

ENHANCING MODULARITY IN BUSINESS ECOSYSTEMS THROUGH BLOCKCHAIN TOKENS: A MULTIPLE CASE STUDY

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ABSTRACT

The growing importance of business ecosystems for inter-organizational value creation has drawn attention to how diverse actors coordinate activities while maintaining autonomy. Simultaneously, blockchain technology and tokenization have gained traction as innovative digital solutions across industries, yet their potential impact on business ecosystem modularity remains underexplored. This study investigates how blockchain tokens enhance modularity in business ecosystems by analyzing twelve cases across diverse industries where focal actors leveraged tokens as coordination mechanisms, functioning as standardized interfaces. Through semi-structured interviews and analysis of secondary data, we identify three key token-enabled interactions (information exchange, ownership transfers, and ownership verification) facilitating ecosystem coordination. Our findings reveal that two critical dimensions – accessibility and reliability – function as modularity enhancers, complementing established standardization approaches. These dimensions influence how stakeholders can engage with business ecosystems without requiring special permissions or bilateral agreements, while ensuring that ecosystem interactions are executed as expected without supervision. The study contributes to modularity theory by extending design rules for digital contexts beyond structural considerations, providing a more nuanced explanation of how business ecosystems position along the modularity continuum. For practitioners, our research offers insights into strategically designing token interfaces to reduce transaction costs and enable complementors to join their business ecosystem.

Keywords: modularity, business ecosystem, blockchain, token, coordination.

1. INTRODUCTION

In an increasingly interdependent business landscape, firms no longer operate in isolation but as part of broader ecosystems [1], which are composed of autonomous yet interconnected organizations that rely on intricate coordination mechanisms to function effectively [2]. This coordination is often facilitated by a modular architecture, which divides complex entities into discrete components with "thin crossing points" among them [3]. The enhancement of modularity through digital technologies and standardized interfaces has fundamentally transformed coordination possibilities among different actors [4], leading to a surge of scientific interest within the context of interdependence [2], [4], [5].

Emerging digital technologies, such as blockchain, are transforming business ecosystems by enabling new forms of coordination, enhancing transparency, reducing the need for intermediaries and, more generally, lowering coordination costs [6], [7], [8], [9], [10]. Tokens are digital objects used for the management of native and non-native assets within a blockchain [12] and are often created following common open standards [13]. In business literature, scholars have commenced studying NFTs and, more generally, token-based business models and ecosystems [19], highlighting the pivotal role that tokens play in blockchain platforms, serving as the foundation for emerging ecosystems [17].

While both scholars and practitioners have recognized that tokens can enable value creation in business ecosystems [17], [22], empirical research on how tokens specifically facilitate coordination through modular architecture in these ecosystems remains limited. Without understanding tokens' role in enabling such modular interactions, we cannot fully explain how blockchain technologies transform business ecosystem coordination and value creation [23], [24].

Thus, we aim to address the following research question: how do tokens enhance modularity in business ecosystems?

To address this gap, we examine twelve real-world cases in which companies relied on tokens as modular interfaces to connect multiple stakeholders.

This study contributes to modularity and business ecosystem theory showcasing how certain characteristics, such as trust and public accessibility, can act as enhancer within the modular-integral architectural continuum, facilitating the emergence of new relations and increasing the combinatorial potential of diverse modules that collectively constitute the business ecosystem's value proposition. From a practitioner's perspective, this research highlights the strategic importance of tokens in forming new interactions among business ecosystem's participants. Our findings can assist companies in understanding the potential of tokens for integrating with their business ecosystem's stakeholders.

2. THEORETICAL BACKGROUND

2.1 ECOSYSTEMS, MODULARITY AND DIGITAL TECHNOLOGIES

Following the emergence of Moore's [1] concept of ecosystems in business literature, there has been a surge of interest in ecosystems as a novel framework for understanding the competitive environment [1], [24].

Business ecosystems represent an intermediate organizational form between loosely coordinated markets and tightly integrated supply chains, with the degree of coordination serving as a key differentiator among these value system structures [24]. A second crucial characteristic of business ecosystems is modularity, which enables them to function as modular systems of activities where distinct components can interact through "thin crossing points" while maintaining their autonomy [3], [24]. These essential features are synthesized in Jacobides' framework, which identifies coordination and modularity as the two theoretical foundations describing business ecosystems [24].

Despite modularity's capacity to enable the mixing and matching of different product or service components through standardized interfaces [30], [26], [28], [4], it operates on a continuum between fully integrated and fully modular architectures rather than as a simple dichotomy [27], [31].

As digital technologies emerged, the concept of interfaces expanded beyond physical connections. Henfridsson et al. [32] noted that digital innovation demands a more sophisticated understanding of interfaces, encompassing physical and logical design perspectives. While design rules of interfaces still are a valid approach to business ecosystem coordination and governance, the management of complex of interdependencies coupled to the advent of digital technologies require a broader toolset of governance mechanisms that goes beyond standard setting [33], [34], [35], [23].

As Baldwin's design rules stems from studies of physical products [3], [23], complexities introduced by modern digital business ecosystems require an updated version of what should be considered in the design of interfaces [32], [35].

Such intersection between digital technologies and modularity has not been yet thoroughly studied. This research gap becomes particularly significant when examining

emerging technologies, such as blockchain, which enables a range of efficiency gains, novelties, and lock-in reductions [8].

2.2 BLOCKCHAIN, TOKENS AND ECOSYSTEMS

Blockchain in general and tokens in particular are promising digital solutions that might affect how actors within a business ecosystem coordinate [22], [36], [37].

Specifically, Wilson highlights that NFTs are used to connect multiple stakeholders, from content owners and individual creators to marketplaces and consumers [22].

Scholars have shown that blockchain enables a range of efficiency gains, innovations, and reductions in lock-in effects, with sustaining, enabling, and threatening implications for the emergence and attractiveness of business ecosystems [8].

Yet, the academic understanding of blockchain's full potential remains nascent [8].

Among its wide range of applications, one of the key innovations brought by blockchain and its versatility is represented by token standards [12], which have become instrumental in creating and supporting business ecosystems within blockchain platforms, as they enable companies to digitally represent various rights, assets, and functional roles, fostering the creation of joint value propositions around these rights and assets [19], [17], [21], [22].

Within ecosystem research, Tönnissen et al. [17] highlighted the pivotal role that tokens play in blockchain platforms, serving as the foundation for emerging ecosystems. Authors developed a definition and a taxonomy for token-based ecosystems by analyzing 195 real-world startups, though they did not address the actual impacts of tokens on the theoretical primers of ecosystems, such as modularity and coordination [24].

Despite the growing significance of business ecosystems and the recognition of tokens as a radical innovation promoting novel ways of value creation within them [22], there remains a gap in understanding how tokens can enable modular value propositions in these settings [17], [22].

As academics [14], [17], [19] are discovering unique dynamics linked to token-based value networks, research on digitally-driven (and, in particular, token-driven) modularity creates opportunities for examining the effects of such coordination mechanisms in business ecosystems.

Building on the research opportunity identified at the intersection of business ecosystems, modularity and digital innovation, we aim to produce insights on how navigating the continuum between modular and integral architectures in the digital realm, leveraging real world cases in which tokens acted as enhancer of modularity in business ecosystems.

3. METHODOLOGY

Given the limited research on token impact on business ecosystem modularity, an exploratory approach was considered necessary [48].

3.1 CASE SELECTION

We employed theoretical sampling to select twelve cases of business ecosystems, prioritizing those that demonstrated replication [49].

The selected cases leveraged tokens in diverse forms (e.g., digital product passports, memberships, stablecoins) and operated within ecosystems varying in underlying industry and target audience. At the same time, to compare similar token-based coordination approaches rather than entirely heterogeneous implementation models, we

focused on projects sharing a fundamental characteristic: all used tokens as coordination mechanisms functioning as standardized interfaces enabling modular interactions between actors within their respective ecosystems.

3.2 DATA COLLECTION

To gather data, the study relied on multiple sources of evidence. The main source includes primary data, gathered through 16 semi-structured interviews with the main team members involved in each project of the business ecosystem’s focal companies. The informants comprised chairmen, general managers, and project managers, with each interview lasting 1-2 hours. A minimum of two researchers participated in each interview, documenting observations through field notes. Although semi-structured, the interviews followed a systematic progression. The initial segment focused on exploring the case in depth by confirming relationships between the business ecosystem's focal actors and their users and complementors. After having established these relationships, we examined the enabling factors underlying these connections and investigated how solution design influenced their development.

Several measures were implemented to mitigate potential information bias. First, all informants were guaranteed anonymity [49]. Second, the study included informants with diverse perspectives and organizational roles [50]. Third, interview data were triangulated with archival and observational data [50]. Recall bias was specifically addressed through cross-referencing information between third-party sources and multiple interviewees. To minimize observer bias, researchers compared their interpretations, ensuring analytical validation through multiple observers.

Table 1 provides a summary of all informants interviewed for data collection across the different case studies. The interviews started from a set of predetermined questions to drive the discussion. However, given the exploratory approach followed, we let informants go beyond predefined questions.

Project name	Company	Job Title
Car NFT	Carmaker	Head of Products
Watch Digital Passport (1)	Watchmaker (1)	Chief Technology Officer
Watch Digital Passport (2)	Watchmaker (2)	Head of Operation Excellence & Technology
T-shirt Digital Passport	Football team tech provider	Chief Executive Officer
Sustainability incentives	Sustainability platform	Business Development Manager
Fashion NFTs	Fashion conglomerate	Innovation manager
Membership NFT	Tolling company	Product Manager Cloud Software Engineer
Tokenized bookings	Hotel company	Director Dev & Digital Ecosystem
Tokenized bookings	Hotel company tech provider	Chief Executive Officer and Co-Founder
Web3 stablecoin	Web3 stablecoin user	Governance Liaison
Yield bearing stablecoin	Stablecoin issuer	Head of Sales & Expansion

Institutional stablecoin	Institutional stablecoin issuer	Business Development Manager
Institutional stablecoin	Institutional stablecoin issuer parent company	Head of Innovation
Decentralized exchange	Dex governance participant	Governance Liaison
Decentralized exchange	Dex Protocol governance participant	Smart Contract Engineer

Table 1. Informants

To enhance the preparation for the interviews and enrich the empirical base, we also consulted secondary sources, including: (1) companies' websites; (2) news articles; (3) blockchain explorers; and (4) third-party platforms.

3.3 DATA ANALYSIS

The interviews were recorded, transcribed verbatim, and analyzed adopting an abductive approach [49], [50]. The text is coded by using in vivo code and building an abductive coding tree. During the coding, we labeled the essential elements and data and then grouped homogeneous codes into categories, to synthesize the different variables that emerged. Despite the abductive approach, we define more abstract concepts to contribute to the theory by also using the extant literature on business ecosystems.

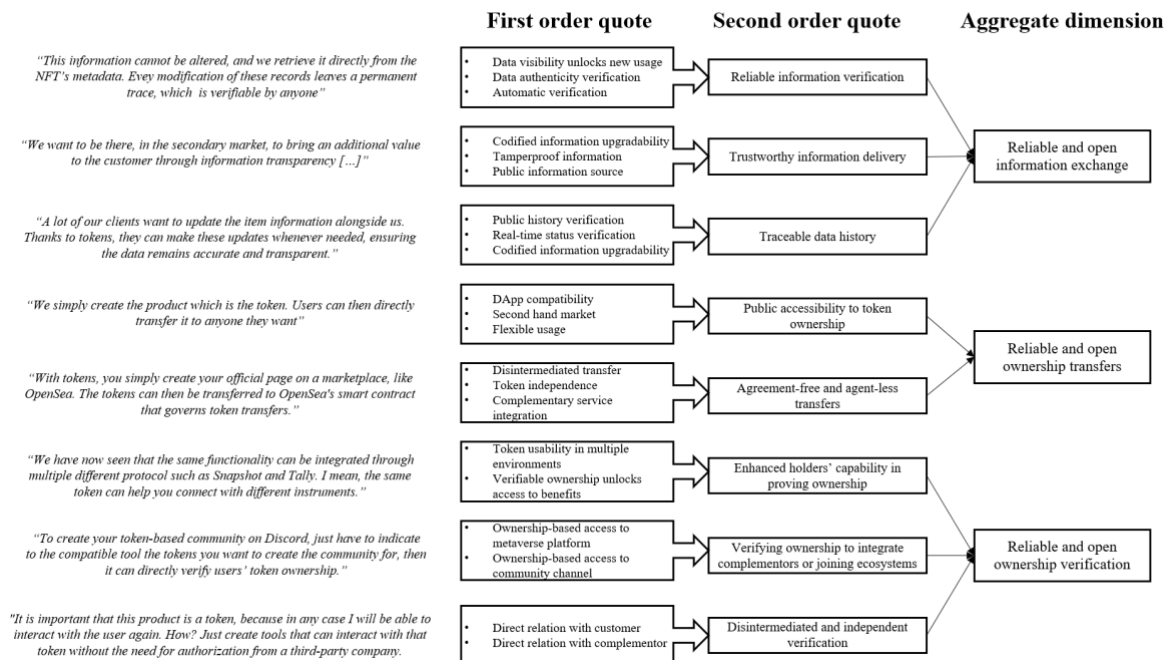


Figure 1. Coding tree

The visual representation of the coding structure, provided in Figure 1, illustrates the progression from raw data to theoretical abstraction, ensuring transparency and traceability in the analytical process [48], [49].

4. RESULTS

Leveraging previous literature on modularity [3], [4], [26], [31], [32], [32], [51], [52] and business ecosystems [1], [24], [25], [53], [54], we investigated how blockchain tokens enhance modularity in business ecosystems. We structure our results by examining how the fundamental dimensions of token-based interfaces reshape business ecosystem architecture and participation.

4.1 RELIABLE AND OPEN INFORMATION EXCHANGE

The public and immutable nature of blockchain enables tokens to serve as reliable carriers of product and ownership information [12]. All information stored on a blockchain – and consequently, all information embedded in a token – is immutable and transparent, allowing authorized participants to access and verify data without risk of tampering or modification [12], [55].

Our analysis identifies how token-based information exchange enhances modularity in business ecosystems by enabling new actors, services, and relationships.

Token-based information exchange alters how business ecosystem participants interact by eliminating information asymmetries and verification uncertainties. As the carmaker's representative explained:

“Using a blockchain has the great value that no one can modify the information without leaving a trace. [...] Blockchain and tokens, by definition, cannot be “touched”, and this gives unparalleled protection guarantees that cannot be found in other systems. The reliability of this data is valuable and allows for meaningful interactions with those who read it. Who is guaranteeing that no one has modified the information? Who is guaranteeing its origin? The token and its underlying blockchain. I do not have to trust the information holder...”

Third-party platforms can also contribute critical information to tokens, expanding business ecosystem capabilities. A luxury watchmaker described how this works with stolen items:

“When a timepiece is reported as lost or stolen, its serial number is recorded in our system, and the digital passport associated with that timepiece is immediately marked with this status. Subsequently, any interface displaying information about this item will clearly indicate that the piece is frozen.”

This information accessibility transforms secondary market dynamics by eliminating complex verification processes. As watchmaker (1) CTO described:

“As a new customer, if you want to buy a second-hand watch, most of the time is actually spent on validating its authenticity, documenting repair history, and assessing quality. This entire process is manual and time-consuming. With tokens integrated into a trading

platform, this verification can be performed instantly because anyone can access updated reliable information directly from the authenticity certificate."

Beyond information embedded within tokens, there is also critical information about the tokens themselves on the blockchain – including transaction history, ownership transfers, token quantities, minting dates, and trading volumes. This token-level information is equally accessible to business ecosystem participants and enables similar modularity benefits. Both types of information – within tokens and about tokens – enable specialized business ecosystem actors to develop complementary services and facilitate market transactions. As the institutional stablecoin issuer's informant explained:

"Using tokens adds the benefit of real-time Assets Under Management visibility, whereas traditional money funds typically report AUM monthly or quarterly. Additional services, or even competitors, can leverage access to this reliable information source within their own services, potentially amplifying or transforming the perceived value for customers."

This capacity for independent verification supports business ecosystem modularity by enabling flexible entry and exit of participants while maintaining information integrity. By establishing open interfaces between business ecosystem stakeholders, tokens enhance business ecosystem modularity by lowering entry barriers and simplifying integration of complementary services. This technological disintermediation enables mix-and-match business ecosystem participation even by actors not originally envisioned as stakeholders, a fundamental requirement for enhanced modularity as defined by Jacobides et al. [24]. Overall, the findings lead to our first proposition:

Proposition 1: The token-based exchange of information enhances business ecosystem modularity through reliable and publicly accessible data that enables independent verification.

4.2 RELIABLE AND OPEN OWNERSHIP TRANSFERS

The blockchain-based nature of tokens establishes a transparent and immutable record of ownership, while enabling native transfer capabilities among stakeholders. Our analysis reveals how token-based ownership transfers transform modularity in business ecosystems by creating new service opportunities, enabling cross-platform interactions, and reducing coordination costs.

Token-based ownership transfers create new possibilities for business ecosystem participation by reducing intermediation requirements and enabling direct peer-to-peer exchanges. As the stablecoin issuer's representative explained:

"Trading tokens on decentralized networks creates a reliable trading environment where no middleman can block owners from trading or transferring their tokens. Plus, with the system being completely transparent, there are no hidden backdoors or special privileges available only to select users. These safeguards allow any protocols or user to operate independently without needing formal guarantees or asking for SLAs."

These programmable transfer rules enable business ecosystem orchestrators to implement governance protocols directly through the token. By encoding rules into the token itself, complex coordination can be achieved without relying on external enforcement mechanisms. Token transferability transforms secondary market dynamics by enabling exchanges across multiple platforms without requiring custom integration. As described by fashion conglomerate's representative:

"We find many services such as token marketplaces (e.g., OpenSea, Rarible) which seamlessly handle token transfers despite not being our suppliers. Their presence increases the value of our product. This universal transferability means any marketplace which provides a better experience tomorrow can handle our tokens, as they can be sent to any recipient or platform without technical limitations or permissions."

This statement highlights how token transferability enables emergent business ecosystem relationships that were not necessarily anticipated in the original system design. Token transferability creates business ecosystem integration opportunities by reducing coordination costs. While hierarchical relationships typically require formal partnerships and contracts, token-based systems enable seamless interactions with minimal overhead. A representative from a tolling company described this distinction:

"To create an internal exchange marketplace with traditional 'web 2' tokens, which are essentially entries in a traditional database, it's not just a matter of writing a few lines of code. I might consider outsourcing this function by leveraging a marketplace with similar features to eBay through API integration. However, with this solution, I must trust eBay's operations, and it's not even guaranteed that eBay offers open APIs, and I might need to establish formal agreements. With tokens, you simply create your official page on a marketplace, like OpenSea. The tokens can be transferred to OpenSea's smart contract that governs token transfers. This allows me to integrate a reliable third-party service without negotiating a supply contract."

This frictionless integration capability directly supports business ecosystem modularity by enabling flexible composition of complementary services without requiring bilateral agreements. Token transferability also enables actors to create entirely new derivative services by utilizing the open transfer capabilities of existing tokens. As one participant in the Web3 stablecoin ecosystem explained:

"A developer built this contract called Savings DAI, and what it does is tracking your balance and generating a new receipt token called sDAI. So, what happens is this token contract ends up sitting between you and Maker. Technically this token contract owns like everything that gets deposited because users can freely transfer their DAI tokens to

this contract without requiring permission from Maker. And so now you can go to Aave or Spark or any of these other places and say, hey, here's some sDAI, this savings DAI. I want to borrow Tether against it or something like that. And you can. It's important to note that Maker didn't give you a token or authorize this service. This is totally something invented as an intermediary, made possible because tokens can be transferred to any address without restrictions."

These capabilities for permissionless innovation directly support business ecosystem modularity by enabling new complementary services to be developed independently, leveraging the standardized, reliable and open transfer interfaces to create value-added services not envisioned by the original system designers. By establishing such transfer mechanisms between stakeholders, tokens enhance business ecosystem modularity by lowering entry barriers and simplifying integration.

Proposition 2: Tokens transferability enhances business ecosystem modularity by enabling permissionless and contract-free integration of complementary functionalities. Reliable and open ownership transfers

4.3 RELIABLE AND OPEN OWNERSHIP VERIFICATION

Beyond functioning as information carriers and transferable assets, tokens serve as ownership credentials that can be verified by third parties across multiple platforms and applications. This verification capability extends the utility of tokens beyond their original issuance context, enabling broader business ecosystem participation and novel value propositions. Our analysis reveals how token-based ownership verification enhances modularity in business ecosystems.

Token-based ownership verification creates new opportunities for cross-platform integration by eliminating the need for trusted intermediaries. Unlike other verification systems that rely on centralized databases, blockchain-based tokens provide autonomous verification capabilities that can be independently checked by any compatible service. This enables new types of business ecosystem participants to build complementary services without requiring direct relationships with token issuers. As a fashion conglomerate's representative described within the context of digital experiences:

"[...] the critical advantage is that third-party platforms, like Decentraland, can independently verify token ownership with complete reliability, with no manual confirmation. This process is entirely autonomous and 100% trustworthy due to the underlying blockchain technology. If we needed to implement external authentication systems or personally vouch for each user's ownership status, cross-platform collaboration would be significantly more complex and resource-intensive. Instead, like this we can in seconds decide to switch between different metaverse platforms as no rigid process has been put in place."

This statement illustrates how independent verification mechanisms reduce transaction costs between business ecosystem participants, enabling flexible integration across different platforms. Token-based verification enables also financial service providers to offer new composable services by easily integrating with tokenized assets. A stablecoin issuer's representative explains:

"Much of the money held in traditional banking systems is confined within their infrastructure, lacking any meaningful interoperability with broader financial markets. Assets like certificates of deposit and high-yield savings accounts are essentially liabilities recorded on the bank's balance sheet. This setup limits the utility of these funds, while token ownership can be reliably verified by any protocol without requiring trusted intermediaries or complex verification processes. The universal accessibility of blockchain assets means I can instantly demonstrate ownership to countless different applications and services simply by connecting my wallet, enabling seamless participation across the entire financial landscape."

This capability allows lending platforms, investment protocols, and other financial services to independently verify asset ownership and offer complementary services without requiring formal partnerships with asset issuers or any system integration.

The cryptographic nature of token verification enables diverse participants – from metaverse platforms and social communities to financial services and governance tools – to independently validate ownership claims without requiring privileged relationships or integration efforts.

Proposition 3: Independent token ownership verification enhances business ecosystem modularity by enabling cross-platform integration without a central coordinator.

5. DISCUSSION

The relationship between product design and business ecosystem coordination has long been recognized in modularity theory as a critical aspect of strategic management [3], [24], [51]. Modularity theory acknowledges that the design of technological artifacts directly influences business ecosystem structure [3], [4], [24], [51]. Our research extends this understanding by examining empirical examples from digital technologies to observe "design rules" in action.

The modular architecture of business ecosystems enabled by tokens alters traditional value chains "by enabling their decomposition into discrete, independently managed segments" [28], creating what Yoo et al. [4] describe as "loosely coupled value networks". This shift from hierarchical coordination to design-embedded coordination aligns with Baldwin and Clark's vision of "design rules" [3] but extends their application beyond physical products to business ecosystems.

Our analysis of the three fundamental business ecosystem interactions – information exchange, ownership transfers, and ownership verification – reveals two critical design dimensions that consistently emerge as enhancers of modularity in business ecosystems:

accessibility and reliability. As demonstrated in our findings, these dimensions are inherent to the token-based interfaces that facilitate business ecosystem coordination. Accessibility, evident in our findings on "reliable and open information exchange" (Proposition 1) and "reliable and open ownership transfers" (Proposition 2), refers to the degree to which business ecosystem participants can engage with token-related functionalities (such as transferring tokens or verifying their ownership) without requiring special permissions, privileged access, or bilateral agreements. High accessibility enables permissionless participation, allowing complementors to contribute to the business ecosystem without formal onboarding processes.

Reliability, prominently featured across all three propositions but particularly emphasized in the "reliable and open ownership verification" (Proposition 3), encompasses the degree to which token-based interactions can be trusted to execute as expected without intervention or supervision. Reliability stems from the immutable and deterministic nature of blockchain technologies, creating predictable and tamper-resistant interactions. When business ecosystem participants can trust the underlying technological infrastructure, they can form relationships with minimal contractual safeguards, reducing transaction costs that typically limit business ecosystem expansion.

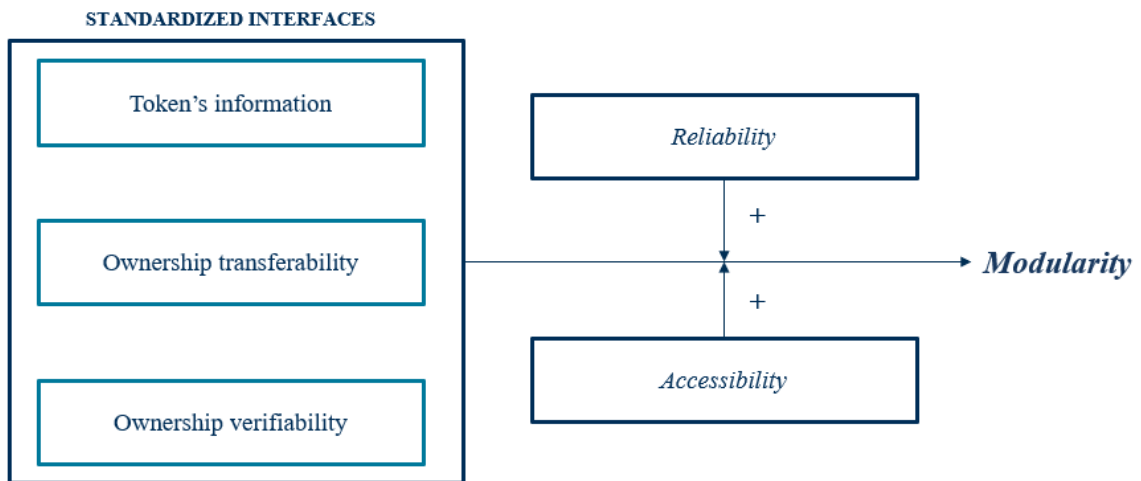


Figure 2. Framework

These dimensions interact synergistically. High accessibility without reliability would create open but unreliable business ecosystem interactions, while high reliability without accessibility would create trustworthy but closed business ecosystems.

Our research indicates that these properties – accessibility and reliability – influence modularity in business ecosystems. By identifying these specific dimensions, our study provides concrete guidance for updating design rules in digital contexts. Designers must consider not only how components connect structurally but also how accessible and reliable these connections are for diverse business ecosystem participants. These findings contribute to understanding modularity as a continuum rather than a dichotomy. As scholars have noted, modularity operates on a spectrum between fully integrated and fully modular architectures [27], [31].

6. CONCLUSIONS

This study investigated how blockchain tokens enhance modularity in business ecosystems by examining twelve cases across diverse industries. Our findings demonstrate that tokens function as interfaces that standardize interactions between

business ecosystem participants, facilitating coordination without requiring hierarchical governance structures. This study has several limitations that warrant consideration. First, the nascent state of token implementations in business ecosystems means that our observations capture early-stage developments rather than mature, stable arrangements. Second, our sample focused on cases where tokens were successfully implemented, potentially overlooking failures or challenges that could provide additional insights. Third, our exclusive focus on blockchain token context limits the generalizability of our findings on accessibility and reliability as modularity enhancers to other technological domains and coordination mechanisms. Future research should examine how the identified dimensions of accessibility and reliability evolve as token-based business ecosystems mature. Longitudinal studies could track changes in modular interactions over time, revealing how ecosystem governance and value capture mechanisms develop.

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