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EXECUTIVE SUMMARY OF THE THESIS

Token and Business Ecosystems: A Multiple Case Analysis

TESI MAGISTRALE IN MANAGEMENT ENGINEERING – INGEGNERIA GESTIONALE

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1. Introduction

Over the past decade, blockchain technology and tokenization have reshaped business ecosystems, fostering new models of economic coordination, governance, and asset management (Davidson et al., 2018). By enabling the digital representation of assets on blockchain infrastructures, tokenization facilitates transparent, programmable, and efficient transactions across various industries, including finance, supply chain management, and customer engagement (Iansiti & Lakhani, 2017). These advancements have driven the adoption of decentralized digital infrastructures, requiring firms to rethink their business models to remain competitive in an increasingly tokenized economy (Davidson et al., 2018; Subramaniam et al., 2019). At the same time, research on modularity has expanded significantly, emphasizing its role in fostering adaptability, scalability, and innovation across complex business ecosystems (Baldwin & Clark, 2000; Jacobides et al., 2018). Similarly, the study of business ecosystems has gained traction, particularly in understanding interdependencies among firms, governance mechanisms, and digital transformation strategies (Adner, 2017; Gawer & Cusumano, 2014).

Industry trends highlight the growing relevance of blockchain tokens. The Blockchain & Web3 Observatory of the Politecnico di Milano reports a 43% growth in "*Blockchain for Business*" projects in 2024, reflecting a shift towards operational and scalable solutions. The number of live projects in this area has surged by 122%, with financial asset tokenization emerging as a dominant trend. Meanwhile, non-financial applications, such as Digital Product Passports (DPPs), are gaining traction, particularly in European markets. These developments underscore the potential of blockchain to enhance efficiency, modularity, and interoperability within business ecosystems (Schneider et al., 2020).

Despite its rapid adoption, blockchain tokens remains an underexplored phenomenon in business research, particularly concerning its role in modular governance and decentralized coordination. While existing literature examines blockchain applications in finance and supply chains, there is limited research on how firms integrate tokens to structure modular business ecosystems. Specifically, gaps remain in understanding how tokenization affects data traceability, asset transferability, and ecosystem interoperability. Although modularity has been widely studied in product and organizational

design, its application to blockchain-based coordination models requires further empirical validation.

The dissertation follows a structured research framework to analyze these dynamics. The study begins with an examination of existing literature on modularity, business ecosystems, and blockchain tokens, establishing a conceptual foundation. A multiple-case study approach is then employed to investigate real-world implementations, drawing insights from interviews and secondary sources. The findings contribute to the development of a conceptual framework that captures the interplay between modularity, traceability, and interoperability in business ecosystems.

2. Literature Review

The concept of business ecosystems has evolved as a crucial analytical framework for understanding the dynamic and interconnected nature of modern industries. Moore (1993) introduced the term to describe an economic community of organizations and individuals co-evolving through competition and collaboration. Adner (2017) expanded this view by emphasizing how structured networks align their activities around a shared value proposition. Jacobides et al. (2018) further investigated ecosystem structures by defining the role of strategic interdependencies, the mechanisms enabling ecosystem coordination, and the influence of modularity in ecosystem governance. These perspectives are essential for understanding how digital transformation is reshaping business ecosystems (Subramaniam et al., 2019).

Modularity represents a fundamental characteristic of business ecosystems, allowing firms to structure interdependencies while preserving adaptability (Jacobides et al., 2018). Baldwin & Clark (2000) emphasize how modular architectures support incremental innovation and system adaptability by decomposing complex systems into independent modules. Sanchez & Mahoney (1996) further highlight that modularity facilitates strategic flexibility, allowing firms to restructure governance and operational mechanisms without disrupting the overall system. Jacobides et al. (2018) examine modularity within business ecosystems, emphasizing how modular structures enable efficient coordination among interdependent actors. This perspective provides insights into how modular business ecosystems evolve, particularly in relation to transaction costs and firm boundaries (Baldwin, 2008). Thun (2022) extends this view by analyzing modularity in digital industries, illustrating how modular designs foster interoperability and ecosystem scalability. Understanding modularity is fundamental to analyzing how digital ecosystems evolve, particularly in relation to interoperability and governance (Baldwin & Clark, 2000; Jacobides et al., 2018).

The evolution of digital technologies has significantly transformed business ecosystems, fostering new forms of organizational coordination and value exchange (Jacobides et al., 2018; Subramaniam et al., 2019). By integrating digital infrastructures into their business models, firms increasingly rely on platform-based ecosystems governed by data-driven mechanisms rather than traditional hierarchies (Subramaniam et al., 2019). As digital infrastructures become central to business strategies, these platforms reshape competitive dynamics, enabling new forms of value creation and network effects (Parker et al., 2016). This shift requires firms to adopt strategic approaches to modularity and ecosystem governance, balancing flexibility and coordination in an interconnected environment (Thun, 2022; Baldwin & Clark, 2000).

In this context, blockchain technology has emerged as a fundamental enabler of decentralized coordination, providing a transparent and immutable infrastructure for transactions and governance (Nakamoto, 2008; Buterin, 2014; Schneider et al., 2020). As a distributed ledger system, bockchain enhances security, transparency, and trust in economic interactions by removing the need for centralized authorities (Nakamoto, 2008; Iansiti & Lakhani, 2017). The introduction of smart contracts (Buterin, 2014) extends its functionality, allowing for the automated execution of agreements and reducing reliance on intermediaries (Zheng et al., 2017). These innovations are reshaping business ecosystems by fostering new governance models, where firms coordinate activities through decentralized infrastructures rather than hierarchical control (Di Pierro, 2017; Wang et al., 2019). Consequently, blockchain-based ecosystems require firms to redefine their strategic roles and establish novel mechanisms for coordination,

interoperability, and value creation (Tasca, 2019; Pineda et al., 2020).

Tokens have become a fundamental component of blockchain ecosystems, enabling the digital representation of assets, rights, and utilities recorded and verified on distributed ledgers (Di Pierro, 2017). They are categorized into payment tokens, which function as digital currencies facilitating transactions; utility tokens, which grant access to specific services or applications within a blockchain ecosystem; security tokens, which represent financial assets subject to securities regulations; non-fungible tokens (NFTs), which establish ownership of unique digital assets; and governance tokens, which confer voting rights in decentralized decision-making processes (Colicev, 2023). Additionally, stablecoins serve as a bridge between traditional financial systems and blockchain environments by maintaining a stable value pegged to fiat currencies or commodities, facilitating payments, and mitigating volatility in decentralized finance (DeFi) applications (Bullmann et al., 2019). Furthermore, technical standards such as ERC-20 for fungible tokens and ERC-721 for non-fungible tokens (NFTs) ensure seamless integration, interoperability, and standardization within blockchain applications (Vogelsteller & Buterin, 2015; Entriken et al., 2018).

Building on this foundation, blockchain technology not only enhances decentralized coordination but also plays a critical role in structuring digital business ecosystems, enabling new forms of value exchange, stakeholder coordination, and governance mechanisms (Ribeiro da Silva & Angelis, 2024). Non-fungible tokens (NFTs), in particular, have emerged as tools for managing digital ownership, creating new interactions between content creators, consumers, and intermediaries in decentralized markets (Wilson et al., 2022). Additionally, tokenization supports the programmability of assets, allowing businesses to integrate smart contracts for automated transactions and enforceable digital agreements, expanding the strategic applications of blockchain-based business models (Colicev, 2023).

Although tokenization is becoming increasingly relevant, its impact modularity, adaptability, and coordination within business ecosystems is still not fully explored (Tönnissen et al., 2020; Wilson et al., 2022). While modularity has been widely studied in organizational design (Baldwin & Clark, 2000), its application in token-driven ecosystems lacks empirical validation (Wilson et al., 2022). Additionally, research on how firms integrate tokens into their business strategies remains limited, underscoring the need for further investigation. To address this gap, this study explores the strategic role of tokens in facilitating coordination and enhancing ecosystem scalability. Specifically, it is guided by the following research question:

RQ: *How can tokens enable modular ecosystem design and overcome barriers in business ecosystems?*

This research question explores the role of tokens in designing modular business ecosystems. The study analyzes how firms implement tokenization to structure interactions among actors. Through real-world cases, it provides empirical insights into how tokens enable modular business ecosystems.

3. Methodology

The study employs a multiple-case study approach (Eisenhardt, 1989; Eisenhardt & Graebner, 2007) to investigate how firms leverage tokens in their project. This qualitative method enables an in-depth exploration of diverse token applications across industries, providing empirical insights into the strategic role of tokens as enablers of modular business ecosystems. The cases were selected using a theoretical sampling approach (Eisenhardt, 1989), targeting the replication of similar dynamics across different sectors. This strategy enabled the study to examine how token applications operate in diverse business contexts.

Data collection involved semi-structured interviews with 15 industry stakeholders, including executives, blockchain developers, and innovation managers, along with an extensive review of secondary sources such as white papers, industry reports, and academic studies. The selected cases span multiple sectors to ensure diversity in token applications while maintaining comparability in ecosystem dynamics. This approach allowed for the identification of commonalities and sector-specific variations in token adoption. The combination of primary and secondary data sources provided a comprehensive perspective on the projects, capturing both strategic opportunities and operational challenges faced by industry practitioners.

Companies Interviewed				
Company	Location	Sector	Interviewed Role	Project Type
Company 1	Italy	Automotive	Head of Products	Digital Passport
Company 2	Switzerland	Fashion and Luxury	Chief Technology Officer	Digital Passport
Company 3	Italy	Fashion and Luxury	Head Of Operation Excellence & Technology	Digital Passport
Company 4	Italy	Technology	Chief Executive Officer	Digital Passport
Company 5	San Marino	Technology	Business Development Manager	Supply Chain Traceability
Company 6	Italy	Fashion and Luxury	Innovation Manager	Web 3 Experience
Company 7	Italy	Mobility and Payment Services	Product Manager and Cloud Software Engineer	Web 3 Experience
Company 8	Italy/USA	Hospitality and Tourism	Director Dev & Digital Ecosystem	Booking Tokenization
Company 9	Italy	Hospitality and Tourism	Chief Executive Officer and CO-Founder	Booking Tokenization
Company 10	USA	Finance	Head of Sales & Expansion	Stable Coin
Company 11	France	Finance	Head of Innovation	Stable Coin
Company 12	France	Finance	Business Development Manager	Stable Coin
Company 13	USA	Finance	Portfolio Manager	Assets Tokenization
Company 14	USA	Finance	Governance Liason	De-Fi
Company 15	USA	Finance	Staff Smart Contract Engineer	De-Fi

Table 1: Companies Interviewed

For data analysis, an abductive coding approach was employed to systematically identify key themes related to modularity, governance, and interoperability. First-order concepts were derived from the raw data, followed by the identification of second-order themes capturing broader strategic implications. These were further synthesized into aggregate dimensions, enabling a structured cross-case analysis to compare token implementation strategies, assess their implications for ecosystem coordination, and identify common patterns and divergences across cases. This structured approach provides empirical insights into the role of tokens in business ecosystems, highlighting its strategic implications.

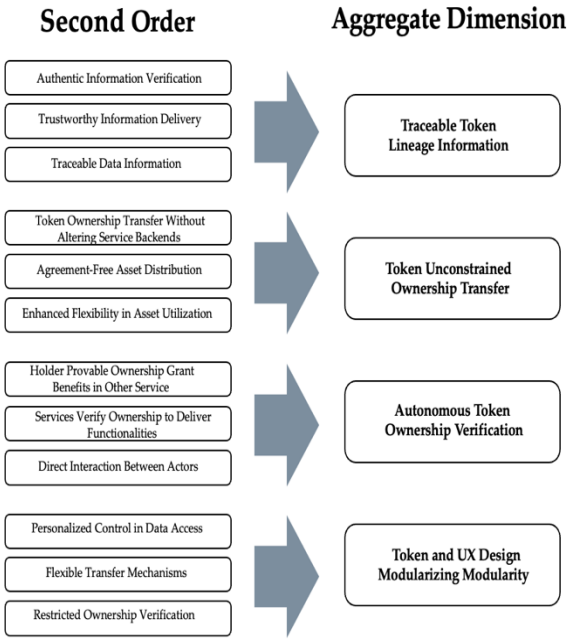

Figure 1: Coding Structure

4. Results

Leveraging previous literature on modularity and ecosystems, we investigate how tokens contribute to business ecosystems by extending modularity principles. Specifically, drawing on modularity literature we explore how tokens may serve as mechanisms that integrate new stakeholders and enable coordination among actors without depending exclusively on market mechanisms or centralized authority structures. The findings are presented through three distinctive token features, with a fourth element addressing how these characteristics influence openness of business ecosystems.

4.1. Traceable Token Lineage Information

The integration of tokens in business ecosystems influences how stakeholders access and update information. Tokens ensure data immutability, guaranteeing that once information is recorded, it cannot be altered without leaving a transparent trace. This mechanism provides enhanced security and trust compared to traditional systems, safeguarding the integrity of the original data. Consequently, tokens enable stakeholders who read the stored information to be assured of its immutability. The open visibility of token data

allows any actor within the business ecosystem to access the information without requiring permission. Stakeholders can instantly access and automatically verify the information, consequently eliminating the dependence on intermediaries and(or) data verification processes. The public nature of tokens marks a significant departure from traditional databases, where data is controlled by centralized entities. With tokens, even actors who neither own nor originally created the token can add information about a product directly to it, ensuring trustworthy and collaboratively maintained data. The information provided by these complementors becomes part of the blockchain, which is verifiable by all ecosystems' stakeholders. As in the case of Company 2, token information such as production details, ownership records, warranty status, and maintenance history can be updated by authorized service centers, which log maintenance events and repairs on the blockchain, ensuring a verifiable and transparent history of the watch. This data is then accessible, real-time to the next owner, who can review the entire usage history, including records added by both the manufacturer (in the case of a digital product passport) or any other complementor. Tokens transparent record-keeping facilitates the modular integration of stakeholders, providing a streamlined method for tracking and sharing real-time, authentic data, ensuring that all stakeholders have access to the latest updates.

Proposition 1. *Publicly accessible and traceable token information simplifies modular integration of stakeholders.*

4.2. Token Unconstrained Ownership Transfer

Tokens, much like physical objects, can be transferred directly between different stakeholder. This characteristic has significant implications for interactions between parties of the ecosystem, as it enables direct exchanges without agreement and custom software, increasing interoperability and reducing coordination efforts. Traditional systems require adherence to distinct rules and limitations of existing complex, often siloed infrastructures. In these systems, stakeholders maintain distinct protocols and settlement processes, typically restricted to specific operating hours, adding further complexity. In contrast, tokens can generally be transferred by any user, company, or application, without time restrictions, operational hours, or access barriers. Token enables any service to incorporate and utilize those owned by other stakeholders, seamlessly integrating and exchanging them without restrictions. Company 5 exemplifies seamless value transfer in a Web3 environment, enabling tokens received in one decentralized application (dApp) to be instantly transferred to another dApp. This process abstracts the underlying infrastructure, enabling tokens, once owned by a user, to be exchanged across protocols without limitations. As a result, interoperability and ownership transfers occur across ecosystem actors with ease. Tokens inherently possess the capability to be freely transferred and distributed without requiring formal agreements. This characteristic enables various complementors, such as blockchain platforms, marketplaces, and wallet providers, to seamlessly interact with and support the token, even without official supplier status or contractual relationships. This capability fosters more open and fluid business ecosystems, allowing participants to interact and exchange value directly, without the friction of negotiating terms or relying on centralized coordination. Consequently, tokens reduce collaboration barriers by enabling stakeholders to interact without formal partnerships or contracts, thereby eliminating time-consuming coordination efforts.

Proposition 2. *Token unconstrained transfer ownership simplifies the entrance of new stakeholders.*

4.3. Autonomous Token Ownership Verification

With distributed ledger technology as the foundation of tokens, all participants share a synchronized copy of the transaction history. This ensures that users can independently verify token ownership without requiring permission from any provider. The verification process is inherently tamper-proof, as interactions are securely recorded on the token, eliminating the risk of falsifying ownership or transfer records. This characteristic significantly impacts ecosystem dynamics by enabling users to leverage their assets or resources (e.g., data or digital products) seamlessly across multiple platforms or services. This approach differs from the current consumer experience with digital goods, where purchasing a song or an e-

book typically only grants a license for access through a specific provider rather than actual ownership of a copy. License-based ownership in Web 2 restricts consumers from switching platforms, as doing so results in losing access to the content. In contrast, Web3 promises a more platform-agnostic consumption experience, where token holders retain full control over their assets regardless of the underlying platform. Unlike traditional assets confined within a company's infrastructure, token ownership can be verified by any compatible service without keep ownership restricted to a specific company. As emerged from interviews, a messaging platform verifies ownership of Company 7's tokens, granting holders access to exclusive chats. Additionally, token ownership enabled users to unlock discounted rides within a scooter-sharing service. Thus, token ownership allows users to unlock access to various services using the same token. From the holder's perspective, a token (e.g., assets, credentials) is portable as it can be used in one application and later be seamlessly moved, along with their data, to another without requiring authorization from the ecosystem creator or token issuer. Similarly, businesses that issue tokens for use on a specific platform can choose to enable those tokens to be verified and utilized across other platforms. This prevents client lock-in, expands interaction channels, and provides clients greater ecosystem reach. Moreover, tokens reshape stakeholder interactions by enabling businesses to directly engage with customers holding tokens even when purchases occur through third parties. Any actor can recognize token holders and engage them directly, providing tailored offers, loyalty rewards, or additional services. Token ownership verification enables new businesses to integrate into ecosystems by directly validating ownership through the token itself, eliminating the need to share or authenticate sensitive user information between participants. Consequently, token ecosystems enable businesses to create more 'plug-and-play' interactions, reducing dependency on intermediaries, fostering a more open and interconnected business ecosystem.

Proposition 3. *Autonomous token ownership verification simplifies the attachment of a third-party service and holder direct interaction.*

4.4. Token and UX Design Modularizing Modularity

There is a continuum of token design choices when companies seek to expand their business ecosystems through tokens. When designing a token, strategic decisions must be made regarding transferability and the rules for authenticating and managing assets. These decisions are enabled by the programmability of tokens, which allows specific rules and functionalities to be embedded directly into the smart contract's code. The case of Company 1 illustrates that not every company chooses to maintain information publicly readable. During its pilot phase, the company chose to restrict on-chain data additions exclusively to the brand, while ecosystem participants were required to submit relevant information through an off-chain information system. These design choices limit the modularity enabled by publicly accessible token information and writing permissions, restricting external actors' ability to contribute or integrate with the token. Otherwise, token transfers can be restricted to a predefined list of whitelisted actors. This approach allowed for greater control over who could own the asset but keep closed the ecosystem. As a result, the ecosystem remains closed, reducing the flexibility for stakeholders to build services around token exchange. A case restricted token acceptance to a single marketplace but retained the flexibility to allow other platforms to verify ownership and provide services to token holders in the future. When token verification is restricted to the issuer's platform rather than being directly recognized by service providers, the token's utility becomes dependent on intermediary control, limiting its interoperability. Ecosystem participants can strategically design token functionalities to support interactions across a spectrum, from open, permissionless engagement to more controlled, managed environments.

Proposition 4. *Token and UX design allow to manage open modular interactions, enabling the customization of ownership verification, ownership transfer and information exchange.*

5. Discussion

Interview results identified three key token features: traceable token lineage information, unconstrained transferability, and autonomous

verification, all of which strengthen ecosystem's modularity. Companies emphasized the role of tokens in inter-actor interactions, highlighting how each feature contributes to the modular integration of stakeholders. When combined, these features generate new dynamics that facilitate stakeholder engagement within business ecosystems by enabling reliable secondary markets, composable value layers, and interoperable systems. Each distinctive feature can function independently or interact selectively through token and UX design, leading to the emergence of new dynamics through their interaction. Ultimately, all three token features can coexist, as demonstrated in various company ecosystems, positioning tokens as an advanced modular instrument for fostering open business ecosystem.

The Emergence of Reliable Secondary Markets in token business ecosystems arises from the integration of publicly accessible and traceable token lineage information alongside unconstrained transferability. In this configuration, autonomous token ownership verification can be deliberately deactivated as a design choice. This arrangement expands modularity theory by demonstrating its applicability to token-enabled reliable secondary markets. Baldwin (2008) highlights modularity as a mechanism for reducing transaction costs by defining standardized interfaces, which facilitate specialization while maintaining interoperability (Jacobides et al., 2018). Traditional secondary markets are often hindered by compatibility requirements and legal agreements that regulate asset transferability (Thun et al., 2022), whereas tokens eliminate these frictions by embedding verifiable ownership history and authenticity within the asset itself (Iansiti & Lakhani, 2017). In platform ecosystems, modular structures have been linked to competitive advantage, allowing firms to align interdependent activities without hierarchical control (Adner, 2017). Additionally, Thun et al. (2022) highlight how modular design enhances scalability through efficient coordination. Moreover, unlike prior conceptualizations of ecosystems where firms must coordinate through negotiated complementarities (Jacobides et al., 2018), this study extends this understanding by demonstrating how token business ecosystems allow for a more trustworthy and unconstrained exchange of ownership. This introduces a novel coordination approach distinct from traditional ecosystem literature; while Jacobides (2018) describes coordination as spanning between markets and hierarchies, tokens bypass central authority by enabling secondary markets that emerge spontaneously based on new, unexplored variables. By removing intermediaries and making the exchange process more fluid, the ecosystem becomes inherently more modular. This increased modularity not only reduces friction in transactions but also facilitates the involvement of new stakeholders in the market. These characteristics of tokens shape the modularity of the ecosystem in ways not previously explored in the literature, highlighting their novel impact on ecosystem design.

Composable Value Layers in Token Ecosystems illustrate how publicly accessible and traceable token information, combined with autonomous token ownership verification, enable seamless attachment of third-party services, while deliberately limiting transferability as a design choice. Together, these factors create a business ecosystem where new actors can easily participate by integrating complementary features or services into stakeholders' products or services. Unlike Baldwin's (2008) firm-driven structures, publicly accessible token information enables permissionless service integration, reducing dependence on intermediaries. This extends beyond Jacobides et al.'s (2018) structured complementarities by encompassing decentralized ownership verification. While Adner (2017) emphasizes partner alignment, accessibility and reliability of information and ownership verification processes are shown to cut coordination costs. This autonomy contrasts with Jacobides et al.'s (2018) structured complementarity models requiring strategic alignment for interdependency management. This study demonstrates that token-based modularity enables permissionless expansion, allowing stakeholders to add services without central entity approval. Token modularity implications include lower entry barriers where third parties integrate services seamlessly, unlike traditional systems requiring negotiated platform access (Gawer & Cusumano, 2014). Moreover, the autonomous verification and protocol-native composability model enable service integration of trustworthy ownership without intermediaries. Furthermore, it reduces dependence on centralized standard-

setting and governance, which typically creates barriers for new entrants and slows the adoption of innovative solutions (Thun et al., 2022).

Unconstrained System Interoperability represent the combination of unconstrained token transfer and autonomous ownership verification, which reshapes business ecosystem dynamics by enabling seamless cross-platform movement of ownership and reducing entry barriers, limiting information accessibility as an intentional design principle. While traditional modular ecosystems reduce complexity through decomposition into interdependent modules (Tatsumoto, 2018), they still rely on platform firms to manage compatibility and enforce governance. Though Tatsumoto (2018) suggests platform firms drive ecosystem expansion through open standards, they nevertheless regulate participation through licensing or proprietary frameworks. As Baldwin and Clark (2000) note, traditional modularity reduces coordination costs only within predefined architectures. While this provides stability, it limits the entry of new stakeholders and slows ecosystem expansion. Traditional modularity theories have emphasized structured verification and control by centralized authority and were enacted through pre-existing relationships to ensure trust and asset authenticity (Jacobides et al., 2018). Unconstrained token transfer marks a shift from firm-led modularity as these findings highlight the significance of unrestricted interoperability, particularly in cross-platform integrations where digital assets must function seamlessly. This challenges dominant firms' orchestration, demonstrating that modular structures can emerge through token-based systems.

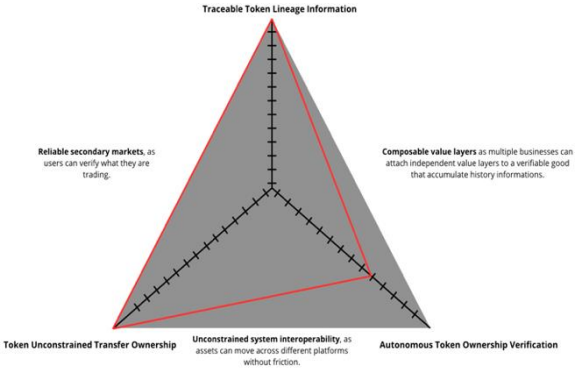

Figure 2: Token Modularity Framework

Tokens as the Most Modular Instrument in Business Ecosystems extends modularity literature by introducing tokens as unprecedentedly modular instruments exhibiting three dynamics — reliable secondary markets, composable value layers, and unconstrained interoperability—that enhance modularity beyond existing frameworks. Traditional modularity theories emphasize standardized interfaces that enable flexibility and scalability (Baldwin, 2008). Scholars identify modular ecosystems as critical for innovation by facilitating independent development while maintaining systemic coherence (Jacobides et al., 2018). Traditional modularity classifications have not accounted for tokens, and this study expands on this by presenting tokens as a modular interface that offers permissionless interoperability and composability across ecosystems. Prior studies have confined modularity within firm-centric structures, where interface control determines competitive positioning (Gawer & Cusumano, 2014). The findings indicate that tokens operate independently of their original issuer, contrasting with systems that rely on centralized gatekeeping (Adner, 2017). While Baldwin (2008) discusses how modularity influences firm boundaries, tokens eliminate the necessity of firm-based boundaries altogether, creating trustless environments for autonomous transactions. Token-based modularity suggests a fundamental shift in the creation and conceptualization of modular ecosystems, facilitating permissionless innovation without prior authorization. The research highlights potential for a decentralized modular economy where interoperability stems from open, composable systems rather than proprietary standards (Jacobides et al., 2018).

6. Conclusion

This dissertation offers significant contributions from both theoretical and practical perspectives. The empirical findings highlight the pivotal role of tokens in enabling reliable secondary markets, facilitating composable value layers, and enhancing interoperability. The immutable and publicly accessible lineage information provided by tokens mitigates verification bottlenecks, reducing reliance on centralized authorities and intermediaries. Additionally, token-based ownership verification ensures seamless asset transfer across platforms without requiring third-party validation, thereby lowering transaction costs and improving market fluidity. By

integrating these features, tokens establish a foundation for modular governance that extends beyond firm-centric structures, fostering permissionless innovation and decentralized trust mechanisms.

Significantly, this research challenges existing modularity theories by illustrating how token ecosystems function outside traditional hierarchical control while maintaining sufficient coordination to eliminate reliance on market-based mechanisms. From a theoretical perspective, this research extends existing literature on modularity by demonstrating how tokens function as hyper-modular instruments. Unlike conventional modularity theories that emphasize firm-controlled interfaces, token ecosystems redefine modularity by introducing transparency as coordination mechanisms by design. Traditional modularity studies primarily focus on product modularity or platform-based governance, where firms act as orchestrators of predefined interfaces. In contrast, token-based modularity introduces a decentralized structure where interoperability of ownership and ecosystem governance emerge dynamically from the tokens themselves. Through traceable lineage information, token transferability, and autonomous verification, firms no longer need to enforce compatibility through centralized control. Instead, token ecosystems facilitate a more autonomous, open, and unconstrained form of modularity, bypassing conventional gatekeeping structures. These findings contribute to business ecosystem theories by demonstrating how tokens reduce coordination costs, facilitate stakeholder entry, and enhance permissionless service composability.

However, this study has several limitations that suggest avenues for further research. The primary constraint concerns the generalizability of the findings, given the limited number of tokenization implementations analyzed. The sample size may not fully capture the diversity of organizations adopting these technologies, and methodological limitations, such as interview bias and variability in secondary sources, further affect robustness. Additionally, the framework's focus on three token features may not fully reflect tokenization's complexity. Rapid technological advancements also introduce temporal constraints, as future developments could challenge the comprehensiveness of these conclusions.

Future research should examine the long-term effects of token-based modularity on industry-wide standardization, competitive positioning, and firm adaptation strategies. Investigating cross-sectoral applications of tokens could further clarify its transformative potential. A critical avenue for future studies involves assessing how existing ecosystem roles evolve when tokenization is recognized as digital ownership, determining whether traditional structures adapt, merge, or become obsolete in response to decentralized governance models. As digital economies develop, understanding how firms navigate the intersection of modularity and decentralization will be essential for fostering resilient, efficient, and scalable business ecosystems.

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