions. However, fee abstraction, Layer-2 architecture, and alternative settlement assets can weaken the relationship between ecosystem activity and end-user token holdings, which may also reflect speculative motives (Cong et al., 2021; Prat et al., 2025). Several theoretical contributions model token value as a function of transactional demand, velocity, and platform growth. Cong et al. (2021) derive token value by aggregating heterogeneous users' transaction demand rather than discounting conventional cash flows, while Prat et al. (2025) endogenize token velocity through a utility-token access constraint. Empirical work on Ethereum further shows that velocity is heterogeneous across addresses and transaction types, complicating the use of a single aggregate velocity parameter (Collibus et al., 2025). Recent work has also refined the equation-of-exchange approach by empirically examining the relationship between token velocity and holding time (Kampakis et al., 2024).

While monetary and tokenomics models provide valuable insight into liquidity demand and token utility, they capture only one dimension of blockchain value formation. Transactional demand alone may not fully account for network security incentives, adoption feedback loops, speculative expectations, or broader social coordination processes that influence blockchain ecosystems.

Furthermore, monetary demand within blockchain ecosystems may itself depend on endogenous expectations regarding future adoption and platform growth (Cong et al., 2021). Consequently, monetary valuation mechanisms cannot easily be isolated from broader network and behavioral dynamics. From a systems perspective, monetary demand is therefore treated as a mechanism within the monetary use and liquidity domain that interacts with adoption, security, productive, scarcity, and reflexive dynamics rather than as a separate subsystem or standalone determinant of value.

3.4 Scarcity and monetary premium models

Scarcity and monetary-premium models explain token value through supply-side mechanisms and the ability of digital assets to function as stores of value. Unlike fundamental approaches that emphasize economic activity or tokenomics models that focus on transactional demand, scarcity-based perspectives argue that value may emerge from constrained access, predictable issuance, and expectations of future scarcity (Papadogiannis, 2025; Soni and Preece, 2023). This line of reasoning is particularly prominent in cryptocurrency markets, where supply design, demand conditions, and collective narratives jointly influence valuation (Marin et al., 2023).

Within Ethereum, scarcity-based arguments gained prominence following EIP-1559, which burns the base-fee component of transaction fees (Buterin et al., 2019). Together with the lower consensus issuance following Ethereum's transition to Proof-of-Stake, this mechanism permits periods of low or negative net issuance when protocol burning exceeds issuance (John et al., 2024). This outcome is not permanent: evidence following the Dencun upgrade indicates that lower fee pressure and reduced ETH burning after EIP-4844 produced a net inflationary environment during parts of 2024 and 2025 (CME Group and Glassnode, 2025). Ethereum's supply dynamics should therefore

be interpreted as state- and protocol-dependent rather than as structurally deflationary. Under this perspective, constrained net supply combined with sustained ecosystem demand may contribute to a monetary premium, although scarcity is economically meaningful only in conjunction with desirability and demand (Papadogiannis, 2025).

Although scarcity-based models capture an important dimension of cryptoasset value formation, scarcity alone cannot fully explain token valuation. Supply constraints may influence prices only when accompanied by sustained demand arising from network participation, economic activity, liquidity needs, security incentives, or investor expectations. Consequently, scarcity mechanisms are difficult to analyze in isolation and may be better understood as interacting with broader adoption, monetary, and behavioral dynamics operating within decentralized blockchain ecosystems.

3.5 Security and staking-based models

Security and staking-based approaches view token value as partly deriving from the role of the native asset in securing decentralized consensus. Under Proof-of-Stake systems, validators stake tokens and receive compensation for verification and consensus services, directly connecting token holdings, protocol cash flows, and network security (Kogan et al., 2021). Consequently, demand for the native token may arise not only from transactional or investment motives but also from the need to provide economic security for the network.

Ethereum's transition from Proof-of-Work to Proof-of-Stake increased the economic importance of staking within the ecosystem. Staked ETH is committed to consensus participation and earns protocol rewards, linking the valuation of ETH to validator incentives and the security budget (John et al., 2024; Kogan et al., 2021). Staking can therefore influence value through security provision, reward cash flows, and temporary reductions in immediately liquid supply.

Despite their relevance, security-based valuation perspectives remain less developed than network, monetary, and scarcity-oriented approaches. Existing work often analyzes staking through validator incentives, yield, token lock-up, or security constraints, while the joint relationship among staking, network security, adoption, and token demand involves feedback effects that static frameworks capture only incompletely (Kogan et al., 2021; Oderbolz et al., 2024). Security mechanisms may therefore be more appropriately viewed as an interacting component of a broader blockchain value-formation system.

3.6 Behavioral and reflexive models

Behavioral and reflexive approaches explain blockchain valuation through investor expectations, market sentiment, social narratives, and collective belief formation. Cryptocurrency returns exhibit strong links with market-specific momentum and investor attention, while empirical studies also identify separable fundamental and speculative components in pricing dynamics (Kukačka and Krištoufek, 2023; Liu and Tsyvinski, 2021). Participants therefore make decisions not only on the basis of current utility but also on beliefs regarding future adoption, technological development, regulatory acceptance, and market sentiment.

This perspective is closely related to reflexivity: market participants' beliefs and actions can influence the outcomes they seek to predict. Rising token prices may attract investor attention and media coverage, reinforcing speculative inflows and optimistic beliefs; declining prices can reverse the same mechanisms (Benetton and Compiani, 2024; Li et al., 2022; Liu and Tsyvinski, 2021). Such feedback can generate self-reinforcing cycles that are difficult to reconcile with valuation models based solely on contemporaneous protocol fundamentals.

Behavioral mechanisms appear particularly relevant within decentralized blockchain ecosystems, where uncertainty about future adoption, technological innovation, and institutional acceptance remains high. Expectations regarding future utility can influence current demand, while narratives involving scarcity, decentralization, or technological superiority may shape holding and investment decisions (Marin et al., 2023).

Although behavioral and reflexive models provide important insights into market dynamics, they often struggle to distinguish between temporary speculative fluctuations and sustainable sources of value creation. Consequently, expectations and sentiment may be better interpreted as interacting with productive activity, network growth, monetary demand, security participation, and scarcity mechanisms rather than serving as independent determinants of value.

Table 1 compares the valuation approaches according to the primary value-formation mechanism they emphasize, the variables they typically employ, and their principal explanatory limitations. Because the categories are partly overlapping, the final column identifies the primary analytical domain emphasized by each approach rather than assigning each perspective to a separate subsystem or feedback loop. Table 1 illustrates that existing blockchain valuation approaches emphasize different mechanisms of value formation rather than competing explanations of a single phenomenon. While each stream contributes valuable insights, none fully captures the interaction between productive activity, adoption, monetary demand, scarcity, security provision, and behavioral dynamics. This observation motivates the adoption of a systems-oriented perspective capable of integrating these mechanisms within a broader framework of decentralized ecosystem evolution.

3.7 Blockchain platforms as complex adaptive systems

The limitations of isolated valuation approaches suggest that decentralized blockchain platforms may be more appropriately understood as complex adaptive socio-economic systems rather than purely productive firms or monetary instruments. Ethereum simultaneously operates as transactional infrastructure, a settlement layer, a collateral asset, a staking mechanism, a speculative instrument, and a monetary-like reserve asset (John et al., 2024). These overlapping functions generate interacting mechanisms of value formation that cannot easily be captured by a single valuation framework (Cesaretti, 2025; Marin et al., 2023). A recent capability-based framework likewise emphasizes that blockchain value depends on interacting capabilities, tokenomics, incentives, and network effects rather than on a single valuation determinant

TABLE 1 Mechanism-based classification of Ethereum valuation approaches and primary analytical domains.

Valuation approach	Primary value formation mechanism	Representative variables	Key strength	Main limitation	Primary analytical domain
Fundamental and on-chain models	Economic activity and value capture	Transaction fees, gas consumption, validator revenues, transaction volume, TVL	Links valuation to observable protocol activity	Ambiguous relationship between protocol activity and token-holder value capture	Productive activity
Network effects models	Ecosystem growth and network externalities	Active users, active addresses, developers, transactions	Captures adoption-driven value creation	Limited explanation of value capture mechanisms	Adoption and utility
Monetary and tokenomics models	Transactional demand and token utility	Velocity, liquidity demand, transaction demand, token utility	Explains demand for token holdings	Often overlooks security and behavioral dynamics	Monetary use and liquidity
Scarcity and monetary premium models	Supply constraints and store-of-value demand	Burn rate, issuance rate, circulating supply, net issuance	Captures supply-side valuation effects	Demand-side mechanisms often underrepresented	Scarcity and monetary-premium dynamics
Security and staking models	Consensus security and validator participation	Staked ETH, staking ratio, validator rewards, security budget	Links token demand to network security	Limited treatment of adoption and monetary utility	Staking and network security
Behavioral and reflexive models	Expectations, narratives, and social coordination	Market sentiment, media attention, speculative demand, expectations	Explains self-reinforcing market dynamics	Difficult to distinguish speculation from sustainable value creation	Speculative and reflexive dynamics

TVL, total value locked; ETH, Ether. The categories represent a mechanism-based conceptual typology and are not intended as mutually exclusive or exhaustive empirical classifications. The assignment of a primary analytical domain indicates the mechanism most strongly emphasized by each approach and does not imply one-to-one correspondence with a separate subsystem or feedback loop.

(Papadogiannis, 2026). Complex adaptive systems are characterized by endogenous interactions, feedback, adaptive behavior, nonlinear dynamics, and evolving structures (Phillips and Ritala, 2019). System Dynamics (SD) offers an appropriate organizing framework because it focuses on feedback structures, endogenous behavior, and system evolution over time (Sterman, 2000). Rather than replacing existing valuation approaches, SD can clarify how the mechanisms emphasized by different theories interact within a broader ecosystem.

Causal loop diagrams (CLDs) are commonly used in SD to visualize feedback structures and distinguish reinforcing from balancing mechanisms (Sterman, 2000). In the context of Ethereum, CLDs can link the major value-formation mechanisms identified in the literature, including productive activity, network growth, monetary utility, scarcity dynamics, security participation, and behavioral expectations. By representing interactions among these mechanisms explicitly, CLDs provide a conceptual foundation for an integrated account of blockchain value formation. A systemic representation is also consistent with tokenomics-auditing approaches, which emphasize that token allocation, participant incentives, demand drivers, sell pressure, external shocks, and feedback loops should be assessed jointly rather than as isolated design parameters. Kampakis and Stankevičius (2023) demonstrate this logic through applications to DeFi projects, Terra/Luna, and Ethereum 2.0. Their checklist is not a validated token-pricing model, but it provides additional conceptual support for examining token economies as interconnected structures whose resilience depends on interactions among multiple mechanisms.

The preceding discussion suggests that the principal streams of blockchain valuation literature emphasize different but partly overlapping mechanisms within a broader decentralized ecosystem. This observation motivates the development of a causal-loop framework that maps the feedback relationships among productive activity, adoption and utility, monetary use and liquidity, scarcity and monetary-premium dynamics, staking and network security, and speculative and reflexive dynamics.

4 Proposed systemic value formation framework

4.1 Framework structure

The proposed framework conceptualizes Ethereum value formation as an emergent outcome of interacting and partly overlapping mechanisms. Rather than treating the six valuation perspectives reviewed above as competing explanations or mapping each of them onto a separate subsystem, the framework draws on them to identify causal structures that operate across the Ethereum ecosystem. The complex-adaptive-systems perspective introduced in Section 3.7 provides the integrating logic for representing these interactions.

Building on the reviewed literature, the framework organizes the relevant mechanisms into six analytical domains: productive activity, adoption and utility, monetary use and liquidity, scarcity and monetary-premium dynamics, staking and network security, and speculative and reflexive dynamics. These domains do not correspond one-to-one to feedback loops. The resulting causal-loop structure contains five reinforcing loops (R1–R5), three balancing loops (B1–B3), and additional productive value-

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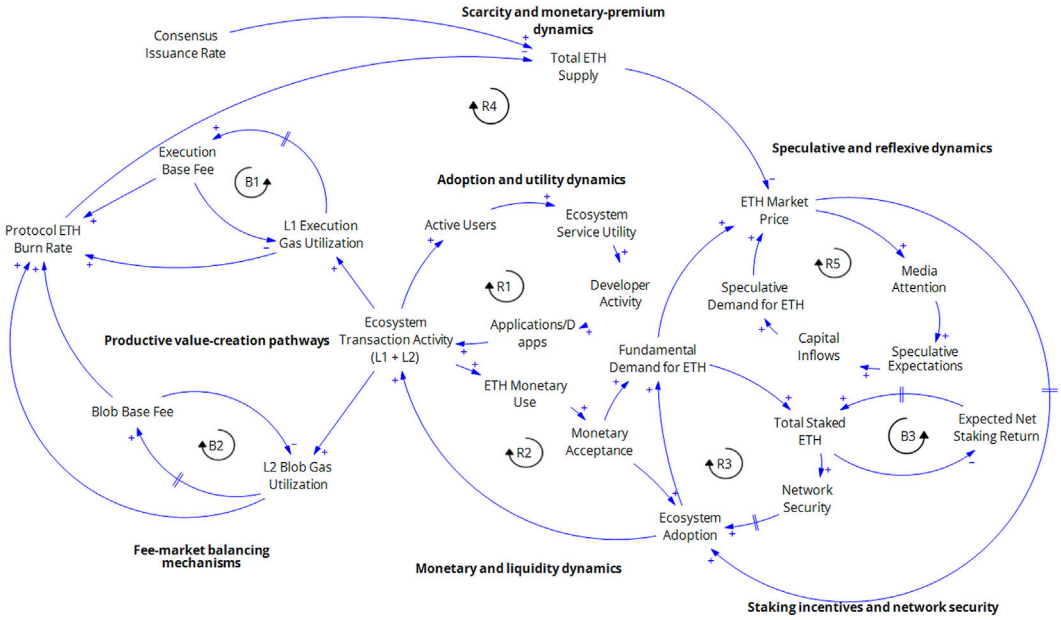


FIGURE 1
Integrated Causal Loop Framework of Ethereum Value Formation. Source: Authors' own elaboration based on the mechanism-based conceptual synthesis, created using Vensim PLE. Note: Arrows represent causal relationships assembled through the mechanism-based conceptual synthesis; Table 2 identifies the supporting source(s) and relationship basis for each link. A plus sign (+) indicates that the variables change in the same direction, whereas a minus sign (–) indicates that they change in opposite directions, all else being equal. Double-slash marks (//) denote material time delays; R and B denote reinforcing and balancing feedback loops, respectively. Total ETH Supply and Total Staked ETH are treated as stock-like accumulations; Consensus Issuance Rate and Protocol ETH Burn Rate are supply flows, while the remaining variables represent rates, activities, expectations, or auxiliary constructs. The link from Ecosystem Transaction Activity to L2 Blob Gas Utilization operates through rollups' submission of batched data to Ethereum. Expected Net Staking Return comprises issuance-based consensus rewards, priority fees, and potential MEV, net of penalties and slashing risk. Formal stock-and-flow notation is reserved for subsequent model development.

creation pathways that are not represented as a closed loop. Reinforcing mechanisms may amplify both increases and decreases, whereas the balancing mechanisms regulate L1 execution-gas utilization, L2 blob-gas utilization, and staking participation through endogenous fee and return adjustments. Ethereum value formation is therefore conceptualized as the joint outcome of ecosystem value creation, ETH-related value capture, security provision, and market-price dynamics rather than as the result of any single valuation determinant.

Figure 1 integrates these mechanisms within the proposed causal-loop framework. To preserve the conceptual distinctions introduced above, the diagram represents ecosystem service utility, fundamental demand for ETH, speculative demand for ETH, and ETH market price as analytically separate variables. This separation is consistent with token-platform models that connect user utility and adoption to token demand and price while allowing user optimism and speculative sentiment to affect participation and market outcomes differently (Cong et al., 2021; Sockin and Xiong, 2023). Accordingly, a change in ETH market price need not indicate a contemporaneous change in ecosystem service utility or in the mechanisms through which ETH captures value. The diagram should not be interpreted as a direct pricing model or as an empirically validated representation. Instead, it illustrates the hypothesized feedback structures through which value may be formed within the Ethereum ecosystem and provides a conceptual foundation for subsequent formal model development.

To make the basis of the individual links transparent, Table 2 lists each causal relationship shown in Figure 1 together with its polarity and delay, supporting source(s), and relationship basis. It thereby distinguishes protocol-defined and literature-supported relationships from links introduced as part of the authors' conceptual synthesis.

4.2 Reinforcing and balancing feedback mechanisms

The proposed causal-loop structure differentiates mechanisms by their primary analytical function rather than treating them as equivalent sources of value or as mutually exclusive subsystems. The productive value-creation pathways and R1 primarily represent ecosystem service creation through developer activity, applications, user participation, and transaction activity. R2 and R4 represent channels through which ecosystem use and protocol design affect ETH monetary use, demand, burn, supply, and market price, and therefore concern ETH-related value capture rather than ecosystem value creation alone. R3, together with B3, represents the interaction among staking incentives, total staked ETH, network security, and adoption. R5 represents speculative market-price amplification and may operate without a contemporaneous change in ecosystem service utility or fundamental demand. B1 and B2 represent endogenous fee adjustments in the separate L1 execution-gas and L2 blob-gas markets. Because these mechanisms interact and overlap, the labels identify their

TABLE 2 **Causal relationships, polarities, delays, and evidentiary basis of the proposed framework.**

Loop/ path	Causal relationship	Polarity/ delay	Supporting source(s)	Relationship basis
R1	Active users - > ecosystem service utility	+	Cong et al. (2021); Scala and Delmastro (2023)	Prior literature (theoretical network effects)
R1	Ecosystem service utility - > developer activity	+	Cong et al. (2021); Scala and Delmastro (2023)	Authors' synthesis (literature-informed)
R1	Developer activity - > Applications/dApps	+	Eick (2018); Soni and Preece (2023)	Authors' synthesis (literature-informed)
R1/productive path	Applications/dApps - > ecosystem transaction activity (L1+L2)	+	Eick (2018); Soni and Preece (2023)	Authors' synthesis (literature-informed and conditional on application use)
R1	Ecosystem transaction activity (L1+L2) - > active users	+	Cong et al. (2021); Moncada et al. (2024)	Mixed theoretical and associational evidence; causal direction proposed
R2	Ecosystem transaction activity (L1+L2) - > ETH monetary use	+	Cong et al. (2021); Prat et al. (2025); Buterin et al. (2022)	Authors' conditional synthesis, particularly for L2 activity
R2	ETH monetary use - > monetary acceptance	+	Cong et al. (2021); Prat et al. (2025)	Prior literature (theoretical)
R2	Monetary acceptance - > ecosystem adoption	+	Cong et al. (2021); Prat et al. (2025)	Authors' synthesis (literature-informed)
R2/R4	Ecosystem adoption - > ecosystem transaction activity (L1+L2)	+	Cong et al. (2021); Scala and Delmastro (2023)	Prior literature (theoretical platform-adoption mechanism)
Cross-domain	Monetary acceptance - > fundamental demand for ETH	+	Cong et al. (2021); Prat et al. (2025)	Prior literature (theoretical)
R3	Ecosystem adoption - > fundamental demand for ETH	+	Cong et al. (2021); Prat et al. (2025)	Prior literature (theoretical); Ethereum application proposed
R3	Fundamental demand for ETH - > total staked ETH	+	John et al. (2024); Kogan et al. (2021)	Authors' synthesis (conditional allocation-to-staking assumption)
R3	Total staked ETH - > network security	+	Kogan et al. (2021); Oderbolz et al. (2024); Ethereum.org (2026)	Prior literature and protocol-security logic
R3	Network security - > ecosystem adoption	+; delayed	Kogan et al. (2021); Oderbolz et al. (2024)	Authors' proposed delayed link; no direct Ethereum-specific causal estimate
B3	Expected net staking return - > total staked ETH	+; delayed	John et al. (2024); Kogan et al. (2021); Oderbolz et al. (2024)	Prior literature (economic incentive mechanism)
B3	Total staked ETH - > expected net staking return	-	John et al. (2024); Ethereum.org (2026)	Protocol-defined reward-rate relationship, holding other revenue components constant
Price link	Fundamental demand for ETH - > ETH market price	+	Cong et al. (2021); Nadler and Guo (2020); Prat et al. (2025)	Prior literature (theoretical valuation relation)
Productive path/R4	Ecosystem transaction activity (L1+L2) - > L1 execution gas utilization	+	Buterin et al. (2019); Soni and Preece (2023)	Authors' protocol-informed mapping; conditional on L1 execution demand
B1	L1 execution gas utilization - > execution base fee	+; protocol lag	Buterin et al. (2019); Roughgarden (2024)	Protocol-defined fee adjustment
B1	Execution base fee - > L1 execution gas utilization	-	Buterin et al. (2019); Roughgarden (2024)	Authors' conditional demand-response interpretation
Productive path/R4	L1 execution gas utilization - > protocol ETH burn rate	+	Buterin et al. (2019)	Protocol-defined mechanical component of base-fee burn
Productive path/R4	Execution base fee - > protocol ETH burn rate	+	Buterin et al. (2019)	Protocol-defined mechanical component of base-fee burn

(*Continued*)

TABLE 2 Continued

Loop/ path	Causal relationship	Polarity/ delay	Supporting source(s)	Relationship basis
Productive path/R4	Ecosystem transaction activity (L1+L2) - > L2 blob gas utilization	+	Buterin et al. (2022); Park et al. (2026)	Authors' conditional mapping through batched rollup-data submission
B2	L2 blob gas utilization - > blob base fee	+; protocol lag	Buterin et al. (2022)	Protocol-defined fee adjustment
B2	Blob base fee - > L2 blob gas utilization	-	Buterin et al. (2022); Park et al. (2026)	Protocol-design expectation; realized strength depends on demand elasticity
Productive path/R4	L2 blob gas utilization - > protocol ETH burn rate	+	Buterin et al. (2022)	Protocol-defined mechanical component of blob-fee burn
Productive path/R4	Blob base fee - > protocol ETH burn rate	+	Buterin et al. (2022)	Protocol-defined mechanical component of blob-fee burn
R4	Protocol ETH burn rate - > total ETH supply	-	Buterin et al. (2019), (2022); John et al. (2024)	Accounting identity and protocol-defined outflow
External inflow	Consensus issuance rate - > total ETH supply	+	John et al. (2024); Ethereum.org (2026)	Accounting identity and protocol-defined inflow
R4	Total ETH supply - > ETH market price	-	Papadogiannis (2025); Soni and Preece (2023)	Authors' conditional synthesis, holding demand and market conditions constant
R4	ETH market price - > ecosystem adoption	+; delayed	Cong et al. (2021)	Literature-supported theoretical feedback; Ethereum application proposed
R5	ETH market price - > media attention	+	Li et al. (2022); Liu and Tsyvinski (2021)	Prior empirical evidence from cryptocurrency markets; not Ethereum-specific
R5	Media attention - > speculative expectations	+	Li et al. (2022); Liu and Tsyvinski (2021)	Authors' synthesis (behavioral literature-informed)
R5	Speculative expectations - > capital inflows	+	Benetton and Compiani (2024)	Prior literature (beliefs, portfolio allocation, and crypto demand)
R5	Capital inflows - > speculative demand for ETH	+	Benetton and Compiani (2024)	Authors' synthesis of portfolio-allocation mechanism
R5	Speculative demand for ETH - > ETH market price	+	Benetton and Compiani (2024); Kukacka and Kristoufek (2023)	Prior literature (speculative demand and price formation)

A positive polarity (+) means that, all else equal, a change in the cause produces a change in the same direction in the affected variable; a negative polarity (−) indicates a change in the opposite direction. Double-slash marks in Figure 1 denote material behavioral or adoption delays. Entries identified as "protocol lag" in Table 2 refer to mechanically specified next-block fee adjustments and are therefore not separately marked in the diagram. 'Authors' synthesis' identifies links proposed by the present study rather than causal effects directly established for Ethereum. Protocol-defined relationships are mechanical rules or accounting identities established by Ethereum's protocol specifications.

primary roles within the framework rather than discrete or self-contained components of value formation.

The propositions developed below translate the depicted relationships into conditional theoretical expectations that can subsequently be evaluated using observable indicators and specified time horizons. They should be interpreted as theoretically grounded and potentially falsifiable statements rather than as empirically confirmed causal effects.

R1 represents adoption and utility dynamics. The hypothesized causal sequence is Active Users → Ecosystem Service Utility → Developer Activity → Applications/dApps → Ecosystem Transaction Activity (L1+L2) → Active Users. An expansion of the active user base can increase the service utility available within the ecosystem; greater utility may attract developer activity and support a broader range of applications, which can generate additional transaction activity and attract further users. R1 therefore represents feedback between ecosystem service creation and adoption rather than a direct token-price formation mechanism. This reinforcing logic is consistent with models of endogenous platform adoption and network externalities (Cong et al., 2021; Scala and Delmastro, 2023). Moncada et al. (2024) additionally report an association between active-user bases and token-market outcomes; however, R1 does not treat market price as a component of this loop. Because reinforcing feedback can operate in either direction, declining participation may likewise reduce ecosystem utility, developer activity, and subsequent use.

Proposition 1. Adoption and utility. Conditional on broadly stable protocol conditions and after accounting for market-wide shocks, an increase in active ecosystem participation should be followed by greater use of ecosystem services, higher developer activity, a larger set of active applications, and increased ecosystem transaction

activity; these changes should, with a positive time lag, predict further growth in active participation. The proposition would not be supported if the intermediate variables do not respond in the expected direction or do not precede subsequent participation growth.

R2 represents monetary and liquidity dynamics. In the framework, ETH Monetary Use denotes the actual use of ETH for fee payment, settlement, collateral, and liquidity provision, whereas Monetary Acceptance denotes the willingness of ecosystem participants to hold or accept ETH in these roles. At the protocol level, Layer-1 execution fees are denominated and settled in ETH. For Layer-2 activity, however, the relationship between individual user transactions and demand for ETH balances is less direct: transactions are batched, and rollups that use Ethereum for data availability submit data through the separate blob-gas fee market introduced by EIP-4844 (Buterin et al., 2022). Growth in total ecosystem transaction activity therefore does not mechanically produce a proportional increase in demand for ETH. R2 instead represents a conditional feedback: to the extent that greater Layer-1 and Layer-2 activity expands the monetary use of ETH, broader monetary acceptance may support ecosystem adoption and subsequent activity. This logic is consistent with utility-token models in which transactional demand and circulation velocity shape equilibrium token holdings (Cong et al., 2021; Prat et al., 2025). Because ETH velocity varies across address and transaction categories, the strength of this mechanism is unlikely to be captured adequately by a single static turnover ratio (Collibus et al., 2025).

Proposition 2. Monetary-use and adoption feedback. Conditional on the proportion of ecosystem activity that generates ETH-denominated fee, settlement, collateral, or liquidity needs, increases in Layer-1 and Layer-2 activity should be followed by greater observable monetary use and acceptance of ETH; with a positive time lag, these changes should predict higher ecosystem adoption and subsequent transaction activity. The relationship should be stronger when a larger share of ecosystem activity involves ETH and weaker when fee abstraction, alternative settlement assets, or higher circulation velocity reduce the need to maintain ETH balances. The proposition would not be supported if growth in ecosystem activity is not followed by increased ETH monetary use or if increased monetary use and acceptance fail to predict subsequent adoption and activity.

R3 represents staking incentives and network security, while B3 captures the associated balancing adjustment in staking returns. Greater ecosystem adoption can increase fundamental demand for ETH, part of which may be allocated to staking. A larger amount of total staked ETH can, ceteris paribus, increase the economic resources required to compromise consensus. Any subsequent effect of stronger network security on ecosystem adoption is indirect and is therefore represented as a delayed theoretical relationship rather than as an empirically established Ethereum-specific causal effect (Kogan et al., 2021; Oderbolz et al., 2024). Validator compensation should not be equated with company-like cash flow generated solely by transaction fees. Expected Net Staking Return comprises issuance-based consensus rewards, priority fees, and potential MEV, net of penalties and slashing risk, while the EIP-1559 base fee is burned rather than paid to validators (Buterin et al., 2019). Because the protocol reward rate per unit staked decreases as total stake increases, B3 counteracts unlimited growth in staking participation: a higher expected net return attracts additional stake after a delay, whereas a larger amount of total staked ETH reduces the expected return available to an additional staker, all else being equal. R3 and B3 therefore jointly represent a reinforcing security-adoption pathway and a balancing staking-return adjustment.

Proposition 3. Staking incentives, security, and adoption. Conditional on part of the fundamental demand for ETH being allocated to staking, greater ecosystem adoption should predict subsequent net staking inflows and growth in total staked ETH. Provided that stake remains sufficiently distributed and validators participate effectively, a larger amount of total staked ETH should increase the economic security of the network, while improvements in network security should predict further ecosystem adoption only after a positive time lag. At the same time, holding the protocol reward schedule and execution-layer revenue conditions constant, a higher expected net staking return should predict subsequent staking inflows, whereas growth in total staked ETH should reduce the expected return per unit staked and moderate further inflows. The proposition would not be supported if these temporal relationships and directional effects are not observed after accounting for ETH market conditions, protocol changes, and validator concentration.

R4 represents scarcity and monetary-premium dynamics through the interaction of activity-dependent ETH burning and consensus issuance. In the framework, Total ETH Supply is treated as a stock-like variable: the Consensus Issuance Rate adds ETH to supply, whereas the Protocol ETH Burn Rate removes it. The burn rate is not determined by transaction counts alone. For Layer-1 execution, it depends jointly on execution gas utilization and the execution base fee; for rollup data, it depends on blob-gas utilization and the blob base fee introduced through the separate EIP-4844 fee market (Buterin et al., 2019; Buterin et al., 2022). Growth in ecosystem transaction activity therefore affects ETH burning only insofar as it increases demand for Layer-1 execution or Ethereum blob data. Net supply change may be positive or negative depending on the relative magnitudes of consensus issuance and protocol burning. Holding demand and other market conditions constant, lower total supply or lower expected supply growth may place upward pressure on ETH market price, but this effect is conditional rather than mechanical and does not imply that scarcity independently creates ecosystem value (Papadogiannis, 2025). The delayed positive relationship from ETH market price to Ecosystem Adoption closes R4 and reflects the theoretical possibility that token-price appreciation supports subsequent platform participation (Cong et al., 2021). Within the current conceptual boundary, Consensus Issuance Rate is treated as a protocol-determined external inflow; its endogenous dependence on active stake can be represented explicitly in subsequent stock-and-flow model development.

Proposition 4. Supply, scarcity, and adoption feedback. Conditional on ecosystem activity increasing either Layer-1 execution-gas utilization or Layer-2 blob-gas utilization, the combination of higher gas utilization and the corresponding base fee should increase the Protocol ETH Burn Rate. When protocol

burning rises relative to the Consensus Issuance Rate, net ETH supply growth should decline. After accounting for fundamental and speculative demand and broader market conditions, a lower level or lower expected growth of Total ETH Supply should place upward pressure on ETH Market Price; increases in market price should, with a positive time lag, predict greater ecosystem adoption and subsequent transaction activity. The reinforcing-loop interpretation would not be supported if burn-adjusted supply changes fail to influence market price in the expected direction or if price changes do not precede subsequent adoption and activity. R5 represents speculative and reflexive market-price dynamics. Its hypothesized causal sequence is ETH Market Price → Media Attention → Speculative Expectations → Capital Inflows → Speculative Demand for ETH → ETH Market Price. An increase in market price can attract media attention, strengthen expectations of further appreciation, draw additional capital into ETH positions, and increase speculative demand, thereby amplifying the initial price movement. The same mechanism may operate in the opposite direction and amplify price declines. In this loop, Speculative Expectations refers to beliefs concerning future price movements, Capital Inflows denotes additional funds allocated to ETH exposure, and Speculative Demand for ETH denotes demand motivated primarily by expected price appreciation rather than contemporaneous ecosystem use.

Momentum, investor-attention, heterogeneous-belief, and media-coverage effects documented in cryptocurrency markets are consistent with individual relationships represented in R5 (Benetton and Compiani, 2024; Li et al., 2022; Liu and Tsyvinski, 2021). However, this evidence does not by itself establish the complete feedback loop specifically for Ethereum. R5 is therefore interpreted as a market-price amplification mechanism rather than as an independent source of ecosystem value creation or fundamental ETH value capture. It may operate without contemporaneous changes in ecosystem service utility, transaction activity, network security, or supply conditions, although fundamental developments may still initiate or constrain the resulting price movement.

Proposition 5. Speculative and reflexive price amplification. Conditional on the absence of a major contemporaneous protocol or ecosystem shock, and after accounting for changes in productive activity, adoption, security, ETH supply, and broader cryptocurrency-market conditions, an increase in ETH Market Price should be followed over subsequent daily or weekly periods by greater Media Attention, more optimistic Speculative Expectations, additional Capital Inflows, and stronger Speculative Demand for ETH, thereby amplifying the initial price movement. A corresponding negative sequence should follow sufficiently large price declines. The proposition would not be supported if attention, expectations, and capital inflows do not temporally follow price changes or if they fail to predict subsequent price movements after controlling for fundamental conditions.

Figure 1 also includes productive value-creation pathways that are not represented as a separate feedback loop. Developer Activity supports the creation and maintenance of Applications/dApps, which contributes to Ecosystem Transaction Activity. This activity may subsequently increase Layer-1 execution-gas utilization or Layer-2 blob-gas utilization and, through their respective base-fee mechanisms, contribute to the Protocol ETH Burn Rate. These pathways connect ecosystem service production with potential ETH-related value capture, but the relationship is neither automatic nor equivalent to corporate cash flow: ETH holders have no residual claim, validators do not receive the burned base fee, and growth in rollup activity need not produce a proportional increase in Layer-1 fees or ETH burning (Buterin et al., 2019; Buterin et al., 2022; John et al., 2024; Soni and Preece, 2023). Because the reviewed literature does not establish a sufficiently supported causal return from protocol fees or ETH burning to developer activity, the productive pathway is represented as an open causal structure rather than designated as R6.

Proposition 6. Productive activity and conditional ETH value capture. Conditional on application deployment and subsequent user uptake, increases in Developer Activity should precede growth in the number and use of active Applications/dApps and, over subsequent monthly or quarterly periods, higher Ecosystem Transaction Activity. The magnitude of any associated ETH-related value capture should depend on whether this activity increases Layer-1 execution-gas utilization or Layer-2 blob-gas utilization. Productive ecosystem activity may therefore expand without a proportional increase in the Protocol ETH Burn Rate or ETH Market Price. The proposition would not be supported if changes in developer and application activity do not temporally precede ecosystem use or if the composition of transaction activity does not explain subsequent variation in execution-gas utilization, blob-gas utilization, and protocol ETH burning. Figure 1 distinguishes two fee-market balancing mechanisms rather than representing congestion as a single general constraint. In B1, greater Layer-1 Execution Gas Utilization relative to the protocol target increases the Execution Base Fee through the EIP-1559 adjustment mechanism; a higher base fee can subsequently reduce, postpone, or redirect marginal demand for Layer-1 execution, thereby moderating utilization. In B2, greater Layer-2 Blob Gas Utilization relative to its target increases the Blob Base Fee; higher blob-data costs can encourage rollups to increase batching efficiency, compress data, postpone publication, or otherwise moderate their demand for Ethereum data availability. Layer-2 user activity affects B2 only insofar as rollups submit batched transaction data to Ethereum, so growth in Layer-2 transactions does not translate mechanically into equivalent Layer-1 execution demand or congestion. The strengths of both balancing effects depend on the price elasticity of execution and data-availability demand: when demand is relatively insensitive to fees, adjustment may be weaker or delayed. Because both execution and blob base fees also contribute to the Protocol ETH Burn Rate, B1 and B2 simultaneously regulate resource utilization and connect ecosystem activity to the supply dynamics represented in R4. B3, which regulates staking participation through changes in Expected Net Staking Return, is discussed jointly with R3 above.

Proposition 7. Layer-specific fee-market balancing. Conditional on unchanged protocol fee parameters and after accounting for broader demand shocks, Layer-1 execution-gas utilization above its protocol target should increase the Execution Base Fee in the subsequent block, while Layer-2 blob-gas utilization above its target should increase the Blob Base Fee over subsequent blocks

(Buterin et al., 2019; Buterin et al., 2022). Higher resource prices should then, over subsequent blocks or days, reduce, postpone, redirect, or induce greater efficiency in marginal demand, causing the corresponding utilization measure to move back toward its protocol target. This adjustment should be weaker or more delayed when execution or data-availability demand is relatively price-inelastic. The proposition would not be supported if above-target utilization fails to raise the relevant base fee or if higher fees do not moderate subsequent utilization after accounting for continued demand growth and protocol changes.

4.3 Illustrative plausibility check: EIP-4844

Although the proposed framework has not been empirically validated, EIP-4844 provides an illustrative plausibility check. Activated on 13 March 2024, the upgrade introduced blob transactions and a distinct blob-gas fee market for rollup data, thereby separating Layer-2 data-availability demand from ordinary Layer-1 execution gas (Buterin et al., 2022; Park et al., 2026). Park et al. (2026) report that EIP-4844 increased rollups' use of Ethereum while reducing rollup transaction fees. They also find that cost-minimizing batching strategies can delay the inclusion of rollup transactions in Ethereum blocks. These observations are consistent with the framework's distinction between Ecosystem Transaction Activity, L1 Execution Gas Utilization, and L2 Blob Gas Utilization: growth in Layer-2 activity need not translate proportionally into Layer-1 execution congestion, fees, or ETH burning.

Within the causal-loop framework, the event is consistent with the conditional pathway from ecosystem activity to blob-gas utilization and with B2, in which the Blob Base Fee influences the timing, efficiency, and quantity of rollup data posting. The observed combination of lower rollup fees, increased rollup use, and strategic batching also illustrates why activity-to-fee and activity-to-burn relationships are protocol- and layer-dependent rather than mechanical. This comparison does not validate the complete feedback structure or establish causal effect sizes; it constitutes an event-based consistency check showing that the framework can accommodate the heterogeneous consequences of a major Ethereum protocol change.

5 Implications for blockchain valuation

The proposed systemic framework suggests that blockchain valuation should be viewed as a multidimensional process rather than the outcome of a single valuation mechanism. The literature reviewed in this paper indicates that existing approaches emphasize different sources of value formation, including productive activity, network growth, monetary utility, scarcity dynamics, security participation, and behavioral expectations. Rather than competing explanations, these mechanisms may be interpreted as complementary components of a broader adaptive ecosystem.

From this perspective, valuation models may differ not because some are inherently correct and others incorrect, but because they focus on different dimensions of blockchain value creation. Fundamental and on-chain approaches emphasize productive activity and value capture, network models focus on adoption and ecosystem growth, tokenomics frameworks highlight transactional demand and monetary utility, scarcity-based approaches stress supply-side dynamics, security models emphasize staking participation and consensus provision, while behavioral perspectives focus on expectations and reflexive market processes.

This interpretation may help explain why different valuation approaches generate divergent estimates or assessments of Ethereum value and market price by emphasizing different mechanisms. Such divergence may also arise from differences in assumptions, data inputs, time horizons, and functional forms; the proposed framework therefore does not attribute it solely to the mechanism emphasized. Blockchain ecosystems operate within highly adaptive environments characterized by strong network externalities, evolving participant behavior, endogenous feedback mechanisms, and reflexive expectations. Consequently, ETH market price may reflect the combined influence of ecosystem service utility, ETH-related value-capture mechanisms, and speculative or reflexive market forces rather than a single underlying determinant. Within such a framework, discounted cash flow valuation remains analytically relevant but should be interpreted as capturing only the productive dimension of blockchain value formation. Productive revenues themselves emerge from broader interactions involving adoption dynamics, liquidity demand, security participation, scarcity mechanisms, and behavioral expectations. As a result, DCF-based approaches may provide valuable insight into productive activity and selected ETH-related value-capture mechanisms while offering only a partial representation of the broader process of Ethereum value formation and market-price dynamics. Consequently, the challenge of blockchain valuation may be less about identifying a single superior valuation model and more about understanding how multiple value formation mechanisms interact within a decentralized adaptive system.

6 Limitations and future research

This study has several limitations. First, the proposed framework is conceptual and has not yet been empirically estimated or validated. The causal relationships and feedback structures are derived from the reviewed literature and should therefore be interpreted as theoretically grounded propositions rather than confirmed causal effects. Second, the targeted literature search was structured but was not designed as a systematic review and does not claim exhaustive or independently reproducible coverage. The qualitative synthesis necessarily involved interpretive judgment when classifying studies and translating their findings into system variables and causal links. Third, the framework focuses primarily on Ethereum. Although several identified mechanisms may apply to other blockchain platforms, their relevance and relative importance may differ across consensus mechanisms, token designs, governance arrangements, and ecosystem architectures. Fourth, the directional links represented in the CLD do not exclude reverse causality, reciprocal influence, or omitted external drivers. Macroeconomic conditions, regulation, spot-ETF and other institutional flows, technological competition, and market-wide shocks may affect adoption, demand, staking participation, and ETH market price without being endogenously represented in the framework. Several

constructs-including ecosystem service utility, monetary acceptance, speculative expectations, and perceived network security-are latent or dependent on imperfect empirical proxies, while aggregate variables may conceal important differences among users, developers, validators, rollups, and investors. Rapid protocol development may also alter fee-market parameters, issuance dynamics, staking incentives, and Layer-2 relationships, making some causal links time- and regime-dependent. Finally, the selection, aggregation, and polarity of the causal links reflect the authors' interpretive judgment and may therefore be affected by model-boundary choices and conceptual bias.

An additional limitation concerns the scope of value represented in the framework. The CLD is restricted to mechanisms for which the reviewed valuation literature articulates a theoretically relevant connection to economic value formation. It does not attempt to represent the full range of social, ethical, political, or normative values shaping the Ethereum ecosystem, including community norms, governance legitimacy, power asymmetries, strategic interests, distributive conflicts, and conflict-resolution practices. Such factors may influence participant behavior and economic value flows even when their effects cannot be adequately represented through stable causal or correlational relationships. Consequently, the framework should be interpreted as an integrative representation of selected economic value-formation mechanisms rather than as an exhaustive model or measurement of the overall value generated within a peer-to-peer ecosystem. Addressing these additional dimensions would require complementary approaches, including participatory system mapping, qualitative case studies, stakeholder interviews, governance analysis, and mixed-method research designs.

Future research may operationalize the proposed causal structure through a formal stock-and-flow model and simulation-based analysis. Empirical data on network activity, transaction fees, token burning, staking participation, supply dynamics, adoption, and market expectations could be used to calibrate and test individual relationships. Sensitivity analysis and scenario simulation could then examine how changes in protocol parameters, adoption trajectories, or market conditions affect the interaction among value-formation mechanisms. Comparative application to other Layer-1 blockchain platforms could additionally determine which elements of the framework are platform-specific and which may be generalized.

7 Conclusion

This paper argues that decentralized blockchain platforms may be more appropriately understood as complex adaptive socio-economic systems characterized by interacting and partly overlapping domains of productive activity, adoption and utility, monetary use and liquidity, scarcity and monetary-premium dynamics, staking and network security, and speculative and reflexive dynamics. Rather than representing competing explanations of value, existing blockchain valuation approaches can be interpreted as emphasizing different mechanisms operating across these domains within a broader ecosystem.

The literature review suggests that no single valuation framework fully captures the multidimensional nature of blockchain platforms. Fundamental and on-chain models emphasize productive activity, network-based approaches focus on ecosystem growth, tokenomics models highlight transactional demand and monetary utility, scarcity-oriented perspectives stress supply-side dynamics, security-based approaches consider staking and consensus participation, while behavioral models emphasize expectations and reflexive feedback processes. Each perspective provides valuable insight but captures only part of a more complex system.

The proposed framework does not seek to identify a single "correct" valuation model for Ethereum or to estimate an intrinsic token price. Its contribution lies in integrating five reinforcing feedback loops, three balancing feedback loops, and open productive value-creation pathways within a single structural representation that analytically distinguishes ecosystem value creation, ETH-related value capture, and market-price formation. By applying System Dynamics and causal-loop thinking, the paper formulates a theory-building structural hypothesis through which existing valuation approaches can be interpreted as complementary but partly overlapping explanations and from which empirically testable relationships can be derived. The framework remains conceptual and requires subsequent empirical evaluation.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

VK: Writing – review and editing, Methodology, Visualization, Writing – original draft, Formal Analysis, Investigation, Conceptualization, Funding acquisition. ZLV: Project administration, Investigation, Writing – review and editing, Validation. SKK: Validation, Investigation, Writing – review and editing.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was used in the creation of this manuscript. During the preparation of this manuscript, the authors used ChatGPT (OpenAI, GPT-5) to support language editing, improve clarity and readability, and assist with the stylistic refinement of selected passages. All AI-assisted content was critically reviewed, revised, and verified by the authors, who take full responsibility for the accuracy, originality, and integrity of the final manuscript.

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